Selecting BOT/PPP Infrastructure Projects for Government Guarantee Portfolio under Conditions of Budget and Risk in the Indonesian Context

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Abstract: Guarantee provision in privately financed infrastructure projects implemented as build-operate-transfer/public-private-partnership (BOT/PPP) arrangements is not uncommon in many countries, and Indonesia is no exception. But, given that the government budget is, in most if not all cases, not unlimited, there must be a selection of BOT/PPP projects posing proposals for seeking government guarantees. This paper presents a project selection methodology under the chance-constrained goal-programming framework in the context of the Indonesian BOT/PPP infrastructure industry. The ultimate objective of the selection is to result in a portfolio of guaranteed projects that brings maximum welfare gain to the economy as a whole, maximum total net change in financial net present value but, at the same time, puts the government at the lowest fiscal risk for a given budget constraint. The proposed methodology allows the government to examine relationships among the expected total payment, budget-at-risk allocated, and a desired confidence interval of actual payment not exceeding the budget-at-risk. The government can also compare two or more alternative scenarios and choose the optimal one that delivers the highest value for the money. To illustrate the model application, without sacrificing the generality of the proposed methodology, a much-simplified hypothetical case is presented, examined, and discussed. **DOI:** 10.1061/(ASCE)CO.1943-7862.0000312.

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Introduction

Most, if not all, governments around the world have acknowledged the significance of adequate and reliable infrastructure facilities in stimulating and promoting national economic growth. Despite a lack of unanimity among economists concerning the elasticity of infrastructure investments, numerous studies have attested that infrastructure plays a pivotal role; if infrastructure is not the engine, it is at least the wheels of economic activity (World Bank 1994). However, many governments, especially in developing economies, are often lacking in the financial resources essential for building new and maintaining existing infrastructure facilities. Exacerbated by low efficiency and lack of transparency in their management, poor quality infrastructure service to the community is inevitable.

In the case of Indonesia, a total infrastructure investment of about IDR 1,400 trillion (approximately USD 140 billion) will be needed to support 6.5–7.0% national economic growth for 2010–2014. Given a limited budget, the Government of Indonesia (GoI) can only afford to finance about one-third of the total investment required, thus leaving a substantial gap and signifying the urgent need for alternative solutions other than traditional tax-based public funding (Susantono 2010). As with other governments, the GoI seeks private financing to bridge the gap. However, the effort is not as simple as it appears, especially when looking into the specific requirements of infrastructure investment.

Infrastructure investment is typically characterized by a high degree of asset specificity and large project-specific risks that cannot be diversified in financial markets (Dailami et al. 1999). The International Infrastructure Summits of 2005 and 2006, hosted by the GoI, demonstrated how difficult it is to attract private participation in the infrastructure sector. At these events, a total of 91 infrastructure projects across sectors were offered for build-operate-transfer/public-private-partnership (BOT/PPP). Both events failed to attract the anticipated large number of domestic and international investors, despite claims being made by government officials that prospective investors had, indeed, expressed great interest in participating (Wibowo and Mohamed 2010).

In 2006, the GoI embarked on a new policy reform, including the provision of guarantees to protect private investors from project risks related to the GoI's responsibilities or payment obligations, political risks, and market demand. Although the guarantee provision has not yet been tested in practice because the guarantee program is still in its infancy, the initiative to provide guarantees should be deemed as, at least, a stepping-stone on the way to making the investment environment friendlier. To bring the initiative closer to becoming a reality, the GoI established the Indonesia Guarantee Fund (IGF) in 2009, authorized to manage all government guarantees provided for BOT (build-operate-transfer)/PPP projects requiring such support. At present, the exact format of the Fund is still under intensive discussion by relevant ministries. For the IGF's operation and management, the GoI has reportedly injected an initial capital of IDR 1 trillion.

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When offering guarantees, the government may incur substantial contingent liabilities that, if called upon to be paid, can be a severe obligation. Given that the budget is not unlimited, the key issue for the government is to select the most appropriate BOT/PPP projects to be guaranteed. Selection naturally depends on the riskiness of projects, the risk acceptance level of the government, budget availability, project significance, and objectives of guarantee provision. The present paper, under the chance-constrained goal-programming (CCGP) model combined with Monte Carlo simulation (MCS), develops a model for decision-making when selecting the most appropriate BOT/PPP infrastructure project(s) to be guaranteed.

The problem of interest shares some characteristics with those in the traditional capital rationing theory, with the exception that it involves both multiple objectives and uncertainties. Although the present study only focuses on minimum revenue guarantee, the methodology introduced can also be applied to other types of guarantees. Given the distribution of risky variables, the quantification of minimum revenue guarantee is relatively straightforward. In addition, it is not the objective of this paper to discuss the valuation technique of guarantees, including the modeling of variable uncertainties, because this issue has been covered elsewhere in more detail (Irwin 2007; Mody and Patro 1996).

The paper is organized as follows. A brief description of guarantee provision in private infrastructure and Indonesia's guarantee program is presented, followed by the argument for making use of the CCGP framework and model formulation. To illustrate model application, a numerical example is presented, examined, and discussed. Limitations of the present study and future works are acknowledged, and the paper closes with conclusions.

Guarantee Provision in Private Infrastructure

Historically, traditional government guarantee provision can be dated back to biblical times. Possibly the earliest evidence of government guarantee is contained in the Code of Hammurabi, written 4,000 years ago (Irwin 2007). In privately financed infrastructure projects, host governments often provide financial support by means of guarantees (Dailami and Klein 1998). When offering guarantees, the governments do not incur an immediate cost, but they must assume contingent liabilities (Irwin 2003).

While contingent liabilities represent real liabilities (Lewis and Mody 1998), most governments do not account for the contingent liabilities they incur. Because no attempt has been made to systematically estimate contingent liabilities, the full extent of these liabilities is not known (Mody and Patro 1996). In some cases, government guarantees may soon represent an unmanageable level of exposure, not only because of their size relative to the size of the government's balance sheet, but also because their contingent nature implies the possibility of sudden and substantial obligations due over a short period of time (Lewis and Mody 1997). Starting with the U.S. 1991 Credit Reform Act, some governments have begun assessing the fiscal impact of guarantees (Klein 1997). Thobani (1999) asserted that governments would have no fiscal incentive to issue guarantees rather than giving subsidies, because both would show up as expenditures, affecting the deficit, and both would require appropriation by legislation.

Indonesia's Infrastructure Guarantee Program

The Indonesian infrastructure guarantee program for BOT/PPP infrastructure development was officially launched in 2006, as Ministry of Finance Regulation No. 38/PMK/2006. The regulation prescribes the procedure of submitting proposals to seek government guarantees against political, project performance, and demand risks. Included in the political risks category are any unilateral action by the government that adversely affects the project profitability, including expropriation, changes in legislation, and inconvertibility/transferability of foreign exchange. The project performance risks encompass land acquisition risk, tariff risk, and changes in output specification. Under the demand risk guarantee, the GoI must reimburse the project sponsor for any shortfall of guaranteed demand but is entitled to claim excessive demand. The guarantee scheme aims to protect the project sponsor from up- and downside demand risk. The default requirements for qualifying for a government guarantee are that the project of interest must be both technically and financially feasible, and the cost and fiscal risk arising from the guarantee provision do not exceed the government's ability to pay.

