CURATED PAST EXAM ITEMS
- Solutions -

CP 312 – Model Development and Governance

Important Information:

- These curated past exam items are intended to allow candidates to focus on past SOA fellowship assessments. These items are organized by topic and learning objective with relevant learning outcomes, source materials, and candidate commentary identified. We have included items that are relevant in the new course structure, and where feasible we have made updates to questions to make them relevant.
- Where an item applies to multiple learning objectives, it has been placed under each applicable learning objective.
- Candidate solutions other than those presented in this material, if appropriate for the context, could receive full marks. For interpretation items, solutions presented in these documents are not necessarily the only valid solutions.
- Learning Outcome Statements and supporting syllabus materials may have changed since each exam was administered. New assessment items are developed from the current Learning Outcome Statements and syllabus materials. The inclusion in these curated past exam questions of material that is no longer current does not bring such material into scope for current assessments.
- Thus, while we have made our best effort and conducted multiple reviews, alignment with the current system or choice of classification may not be perfect. Candidates with questions or ideas for improvement may reach out to education@soa.org. We expect to make updates annually.

Course CP 312

Curated Past Exam Solutions

All Learning Objectives

Learning Objective 1: Cash Flow Models for Long-Term Insurance Business

Learning Objective 2: Non-Cash Flow and Supplementary Models for Financial Business

Learning Objective 3: Model Governance

The following solutions are taken from Life ALM and Modeling Exams and Foundations of CFE Exams from 2020 – 2024. They have been mapped to the learning objectives and syllabus materials for the CP 312 2025-2026 course and in some cases modified to fit the 2025-2026 curriculum.

The related questions and Excel spreadsheets are provided in separate files.

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1. Fall 2020 ILA LAM Exam (LO 3a)

Learning Objectives:

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

3a) Describe and apply model governance best practices such as:

- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures

Relevant Sources:

ASOP 56: Modeling, Dec 2019, pp. 1-9

CIA Educational Note: Use of Models, Jan 2017

Model Validation for Insurance Enterprise Risk and Capital Models, CAS/CIA/SOA, 2014 (excluding Appendices)

Commentary on Question:
Commentary listed underneath question component.

Solution:

(a) **(LO 3a)**

Critique each statement below in the context of Model Risk Management.

A. *There are five elements of model risk defined in "Model Validation for Insurance Enterprise Risk and Capital Models". With respect to the management of this actuarial software, ABC should be concerned with all five risks.*

1. Continued

B. *To assess and manage model reporting risk, ABC plans to survey business users as to whether they consider the reports to be useful and meaningful for decision support. To avoid asymmetric user feedback, only users that are significantly affected by the model's output are included in the survey.*

C. *Allowing only in-house data and assumptions is the most effective way to manage vendor risks.*

D. *An internal review group within XYZ performed a validation of the calculation engine prior to releasing the software to ABC. No further validation of the software is required by ABC.*

E. *ABC's actuarial model validation framework is deemed satisfactory because ABC periodically reviews the quality and conceptual soundness of the model design and construction, and the methodologies used.*

Commentary on Question:
To get full credit, candidate must give a critique instead of only stating true or false with critique covering the key points. Most candidates did well on this section by providing correct judgement and reasonable justification.

A. This statement is incorrect
   Only 3 of the 5 elements are applicable to ABC: Input risk, Output risk, and Reporting risk.
   ABC will not have to manage conceptual risk and implementation risk since this is maintained and developed by XYZ.
B. This statement is incorrect
   These users might also be motivated to provide asymmetrical feedbacks. These users often mix the report's usefulness with the effect the report's numbers have on the user's business. If the model results are favorable, then these users are inclined to give a more positive review than if the model outputs are putting the manager's unit under pressure

1. Continued

C. This statement is incorrect

This statement assumes non-in-house input data cannot be properly reviewed for reasonableness and relevance.

If the company can develop a framework to properly investigate whether vendor provided input data or assumptions is relevant for the company's situation, the restriction of only using in-house data/assumptions is not the best approach.

D. This statement is incorrect

Independence is not an end in itself but rather helps ensure that incentives are aligned with the goals of model validation.

ABC is required to judge the actions and outcomes to ensure objectivity and prevent any bias in XYZ's process of selecting staffs for the model validation work.

E. This statement is incorrect

Validation does not only include assessment of the conceptual soundness of the model and ongoing monitoring for process verification and benchmarking, but also includes assessing if the model is performing as intended.

This means comparing model outputs to corresponding actual outcomes, such as back-testing.

ABC also needs to evaluate the extent and clarity of the model validation documentations provided, the issues identified and the actions taken by XYZ to address any modeling issues.

1. Continued

(b) **(LO 3a)** Identify the types of model documentation ABC should develop. Justify your answer.

Commentary on Question:
To receive full credit, candidate must justify their response and give a reasonable explanation of what additional document is needed.
Most candidates did not perform well on this part. Most candidates did not cover the three types of documentation or only knew the partial contents of model documentation.

- The user guide alone is not sufficient documentation to manage model risk. Comprehensive documentation includes model development documentation, model implementation documentation and on-going model governance documentation.
- The user guide provided by XYZ is considered model implementation documentation and is only 1 category of model documentation.
- ABC should also enhance the model implementation documentation to include information such as ABC-specific inputs and assumptions, description of ABC's process for the model, and how the model outputs will be used.
- While XYZ may not be able to provide specific detail around the proprietary information on the model development, they should still provide model development documentation.
- This documentation should include developmental tests performed on the model by XYZ, intended use and limitations of the model, and developmental data that can be shared with ABC, such as a data dictionary.
- ABC will also have to create on-going model governance documentation. This documentation will include plans for on-going model performance monitoring and outline the process for implementing and reviewing model changes.

3. Fall 2020 ILA LAM Exam (LOs 2a, 2c)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

2c) Describe, apply, and evaluate model *efficiency* techniques

Relevant Sources:

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

Economic Scenario Generators – three-part series, SOA:

- Part I –Motivation for Stochastic Modeling, The Modeling Platform, Nov 2019
- Part II – Understanding Economic Scenario Generators, The Modeling Platform, Aug 2020

CP312-101-25: Stochastic Modeling, Theory and Reality from an Actuarial Perspective, sections I.A, I.B-B.2, I.B.3.a, II.B-B.1.d

Commentary on Question:

The purpose of the question was to test the Candidates knowledge of modeling concepts, random number generators and the application of risk neutral vs real world cash flow scenarios. Candidates performed fairly consistently across all subject areas and sub-questions.

Solution:

(a) **(LO 2a)** Critique the following statements about stochastic modeling:

A. A stochastic model with a Normal distribution is a good option if it is difficult to determine the actual underlying distribution of the process being modeled.

3. Continued

B. *Stress testing is always a good alternative to stochastic modeling.*

C. When using an Economic Scenario Generator, real-world scenarios will produce a more realistic expected present value of cash flows than risk-neutral scenarios. This is because the real-world scenarios use a discount rate that reflects the risk associated with the cash flows.

~~*D.*~~ **No Longer Relevant** ~~*Real-world scenarios cannot be used for a market-consistent valuation.*~~

E. Risk-neutral scenarios are calibrated using observed market prices and therefore the calibration requires very little judgment.

F. The difference between the risk-neutral and real-world scenario paths is smaller when valuing long-term insurance contracts than when valuing short-term contracts.

Commentary on Question:
The candidates that offered well defended and focused opinions regarding the statements did the best on this question.

A. Using a Normal Distribution should not be the default for uncertain distributions. The Normal distribution does a poor job addressing distributions with fatter tails and other distribution alternatives may need to be considered.
B. Stress testing is not always a good alternative to stochastic modeling. It is a good alternative if a model is sensitive to a particular assumption but stress testing does not address tail concerns adequately.
C. Expected PV of cash flows is identical under real world or risk neutral valuations. Real world scenarios adjust the discount rate for risk while risk neutral scenarios adjust the cash flows.
~~D. Real world scenarios can be used for market consistent valuation if they are calibrated on the valuation date for interest rates, volatility and the market price of risk.~~
E. While this is not completely correct, it was important to note that significant judgment is required to determine the choice of the underlying stochastic process, volatility assumptions and the appropriate risk free rate.
F. This is an incorrect statement since the difference is larger as time progresses. Real world interest rates have a term premium, which is a form of a risk premium, which increases by the length of time from the valuation date.

3. Continued

(b) NO LONGER RELEVANT

~~Recommend which Random Number Generator BNT should use. Justify your answer.~~

~~A Pseudo Random Number Generator would be appropriate since it is efficient and reproducible, if the same seed is selected. Defending why Pseudo Random Number Generator would be the best choice for BNT life, such as allowing for an audit trail, would also be required for full credit.~~

(c) **(LOs 2a, 2c)** The Chief Actuary recommends that BNT use Monte Carlo modeling instead of Nested Stochastic modeling because it is more straightforward, and simulations would take less time.

Assess the Chief Actuary's recommendation. Justify your answer.

- For full credit, the candidate must defend either a recommendation for Monte Carlo or Nested Stochastic simulations based on the business case presented.
- Drawback of Monte Carlo simulation is the time required for convergence.
- Recommendation needs to address VA with guarantees issues: if BNT implements hedging, then Nested Stochastic would be best. Nested Stochastic uses an outer path (economic conditions) and inner path (fair market liabilities at select periods). Various shocks to the inner path can be used to determine the "Greeks", which help to improve hedge effectiveness.
- Procedures exist that can be used to make Nested Stochastics perform more efficiently, such as distributed processing. Other techniques BNT could use to increase efficiency without losing much accuracy include reducing the number of model points, or reducing the number of outer paths, inner paths, or nodes. For example, they could only use the "worst case" inner paths.

