Treatment of Uncertainty in Input Variables for a Net Present Value computation for a New Research Survey Vessel Investment Appraisal

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Abstract

This paper presents a Net Present Value (NPV) analysis for the replacement of Research Vessel (RV) Africana, South Africa's primary platform for marine living resources research. The analysis employs a simulation-based approach to evaluate project viability, future Total Allowable Catches (TACs) for 13 key species derived from the Operational Management Procedure (OMP) for hake and sampled from uniform distribution for other species, based on historical catch distributions, operational survey costs, and revenue streams from both levies and taxation. Future TACs are projected over a 49-year horizon.

Revenue projections combine levy income based on gazetted prices and tax collections derived from bootstrap resampling of 16 years of historical data. The NPV calculations consider an initial investment of R1 billion and evaluate three discount rate scenarios: 12% (reflecting long-term government bond yields), 8%(as a suggestion for appraising public sector projects) and 18% (representing a conservative cost of capital estimates). Only survey costs are considered in this analysis other relevant costs such as vessel management and insurance are not considered yet. Survey costs also do not take inflation into account to adjust for future costs.

Results demonstrate positive NPV distributions under all three discount rate assumptions, indicating project viability. At 8% discount rate, the analysis yields favourable returns, while the 18% scenario, though more conservative, still supports justification of the investment. This framework could form the basis for further refined analysis incorporating vessel design specifications, all relevant operational parameters such management costs, inflation on costs, levy adjustments and realistic asset lifecycle considerations.

1. Introduction

The Department of Forestry, Fisheries and Environment (DFFE) is currently considering a major strategic decision to replace Research Vessel (RV) Africana, which serves as the primary platform for conducting research on living marine resources in South Africa. A detailed business case is being prepared to investigate the optimal investment option among available alternatives, considering all relevant information. This comprehensive proposal will be evaluated by the South African National Treasury as the basis for capital budget allocation, competing against other national priorities. Future Total Allowable Catches (TACs), derived from the mathematical modelling conducted annually by DFFE, are foundational to understanding how future revenue into the Marine Living Resource Fund will evolve and how future costs will impact the planning for acquisition of the new vessel.

To evaluate the prospect of vessel acquisition, the National Treasury applies several criteria to determine project viability as well as the value to the fiscus. Net Present Value (NPV) is a priority criterion for evaluating all mega projects—typically those requiring more than R400 million per year for at least three years, or those requiring at least R1 billion for implementation. Such mega projects demand comprehensive analysis informed by available data as the basis for decision-making, and any proposal undergoes rigorous scrutiny by the National Treasury.

2. Methods

This analysis focuses on the required inputs for NPV calculations: initial investment, annual future cash flows over the project lifetime, and discount rates representing the cost of capital for asset acquisition. Future cash flows depend on the trajectory of future TACs and assumptions regarding future vessel operational costs. A simulation approach is employed to calculate the NPV of the new vessel, with inputs based on future revenue projections and assumed operational costs.

2.1. Future Total Allowable Catches (TACs)

RV Africana monitors more than 100 species; however, this analysis focuses on 13 species only with associated price levies (**Table 1**). TACs for major species are established through Operation Management Procedures (OMPs), while some species use integrated stock assessments that enable understanding of TAC trajectories over extended periods or appropriate effort levels for catch quotas. For the purposes of this study on hake TAC was derived from an OMP. Species with assessments that allow only short-term TAC setting, such as bycatch species, are assumed to maintain catches consistent with previous years. For species without assessments, ranges of previous catches are used to generate future catch projections. These future catches form the basis for future revenues derived from levies (see **Tables 1 & 2**).

Table 1: Indicates species considered when cash flows from levies are computed

Sector	Species	Levy rate per ton
Small pelagic	Sardine	R58,00
Small pelagic	Round herring	R17,00
Small pelagic	Anchovy	R17,00
Small pelagic	Horse mackerel	R17,00
Small pelagic	Monk	R17,00
Small pelagic	Meso pelagic	R17,00
Demersal	Robbinfish	R22,00
Demersal	Squid	R427,00
Demersal	Hake	R227,00
Demersal	Kingklip	R349,00
Demersal	Horse Mackerel	R19,00
Demersal	Snoek	R27,00
Demersal	Monkfish	R230,00
Demersal	Sole	R345,00

(**Source**: Government Gazette, 10 September 2010)

2.1.1. Computation of future hake TACs from hake OMP22

Ross-Gillespie and Butterworth (2024) present Operational Management Procedure (OMP) projection calculations for the catch per unit effort (CPUE) and survey indices of both hake species, derived from reference set models for the West and South Coasts (Figures 1 and 2).