Prior to the enactment of the regulation, the guarantee provision was typically project-based and sometimes merely resulted from outcomes of a series of negotiations held by the project sponsor and the government, thereby raising the issue of transparency and accountability (Wibowo 2005). Under the regulation, the guarantee proposal is prepared and submitted by the proposing technical ministry to the Committee for Infrastructure Acceleration Development for preliminary examination before being forwarded to the Minister of Finance via the Risk Management Unit (RMU) for further consideration. The RMU provides the Minister with a recommendation on whether to approve or disapprove the proposal. If approved, the proposal will be forwarded to the parliament for final approval. The proposing technical ministry will stipulate the provision of guarantee in the tender document if the parliament approves the guarantee proposal.

Rationale of Use of Chance-Constrained Goal Programming

Conflict of interest in today's decision-making is not uncommon. The conflict may be rooted in multiple decision makers with different vested interests, or the existence of multiple objectives that consume common resources. The uncertain nature of the decision-making complicates the problem. While the former problem situation can be dealt with using goal programming (GP) (Charnes et al. 1955; Tamiz et al. 1998), the latter can be solved with chance-constrained programming (CCP) to determine the optimal stochastic decision rule under the prescribed levels of probability constraint (Charnes et al. 1958; Charnes and Cooper 1959).

The problem at hand is that the GoI is faced with a set of feasible project alternatives that are difficult or impossible to implement without guarantees. When issuing guarantees, the GoI needs to budget every year for the guarantee claims, as part of risk management policies, with the budget level determined by the tolerance degree the GoI can accept. The GoI is put at greater risk if it accepts more than one project whose risks and uncertainties are positively correlated one to the other. This may trigger all the projects calling in the guarantees at the same time, requiring the GoI to pay out a substantial sum of money, jeopardizing fiscal sustainability. If the GoI decides to offer guarantees, it must be ensured that the guarantee provision will bring a positive impact to the economy and the financial viability of the guaranteed projects.

Bearing all these in mind, the GoI should, therefore, not only evaluate the guarantee impact on the project on an individual basis, but also on an aggregate basis. This facet of the problem has not been addressed in the existing studies that exclusively focused on individual projects (e.g., Dias and Ioannou 1995; Irwin 2007; Mody and Patro 1996; Sosin 1980; Wibowo 2004; Wibowo 2006). Neither GP nor the CCP can be used to solve this aspect

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of the problem. Another approach is needed that can take advantage of the individual virtues of GP and CCP, and the CCGP perfectly meets this requirement. Since its development, CCGP has received much attention from experts and practitioners in assorted disciplines (e.g., Choi and Levary 1989; Keown 1978; Mohammed 2000; Rakes et al. 1984; Song et al. 2008).

Problem Statement and Model Formulation

We used net present value (NPV), not internal rate of return (IRR) as the project viability indicator because of its additive property (Crundwell 2008) that is useful for the model formulation. In the modeling, the viability in economic terms, measured by the economic NPV (ENPV), was distinguished from that in financial terms, measured by financial NPV (FNPV). Hence, this requires the governments to do both financial and economic analysis under the proposed methodology. Whereas the financial analysis of a project assesses whether it will be commercially profitable for the enterprise implementing it (Perkins 1994), economic analysis attempts to assess the overall impact of a project on improving the economic welfare of the citizens in the country concerned (Economic and Development Resource Center 1997).

The government is keen to see all the economically feasible projects requiring guarantees implemented. On the other hand, it is also in the government's interest to ensure fiscal sustainability. Because room for contingent liability is not unlimited, not every project can be guaranteed; fewer projects to guarantee means less fiscal burden and risk for the government. This conflict situation well represents the two different government positions—that of the ministry of finance as the fiscal keeper and the technical ministries as the agents of development. Given this situation, we formulated a problem statement as follows: "How to select BOT/PPP infrastructure projects to obtain an optimal portfolio of guaranteed projects that brings the maximum economic NPV and net change in financial NPV but puts the government at the lowest fiscal risk for a given budget constraint."

Economic Constraint

It has been a norm in any public investment decision analysis that governments only accept economically feasible projects that require public funding intervention, irrespective of the projects' being guaranteed or not. The first goal of the government is to maximize the total ENPV resulting from the implementation of guaranteed projects. In this paper, the terms of goal and objective are used interchangeably and the tilde symbol (~) over a variable denotes that the variable is stochastic.

For the sake of simplicity, it is assumed that the project ENPV is known with certainty or can at least be fairly assumed. It is worth noting here that the methodology for calculating ENPV is beyond the scope of this paper; that issue is best handled elsewhere (World Bank 1996). Under the CCGP framework, the objective is written as follows:

$$\sum_{i=1}^{m} X_i \mathrm{ENPV}_i - \delta_{\mathrm{ENPV}}^{+} + \delta_{\mathrm{ENPV}}^{-} = \sum_{i=1}^{m} \mathrm{ENPV}_i \tag{1}$$

where $X_i = 1$ if the project i is guaranteed; otherwise, $X_i = 0$; m = number of qualified projects; ENPV_i = project i's ENPV; $\delta_{\mathrm{ENPV}}^{+}$ = positive deviational variable (overachievement) of the ENPV target; and $\delta_{\mathrm{ENPV}}^{-}$ = negative deviational variable (underachievement) of the ENPV target. Under the goal-programming framework, the deviational variable is an auxiliary variable used to represent either a negative or positive deviation from the defined target value. Because we are only concerned with underachievement in the economic constraint, the negative deviational variable in Eq. (1) is undesired and must be correspondingly minimized.

Budget Constraint

All things being equal, it is generally accepted that the government prefers projects with less cost to taxpayers. We translated this conventional wisdom into minimization of the expected guarantee payment. Let C be the expected total payment in present-value terms. The objective of minimizing the expected total payment can be written as follows:

$$\sum_{i=1}^{m} X_i E(\tilde{G}_i) - \delta_C^{+} + \delta_C^{-} = C \tag{2}$$

where $E(\tilde{G}_i)$ = expected total payment of guarantee portfolio in present-value terms; δ_C^{+} = positive deviational variable of expected total payment target; and δ_C^{-} = negative deviational variable of expected total payment target. The positive deviational variable in Eq. (2) is the unwanted one because it increases cost to the government and needs, therefore, to be minimized.