4. Fall 2020 ILA LAM Exam (LOs 1a, 2a)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1a) Describe, develop, and evaluate models for insurance products including those with complex components such as:

- dynamic policyholder assumptions
- multi-states
- equity-linked guarantees
- index-linked credits

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

4. Continued

Relevant Sources:

Long-Term Actuarial Models Part II, Cardinal, Timothy, Cardinalis 1 LLC, 2024

- Ch. 1: Introduction to Modeling (excluding section 1.5)

Metamodeling for Variable Annuities, Valdez, Emiliano and Gan, Guojun

- Chapters 1-3, 6

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

Commentary on Question:
This question tested the candidate's understanding of Economic Scenario Generators and products with various forms of financial guarantees

Solution:

(a) **(LOs 1a, 2a)** You are developing an Economic Scenario Generator (ESG) suitable for this product.

(i) Identify the key market variables required for the ESG.

(ii) Justify why these variables are important for determining the liability of this product.

Commentary on Question:
Most Candidates identified at least two relevant variables with the foreign exchange rate being the most common one missed.

4. Continued

- Sovereign Interest Rates
  - Interest rates are used to discount the liability cash flows. Liabilities will increase as interest rates decrease
- Nikkei Equity Returns
  - The company credits the policyholders with the Nikkei return. Decreases in the Nikkei index will increase the guaranteed benefit payout and increase the liability
- Foreign Exchange Rates
  - ABC Life is a U.S. based company and its reserves are based in U.S. dollars. Even if the Nikkei index does not change the change in the foreign-exchange rate will impact the how much reserve ABC Life will need to hold

NO LONGER RELEVANT

~~(b) **(LOs 1a, 2a)** Based on historical returns of the Nikkei 225, YYG decided to adopt a regime-switching log-normal model to project real-world equity returns.~~

~~Discuss the pros and cons of this ESG choice.~~

~~**Commentary on Question:**~~
~~*Most candidates identified the advantage of having fat-tails and having more than a single volatility regime as an advantage. Very few identified the path dependency advantage.*~~

~~Pros~~

- ~~It has a sound foundation, balancing practicality and completeness. This model is based on the logic that equity return volatility is different under recession and expansion conditions.~~
- ~~It exhibits the fat-tail behavior, or it produces some extreme but plausible outcomes. When markets become more volatile, the risk of sudden decline in equity price is elevated.~~
- ~~It is path dependent, the variable depends on the prior value of the variable~~
- ~~It can accommodate many types of calibration across a range of benchmarks~~
- ~~It can reflect historical equity returns and volatilities at different time horizons~~

~~Cons~~

- ~~It may not be computationally efficient, having longer run times than a single-regime model~~
- ~~Calibrating parameter and regime-switching probabilities can be complex and require significant expertise~~

4. Continued

(c) **(LO 1a)** Calculate the Expected Nikkei 225 Index Return in year 7 if the present value of future profit YYG expects to earn for this product is 0.
Show all work, including writing out relevant formulas used in any calculations

Commentary on Question:
Overall most candidates did and adequate job projecting fund values and decrements. Common mistakes included, reflecting company expenses as a charge against the fund value, excluding the rider fee as a charge against the fund and not including the M&E fee in the company profit calculations.

Model solution provided in excel

(d) **(LO 1a)** To improve competitiveness, the Marketing Officer has proposed a new voluntary reset feature for the GMAB rider:

> *"Policyholders are allowed a one-time reset of the GMAB guarantee to the current fund level at any time prior to maturity. If the reset is exercised, the maturity date of the Variable Annuity policy is reset to 7 years from the exercise date."*

(i) Describe the additional risks YYG may face by adding this feature.

(ii) Recommend possible ways to mitigate these risks.

Commentary on Question:
While most candidates identified the risks inherent in introducing the feature, very few provided recommendations on ways to mitigate the risks for all of the risks identified

(i)

- ABC would need policyholder behavior assumptions for how policyholders will choose to exercise this option. If ABC does not have the data to establish this assumption it would present a significant modelling risk
- Usually GMAB does not appear very valuable but adding a reset can significantly increase tail risk as policyholder will reset when account values are higher than the guarantee increasing the change of a payout at a higher guarantee level
- Increases the effect of concentrating risk across cohorts. Policyholders tend to reset when markets are good. In an extreme case all policyholders would have the same maturity date. If following returns are poor there will be a significant loss to fulfill the GMAB. Time diversification is lost

4. Continued

- It would create liquidity issues. Without the reset feature the maturity benefit is due at dates set at issue. With the reset the maturity date could extend at any time which makes liquidity planning more difficult.

(ii)

- Run full simulations to assess policyholder behavior under several possible responses to capture a range of possible reset option possibilities.
- Incorporate restrictions on the timing of the exercise the reset option.
- Establish frequent liquidity forecasts and conduct minimum liquidity access tests

(e) **NO LONGER RELEVANT**

~~Critique the following statement from YYG's ALM department.~~

~~*"For this product we recommend dynamically hedging delta and rho by rebalancing our hedge portfolio daily to ensure a close match. We are confident this is a cost-effective way to eliminate all risk for the company."*~~

~~**Commentary on Question**:~~

~~*Most candidates identified daily rebalancing as being potentially very costly and that not all risks were hedged using just rho and delta. Very few identified that dynamic hedging can be ineffective in extreme market circumstance or the introduction of basis and operational risks.*~~

- ~~Hedging delta and rho only hedges the first order liability sensitivity to changes in the price of the stock index and interest rates respectively. These are the main market risks of this product and closely managing these exposures through dynamic hedging is a sound approach~~
- ~~The company is not hedging second order sensitivities (gamma/convexity), nor are they hedging volatility (vega). Hedging these sensitivities could improve effectiveness.~~
- ~~Daily rebalancing could be too frequent and not cost effective. Hedging second order risks or volatility may not be cost effective either as the options required to hedge these risks are more costly than futures/swaps~~
- ~~Dynamic hedging may be temporarily ineffective in extreme circumstances~~
- ~~Other risks such as basis risk and operational risks are created~~

1. Fall 2021 ILA LAM Exam (LOs 1a, 1c)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1a) Describe, develop, and evaluate models for insurance products including those with complex components such as:

- dynamic policyholder assumptions
- multi-states
- equity-linked guarantees
- index-linked credits

1c) Describe, apply, and evaluate model *validation* techniques

Relevant Sources:

CP312-101-25: Stochastic Modeling, Theory and Reality from and Actuarial Perspective, sections I.A, I.B-1.B.3.a, I.B.4, and III

Commentary on Question:

This question tests the candidates understanding of the advantages and risks of stochastic modeling, along with efficient methodologies for performing stochastic modeling. It also tests the candidate's ability to build and use a general Linear Congruential Generator.

1. Continued

Solution:

(a) **(LOs 1a, 1c)** Critique the following statements:

A. While the stochastic model will be useful for calculating the average outcome, there is no reliable method for analyzing tail risks given the low probability of them occurring.

B. We will be able to gain a better understanding of our existing single scenario stress test results by comparing with the stochastic distribution of results.

C. *We assume a normal distribution for the variables projected by the stochastic model, as the normal distribution is relatively easy to use and therefore less risky than assuming a more complex distribution.*

D. 10,000 scenarios should be produced each time the model is run, because having more scenarios always provides additional information about the shape of the distribution.

E. The model's input parameters are calibrated using the past 2 years of historical experience, about 100 data points in total.

F. During model validation, it is normal to see the stochastic mean being more than double the deterministic best estimate.

Commentary on Question:
Most candidates performed well on this part.

Stronger candidates were able to provide thorough critique to demonstrate their understanding on the topics. No credit was given for simply stating True or False.

A. This statement is incorrect. While the stochastic set may be used to help determine the average, one key advantage of stochastic results is enabling tail analysis. Risk metrics such as VaR and CTE can be used to effectively analyze behavior in the tails of the distribution.

B. This is an accurate statement. Deterministic or stress test scenario results can be compared to the stochastic distribution of results to understand where they fall in the broader range of possible outcomes and help determine where they fall between specified percentiles.

1. Continued

C. This statement is incorrect. It is common to assume a simpler or more standard distribution like the normal distribution would closely fit many variables projected, but this often isn't the case. Distributions should be chosen based on what best describes available information, if possible. An inappropriate distribution can generate meaningless results and miss skewed outcomes, resulting in misleading tails.

D. This statement is incorrect. To avoid excessive run requirements, the number of scenarios necessary to reach the point at which additional iterations provide no additional information about the shape of the distribution should be determined. This can be done by testing increasing amounts of scenarios until the full distribution is realized.

E. There is insufficient credibility for the historical data points used. The model cannot be fully calibrated, and the actuary should carefully consider if the use of this model is appropriate.

F. This is a red flag and can possibly mean the model is mis-calibrated.

NO LONGER RELEVANT

~~(b)~~

~~(i) Calculate the active or disabled status generated by the uniform random number sequence for the first 4 policyholders. Show all work.~~

~~(ii) You are also given that:~~

- ~~The LCG model generated 0.727 for policyholder X at time 0~~
- ~~Discount rate of 5%~~
- ~~All cashflows are at the beginning of year~~

~~Calculate the time 0 actuarial present value of payments caused by this rider over the next two periods.~~

~~**Commentary on Question**:~~
~~*Most candidates performed well on this part.*~~

~~*To receive full credit, the candidate*~~
~~*b(i) calculated the active or disabled status; partial credit was given for each of the following:*~~

- ~~*using the correct formula for general linear congruential generator*~~
- ~~*generates first 4 X(i) numbers in sequence*~~
- ~~*applies uniform distribution (Xi/M) for each policyholder*~~

- ~~*applies correct logic to Ui to determine active/disabled status for each policyholder*~~

1. Continued

b(ii) calculated the actuarial present value of the payment at time zero. The candidate could receive full credit for either of two alternative calculation methods.