For each of the 1000 simulations in the OMP, future survey indices are generated through a multi-step process. First, exploitable biomass is calculated for each survey and year using the survey selectivities estimated by the assessment models. This biomass is then multiplied by the survey catchability coefficient estimated by the models and an error term. The error term comprises two components: a fixed variance term based on historical survey variance and an additional variance term estimated within the assessment models. Future CPUE indices are generated analogously by multiplying the predicted exploitable biomass by the catchability coefficients estimated by the assessment models and applying an error term based on the model-predicted CPUE variance (A. Ross-Gillespie, *pers. Comm*).

These projected indices serve as the foundational inputs for calculating future Total Allowable Catches (TACs) for the hake species, as defined by the OMP formulae in equations 3 to 6 of the paper. The OMP's tuning parameters, J_0^{spp} and b^{spp}, are set as constants: 88.02 and -0.268 for *M. paradoxus*, and 35 and -0.160 for *M. capensis*.

The projection time horizon spans from 2026 to 2074. For each year within this period, a set of 1,000 TAC values is generated. The annual average of these 1,000 TACs is then computed, and this averaged value is used to determine the expected levy revenue for the corresponding year. An upper cap of 160,000 tonnes is applied to the TAC, ensuring it cannot exceed this threshold.

Table 2: Indicates the sources of the future catches, in all cases future catches are sampled from the uniform distribution and hake TACs from OMP22.

Species as per levy Table 1	**Future catches (tonnes)**	**Source of future catch**	**Period to the future**
Anchovy	~U (100 000, 120 000)	Historical TAC constraint landings (OMP should be used)	49 years
Sardine	~U (20 000, 120 000)	Historical TAC constraint landings (OMP should be used)	49 years
Round herring	~U (70 000, 120 000)	Historical landings (Assessment models could be used)	49 years
Chub mackerel	~U (20, 650)	From historical landings	49 years
Meso pelagic	~ U(5, 100)	Historical landings	49 years
Hake	OMP	OMP (future catches are averaged over a range of outputs)	49 years
Horse mackerel	~(5000, 15 000)	Historical landings (previous TACs are from models)	49 years
Squid	~U(2000, 12 000)	Historical landings (previous TAEs are from models)	49 years
Kingklip	~U(2000, 4500)	Historical landings (previous TACs are from models)	49 years
Monk	~U(3000, 11 000)	Historical landings (previous TACs are from models)	49 years
Ribbon fish	~U (100, 200)	Historical landings	49 years
Sole	~U (0, 800)	Historical landings (previous TACs are from models)	49 years
Snoek	~ U(100, 2000)	Historical landings	49 years

2.2. Future surveys and associated costs

The key future running costs of operating a vessel would be those coming from future surveys. Future sea days assumed in this analysis are given in Table 3 and associated costs per day assumed are also given. Other important surveys such as those for horse mackerel, squid and other ad hoc surveys are not included in this analysis yet.

Table 3: Future surveys for hake and small pelagic species, other surveys are not included in this analysis.

survey	time	survey name	days
demersal	January	west coast	~U(35,45)
	March	south coast	~U(35,45)
	July	winter	~U(35,45)
	September	spring	~U(35,45)
small pelagic	November	spawner biomass	~U(40,50)
	May/April	recruitment surveys	~U(40,50)

Cost per survey per day is $Co_{surv,y}\ is \sim U(180\ 000,\ 200\ 000)$ Rands per day ....(1).

These costs are not adjusted for inflation into the future and other relevant costs that still need to be included are vessel management and insurance costs. These costs will be included for the next revision of this analysis after consideration of the overall vessel fleet costs.

2.3. Future cash flows

Revenue collected by the state comprises two components, a levy based on unprocessed landed tonnage and tax collection from companies following value addition through industrial processing. Revenue from levies uses current gazetted prices per tonne for each species monitored by RV Africana, as listed in **Table 1**.