Financial Impact Constraint

Guarantees are provided to render projects financially more attractive. We expressed the objective as maximization of total net change in FNPV of projects before and after guarantee. While the previous objective was to minimize the expected payment of the guarantee portfolio, the present goal is to maximize the expected benefit. The approach resembles the concept of traditional benefit-cost ratio (BCR) assessment. But, instead of aggregating benefit and cost information into a single metric, we handled them individually. The goal is mathematically written as follows:

$$\begin{aligned} &\sum_{i=1}^{m} \left[E(\widetilde{\mathrm{FNPV}}_i^{*}) - E(\widetilde{\mathrm{FNPV}}_i) \right] X_i - \delta_B^{+} + \delta_B^{-} \\ &= \sum_{i=1}^{m} \left[E(\widetilde{\mathrm{FNPV}}_i^{*}) - E(\widetilde{\mathrm{FNPV}}_i) \right] \end{aligned} \tag{3}$$

where $E(\widetilde{\mathrm{FNPV}}_i^{*})$ = expected FNPV of project i after guarantee; $E(\widetilde{\mathrm{FNPV}}_i)$ = expected FNPV of project i before guarantee; δ_B^{+} = positive deviational variable of net change; and δ_B^{-} = negative deviational variable of net change. The unwanted variable in Eq. (3) is underachievement of the target.

Annual Fiscal Risk Constraints

The expected guarantee payment has been a useful measure of government exposure. However, the government needs to remain attentive to the worst-scenario payment because guarantee payment can theoretically run from zero to infinity. We argued that the government must limit the likelihood of annual total payment exceeding the allocated annual budget, which is termed by Irwin (2007) as "the excess-payment-probability." Compared to deriving mathematical formulations for goals that are relatively straightforward, modeling fiscal risk constraints is rather complicated. Under a CCP framework, the objective to minimize fiscal risk can be modeled as follows:

$$P\left(\sum_{i=0}^{m} X_i \tilde{G}_{it} > A_t \right) \leq \alpha \quad \text{for } t = 1, 2, \ldots, K \tag{4}$$

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where P = probability; $\tilde{G}_{it}$ = portfolio guarantee payment made for project i at period t; A_t = annual budget-at-risk allocated for period t; α = allowed excess-payment-probability; and K = horizon period of the guarantee program. We defined the budget-at-risk as an amount of money the government must allocate with a particular degree of confidence $(1-\alpha)$ that actual payment will not exceed the amount. If α is set at 0.05, there is a 95% confidence interval that actual payment is below the budget-at-risk. It is worth noting here that the budget-at-risk or excess payment should not be confused with the expected payment. While the former typically represents the worst-scenario payment, the latter reflects the payment the government may expect.

To model the fiscal risk, we adopted the safety first principle (Roy 1952). The principle implies that an investor would prefer the investment with the smallest probability of going below the "disaster level" or target return. We employed the Gauss inequality that states that if there exists a random variable $\tilde{S}$ with mode m_s, mean μ_s, and standard deviation σ_s, then for any positive value of k (Sellke 1996)

$$P\left(|\tilde{S}-m_s|>k\right)\leq\alpha \tag{5}$$

where

$$\alpha=\begin{cases}\left(\frac{2\tau}{3k}\right)^2 & \text{for } k\geq\frac{2\tau}{\sqrt{3}}\\ 1-\frac{k}{\tau\sqrt{3}} & \text{for } 0\leq k\leq\frac{2\tau}{\sqrt{3}}\end{cases} \tag{6}$$

and

$$\tau^2=(\mu_s-m_s)^2+\sigma_s^2 \tag{7}$$

This inequality is distribution-free and only requires information on the first two moments and the mode. The mean and variance of a guarantee portfolio for period t can be calculated as

$$E(\tilde{G}_t)=\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\quad\text{for } t=1,2,\ldots,K \tag{8}$$

$$\sigma^2(\tilde{G}_t)=\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})+2\sum_{i=1}^{m}\sum_{\substack{j=1\\ i\neq j}}^{m}X_{it}X_{jt}\rho_{G_{it},G_{jt}}\sigma(\tilde{G}_{it})\sigma(\tilde{G}_{jt})\quad\text{for } t=1,2,\ldots,K \tag{9}$$

where $E(\tilde{G}_t)$ = expected guarantee payment for period t; $E(\tilde{G}_{it})$ = expected guarantee payment for project i for period t; $\sigma(\tilde{G}_t)$ = standard deviation of guarantee payment for project i for period t; and $\rho_{G_{it},G_{jt}}$ = coefficient of correlation between the government payments for projects i and j for period t.

We borrowed the idea of the single index model in the finance theory (Elton and Gruber 1995) by assuming that comovement between project performances is the result of a common factor. We directly correlated individual project performance and the market movement so that the second term of the right-hand side of Eq. (9) can be dropped; if not, the resulting correlation is double counted. This idea simplifies the computational processes because only m, instead of $1/2(m^2+m)$, input data are needed to calculate the variance.

If only one underlying risky variable with a particular distribution function (e.g., normal, exponential, double exponential, Cauchy) is involved, the first two moments of distribution i.e., expected value and variance, have explicit forms (see, for example, Olive 2002). However, a real world problem is not that simple. A guarantee payment often depends on the project performance. In reality, the project performance is heavily influenced by many random variables with different distributions (e.g., demand, tariff, interest rate, inflation rate, construction cost, and operation and maintenance cost). Consequently, the analytical solution requires solving complex mathematical problems that are often cumbersome for decision makers to use. Therefore, the use of simulation is essential, especially when a situation arises that is very difficult (or even impossible) to represent by tractable mathematical models (Better and Glover 2006). With simulation, obtaining the first or a higher moment of the government payment distribution is no longer an issue.

One problem that remains is to derive the explicit form of mode. Fortunately, the guarantee payment can be safely assumed to have mode 0; if not, the guarantee no longer contains a contingent liability and has effectively been transferred to a noncontingent liability, just like a direct subsidy, with the likelihood of being called effectively one. This could happen if the threshold is set extremely far below (or above) the forecast. For instance, the government might be willing to guarantee minimum revenue of 300% of the forecast. In fact, no such guarantee would be available if the government is rational. Additionally, the guarantee payment distribution is truncated at zero. The validity of a zero-mode assumption can be easily verified with simulations.

Substituting Eqs. (8) and (9) into Eqs. (4)–(7) yields

$$P\left(\sum_{i=1}^{m}X_i\tilde{G}_{it}>A_t\right)\leq\begin{cases}\frac{4}{9A_t}\left\{\left[\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\right]^2+\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})\right\} & \text{if } A_t>\lambda\\ 1-\frac{A_t}{\sqrt{3\left\{\left[\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\right]^2+\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})\right\}}} & \text{if } 0\leq A_t\leq\lambda\end{cases}\quad\text{for } t=1,2,\ldots,K \tag{10}$$

where

$$\lambda=2\sqrt{\frac{\left[\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\right]^2+\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})}{3}} \tag{11}$$

Under the safety first principle, instead of minimizing the left-hand side, the right-hand side of Eq. (10) is minimized, and following the CCGP framework

$$\frac{4}{9A_t}\left\{\left[\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\right]^2+\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})\right\}-\delta_{G_t}^{+}+\delta_{G_t}^{-}=\alpha\quad\text{if } A_t>\lambda\quad\text{for } t=1,2,\ldots,K \tag{12}$$

and

$$1-\frac{A_t}{\sqrt{3\left\{\left[\sum_{i=1}^{m}X_iE(\tilde{G}_{it})\right]^2+\sum_{i=1}^{m}X_i^2\sigma^2(\tilde{G}_{it})\right\}}}-\delta_{G_t}^{+}+\delta_{G_t}^{-}=\alpha\quad\text{if } 0\leq A_t\leq\lambda\quad\text{for } t=1,2,\ldots,K \tag{13}$$