Partial credit was given for each of the following:

- *correctly identifies initial Active Status for this policyholder*
- *correctly identifies status change paths, probability and payment patterns associated with each path (or each time period)*
- *calculates the PV of payments for each path or time period*
- *calculates the correct PV total for all possible paths with payments*

b(i) Given:
Multiplier = 2
Increment = 5
Modulus = 11
Initial Seed = 88

Solution:

- X(i) = (aX(i-1) + c) mod(M)
- Status = Active if Ui < 0.8

Policyholder	X(i)	Ui	Status
1	5 = Mod (2*88+5,11)	0.455=5/11	Active
2	4 = Mod (2 * 5+5,11)	0.364=4/11	Active
3	2 = Mod (2 * 4+5,11)	0.182=2/11	Active
4	9 = Mod (2 * 2+5,11	0.818=9/11	Disabled

(ii)
Given:

$$Q = \begin{bmatrix} 0.9 & 0.1 \\ 0.3 & 0.7 \end{bmatrix}$$

Solution:
Initial status: 0.727 is less than 0.80, therefore this policyholder starts in active state.

	A	D
A	0.9	0.1
D	0.3	0.7

1. Continued

Method 1

	t=0	t=1	t=2	Probability
Path 1	A	A	A	0.81=0.9*0.9
Path 2	A	A	D	0.09=0.9*0.1
Path 3	A	D	A	0.03=0.3*0.1
Path 4	A	D	D	0.07=0.1*0.7

Corresponding Payments,

	0.9524=1/(1.05)	0.9070=1/(1.05)^2	PV	
	t=1	t=2		
Path 1	0	0	0	
Path 2	0	900	73.47	= 0.09*900/1.05^(2)
Path 3	900	0	25.71	= 0.03*900/1.05
Path 4	900	850	113.97	= 0.07*[900/1.05+850/1.05^2]

Total AVP = 213.15

Method 2

Making payment at time 1

Probability = 0.1 from A -> D

85.71 = 0.1*(850+50)/1.05

Making payment at time 2

- Expense needs to be paid

  Probability = 0.09 from A ->A -> D

  73.47 = 0.9*0.1*(50+850)/1.05^(2)
- Expense does NOT need to be paid

  Probability = 0.07 from A ->D -> D

  53.97 = 0.1*0.7*850/1.05^(2)

Total AVP = 213.15

2. Fall 2021 ILA LAM Exam (LOs 3a, 3b)

Learning Objectives:

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

3a) Describe and apply model governance best practices such as:

- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures

3b) Describe, compare and evaluate organizational structures for model governance, including controls, roles, and responsibilities

Relevant Sources:

ASOP 56: Modeling, Dec 2019, pp. 1-9

The Importance of Centralization of Actuarial Modeling Functions, Part 1: Focus on Modularization and Reuse, The Modeling Platform, Nov 2019

Commentary on Question:
Commentary listed underneath question component.

Solution:

(a) **(LO 3a)** XYZ uses a compliance-based Assumption Governance framework with the main objective of satisfying regulatory requirements.

(i) Critique the use of a compliance focused approach to Assumption Governance.

(ii) Recommend an alternative Assumption Governance framework for XYZ and describe the benefits they would realize.

2. Continued

Commentary on Question:
Candidates scored about half the points available on average. Points were dropped for missing some of the requisite items,

The paper that was the source for this question is not on the CP 312 syllabus. Candidates taking CP 312 would not be expected to answer with all the specifics shown in the following solution.

(i) Problems with compliance focused approach
-feelings of simply completing a checklist will not engage employees, could lead to retention issues
-resources are used on things not necessarily adding value to the company
-may remove actuarial judgment from the process – losing opportunities for improvement to that process

(ii) -employees should be encouraged to use actuarial judgment in the process
-implementing a more strategic focus
-more employee engagement may lead to less turnover
-should improve communication between the teams
-can allocate more resources to process improvement – possibly with new technologies

(b) **(LOs 3a, 3b)** XYZ's modeling function is decentralized into small teams that independently maintain a model for each product. XYZ would like to create a centralized modeling function to improve efficiency, with a specific focus on optimizing new product development.

(i) Recommend the approach XYZ should follow when creating their centralized modeling function. Justify your answer.

(ii) Identify the relevant considerations and recommended practices of ASOP 56 that XYZ needs to consider when creating the centralized modeling function. Justify how they apply to XYZ's approach.

2. Continued

Commentary on question
On part (i) many candidates did quite well – the question was looking for a reusable library approach as opposed to copying existing code. On part (ii) many candidates did very well – some however were not conversant with ASOP 56 and a number of candidates simply omitted this part

(i) XYZ should focus on building reusable libraries rather than starting from scratch or copying existing code
-will reduce resources required going forward
-less duplication in effort
-may lessen testing required
-should improve control of assumptions

(ii) Key provisions of ASOP 56
-reliance on models developed by others
-actuary should understand the model and disclose the extent of the reliance

-reliance on experts who developed the models
-evaluation and mitigation of model risks
-documentation
-of the model's purpose and the testing results

(c) **NO LONGER RELEVANT**

~~Critique the recommendations made in the report. Justify your answer.~~

A. ~~Introducing segment boundaries is not advised as it will increase run time and add more constraints.~~

B. ~~When mapping policies, we start with the pair with the lowest distance (i.e. policy pair #1 and #4) and map to the policy with higher face amount between the pair (i.e. map policy #4 to policy #1).~~

C. ~~When there are pairs with similar distance (such as policy pairs #1 and #3 and policy pairs #3 and #4), to avoid bias, the company can use a random number generator to determine which pairs of policies should be mapped first.~~

D. ~~The UL cluster model is calibrated and uses the same weights for account value as the variable annuity cluster model with compression ratio of 50-to-1.~~

E. ~~A small cluster model size is preferred over larger cluster model sizes.~~

2. Continued

~~Commentary on Question~~:
~~Points were dropped by not actually providing a critique (Incorrect, false or, in some cases, partially true were accepted). A critique without backing was awarded no points. Some points were dropped for an incomplete explanation.~~

~~A – this is incorrect~~
~~- increasing the number of segments will actually reduce run time~~
~~- run time savings approximately proportional to the sum of squares of policies in each segment~~

~~B – this is incorrect – not just distance – importance needs to be calculated to determine mapping priority~~

~~C – this is incorrect – again, importance needs to be calculated~~

~~D – this is incorrect~~
~~- substantial differences between the two products will necessitate recalibration with the new policy exposures.~~
~~- different variables may require different weights~~

~~E – this is incorrect~~
~~- a smaller cluster size is not always better – must consider the trade-off between run time savings and better model fit with more cells~~
~~- depends on the intended use of the model~~

4. Fall 2021 ILA LAM Exam (LOs 1a, 2a)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1a) Describe, develop, and evaluate models for insurance products including those with complex components such as:

- dynamic policyholder assumptions
- multi-states
- equity-linked guarantees
- index-linked credits

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

Relevant Sources:

Metamodeling for Variable Annuities, Valdez, Emiliano and Gan, Guojun

- Chapters 1-3, 6

CP312-101-25: Stochastic Modeling, Theory and Reality from and Actuarial Perspective, sections I.A, I.B-1.B.3.a, I.B.4, and III

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

4. Continued

Commentary on Question:
This question was designed to test the candidate's basic understanding of using Economic Scenario Generators (ESGs) for market consistent (risk neutral) valuation of financial guarantees and identify limitations of the models

Solution:

(a) **(LO 2a)** Critique the following statements from QRF's Model Risk Management group regarding the ESG model.

A. The real-world scenarios can provide more intuitive results than the risk-neutral scenarios

B. Correlation between modeled economic and financial market variables are set and held constant at model development.

C. Spread inputs for a real estate investment trust in our portfolio were not readily available in the market. The actuary estimated the spreads based on fixed income bond spreads from an Oil & Gas bond with the same term-to-maturity.

D. The model is calibrated using historical data from 2010 to 2019.

4. Continued

Commentary on Question:
Company QRF has a Universal Life portfolio and uses an ESG to model the guarantees and for stress testing. The candidate is asked to comment on a number of statements.

Candidates did fairly well on this question.

A. The candidate needs to state if they agree or disagree with the statement. No points are given if the candidate just lists out facts about real-world and risk-neutral scenarios. No points are given if the candidate simply stated agree or disagree without explanations.

   If the candidate agrees that real-world is more intuitive, then they need to explain that real-world scenarios reflect market dynamics, risk and stylized facts. These scenarios are calibrated to historical experience so the model output is more realistic. Risk-neutral scenarios are less intuitive as the risk-free rate is not realistic and are calibrated to current market prices and mainly used for market consistency (it is a mathematical way to arrive a closed-form solution).

   If the candidate disagrees, then they need to explain that real-world is intuitive when used for capital, risk management and produce company forward view (earnings) projections as it reflects market dynamics, risk and stylized facts. Real-world scenarios calibrate to historical experience so the model output is more realistic. Risk-neutral scenarios are more intuitive for pricing/valuation as they are calibrated to current market prices for market consistency and provide closed form solutions.