Revenue from taxation is assumed to originate from tax-paying entities that depend on species monitored by RV Africana. Ignoring the sector in which each entity operates, the rand value paid by the i^{th}entity in year y is as follows:

$\{X_{1,y}, X_{2,y}, X_{3,y} \ldots X_{i,y} .. X_{n,y}\}$. .... (2)

Annual tax collections from all entities in year y

$X_y = \sum_{i=1}^{n,y} X_{i,y}$ where $y = \{1,2,3, \ldots ,16\}$ .... (3)

The set of annual taxes for 16 years are as follows

$P = \{X_1, X_2, X_3, \ldots .., X_{16}\}$ when they are plotted, they produce Figure 1. ....(4)

Sampling set P with replacement 30 times to calculate a single mean and repeating the process 300 times produces the following set

$\boldsymbol{S} = \{\bar{X}_1^s, \bar{X}_2^s, \bar{X}_3^s, \ldots , \bar{X}_{300}^s\}$ when $\bar{X}_i^s \in \boldsymbol{S}$ is the mean of 30 observations. ....(5)

Future taxes are then sampled from the following normal distribution:

$Re^{taxes} \sim N(\mu_{\bar{S}}\ , \sigma_{\bar{S}})$ where $\mu_{\bar{S}}$ is a mean of means making up set $\boldsymbol{S}$ and $\sigma_{\bar{S}}$ an associated standard deviation. ....(6)

Total revenue is the sum from the levies and tax revenues.

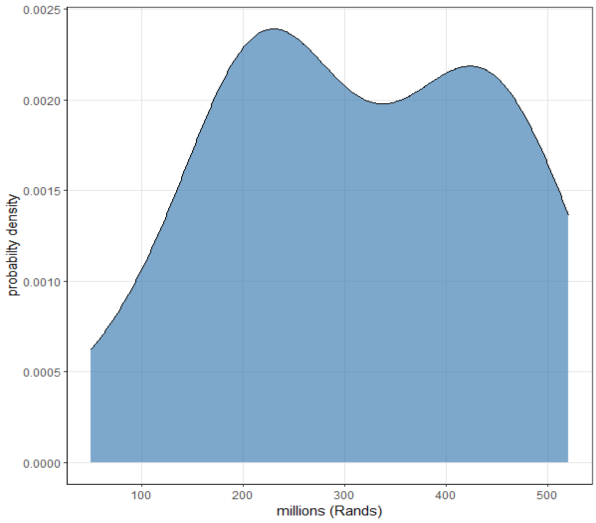


Figure 1: An assumed distribution of revenue collected by National Treasury over 16 years from industries reliant on species monitored by RV Africana

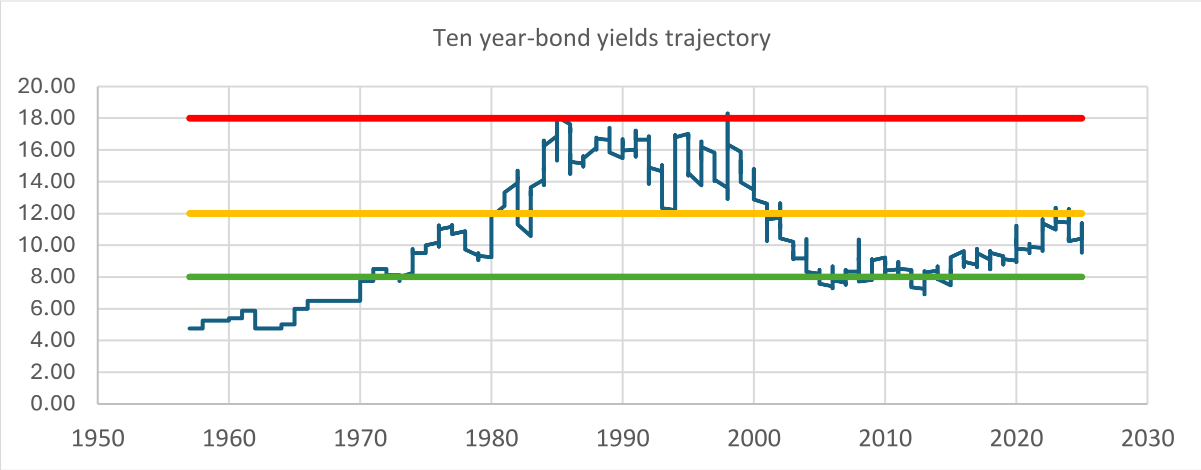
2.4. Interest rates

Discount rates used to appraise government projects are usually standardized such that the same rate is usually used to facilitate comparability across the different projects competing for funding. Three levels of Interest rates are considered in this analysis an 18% level which is considered highly unrealistic as the cost of capital that can be paid by South Africa Government which is set almost above 10 year bond yields trajectory since 1957, a 12% level which is closer to the yields paid on the longest South African bond (31 year bond) and 8% rate which is close to what is set for Public Sector Projects (see **Figures 1-2** and **Table 4**). To demonstrate the scale of the three rates plots are provided that compares them to ten-year yields and the prime rates trajectories over time (**Figures 1&2**). Ten-year yields approximates costs of government borrowing for the longer term and prime rates is the base rates used by commercial banks for lending ton individuals and companies.