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Table 1. ENPV Forecast of Qualified Projects (in IDR billion)

	Year											
#Project	0	1	2	3	4	5	6	7	8	9	10	ENPV @ 10%
1	−256.00	40.00	44.00	48.40	53.24	58.56	64.42	70.86	77.95	85.74	94.32	107.64
2	−415.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00				135.66
3	−200.00	56.00	60.48	65.32	70.54	76.19	82.28					91.90
4	−50.00	38.00	25.00	25.00	25.00	25.00						56.59
5	−225.00	58.00	63.00	68.00	73.00	78.00	83.00	88.00				121.18
6	−80.00	22.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00			50.65
7	−75.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00		74.73
8	−140.00	42.00	42.00	42.00	42.00	42.00	42.00					42.92
9	−175.00	40.00	42.00	44.10	46.31	48.62	51.05	53.60				47.35
10	−88.00	24.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00			57.74
11	−165.00	40.00	44.80	50.18	56.20	62.94	70.49					63.34
12	−100.00	42.00	44.52	47.19	50.02	53.02						77.52
13	−98.00	37.00	38.11	39.25	40.43	41.64	42.89					74.31
14	−118.00	28.00	25.00	27.50	27.50	30.25	30.25	33.28	33.28			36.02
15	−180.00	45.00	45.00	45.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	114.79

Table 2. FNPV Forecast of Qualified Projects (in IDR billion)

	Year												
# Project	0	1	2	3	4	5	6	7	8	9	10	r	FNPV
1	−256.00	35.00	38.50	42.35	46.59	51.24	56.37	62.00	68.21	75.03	82.53	11.0	46.83
2	−415.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00				14.0	24.19
3	−200.00	48.00	51.84	55.99	60.47	65.30	70.53					15.0	15.28
4	−50.00	25.00	25.00	25.00	25.00	25.00						13.5	36.87
5	−225.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00				18.0	10.41
6	−80.00	20.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00			20.0	11.76
7	−75.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00		25.0	1.19
8	−140.00	35.00	40.00	40.00	40.00	40.00	40.00					12.0	19.99
9	−175.00	38.00	39.90	41.90	43.99	46.19	48.50	50.92				12.0	22.33
10	−88.00	22.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00			14.0	25.34
11	−165.00	35.00	39.20	43.90	49.17	55.07	61.68					15.0	6.11
12	−100.00	40.00	42.40	44.94	47.64	50.50						16.0	45.14
13	−98.00	30.00	30.90	31.83	32.78	33.77	34.78					18.0	13.54
14	−118.00	25.00	25.00	27.50	27.50	30.25	30.25	33.28	33.28			15.0	7.95
15	−180.00	40.00	42.00	42.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	20.0	6.93

In the fiscal risk constraint, the goal is to minimize positive deviational variables. In a more complex situation, the annual budget-at-risk is stochastic. In this case, the Gauss inequality cannot be used, and one has recourse to the one-sided Chebyschev's inequality called Cantelli's inequality (Benzi et al. 2007). However, as with the Chebyschev's inequality, the Cantelli's gives a very rough approximation in the case in which the distribution is known (see Appendix 1).

Ultimate Objective

The ultimate objective of the government is to minimize the unwanted deviational variables

$$\min Z(\delta^{-}_{\mathrm{ENPV}}, \delta^{+}_{C}, \delta^{-}_{B}, \delta^{+}_{G_1}, \delta^{+}_{G_2}, \ldots \delta^{+}_{G_K}) \quad (14)$$

GP models can be classified into two subsets: weighted GP (WGP), and lexicographic GP (LGP). Under the WGP approach, the decision maker assigns weights to the deviational variables according to their relative importance and minimizes the weighted sum (or archimedian sum), whereas under the LGP, the decision maker sets the deviational variables into a number of priority levels and minimizes in a lexicographic sense [see detailed discussion in Tamiz et al. (1998)]. We adopted the former because the calculation can be performed in one sitting. In so doing, Eq. (14) can be rewritten as

$$\min Z = w_{\mathrm{ENPV}}\delta^{-}_{\mathrm{ENPV}} + w_C\delta^{+}_{C} + w_B\delta^{-}_{B} + \sum_{t=1}^{K} w_{G_t}\delta^{+}_{G_t} \quad (15)$$

where w_{ENPV} = relative weight for underachievement of ENPV target; w_C = relative weight for overachievement of expected total payment; w_B = relative weight for target underachievement of change in expected FNPV; and w_{G_t} = target overachievement of excess-payment-probability for period t. Another issue in using the GP approach is noncommensurability among the goals, i.e., the deviational variables are measured in different units but summed up directly, which can cause an unintentional bias toward

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Table 3. Input Data

Decision variable	Notation	Value
Expected payment in present value term	C	IDR 8 billion
Annual budget-at-risk	A_t	IDR 10 billion
Horizon period of guarantee program	K	10 years
Excess payment probability	α	5%
Weight decision for economic NPV	w_{ENPV}	5.00
Weight decision for expected guarantee payment	w_C	4.00
Weight decision for expected guarantee benefit	w_B	3.00
Weight decision for excess payment probability	$w_{G1},\ldots w_{G10}$	varied, decreasing from 1.00 (w_{G1}) to 0.55 (w_{G10}) at 0.05 interval

the objectives with a larger magnitude (Tamiz et al. 1998). Normalization by dividing the terms on the left-hand side of all the system constraints by the corresponding targets can be performed to solve the problem.

Optimization Model Revisited

With the left-hand side of the equations divided by the corresponding targets, the optimization model can be rewritten as follows:

$$\min Z^* = w_{\mathrm{ENPV}} d_{\mathrm{ENPV}}^- + w_C d_C^+ + w_B d_B^- + \sum_{t=1}^{K} w_{G_t} d_{G_t}^+ \quad (16)$$

Subject to

$$F_{\mathrm{ENPV}} - d_{\mathrm{ENPV}}^+ + d_{\mathrm{ENPV}}^- = 1 \quad (17)$$

$$F_C - d_C^+ + d_C^- = 1 \quad (18)$$

$$F_B - d_B^+ + d_B^- = 1 \quad (19)$$

$$\begin{aligned} & F_{G_t} - d_{G_t}^+ + d_{G_t}^- = 1 \quad \text{if } A_t > \lambda \quad \text{for } t = 1, 2, \ldots, K \\ & d_{\mathrm{ENPV}}^-, d_B^-, d_C^+, d_{G_1}^+, d_{G_2}^+, \ldots, d_{G_K}^+ \geq 0 \\ & X_1, X_2, \ldots, X_m = 0 \quad \text{or } 1 \end{aligned} \quad (20)$$

where

$$F_{\mathrm{ENPV}} = \frac{\sum_{i=1}^m X_i \mathrm{ENPV}_i}{\sum_{i=1}^m \mathrm{ENPV}_i} \quad (21)$$