B. This is not correct. The relationship between economic and financial market variables changes over time and depends on the situation.

C. It is not appropriate to use an Oil and Gas bond as a proxy for a REIT. Corporate bond spreads are firm and industry specific and based on default probability. Also need to consider credit rating of the proxy bond

D. This is a period of sustained low interest rates and the calibration period used is not long enough. Should include a longer period and include periods of higher interest rates. Also, expert opinion is needed on future interest rate trends

4. Continued

(b) **(LO 1a)**

(i) Calculate the market-consistent value of the cost of guarantee.

(ii) Using a quantitative measure, analyze the appropriateness of the scenario reduction techniques. Recommend changes if needed.

Commentary on Question:
The candidate is required to determine the market consistent cost of guarantee on UL products, given reserves calculated under scenarios with and without a minimum crediting rate. The candidate is also required to assess whether the scenario reduction technique is appropriate.
The majority of candidates correctly calculated the market consistent cost of the guarantee. However, only a few candidates correctly concluded that the number of scenarios was too small and more scenarios were necessary. This was determined by calculating the standard deviation of the expected cost, and was not well done by the candidates.

(i) Expected cost of the guarantee = reserves with minimum crediting rate guarantee – reserves without minimum crediting rate guarantee

Scenario Set #	Reserves with minimum crediting rate guarantee	Reserves without minimum crediting rate guarantee	Expected cost of guarantee reserve
1	120	100	20
2	150	135	15
3	200	150	50
4	170	150	20
5	80	45	35
6	95	60	35
7	45	45	0
8	250	200	50
9	300	250	50
10	350	300	50

4. Continued

(ii) Market consistent cost of the guarantee = average over 10 scenarios of the expected cost of the guarantee = 32.5

The technique is appropriate is appropriate if the standard deviation of the expected cost is relatively small. Standard deviation = 18.0. As a percentage of the market consistent cost, this is 55% which is fairly large

Therefore, the recommendation is to increase the number of scenarios.

c) **(LO 2a)** Your student complied the following list of observations and considerations. Assess each of the findings.

A. Probabilities of default will rise with general economic conditions as evidenced in 2009 and 2020.

B. Widening corporate spreads will always track realized default rates.

C. Corporate spreads gross of defaults fluctuated more because of 2008 and 2020 recessions.

Commentary on Question:
The candidate is presented with a number of charts to analyze the impacts on ESG parameters:

1. *Corporate default rates*
2. *Yield spreads between corporate and US Treasure bonds*
3. *Yield curve spot rates for US Treasuries*

The candidate is then asked to assess a number of observations and findings based on the charts given.

The majority of candidates scored well on this section partly because the answers required either a true or false response, followed up with an explanation. In general, points were given based on whether the candidate answered true or false, and additional points were given if the explanation backing up the observation was reasonable. If the explanation cancelled out the answer, then no points were given.

A: TRUE. Probabilities of default will rise as economic conditions worsen, as evidenced by the financial tsunami in 2009 and COVID-19 in 2020

B: FALSE, as widening corporate spreads do not always track to realized default rates

4. Continued

C: TRUE, defaults during stressed economic environment can be volatile, which impacts spread.

D: TRUE, lower rated bonds are more exposed to change in economic conditions.

E: FALSE, since interest rates can be negative and should be considered in the ESG

F: FALSE. An inverted yield curve is when short-maturity yields are higher than longer-maturity yields. There is a period of inverted yield curve between time 0 and 1 only.

G: This is FALSE. A 10-year look back period is too short since it captures a period of very low rates. Should include a longer look back period. Also make use of expert judgement in determining the look back period. COVID-19 is a one-off event that could skew results.

1. Spring 2022 ILA LAM Exam (LO 1a)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1a) Describe, develop, and evaluate models for insurance products including those with complex components such as:

- dynamic policyholder assumptions
- multi-states
- equity-linked guarantees
- index-linked credits

Relevant Sources:

CP312-101-25: Stochastic Modeling, Theory and Reality from and Actuarial Perspective, sections I.A, I.B-1.B.3.a, I.B.4, and III

Commentary on Question:

Candidates are expected to demonstrate solid understanding of various concepts related to stochastic modelling, including tail risk metrics, risk-neutral vs. real-world scenarios, and their applications in real life practice.

Many candidates were successful at reiterating theoretical concepts, but showed difficulty in integrating theories into real case applications.

Solution:

(a) **NO LONGER RELEVANT**

~~ABC Life is planning to develop a set of first principles mortality assumptions for its block of Long-Term Care (LTC) business. Mortality is the only decrement for this business. LTC mortality experience and the legacy total life mortality assumption are provided in the excel workbook.~~

~~Recommend an appropriate approach ABC should use to develop its first principles LTC mortality assumption. Justify your answer.~~

1. Continued

~~**Commentary on Question**~~:

~~*To earn full credit, candidates are expected to demonstrate calculating active, disabled and total life mortality and show that calculated total mortality does not compare well with legacy experience in order to make conclusion of developing implied disabled life mortality. Many candidates recommended using legacy mortality to calculate implied disabled life mortality purely based on lack of disabled life data, although correct, this would not earn full credit.*~~

~~Response to part (a) can be found in the attached Excel spreadsheet.~~

(b) **(LO 1a)** Due to the impact of the COVID-19 pandemic on insurance and economic experience, ABC Life has decided to develop stochastic mortality and interest rates models.

(i) Explain how stochastic modeling could improve ABC's understanding of its COVID-19 driven mortality risk compared to deterministic modeling.

(ii) NO LONGER RELEVANT

~~You use the newly developed stochastic mortality model to generate loss results from 10,000 simulated scenarios (provided in the Excel workbook).~~

1. Continued

~~Prepare a report for senior management which summarizes the conclusions which can be drawn from the model with respect to ABC's risk and capital profile.~~

~~No calculations are required for this part.~~

Commentary on Question:
Part (i), the candidates are expected to clearly explain the distinction between stochastic and deterministic methods, and explain why COVID-19 mortality risk requires the application of stochastic modelling. Most candidates were able to list out advantages of stochastic modelling in general, yet did not provide reasons for its application particularly on pandemic risk such as COVID-19.

~~*Part (ii) tests the candidates on the application of stochastic modelling in real practice. Many candidates were able to calculate VaR and CTE measures given the data, yet were unable to discuss the meaning of these metrics in the context of management's understanding of tail risk. Only few candidates made recommendations on setting capital levels based on calculated VaR measure.*~~

(i) A stochastic model is able to simulate a distribution of possible outcomes that reflect the random variations in the inputs. In contrast, a deterministic method is a mathematical simplification involving a few scenario outcomes based on pre-determined input variables.

Stochastic methods are more adequate at dealing with complex risks such Covid-19 pandemic mortality, as its insufficient experience data, rapidly evolving health technology and increasing globalization could alter the outcome of the pandemic and call into question the credibility of using only a few select scenarios (deterministic) to understand its true risk exposure.

~~(ii) Response to part (ii) can be found in the attached Excel spreadsheet.~~

(c) **(LO 1a)** ABC Life is developing assumptions for its stochastic interest rate model and is faced with the choice between using risk-neutral and real-world scenarios

(i) Recommend the appropriate scenario choice for each of the following situations. Justify your answer.

1. Management wants to determine the market-consistent view of liabilities under a stressed interest rate environment due to the global pandemic.

1. **Continued**

B. Management wants to know how much capital is needed to absorb the potential earnings loss in the current low interest rate environment.

C. To calculate the hedging cost when pricing a new Universal Life product with a minimum crediting rate guarantee.

D. When monitoring residual market risk of a Universal Life product with a minimum crediting rate guarantee.

(ii) Critique the following statement:

Short-term risk-free interest rates calculated using risk-neutral stochastic scenarios will be more conservative than those calculated using real-world scenarios.

Commentary on Question:
Part (i) was done well. Most candidates were able to differentiate the different uses of risk-neutral and real-world scenarios and recommend appropriate methods. Some candidates had difficulty providing sufficient justifications to support their choice.

For Part (ii), most candidates were able to state the existence of "term premium", however one needs to explain the concept behind the term premium in order to earn full credit. Candidates are also expected to recognize the source of this misunderstanding arising from equity securities as covered in the reading "Common Misunderstanding of Risk-neutral Valuation".

(i) A. Risk-neutral scenarios. This question is asking what the loss in cash flows due to pandemic is worth, which involves discounting liability cash flows to obtain an expected present value, a typical use of risk-neutral valuation.

B. Real-world scenarios. This is a "what-if" type of question asking for the loss impact (capital required) under a stressed scenario, a common use of real-world scenarios.

C. Risk-neutral scenarios. Calculating expected hedge cost of an insurance guarantee with embedded derivative is another typical use of risk-neutral scenarios, as it involves calculating market-consistent present value of hedge cash flows.

1. Continued

D. Real-world scenarios. This looks for the outcome of post-hedging residual risk expected from realistic market outcomes.

(ii) This statement is false. In the context of interest rate scenario generations, being conservative means lower rates.

This is a common misunderstanding that real-world scenarios would produce higher short-term returns than risk-neutral scenarios. This misunderstanding may have arisen as real-world simulations for equity returns tend to be higher than risk-neutral simulations. However, fixed-income securities are treated differently than equities.

For the risk-free yield curve, only the short-term rates are risk-free, all longer-term rates involve a "term-premium", representing the price for the risk of locking-in an interest rate in an environment where interest rates can change. Under real-world scenarios, to get the market's expectation of the path of the short-term rates, the term premiums are removed. Due to the existence of term premiums, short-term interest rates are typically higher under risk-neutral environment compared to real-world.