Table 4: South African Government bonds of different periods and associated yields (in colour) which is proxy for the cost of borrowing for longer lived projects.

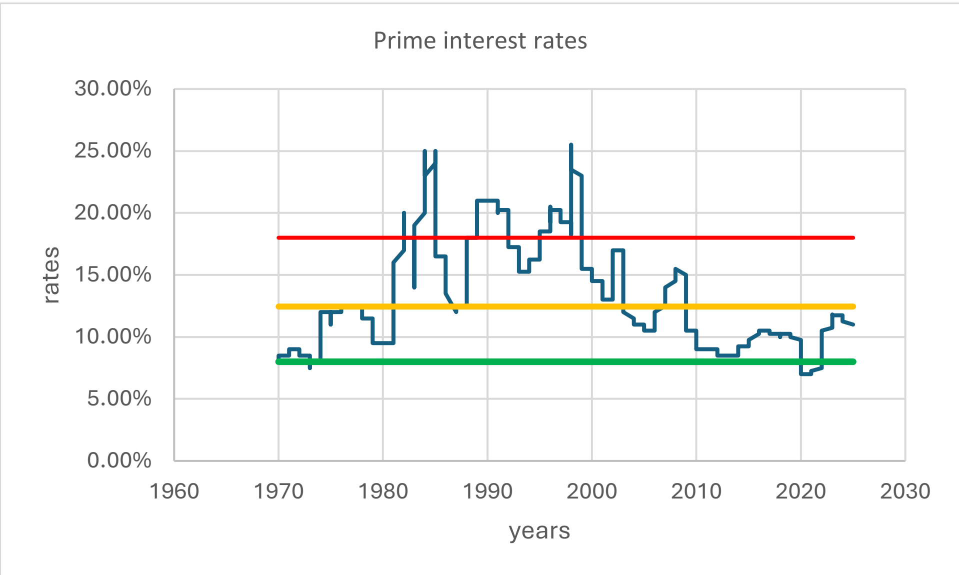
Bond Code	Coupon Rate	Aproximate Yield to Maturity	Maturity Date	Approximate Years to Maturity
R2 030	8,00%	10,80%	21-Dec-30	~7 years
R2 033	7,00%	11,20%	31-Mar-33	~9 years
R2 035	8,25%	11,50%	28-Feb-35	~11 years
R2 040	5,50%	12,00%	28-Feb-40	~16 years
R2 048	7,75%	12,20%	28-Feb-48	~24 years
R2 052	8,00%	12,30%	31-Mar-52	~28 years
R2 055	6,25%	12,45%	28-Feb-55	~31 years

(**Source**: National Treasury and JSE debt market)



(**Source**: Organization for Economic Co-operation and Development (OECD))

Figure 2: Trajectory of 10-year bond government bond from 1957 to 2025, with the lines representing discount rate used in this study, red is 18% and the orange line representing 12.45% for the 31-year bond and the green line representing 8% usually used for public projects.



(**Source**: SA Reserve Bank and World Bank)

Figure 3: Trajectory of prime interest rates from 1970 to March 2025, with the lines representing discount rate used in this study, red is 18% , 12.45% for the 31-year bond and the green line representing 8% usually used for public projects.

2.5. Computation of Net Present Value (NPV)

Net Present Value computation considers three quantities as follows

$$NPV = \sum_{y=1}^{49} \frac{CF_y}{(1+R)^y} - I_{initial\_investment} \quad \text{.........................(7)}$$

where CF_y is the future net cash flow in year $y = \{1, 3, \ldots, 49\}$, where total revenue is decreased by cost of vessel operation. $I_{initial\_investment}$ is the initial investment made and R is the discount rate representing cost of borrowing when buying an asset.

The decision is taken to invest in a project with $NPV > 0$ and not invest if $NPV < 0$.

3. Results

Distributions for NPV at interest rates of 8%, 12% and 18% are presented in **Figure 3**. All distributions yield positive values, demonstrating project viability based on the sampled future cash flows, initial investment of R1 billion, and operational survey costs. As expected, the higher discount rate of 18% produces a lower NPV value relative to the lower discount rates of 12% and 8%.