$$F_C = \frac{\sum_{i=1}^m X_i E(\tilde{G}_i)}{C} \quad (22)$$

$$F_B = \frac{\sum_{i=1}^m \left[E(\widetilde{\mathrm{FNPV}}_i^*) - E(\widetilde{\mathrm{FNPV}}_i)\right] X_i}{\sum_{i=1}^m \left[E(\widetilde{\mathrm{FNPV}}_i^*) - E(\widetilde{\mathrm{FNPV}}_i)\right]} \quad (23)$$

$$F_{G_t} = \begin{cases} \frac{4}{9A_t\alpha}\left\{\left[\sum_{i=1}^m X_i E(\tilde{G}_{it})\right]^2 + \sum_{i=1}^m X_i^2 \sigma^2(\tilde{G}_{it})\right\} & \text{if } A_t > \lambda \\ \frac{1}{\alpha} - \frac{A_t}{\alpha\sqrt{3\left\{\left[\sum_{i=1}^m X_i E(\tilde{G}_{it})\right]^2 + \sum_{i=1}^m X_i^2 \sigma^2(\tilde{G}_{it})\right\}}} & \text{if } 0 \leq A_t \leq \lambda \end{cases} \quad \text{for } t = 1, 2, \ldots K \quad (24)$$

Numerical Example

For an illustration on the model application, without losing the generality of the model, a much-simplified hypothetical case is presented. Let us suppose that the Indonesian Ministry of Finance currently receives 15 proposals of BOT/PPP projects from different technical ministries that all call for minimum revenue guarantees [the interested reader can consult Wibowo (2004) for valuation of other types of guarantees]. In this case, the Ministry has to decide which projects can be guaranteed.

A preliminary analysis from the agency responsible for examining the project viability suggests that the 15 projects are both financially and economically viable (see Tables 1 and 2). The agency applies a 10% interest rate to evaluate the project ENPV but uses different rates depending on individual project risk to determine FNPV. The ENPV aggregate, if all of the projects are implemented is IDR 1,152.34 billions. We assumed that annual project revenue is normally distributed with a mean equal to the forecast, and the coefficient of variation taken as 20%. The market return is also assumed to obey a normal distribution with mean 25% and standard deviation 25%. The coefficient of correlation between project performance and market return is set at 0.8 for all projects.

Table 3 lists data on decision variables required for project selection. The weight decisions denote that the GoI assigns a higher priority for, in a descending order, over- or underachievement as follows: ENPV, expected total payment in present value terms, net change in FNPV, and annual excess payment probabilities. The weight decisions also reflect that the GoI puts less importance on more distant worst-scenario payments. Other information needed for model formulation is the expected benefit of guarantee,

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measured by net change (or increase) in FNPV and the expected guarantee cost for individual projects.

The uncertainties of the project i's FNPV without and with guarantee can be simply written as follows:

$$\widetilde{\text{FNPV}}_i = -I_{i0} + \sum_{t=1}^{T_i} \frac{\tilde{R}_{it}}{(1+r_i)^t}$$

where r_i = discount rate for project i; $\tilde{R}_{it}$ = revenue for project i for period t; I_{i0} = investment cost for project i; and t_i = concession period for project i and

$$\widetilde{\text{FNPV}}_i^* = -I_{i0} + \sum_{t=1}^{T_i} \frac{\tilde{R}_{it} + \tilde{G}_{it}}{(1+r_i)^t}$$

where

$$\tilde{G}_{it} = \begin{cases} 0 & \text{if } \tilde{R}_{it} > R_{it}^g \\ R_{it}^g - \tilde{R}_{it} & \text{if } \tilde{R}_{it} \leq R_{it}^g \end{cases}$$

where $\tilde{G}_{it}$ = guarantee payment made for project i for period t; and R_{it}^g = minimum guaranteed level for project i for period t. We assumed that the discount rate used for evaluating FNPV after guarantee is the same discount rate applied for evaluating FNPV before guarantee. The government payment in present value terms for project i can be modeled as follows:

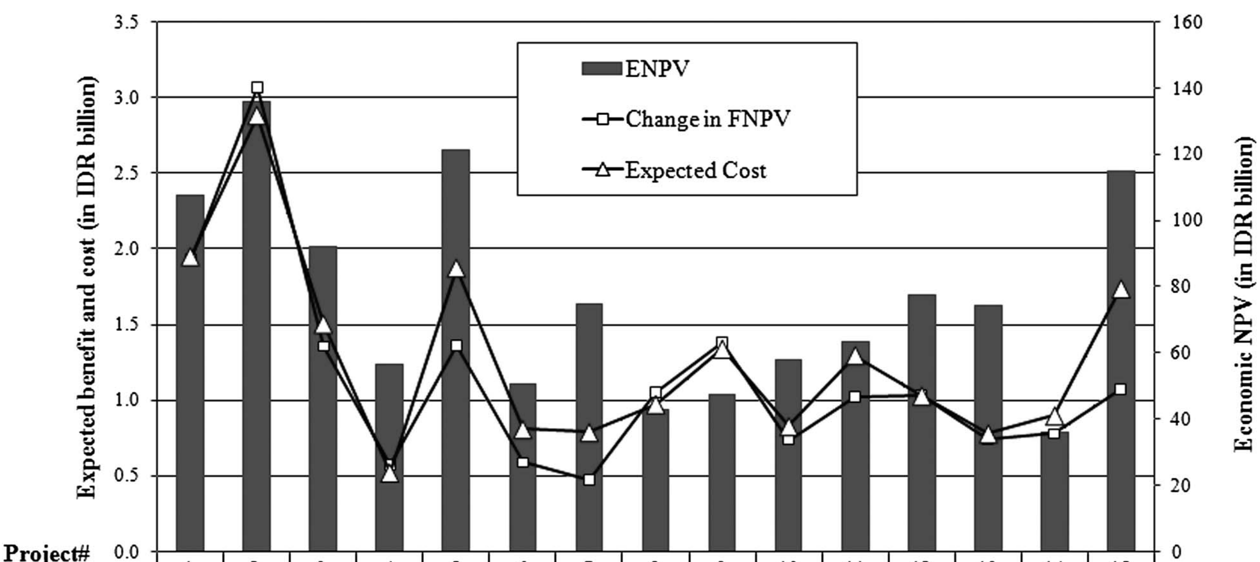
$$\tilde{G}_i = \sum_{t=1}^{T_i} \frac{\tilde{G}_{it}}{(1+r_g)^t}$$

where r_g = discount rate for guarantee payments, which is assumed to be 10%. To simplify the problem, the minimum guaranteed revenue is uniformly set at 70% of the forecast over the concession period for all projects. This level is chosen with the argument that the typical debt-to-equity ratio for infrastructure projects is 70/30, so as to a avoid moral hazard of private equity investors. Under a minimum guarantee scheme, if actual revenue turns out to be lower than the minimum guaranteed level, the government will make up the difference; otherwise, the government pays nothing. We performed a Monte Carlo based simulation with 1,000 iterations using Crystal Ball software to obtain some statistics of FNPV and guarantee payment distributions required for model development. Fig. 1 depicts the expected change in FNPV and expected guarantee payment (cost) of individual projects along with their deterministic ENPV. The total net change in FNPV if all projects are implemented is IDR 17.19 billion.