2. Spring 2022 ILA LAM Exam (LO 1a)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1a) Describe, develop, and evaluate models for insurance products including those with complex components such as:

- dynamic policyholder assumptions
- multi-states
- equity-linked guarantees
- index-linked credits

Relevant Sources:

Long-Term Actuarial Models Part II, Cardinal, Timothy, Cardinalis 1 LLC, 2024

- Ch. 9 Fixed and Fixed Indexed Annuities, including workbooks

Commentary on Question:

The goal of this question is to assess the candidate's understanding of interest rate risk and ways to mitigate its impacts on an insurance company, as well as professionalism in the context of assumption setting and considerations related to modeling simplifications (e.g., issue age modeling). The candidate should be able to demonstrate familiarity with the principles of professionalism that apply to actuarial work, as well as interpret and make modeling recommendations based on scenario analysis.

Solution:

(a) **(LO 1a)** You are the lead pricing actuary of your company's fixed annuity product lines. Senior management has expressed concerns over the risk of a prolonged low-interest rate environment and the risk of a market correction resulting in a sudden upward spike in interest rates

(i) Analyze how your company’s profitability may be impacted under each of the two scenarios.

(ii) Propose two strategies that the company could apply to mitigate interest rate risk on its fixed annuity products.

2. Continued

Commentary on Question:
To earn full credit, the candidate should discuss the impacts on profitability under both interest rate scenarios, in the context of fixed annuity products. Partial credit may be given if the candidate's answer does not reference the annuity portfolio specifically.

(a) (i)
Under the sustained low interest rate scenario:

- Low interest rates reduce the returns from bonds that insurers invest in, hence negatively impacting earned rates and profitability. For fixed deferred annuities, credited rates will likely hit the minimum guarantee rate soon (if they are not already at the minimum credited rate), which puts pressure on the company's ability to earn their expected spreads. In other words, unless the company was able to reduce it's cost of borrowing (crediting rates, expenses etc.), its profit margins will decrease or erode completely, resulting in significant losses.

- Although the company's balance sheet may be strengthened on a market value basis by falling interest rates, in most instances, the corresponding market values of liabilities would have increased by at least as much as any increase of the assets, so any benefits would be minor at best.

Under the sudden spike in rates scenario:

- Writers of fixed products using a credited rate concept must often increase their credited rates or face mass lapses, since the policyholder can choose to invest their money at higher rates elsewhere. This issue is further compounded by the reduced market value of the assets held by the company that have to be sold to fund the resulting lapse or partial withdrawal (i.e., capital loss), which can result in a significant hit to profitability.
- Alternatively, if the company elects to increase the credited rate, this will typically lead to lower interest spreads and reduced profitability.

(a) (ii)
- Reduce minimum guaranteed rates on fixed products; employ a current credited rate mechanism to offer higher rates if interest rates rise and vice versa, and seek to pass on lower costs of interest rate risk to policyholders via enhancement of other features if the interest rate environment improves

- Move products that contain locked-in features to a design that allows them to change product features based on movements in interest rates

2. Continued

- Utilize ALM to match assets fairly closely with liabilities, especially on fixed immediate annuities (which have locked in designs)

- Highlight or push products that offer a greater potential for consumer return in a low interest rate environment (e.g., shrink the company's pure fixed annuity portfolio and expand on indexed annuities, whereas the latter offers potential for upside participation via the equity markets)

- Refine assumption setting on dynamic lapses and other policyholder behavior assumptions for its fixed annuity book

- Pursue asset strategies that are more explicitly linked to hedging interest rate risks identified in the company's repricing gap analysis

- Use reinsurance to transfer interest rate risk.

(b) **NO LONGER RELEVANT**

~~As part of your periodic review of modeling assumptions and simplifications, you are assessing if a new method of defining issue age bands in your pricing model would be appropriate.~~

~~(i) Describe the principles of professionalism outlined in *Application of Professional Judgement by Actuaries,* in the context of assumption setting.~~

~~You are testing five age band definitions of varying size. The associated modeling error arising from each case is summarized below:~~

~~Case~~	~~# of Issue Age Bands~~	~~Age Error (in years)~~	~~Average Known Error~~	~~Average Unknown Error~~
~~1~~	~~15~~	~~0.1~~	~~0.5%~~	~~0.6%~~
~~2~~	~~10~~	~~0.6~~	~~3.2%~~	~~2.3%~~
~~3~~	~~8~~	~~0.7~~	~~1.2%~~	~~1.4%~~
~~4~~	~~4~~	~~0.0~~	~~0.8%~~	~~0.4%~~
~~5~~	~~3~~	~~0.4~~	~~2.4%~~	~~2.0%~~

~~Age error is defined as the weighted average difference between the weighted average issue age for each band as compared to the model issue age for that band.~~

~~(ii) Assess the implications of this analysis and recommend which case(s), if any, should be further considered for implementation.~~

2. Continued

(iii) Your pricing model assumes the issue age of the policy is the mid-point of the age band and all age bands are of uniform width. Your manager suggests that this approach could be applied to all pricing models in the company as it is the simplest to implement.

Critique the above suggestion.

(iv) Compare and contrast static and dynamic model validation.

Commentary on Question:
For b(i), to earn full credit, at least 4 distinct principles of professionalism should be listed.
The candidate should identify both the principle of professionalism and explain how it should be considered during assumption setting.

For b(iii), the candidate should clearly state whether they agree or disagree with both aspects of the current setup, as well as explain why there may be alternative approaches that are also valid.

For b(iv), the candidate should describe both static and dynamic validations and the relative advantages/disadvantages of each.

B(i):
Integrity (i.e., an actuary must act honestly and with highest standards of integrity): taking into consideration all relevant and appropriate data during assumption setting, even if the resulting assumption does not appear favorable; ensuring any professional judgment applied agrees with standard practices

Competence and care (i.e., an actuary must perform professional services competently and with care): ensuring the actuary has enough knowledge on sources, data quality, sample size, and any limiting factors for the choice of variables; considering consistency with similar situations applicable to this assumption; reviewing future trends and expectations for reasonableness; performing regular back-testing on assumptions

Compliance (i.e., an actuary must comply with all relevant legal, regulatory and professional requirements): reviewing appropriate ASOPs, valuation manual chapters, NAIC guidance and state regulatory requirements to ensure the assumptions are derived in accordance with these materials; ensuring assumptions are appropriately documented for regulatory purposes, such as cash flow testing memos and VM-31 reports

2. Continued

Impartiality (i.e., an actuary must not allow bias, conflict of interest or the undue influence of others to override professional judgment): ensuring the actuary is not unduly influenced by senior management or other influential stakeholders to set overly aggressive assumptions; ensuring any potential conflicts of interest are disclosed in advance and separating oneself from the assignment if warranted

Communication (i.e., an actuary must communicate in an appropriate manner and meet all applicable reporting standards): disclosing any material deficiencies with the data and/or methodology used for setting assumptions; ensuring the right people are involved in providing relevant data and feedback for each variable; compiling complete documentation on the key steps of the assumption setting process

B(ii):
The Ultimate goal of the issue age modeling is to reduce the model calculation. The issue age banding should have a good balance between the accuracy and the model complexity (i.e., reduction of data / model run time)
The scenario analysis shows that a larger number of age bands does not necessarily produce a better model; in other words, a more elaborate model is not necessarily a better model. The number of issue age bands is negatively correlated with the final three columns, but the correlation is weak, which is most likely due to the fit of the model age to the average issue age within each band. In contrast, the correlation between the age error and average known/unknown errors is much stronger. Furthermore, the table shows that any error introduced by moving to wider issue age bands can be potentially more than offset by the error removed by having more strategically placed age bands (e.g., moving from Scenario 2 to Scenario 4).

'Therefore, it appears that Scenarios 1 and 4 both produce relatively good fits overall (and hence should be further reviewed/investigated as a potential modeling enhancement), whereas the other scenarios do not fit as well.

B(iii):
Disagree. While potentially easier to implement if assuming a uniform age band width, age bands do not have to be all the same width. It is possible that modeling errors can be reduced by modeling certain ages with one age band width, then using a smaller age band width for very young or old ages. This could also be influenced by the underlying product type and mix of business.

2. Continued

Disagree. While potentially easier to implement, the actuary does not have to use the central ages of the selected age bands as the model age - in fact, the optimal model age may be something other than the central age. In practice, many actuaries will select the model age for a given age bucket by using the age that is closest to the weighted average issue age of that bucket, which can be particularly useful if the actuary chooses very wide age bands.

B(iv):
A static validation compares certain known and modeled values as of the date from which the model projects, which provides a measure of model accuracy. However, it only looks at one point in time (i.e., balance sheet validation), and only at one variable at a time (such as premiums or reserves). It also fails to capture the effect of interactions among variables, and it may hide significant distortions resulting from the modeling approach in the future.

Unlike static validations, dynamic validations can be either prospective (i.e., comparing the trend in actual historical results with the model's projected results) or retrospective/back-cast (i.e., starting with the current portfolio of business and running the model backwards through time, then comparing this against actual historical data). Dynamic validations are analogous to an income statement validation, regardless of whether the model is run forwards or backwards. Dynamic validations also involve looking at many assumptions at once and measuring the accuracy of their interaction, which can make it much more robust of a validation than static validation. However, dynamic validations are not always possible (e.g., if good historical data is not available or credible).