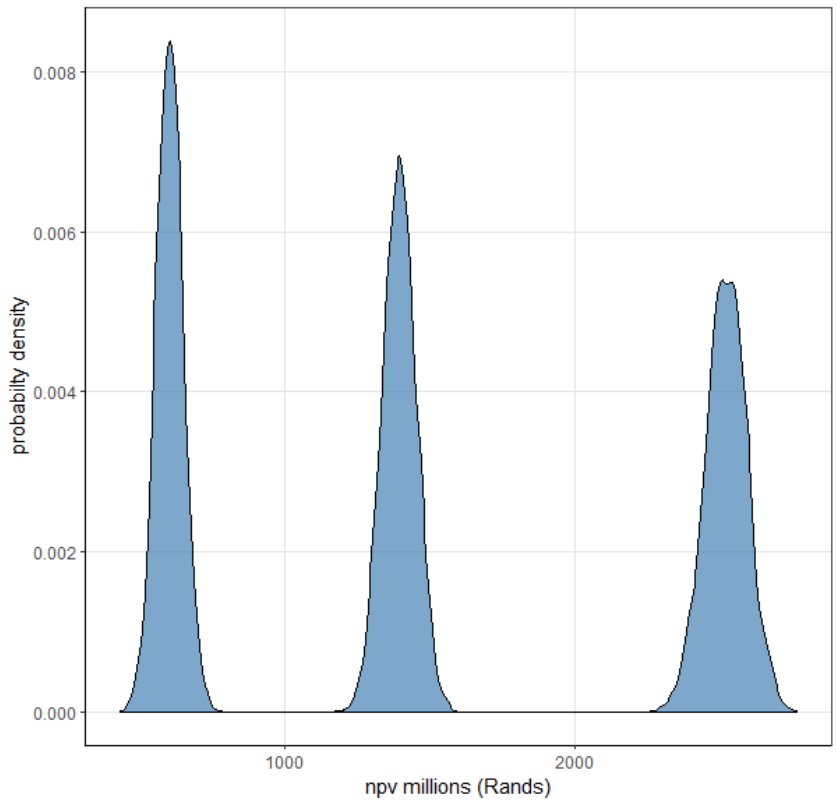


Figure 3: Distributions of NPV assuming 18% discount rate (left panel), 12% discount rate (middle panel) and 8% discount rate (right panel)

4. Discussions and conclusions

The NPV analysis indicates a favourable positive return on investment given the assumed net cash flows for all three discount rates of 8%, 12% and 18%, given the initial investment of R1 billion. Several additional factors require consideration at the vessel design stage, including fuel consumption rates, vessel size, and numerous other specifications. Modelling these additional factors will ultimately determine the precise initial investment required. The general framework employed for this analysis will form the basis for computing the NPV for vessel acquisition.

Further refinement of this analysis should consider factors such as a shorter time span that more realistically matches the expected vessel replacement cycle—most likely between 30 and 40 years rather than the 49 years currently used in this paper. Additional questions requiring further discussion include:

1. Generation of future TACs requires further examination of specific aspects such as:
    a. Use OMP for all species managed under OMPs
    b. How far into the future should OMPs be used for purposes of this analysis?
    c. How are TACs from other models to be produced?
2. Producing future revenue using assumed distributions; are there better alternatives?
3. Three options are being evaluated within the larger feasibility study:
    a. Acquisition of a new vessel (the focus of this analysis)
    b. Chartering of the vessel to conduct surveys
    c. Continuing operations with RV Africana into the future

If option 3(c) is chosen, several surveys will be missed, as has already occurred, in addition to incurring the astronomical costs of operating a vessel that should have been retired. The question of how many surveys are expected to be missed relates directly to the cost of missed opportunities for both industry and government.

Analyses by Coetzee *et al.* (2024) for the Annual International Stock Assessment Workshop in 2025 clearly address this question for the 2024/2025 season, and the analyses in this paper project the likely consequences if option 3(c) is chosen going forward. The analyses provided by Coetzee *et al.* (2024) are sufficient to inform option 3(c) for vessel acquisition discussions. Those analyses demonstrate that revenue losses of between R500 million and R1 billion for small pelagic and R360 million from hake fisheries represent substantial losses to the state through foregone levies and taxes. These losses could compound over time if the status quo represented by option 3(c) is maintained. It should be noted that levies used in this analysis remain unchanged in the time horizon of 49 years which is unlikely to occur.

5. References

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