The optimization problem involves one ultimate objective function and 13 constraints with 15 primary variables (Xs) and 24 deviational variables (see Appendix 2). We used Solver Add-In for Excel to solve the problem and came up with a solution that only eight of 15 projects are selected, namely, project #1, project #4, project #6, project #7, project #8, project #10, project #12, and project #13, that together generate ENPV = IDR 542.10 billion ($F_{\text{ENPV}} = 0.47$), the expected change in FNPV = IDR 7.15 billion ($F_B = 0.42$), and the expected payment = IDR 7.67 billion ($F_C = 0.96$). The upper thresholds of the probabilities of excess payment for year 1–10 are 0.036 ($F_{G_1} = 0.72$); 0.043 ($F_{G_2} = 0.86$); 0.049 ($F_{G_3} = 0.97$); 0.047 ($F_{G_4} = 0.94$); 0.047 ($F_{G_5} = 0.95$); 0.035 ($F_{G_6} = 0.70$); 0.022 ($F_{G_7} = 0.44$); 0.038 ($F_{G_8} = 0.77$); 0.030 ($F_{G_9} = 0.61$); and 0.020 ($F_{G_{10}} = 0.40$), respectively, and they all are below the specified level of 0.05.

Pareto Optimality Test

In the field of risk management, risk allocation between two agents is said to be Pareto optimal or efficient when one or more agents is better off, with none being worse off. In a GP environment, Pareto optimality is defined as the state in which no objective can be improved without degrading another objective (Tamiz et al. 1999). To investigate whether the already obtained solution has been Pareto efficient, we ran a Pareto optimality test using the methodology introduced by Masud and Hwang (1981) by maximizing the *wanted* deviational variables, subject to the condition that the



Project#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ENPV	107.6	135.7	91.9	56.6	121.2	50.6	74.7	42.9	47.3	57.7	63.3	77.5	74.3	36.0	114.8
Change in FNPV	1.93	3.06	1.36	0.57	1.36	0.59	0.47	1.06	1.38	0.74	1.02	1.03	0.75	0.78	1.08
Expected Cost	1.95	2.88	1.50	0.52	1.87	0.81	0.79	0.97	1.34	0.83	1.30	1.03	0.78	0.90	1.73

Fig. 1. Impact of guarantee on individual project

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Table 4. Goal Achievements under Different Scenarios of α, A_t, and C

		$A_t = 5$			$A_t = 10$			$A_t = 15$			$A_t = 20$		
α	C	G_1	G_2	G_3	G_1	G_2	G_3	G_1	G_2	G_3	G_1	G_2	G_3
0.01	10	206	1.80	2.09	206	1.80	2.09	206	1.80	2.09	206	1.80	2.09
	15	350	3.91	4.62	350	3.91	4.62	350	3.91	4.62	350	3.91	4.62
	20	392	4.16	4.75	499	6.09	6.70	499	6.09	6.70	499	6.09	6.70
0.05	10	392	4.16	4.75	614	7.16	8.43	614	7.16	8.43	614	7.16	8.43
	15	392	4.16	4.75	712	8.81	10.07	953	13.10	15.02	953	13.10	15.02
	20	392	4.16	4.75	712	8.81	10.07	1,042	14.78	16.56	1,152	17.19	19.19
0.10	10	392	4.16	4.75	712	8.81	10.07	832	11.74	13.14	832	11.74	13.14
	15	392	4.16	4.75	712	8.81	10.07	1,089	16.17	17.90	1,152	17.19	19.19
	20	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
0.25	10	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
	15	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
	20	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
0.50	10	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
	15	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19
	20	392	4.16	4.75	712	8.81	10.07	1,152	17.19	19.19	1,152	17.19	19.19

Note: G_1 = economic NPV; G_2 = net change in financial NPV; G_3 = expected guarantee payment. All figures are in IDR billions except for α.

resulting achievements must be at least at the same level of the prior achievements, or

$$\max Z^{**} = w_{\mathrm{ENPV}} d^{+}_{\mathrm{ENPV}} + w_C d^{-}_C + w_B d^{+}_B + \sum_{t=1}^{K} w_{G_t} d^{+}_{G_t}$$

subject to

$$F_{\mathrm{ENPV}} \geq 0.47; \quad F_B \geq 0.52; \quad F_C \leq 0.96; \quad F_{G_1} \leq 0.72;$$
$$F_{G_2} \leq 0.86; \quad F_{G_3} \leq 0.97; \quad F_{G_4} \leq 0.94; \quad F_{G_5} \leq 0.95;$$
$$F_{G_6} \leq 0.70; \quad F_{G_7} \leq 0.44; \quad F_{G_8} \leq 0.77; \quad F_{G_9} \leq 0.61;$$
$$F_{G_{10}} \leq 0.40$$

with all other system constraints maintained. The optimality test revealed that the prior solution had been Pareto optimal, implying that no further improvement can be made.

Alternative Scenarios

If the government only cares about the total ENPV and the probability of budget-at-risk being exceeded, the weights for other goals (w_C and w_B) can be simply set at zero and the system recalculated. The solution of this new scenario is that the total ENPV is increased from IDR 542.10 to IDR 613.97 billion by replacing project #8 with project #15, with the other projects retained. Other scenarios can also be built by modifying the weights or the requirements. Table 4 presents a set of optimal solutions under different scenarios of annual budget-at-risk (A_t), risk tolerance level (α), and the expected guarantee payment in *present value terms* (C).

Table 4 conveys much information on the decision variables relationships. For instance, all projects can only be accepted to generate the possible maximum ENPV (IDR 1,152 billion) if the government is willing to (1) allocate an annual budget-at-risk in the amount of IDR 20 billion; (2) to accept a 95% probability that actual payment will not exceed the budget-at-risk; and (3) is prepared to bear the expected total payment of IDR 20 billion. Alternatively, for an equal annual budget-at-risk of IDR 20 billion, the government may only expect guarantee payment of IDR 15 billion, instead of 20 billion, given that the government does not have a problem with relaxing the confidence level from 95% to 90% to accept all projects.

Being a more risk-averse agency, the GoI may impose a more stringent requirement on risk tolerance at, for example $\alpha = 1\%$. In this case, the maximum achievable ENPV is IDR 499 billion, generated from accepting project #1, project #4, project #6, project #7, project #10, project #12, and project #13 (not presented here to limit the length of the paper). For an equal expected payment ($C = 20$) and $\alpha = 1\%$, it is unnecessary to allot the annual budget-at-risk greater than IDR 10 billion to have the same effect. On the contrary, if the GoI behaves more like a risk-seeking agency in the sense that the GoI is willing to assume higher fiscal risk, with an expected total payment of only IDR 15 billion and annual budget-at-risk of IDR 20 billion, the GoI can accept all projects but must tolerate an excess-payment-probability of 10%. In a more extreme case, the GoI can even accept all projects with an expected total payment of only IDR 10 billion and annual budget-at-risk of IDR 15 billion but must be very tolerant of high risk ($\alpha = 25\%$) of the allocated budget-at-risk being insufficient to cover actual payment. There remain countless combinations of alternative scenarios the GoI can compare to choose the one that will deliver the highest value for the money.