1. Fall 2022 ILA LAM Exam (LOs 1c, 2a, 2c)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

1c) Describe, develop, and evaluate nested models

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

2c) Describe, apply, and evaluate model *efficiency* techniques

Relevant Sources:

CP312-103-25: Chapter 8 of Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 (8.1-8.6)

CP312-101-25: Stochastic Modeling, Theory and Reality from and Actuarial Perspective, sections I.A, I.B-B.2, I.B.3.a, II.B-B.1.d

Commentary on Question:

Candidates generally did well in this question. Stronger candidates were able to identify the appropriate source material and applied them correctly in the context of the questions.

1. Continued

Solution:

(a) **(LOs 2a, 2c)** With respect to the Monte Carlo simulation:

(i) Calculate the Monte Carlo estimate of the call option

(ii) Calculate the Monte Carlo sampling standard error of the estimated call option price

(iii) Evaluate the reasonableness of the estimated call option price

(iv) Explain why a company would want to use a variance reduction technique

Commentary on Question:
Candidates did well in part (i) with the correct calculations for the Monte Carlo estimate of the call option. Only a handful of candidates were able to calculate the standard error correctly in part (ii). Candidates generally did well in parts (iii) and (iv)

(i)

S(0) = 100
K = 100
r = 2% *(back-calculated using information provided)*
σ = 0.2
T = 1

To calculate r, use this formula
$S(T)=S(0) * \exp[(r-\sigma^2/2) * T + \sigma * \varepsilon * T^{1/2}]$

	epsilon	S(T)	c [a]
1	-1.7701	70.19	0.00
2	-0.7908	85.37	0.00
3	-0.3590	93.07	0.00
4	0.8190	117.80	17.45
5	-0.5828	89.00	0.00
6	0.7156	115.39	15.09
7	-0.3182	93.83	0.00
8	0.9314	120.48	20.07
9	1.2897	129.43	28.85
10	0.5930	112.59	12.34

a – Calculation of present value of Call Payout (=exp(-r*T)*max(S(T)-K,0))

Estimated call price c = average of column c = 9.38

1. Continued

(ii)

Sample Error = Standard Deviation of column c / SQRT (Sample Size)
= 10.7480 / SQRT (10)
= 3.40

(iii)

Black-Scholes Model = $N(d_1)\ St – N(d_2)\ Ke^{-rt}$,
where $d_1 = [\ \ln(S(t)/K) + (r + \sigma^2/2)*t\ ]/\ \sigma*SQRT(t)$
$d_2 = d_1 – \sigma*SQRT(t)$

Black-Scholes call = 8.92

The calculated Monte Carlo (MC) price should converge to the Black-Scholes price at a sufficient N. One way to assess the reasonableness of the results is to compare the MC price with the Black-Scholes call price. The Black-Scholes price is 8.92. Comparing with the Black-Scholes price, the MC price of 9.38 seems reasonable. This can further be improved by increasing the number of Monte Carlo simulations.

(iv)

Monte Carlo usually requires a large number of iterations to achieve a certain degree of accuracy. This can be very computationally intensive. Variance reduction techniques can greatly reduce computing time while increase the accuracy of the estimate

(b) **(LO 1c, 2c)** Your company would like to explore the use of a nested stochastic model to project equity returns.

(i) Explain how a nested stochastic model could be implemented

(ii) Discuss the advantages and disadvantages of two possible methods that could be used to manage the run-time of the model

1. **Continued**

Commentary on Question:
Most candidates were able to provide some high level overview of the nested stochastic model in part (i), and were able to identify two methods to improve run-time in part (ii)

(i)

In a stochastic model, projections are derived from values projected over time using a set of randomly generated economic scenarios.
A nested stochastic introduces another layer of economic scenarios when it is needed to stochastically derive a variable. Common terms are the inner and outer scenarios when the inner paths are embedded on each other scenario. The point in time at which the inner paths begin is defined as a node.

(ii)

The following is a list of reasonable responses. And credit is awarded for other reasonable responses.

Reduce number of model points by grouping individual policies into model cells.
It may be difficult to achieve high levels of compression. Repeated testing of compression is an ongoing process that must be managed with care.

Reduce the number of inner paths
Focusing on the tail of the distribution allows for efficiency when a CTE measure is used. This could lead to loss of important data outside of the tail region. We must use careful actuarial judgement here because the selected paths may not be the same across all nodes.

Reduce the number of nodes and **Reduce the number of outer scenarios** are other reasonable answers

Others include examples of variance reduction methods and grid processing.

(c) **(LO 2a)** Critique the following statements:

A. *For the underlying index, the volatility parameter is an average of 65 years of data; therefore, the credibility of such a long sample period means it is reasonable to set σ to 20% for all nodes in the model.*

B. *The relation between interest rates and equity returns has been proven beyond statistical doubt. Consequently, in reserve calculations the expected return on equities should exceed the risk-free rate by an expected risk premium at every time step in every scenario.*

1. Continued

C. Stock prices are distributed normally and therefore the company can use the stock price volatility as a parameter in a stochastic model.

Commentary on Question:
Responses for this section vary. Only a handful of candidates were able to obtain full credits for identifying all the mistakes in the statements and provide reasons to back up their critiques.

A.

Regardless of calibration period, models using a single value of a volatility do not fit historical market prices well. The fitting of actual market prices using the Normal distribution results in an "implied volatility surface", which is an array of different values depending on strike price and tenor.

B.

The first sentence is false. The relationship has **NOT** been proven beyond statistical doubt. The lack of statistical proof does not mean such a relationship does not exist. For real-world scenarios, equity returns will exceed the risk-free rates by a risk premiums, whereas all assets under risk-neutral scenarios would earn the risk-free rates.

C.

Stock returns are assumed to be normally distributed and **NOT** stock prices. If stock prices where normally distributed, there would be negative stock prices. Even though it is assumed returns are normally distributed, in practice, there is a much fatter tail and stronger central peak. Often a single volatility parameter is used in modelling stock however it is more appropriate to use an implied volatility.

2. Fall 2022 ALM LAM Exam (LOs 2a, 3b)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

3b) Describe, compare and evaluate organizational structures for model governance, including controls, roles, and responsibilities

Relevant Sources:

Economic Scenario Generators – three-part series, SOA:

- Part III – In-depth ESG Case Study – Academy Interest Rate Generator, The Modeling Platform, Jul 2021

The Importance of Centralization of Actuarial Modeling Functions, Part 1: Focus on Modularization and Reuse, The Modeling Platform, Nov 2019

Model Validation for Insurance Enterprise Risk and Capital Models, 2014 (excluding Appendices)

Commentary on Question:

To receive full credit, Candidates need to provide their critique with justification from cost effective and controlled environment point of views. A lot of candidates mentioned the divide and conquer fallacy. Without clearly explanation of the divided and conquer fallacy from the cost effective and controlled environment perspective, only partial credit will be granted. Many candidates recommended alternative approaches to the statements as a better solution rather than noting the issues and challenges with the proposed approach in the statements

2. Continued

Solution:

(a) **(LO 3b)** You oversee new product modeling at ABC Life Insurance Company. ABC is looking to develop a cost effective and controlled environment for modeling.

Critique the following two statements:

A. To save time and effort a new product will be developed using a decentralized approach where a copy of an existing model will be created for the new product and maintained separately.

B. To avoid replicating errors in the existing model, new products will always need to be developed from first principles.

Do not recommend this approach
Not cost effective: when starting from copying, there are multiple groups effectively maintaining the same functionality and solving similar problems
Not controlled: with multiple models requiring maintenances, it becomes difficult to keep all under control
B.
Do not recommend this approach
Not cost effective: starting from scratch is usually risky and very expensive. There is a bias to underestimate time and effort needed.
Not controlled: no matter the good intentions of starting with a clean slate, there is a good chance that reality will set in and the new model will start having all the same blemishes as all the other models in the organization

(b) **NO LONGER RELEVANT**

~~ABC is growing quickly and it is becoming more challenging to manage assumption governance requirements. You have been asked to replace the current compliance focused framework with a strategic assumption governance framework.~~

~~(i) List four beneficial byproducts of having a strategic assumption governance framework.~~

~~(ii) Recommend improvements to each of the following assumption governance requirements, if necessary. Justify your recommendations.~~

~~*A. The top priority of assumption governance is compliance with regulatory requirements.*~~

~~*B. All models must have consistent assumptions.*~~

~~*C. Each assumption must be reviewed annually.*~~

2. Continued

D. Assumptions should only be passed to modelers for implementation after they have been approved by all relevant stakeholders.

Commentary on Question:
(i) Full credit will be given for every 4 out of the 5 items in the list. Many candidates were able to get full credit. Many candidates provided the full list of 5 points
(ii) In general, most candidates provided good responses to most of the statements statement B: many candidates confused consistent assumptions with the same assumptions. Very few referred to ASOP 56

Statement C: most candidates were able to recommend the risk-based approach

Statement D: only a few candidates clarified that the stakeholders should include the modelers and note the importance of communication and collaboration across all of the stakeholders.

(i) Fostering communication among subject experts
Leveraging the best technology and data
Controlled, accurate implementation
Documentations and defensible processes
Satisfying management, regulator, and auditor requirements

(ii) A.
Although compliance is an important outcome, it should not be the stated objective, as that rarely achieves the desired outcome.
Governance needs to be deeply embedded in the organizations culture to encourage discipline.
Recommend achieving a strategic goal, such as set the best assumptions possible, as the top priority of assumption governance.
B.
ASOP 56 requires that consistency in assumptions across models be considered and explained, not mandated.
Recommend allowing inconsistency, as long as it is appropriately explained. This allows actuaries to make expert decisions but requires them to think deeply about assumption consistency.
C.
When companies review and set assumptions annually, they encounter time and resource constraints.
Recommend risk-based approach that evaluates each assumption to define its risk level, and let risk level dictates the level of review. Assumptions with highest financial impact and most complexity get more scrutiny.

2. Continued

~~D.~~
~~Modelers need to know how assumptions are developed, not just know what assumptions are. Data and assumption owners need to understand the models to better formulate the assumptions that are best for the purpose.~~
~~Recommend regular and consistent feedback loop and collaboration between experts in data, assumptions, and modeling~~

(c) **(LO 2a)** Your manager has suggested to use the interest rate model developed by the American Academy of Actuaries (the Academy model) for the pricing of new products.

Assess if this is reasonable. Justify your response.

Commentary on Question:
This question is not very well done. Many candidates provided very generic responses to the use of an interest rate model for pricing which was not answering the question. Most candidates did not understand any specifics about the American Academy of Actuaries interest model which was required to answer the question for full credit

It will not be reasonable:

- The academy model is stochastic and can be difficult to use for pricing purpose
- The academy model is designed to replicate the general behavior of interest rates, but not periodically calibrated to reflect the latest market condition
- The academy model is intended to be used to measure the volatility of insurer financial results in the outlier scenarios—the ones at the tails of the distribution.
- However, in pricing, the greatest probability weight is placed on the bulk of scenarios in the middle of the distribution

4. Fall 2022 ALM LAM Exam (LO 2a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

Relevant Sources:

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

CP312-103-25: Chapter 8 of Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 (8.1-8.6)

Commentary on Question:

Commentary listed underneath question component.

Solution:

(a) **(LO 2a)** Critique the following statements from their report:

A. The ESG produces thousands of scenarios covering a wide distribution of projected interest rate and equity growth paths so it is ideal for risk management applications.

B. The pricing department follows industry-leading practices to calibrate their ESG to current market conditions, producing near-perfect replication of option prices.

C. The ESG output is regularly tested to verify the absence of arbitrage opportunities.

D. If a new ESG is built for risk management, then for the sake of consistency between the inner loops and outer loops of nested scenarios the company should also use the new ESG for pricing.

4. Continued

Commentary on Question:
The question requests analysis of ESG characteristics in a risk management context, which demands a real-world (RW) ESG instead of a risk-neutral (RN) ESG. Some credits would be given if acknowledging the appropriateness of these ESG characteristics in a pricing context, but the candidates need to address the risk management context in order to earn full credit.

A) Risk neutral ESGs are a math trick to solve partial differential equations to calculate the value of an option. RN ESGs generate scenarios that seem unreal.

In risk management we care about what really happen in different scenarios. The ESG should generate the types of events that result in the outcomes that we care about.

The purpose of a real-world simulation is to capture market dynamics, risks and returns in a way that an insurance company or other financial institution might experience them. Real-world simulations enable the exploration of the what-if questions asked by management as it tries to gauge the likelihood of future events and their business impact.

B) This is appropriate for pricing purposes. Because the market-consistent model calibration process is designed to reproduce the prices of traded derivatives, the ultimate calibration is dependent on both the pricing date and the set of traded derivatives used to calibrate the model. The validation associated with the model calibration is based on how well the model reproduces the market values of the universe of traded derivatives used to calibrate the model.

But the context here is risk management and risk management applications, in contrast, require that ESGs be capable of producing dynamics that are representative of the possible future paths of economic variables. Commonly referred to as “real-world” calibrations, they enable managers to ask what-if questions as they try to gauge the likelihood of future events and their impact on its business.

C) No-arbitrage is absolutely essential to have in a neutral ESG because that was a fundamental assumption in its development.

But for risk management purposes often the no-arbitrage condition severely restricts your ability to generate appropriate real-world behaviors. For a real world ESG, if the model is complex enough that you can't reliably determine with the nature of the model while living within a single scenario, then formal no-arbitrage may not be necessary. And by dropping this requirement you may facilitate a much richer menu of behaviors in your model.

4. Continued

D) Keep using risk-neutral scenarios to price the assets at each node, since the assets do not have closed form formula.

The risk management and hedging of variable annuities is a standard example in which real-world and risk-neutral scenarios are applied together. For such an application that involves nested stochastic (i.e., inner loops) the state of the world or node is simulated under the real-world measure, and cash flows are priced in that state of the world using risk-neutral scenarios projected forward from the current node of the simulation.

NO LONGER RELEVANT

~~(b) Calculate the expected profit and loss for the product under each of the following scenarios:~~

~~(i) The underlying equity index earns 5% per year~~

~~(ii) The underlying equity index earns -5% per year~~

~~**Commentary on Question**:~~
~~*None*~~

~~See "ILALAM Fall22 Calcuation_Q4.xlsx" for detailed calculations~~

~~Calculation of the Account Value (AV):~~

~~AV(EOP) = AV(BOP) + Interest - Rider Fee~~

~~where,~~

~~Interest = AV(BOP) * AV Growth %~~

~~Rider Fee = [AV(BOP) + Interest] * Ride fee %~~

~~(i) Calculation of net income under the 5% scenario~~

~~Profit = Rider Fee - Hedging Cost + Hedging Payout - GMAB Claim Cost~~

~~Where:~~

~~Hedging Cost = AV(BOP) * 25/1000~~

~~Hedging Payout = 0~~

~~GMAB Claim Cost = 0~~

4. Continued

(ii) Calculation of net income under the -5% scenario

Profit = Rider Fee Income - Hedging Cost + Hedging Payout – GMAB Claim Cost

Where:

Hedging Cost = AV(BOP) * 25/1000

Hedging Payout = Loss of AV in down market = MIN [- AV(BOP) * AV Growth %, 0]

GMAB Claim Cost = AV (t= 3) - GMAB(t= 3)

Where:

GMAB(t = 0) = 100,000

GMAB (t) = MAX [GMAB(t-1), AV(t)]

(c) Your manager has expressed a concern that the proposed product is too risky and despite the proposed risk mitigation the company could be exposed to significant claim costs if markets decrease.

Recommend changes to the hedging strategy to address your managers concerns.

Commentary on Question:
Most of the candidates had trouble with this question, possibly due to the wording of the question.

The manager's statement is incorrect. The hedging strategy perfectly offsets all downside risk.
In question (b) calculation, Fee Income + Hedge Payout + Claims cost = 0

1. Spring 2023 ILA LAM Exam (LOs 2a, 3a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

3a) Describe and apply model governance best practices such as:

- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures

Relevant Sources:

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

ASOP 56: Modeling, Dec 2019, pp. 1-9

1. Continued

Commentary on Question:
Commentary listed underneath question component.

Solution:
(a) **NO LONGER RELEVANT**
~~For each scenario listed below:~~

~~(i) Assess the impact on your company~~

~~(ii) Recommend a risk mitigation strategy if appropriate~~

~~(iii) Discuss any potential disadvantages of the risk mitigation strategy proposed in (ii)~~

	~~Economic Scenario~~	~~Asset / Liability~~
~~A~~	~~High Inflation~~	~~Whole Life Insurance with a fixed policy loan rate~~
~~B~~	~~Deflation~~	~~Universal Life with minimum crediting rate guarantee~~
~~C~~	~~Rising Interest Rates~~	~~Universal Life with minimum crediting rate guarantee~~
~~D~~	~~High Inflation~~	~~Fixed annuities with cost-of-living adjustments indexed to inflation~~
~~E~~	~~High Inflation~~	~~Long-term fixed bonds~~

~~**Commentary on Question**:~~
~~*The question was testing the ability of candidates to identify the risk of various inflationary and interest rate scenarios on various Products. Candidates needed to identify valid methods of mitigation for the product or the company. Most candidates were able to identify the risk facing the product or company in scenario A, B and C. Better candidates were able to identify the risks in scenario D and E. Credit was given where reasonable mitigation strategies were proposed. A number of candidates gave generic risks of the mitigation strategies, better candidates were able to give specific risks of the mitigation strategies proposed*~~

~~**Scenario A**~~
~~Risk: Policyholders are likely to take out loans to invest elsewhere if the fixed loan rate is lower than prevailing interest rates. This will force your company to sell assets to meet outgoing cashflows. In other words, disintermediation risk~~
~~Mitigation: Don't offer fixed policy loan rates. Instead, index rates (e.g. central bank rate + x%).~~
~~However, it may not be possible to index rates that were contractually fixed.~~
~~**Scenario B**~~
~~Risk: Investment returns may fall short of the guarantees, creating significant risk for the company~~
~~Mitigation Reduce the minimum guaranteed rates on fixed products, particularly UL; can retain flexibility via the current credited rate mechanism to offer higher rates if interest rates rise. Develop triggers that are linked to the risk of deflation~~
~~Disadvantage: consumer dissatisfaction if eliminate guarantees~~

1. Continued

~~**Scenario C**~~
~~Risk: Disintermediation. Policyholders likely to lapse or withdraw as much cash value as possible to seek higher returns elsewhere. Portfolio rate will be dragged down by Inforce assets purchased at lower rates and will not keep up with new money yields.~~
~~Mitigation: Increase credited rates as much as possible.~~
~~Disadvantage is compressed spreads.~~
~~**Scenario D**~~
~~Risk: Fully indexed for inflation could be cost prohibitive if the risk of hyperinflation is reflected~~
~~Mitigation: Add a cap for unexpected exposure during sustained high inflation/Invest into index linked securities to hedge against the impact of inflation~~
~~Disadvantage is there is counterparty risk introduced/ It may not be possible to fully hedge the risk of sustained or hyper inflationary effects~~
~~**Scenario E**~~
~~Risk: Bond value decreases significantly. They create drag on income and become difficult to sell.~~
~~Mitigation: Reinvest in short-term assets to reduce impact on inflation.~~
~~Disadvantage is reduced investment income~~

(b) **(LO 2a)** You have been asked to review your company's Economic Scenario Generator (ESG) regarding its suitability to simulate future interest rate paths including inflation.