The main challenge of implementing the methodology in practice centers on the skills of government officials in identifying and quantifying the risk of incoming projects to be selected, as well as any contingent liability the government may incur in issuing the guarantees. Risk and contingent liability analysis require robust knowledge, research, and resources to solve technical and sometimes sophisticated mathematical problems. Estimating the risk parameters required as inputs in the model application is trivial, because many commercial software packages are available on the market, but solving the problem of how to model and characterize the risk is not. In the short run, the government might be advised to hire professionals and experts to help assess the project risk while continuing to build the capabilities of officials through in- and out-of-house trainings. This is the approach adopted by the GoI.

Study Limitation and Future Work

The proposed methodology attempts to capture as many practical and relevant issues as possible in a guarantee portfolio problem. Nevertheless, the methodology has several limitations in its use. For example, an annual budget-at-risk should not be idle because

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an idle asset may represent a loss of opportunity to the GoI. Unless prohibited by law, the money can be invested in liquid risk-free securities to generate income for the fund, thus helping to reduce the fiscal burden. This asset allocation is not discussed in the present study.

This numerical example has shown that a number of economically viable projects may be excluded from the guarantee portfolio because of a limited budget. Provided that the key assumptions and parameters have been adjusted accordingly, these projects should again be candidates for inclusion in the next period of evaluation. Hence, every year, the GoI may receive a set of new request-for-guarantee proposals, including those not accepted in the previous year, and they will again have to decide which project(s) will be selected. The fiscal space available for incoming projects must, therefore, take into account the contingent liabilities emanating from the previous year's decisions. In this sense, the yearly guarantee program as discussed in the present paper may only represent a subset of a broader national government program. The methodology used in this study is also promising in that it can be extended to find the optimal level of guarantee to be provided for an individual project, which is beyond the scope of the present study. All these problems leave interesting future research venues.

Conclusions

Government guarantee provision in privately financed infrastructure projects under public-private-partnership arrangements is not uncommon. The present paper discusses the project selection methodology under conditions of budget and risk in the Indonesian context by using the chance-constrained goal-programming technique. The relevant issues raised in this paper include fiscal space, expected cost and benefit of guarantee, and probability of excess payment. The objective is to obtain a portfolio of guaranteed projects that brings the maximum welfare gain to the economy as a whole and net change in net present value, but at the same time puts the government at the lowest fiscal risk under a budgetary constraint. The methodology was applied to a much-simplified hypothetical case for illustration purposes. A set of different scenarios were also presented and, based on the scenario analysis, the government can compare two or more sets of scenarios and choose which one would deliver the highest value for the money.

Appendix I

Rewriting Eq. (4) with α = upper bound and $\tilde{A}_t$ = stochastic variable yields

$$P\left(\sum_{i=1}^{m} X_i \tilde{G}_{it} > \tilde{A}_t\right) \leq \alpha \tag{25}$$

Or

$$P\left(\sum_{i=1}^{m} X_i \tilde{G}_{it} - \tilde{A}_t > 0\right) \leq \alpha \tag{26}$$

Let $E(\tilde{A}_t)$ and $\sigma(\tilde{A}_t)$ = expected budget-at-risk for period t and standard deviation of budget-at-risk for period t, respectively. Eq. (26) can be rearranged by adding both left- and right-hand side terms in the bracket with $E(\tilde{A}_t)$

$$P\left[\sum_{i=1}^{m} X_i \tilde{G}_{it} - \tilde{A}_t + E(\tilde{A}_t) > E(\tilde{A}_t)\right] \leq \alpha \tag{27}$$

and let

$$\tilde{Q}_t = \sum_{i=1}^{m} X_i \tilde{G}_{it} - \tilde{A}_t + E(\tilde{A}_t) \tag{28}$$

For the sake of simplicity, an independency between variables is assumed

$$E(\tilde{Q}_t) = \sum_{i=1}^{m} X_i E(\tilde{A}_t) \tag{29}$$

$$\sigma^2(\tilde{Q}_t) = \sum_{i=1}^{m} X_i^2 \sigma^2(\tilde{G}_{it}) + \sigma^2(\tilde{A}_t) \tag{30}$$

The problem here is that neither zero-modal distribution nor unimodal distribution for $\tilde{Q}_t$ can be conveniently assumed and, accordingly, the Gauss inequality cannot be safely applied. Alternatively, one can use the so-called Cantelli's inequality, which states, for any $\beta > 0$

$$P\left[\tilde{Q}_t - E(\tilde{Q}_t) \geq \beta\sigma(\tilde{Q}_t)\right] \leq \frac{1}{1+\beta^2} \tag{31}$$

which is equal to

$$P\left[\tilde{Q}_t \geq E(\tilde{Q}_t) + \beta\sigma(\tilde{Q}_t)\right] \leq \frac{1}{1+\beta^2} \tag{32}$$

Setting $E(\tilde{A}_t) = E(\tilde{Q}_t) + \beta\sigma(\tilde{Q}_t)$ and rearranging Eq. (32)

$$P\left[\tilde{Q}_t \geq E(\tilde{A}_t)\right] \leq \frac{1}{1+\left[\frac{E(\tilde{A}_t)-E(\tilde{Q}_t)}{\sigma(\tilde{Q}_t)}\right]^2} \tag{33}$$

The concept of the safety first principle can now be used, and the resulting equations can be incorporated into the system constraints.

Appendix II

$$\min Z = 5d^-_{\mathrm{ENPV}} + 4d^+_C + 3d^-_B + d^+_{G_1} + 0.95d^+_{G_2} + 0.90d^+_{G_3} + 0.85d^+_{G_4} + 0.80d^+_{G_5} + 0.75d^+_{G_6} + 070d^+_{G_7} + 0.65d^+_{G_8} + 0.60d^+_{G_9} + 0.55d^+_{G_{10}} \text{ subject to}$$

$$\begin{aligned}\frac{1}{1152.34}&(107.64X_1 + 135.66X_2 + 91.90X_3 + 56.59X_4\\ &+ 121.18X_5 + 50.65X_6 + 74.73X_7 + 42.92X_8 + 47.35X_9\\ &+ 57.74X_{10} + 63.34X_{11} + 77.31X_{12} + 74.31X_{13} + 36.02X_{14}\\ &+ 114.79X_{15}) - d^+_{\mathrm{ENPV}} + d^-_{\mathrm{ENPV}}\\ &= 1.00\end{aligned}$$

$$\begin{aligned}\frac{1}{8}&(1.95X_1 + 2.88X_2 + 1.50X_3 + 0.52X_4 + 1.87X_5 + 0.81X_6\\ &+ 0.79X_7 + 0.97X_8 + 1.34X_9 + 0.83X_{10} + 1.30X_{11} + 1.03X_{12}\\ &+ 0.78X_{13} + 0.90X_{14} + 1.73X_{15}) - d^+_C + d^-_C\\ &= 1.00\end{aligned}$$

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$$\frac{1}{17.19}(1.93X_1 + 3.06X_2 + 1.36X_3 + 0.57X_4 + 1.36X_5 + 0.59X_6 + 0.47X_7 + 1.06X_8 + 1.38X_9 + 0.74X_{10} + 1.02X_{11} + 1.03X_{12} + 0.75X_{13} + 0.78X_{14} + 1.08X_{15}) - d_B^+ + d_B^- = 1.00$$

$$0.89[(0.23X_1 + 0.43X_2 + 0.26X_3 + 0.16X_4 + 0.29X_5 + 0.11X_6 + 0.15X_7 + 0.19X_8 + 0.19X_9 + 0.12X_{10} + 0.23X_{11} + 0.25X_{12} + 0.16X_{13} + 0.16X_{14} + 0.27X_{15})^2 + 1.06X_1^2 + 4.65X_2^2 + 1.68X_3^2 + 0.61X_4^2 + 2.58X_5^2 + 0.24X_6^2 + 0.54X_7^2 + 0.86X_8^2 + 0.99X_9^2 + 0.42X_{10}^2 + 1.45X_{11}^2 + 1.71X_{12}^2 + 0.82X_{13}^2 + 0.57X_{14}^2 + 1.63X_{15}^2] - d_{G_1}^+ + d_{G_1}^- = 1$$

$$0.89[(0.24X_1 + 0.63X_2 + 0.29X_3 + 0.12X_4 + 0.34X_5 + 0.16X_6 + 0.12X_7 + 0.26X_8 + 0.27X_9 + 0.17X_{10} + 0.27X_{11} + 0.27X_{12} + 0.15X_{13} + 0.14X_{14} + 0.24X_{15})^2 + 1.11X_1^2 + 11.89X_2^2 + 2.29X_3^2 + 0.39X_4^2 + 3.26X_5^2 + 0.61X_6^2 + 0.37X_7^2 + 1.56X_8^2 + 1.45X_9^2 + 0.64X_{10}^2 + 1.68X_{11}^2 + 2.11X_{12}^2 + 0.69X_{13}^2 + 0.47X_{14}^2 + 1.48X_{15}^2] - d_{G_2}^+ + d_{G_2}^- = 1$$

$$0.89[(0.34X_1 + 0.57X_2 + 0.33X_3 + 0.15X_4 + 0.32X_5 + 0.18X_6 + 0.14X_7 + 0.23X_8 + 0.25X_9 + 0.17X_{10} + 0.25X_{11} + 0.27X_{12} + 0.17X_{13} + 0.15X_{14} + 0.27X_{15})^2 + 2.37X_1^2 + 8.14X_2^2 + 3.00X_3^2 + 0.67X_4^2 + 2.39X_5^2 + 0.71X_6^2 + 0.40X_7^2 + 1.14X_8^2 + 1.71X_9^2 + 0.61X_{10}^2 + 1.61X_{11}^2 + 1.59X_{12}^2 + 0.76X_{13}^2 + 0.59X_{14}^2 + 1.73X_{15}^2] - d_{G_3}^+ + d_{G_3}^- = 1$$

$$0.89[(0.29X_1 + 0.60X_2 + 0.34X_3 + 0.12X_4 + 0.47X_5 + 0.16X_6 + 0.14X_7 + 0.23X_8 + 0.33X_9 + 0.16X_{10} + 0.33X_{11} + 0.26X_{12} + 0.20X_{13} + 0.17X_{14} + 0.24X_{15})^2 + 1.75X_1^2 + 8.58X_2^2 + 2.72X_3^2 + 0.33X_4^2 + 4.01X_5^2 + 0.74X_6^2 + 0.45X_7^2 + 1.53X_8^2 + 2.40X_9^2 + 0.52X_{10}^2 + 2.73X_{11}^2 + 1.89X_{12}^2 + 0.92X_{13}^2 + 0.79X_{14}^2 + 2.05X_{15}^2] - d_{G_4}^+ + d_{G_4}^- = 1$$

$$0.89[(0.28X_1 + 0.65X_2 + 0.42X_3 + 0.12X_4 + 0.48X_5 + 0.16X_6 + 0.14X_7 + 0.19X_8 + 0.31X_9 + 0.14X_{10} + 0.38X_{11} + 0.31X_{12} + 0.21X_{13} + 0.23X_{14} + 0.30X_{15})^2 + 2.02X_1^2 + 9.59X_2^2 + 3.45X_3^2 + 0.37X_4^2 + 5.81X_5^2 + 0.60X_6^2 + 0.49X_7^2 + 1.02X_8^2 + 2.18X_9^2 + 0.54X_{10}^2 + 3.46X_{11}^2 + 2.19X_{12}^2 + 1.00X_{13}^2 + 1.16X_{14}^2 + 2.38X_{15}^2] - d_{G_5}^+ + d_{G_5}^- = 1$$

$$0.89[(0.29X_1 + 0.71X_2 + 0.51X_3 + 0.39X_5 + 0.17X_6 + 0.13X_7 + 0.25X_8 + 0.29X_9 + 0.13X_{10} + 0.38X_{11} + 0.21X_{13} + 0.13X_{14} + 0.30X_{15})^2 + 2.28X_1^2 + 13.73X_2^2 + 6.00X_3^2 + 4.80X_5^2 + 0.57X_6^2 + 0.51X_7^2 + 1.51X_8^2 + 1.69X_9^2 + 0.50X_{10}^2 + 3.60X_{11}^2 + 1.12X_{13}^2 + 0.46X_{14}^2 + 1.88X_{15}^2] - d_{G_6}^+ + d_{G_6}^- = 1$$

$$0.89[(0.32X_1 + 0.62X_2 + 0.47X_5 + 0.14X_6 + 0.15X_7 + 0.34X_9 + 0.15X_{10} + 0.21X_{14} + 0.31X_{15})^2 + 2.91X_1^2 + 10.04X_2^2 + 5.43X_5^2 + 0.45X_6^2 + 0.48X_7^2 + 3.25X_9^2 + 0.55X_{10}^2 + 1.00X_{14}^2 + 2.09X_{15}^2] - d_{G_7}^+ + d_{G_7}^- = 1$$

$$0.89[(0.48X_1 + 0.14X_6 + 0.12X_7 + 0.19X_{10} + 0.19X_{14} + 0.34X_{15})^2 + 6.08X_1^2 + 0.57X_6^2 + 0.35X_7^2 + 0.79X_{10}^2 + 0.96X_{14}^2 + 2.45X_{15}^2] - d_{G_8}^+ + d_{G_8}^- = 1$$

$$0.89[(0.51X_1 + 0.15X_7 + 0.30X_{15})^2 + 5.85X_1^2 + 0.55X_7^2 + 2.21X_{15}^2] - d_{G_9}^+ + d_{G_9}^- = 1$$

$$0.89[(0.41X_1 + 0.29X_{15})^2 + 4.29X_1^2 + 2.22X_{15}^2] - d_{G_{10}}^+ + d_{G_{10}}^- = 1$$

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