Critique the following statements:

A. *The applications of the ESG are primarily focused on the interaction of interest rate changes and policyholder behavior so its use is limited to liability valuation. It is not suitable for stress testing.*

B. *To model the relationship between inflation and interest rates your company uses parameters based on historical inflation data from the last 30 years.*

C. *For calibrating the parameters within an ESG, making use of a cascade structure where interest rates are at the top of the cascade with inflation below would imply that interest rate changes cause inflation.*

1. Continued

Commentary on Question:
Candidates were asked to comment on various aspects of an ESG and respond to statements about the structure and purpose of an ESG. Candidates who got full credit correctly challenged the validity of statements and explained why the statements were inaccurate or only partially true. Most candidates could identify that Statement A was not completely true, but few were able to acknowledge the uses of the ESG for life insurance liabilities correctly. For scenario B, some candidates confused the question as being about real-world vs risk neutral ESGs versus discussing the broader issues arising from the time period selected to calibrate parameters. Scenario C was poorly answered – most candidates were unable to recognize that the cascade structure for calibration was not meant to imply a direct causal relationship of variables.

Statement A
While it's true that applications of ESGs for life insurance liabilities are primarily focused on the interaction of interest rate changes and policyholder behavior regarding lapses and other optionality, this does NOT mean that ESGs are only suitable for valuation. Other uses include effective duration analysis, stress testing, economic capital (EC) and strategic asset allocation (SAA).
Statement B
This is incorrect due to Insufficient data - A model of future inflation rates should not be parameterized based solely on the levels of inflation experienced in the last few decades. A longer time horizon including the deflation periods and high inflation periods of the past should be used, as well as consideration of developments in other countries that have faced similar economic conditions, needs to be reflected in any inflation model.
Statement C
Not true. The sequence of the cascade is not intended to reflect any cause-and-effect relationship but rather is designed to ease the calibration process while allowing variables to be appropriately correlated.
In the cascade structure a variable lower in the cascade is only affected by variables above it and its prior values. For example, making use of a cascade structure where interest rates are at the top of the cascade with inflation below would not imply that interest rate changes cause inflation. It would, however, allow the simulation of interest rates and inflation to have an appropriate relationship, so that when interest rates are high, inflation will tend to be high, and vice versa.

(c) **(LO 3a)** Identify four relevant recommended practices from *ASOP 56, Modeling,* that should be considered when relying on external experts to develop your company's ESG.

1. **Continued**

Commentary on Question:
Candidates were asked to recall the recommended practices when relying on external experts as per ASOP 56. Candidates scored poorly on this question with few being able to comprehensively recall the material. Better candidates could identify the need to document reliance and to establish expertise and relevance

In determining the appropriate level of reliance, the actuary may consider the following:

a. whether the individual or individuals upon whom the actuary is relying on are experts in the applicable field;
b. The extent to which the model has been reviewed or validated by experts in the applicable field, including known material differences of opinion among experts concerning aspects of the model that could be material to the actuary's use of the model.
c. whether there are industry or regulatory standards that apply to the model or to the testing or validation of the model, and whether the model has been certified as having met such standards; and
d. whether the science underlying the expertise is likely to produce useful models for the intended purpose.

When relying on experts, the actuary should disclose the extent of such reliance.

5. Spring 2023 ILA LAM Exam (LO 2a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

Relevant Sources:

CP312-101-25: Stochastic Modeling, Theory and Reality from an Actuarial Perspective, sections I.A, I.B-B.2, I.B.3.a, II.B-B.1.d

CP312-106-25: Catastrophe Modelling: Guidance for Non-Catastrophe Modelers

Commentary on Question:
Commentary listed underneath question component.

Solution:

~~(a) NO LONGER RELEVANT~~

~~Compare the use of True Random Number Generators and Pseudo Random Number Generators as a source of randomness in a stochastic model.~~

~~**Commentary on Question**:~~

~~*The question asks candidates to describe and evaluate Random Number Generator models, and explain their uses, advantages, and theory. Most candidates performed well on this question. Some candidates only talked about Pseudo Random Number Generators without specifically describing True Random Number Generators, so were only given partial credit.*~~

~~True Random Number Generators make use of naturally occurring events as the source of input for randomness and generate random numbers by detecting small and unpredictable changes in the real-world data~~

5. Continued

~~Pseudo Random Number Generators are mathematical algorithms that produce sequences of numbers that appear random. They are sequences which are deterministic and finite in nature~~

~~True Random Number Generators are a better source of randomness, but Pseudo Random Number Generators are preferred as they are much easier to model and much more efficient when operating in a stochastic environment~~

~~A key criteria in stochastic modeling is the random numbers should be reproducible to ensure changes to the stochastic model work correctly. This is a characteristic of Pseudo Random Number Generators but not True Random Number Generators.~~

(b) **(LO 2a)**

(i) Identify how stochastic modeling could improve each deterministic mortality parameter.

(ii) Describe an approach which could be used to model each parameter stochastically.

Commentary on Question:
The question asks candidates to describe and evaluate how stochastic models may be used to understand mortality risks and why they are needed and how they can be implemented. Candidates generally did not perform well on this question. Many candidates only described why stochastic modeling is better than deterministic modelling in general without providing specific information on each mortality parameter.

Base Mortality Rate
A mortality study can be considered one random sample from the portfolio's "true" mortality. With any random sample, uncertainty exists as to whether the sample is a good representation of the population. The stochastic model can improve upon the deterministic model by modeling this uncertainty stochastically.

Model mortality as a binomial process where the experience study is the mean and 1/sqrt(#claims) is the standard deviation.

For a stochastic iteration, use the normal approximation to the binomial to randomly select a base mortality assumption for that iteration

Mortality Improvement Rate
Mortality Improvement rates vary significantly by attained age so a stochastic process could introduce variability and be expanded to individual ages as opposed to applying a single assumption to all ages

5. Continued

Using the mean and standard deviation of historical mortality improvements, a normal distribution could be used to generate stochastic mortality improvement scenarios

Catastrophic Mortality
The frequency and severity distributions for catastrophes can be modeled based on historical information. That additional mortality can be randomly sampled each year in the stochastic projection

(c) **(LO 2a)** Assess if the proposed capital amount is sufficient to cover expected losses at the 90th percentile. Justify your answer.

Commentary on Question:
The question asks candidates to explain and apply risk measurement metrics in a real-life scenario. It is expected that candidates would consider different metrics to give a full assessment on the scenario as different conclusion could be drawn depending on the chosen metric. Most candidates only based their assessment on one criteria e.g VaR. Another common mistake candidates made is to only include additional capital of $400 without adding average NPV of death benefit when determining the capital constraint. Candidates need to provide explanation to support the conclusion they are offering to receive full credit.

There are different ways to calculate VaR under the given scenario, all reasonable answer will be given full credit. The solution below only lists one of the possible answers.

Average NPV of death benefits = CTE(0) = $173.25M
Management proposes holding capital of $400M in addition to the average NPV of death benefits, so the total capital Management proposes to hold on balance sheet is $400 + $173.25= $573.25M

There are different risk metrics to measure expected losses at the 90th percentile.

- CTE(90) reflects the probability weighted loss at the 90th percentile. Given that there are 50 simulations, CTE(90) is calculated as the average of the worst 5 NPV of death benefit within those 50 simulation.
  CTE(90) = $599.23M > $573.25M

  As CTE(90) loss is greater than proposed capital amount, Senior Management is incorrect that they are sufficiently capitalized

5. Continued

- VaR(90) reflects the loss at the 90th percentile.
  VaR(90) is the worst 46^{th} NPV death benefit when sorting the 50 simulations.
  VaR(90) = \$542.33M < \$572.25M

  As VaR(90) loss is less than proposed capital amount, Senior Management is correct that they are sufficiently capitalized

6. Spring 2023 ILA LAM Exam (LO 3a)

Learning Objectives:

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

3a) Describe and apply model governance best practices such as:

- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures

Relevant Sources:

Model Validation for Insurance Enterprise Risk and Capital Models, CAS/CIA/SOA 2014 (excluding Appendices)

ASOP 56: Modeling, Dec 2019, pp. 1-9

Commentary on Question:

This question tested candidates understanding of ASOP 56, model validation, and model documentation. In Part a candidates needed to critique, with justification, each statement to receive full credit, while in Part b just listing the types of documentation was sufficient for full credit. The majority of answers in part a were partially correct but needed more detail to receive full credit. In part b, most candidates received at least partial credit.

6. Continued

Solution:

(a) **(LO 3a)** Critique each statement in the context of Model Risk Management and *ASOP 56, Modeling*.

A. Your management team suggests to fully rely on MYB for modeling expertise as they control the functionality and are responsible for updating the calculation engines.

B. To assess usefulness of the report you decide to survey a group of actuaries who use the report for their feedback.

C. To mitigate third party risk your company has applied a margin of conservatism to the mortality table

D. MYB failed to deliver your stress testing model on time. As a result, your risk department is repurposing a pricing model to conduct their regulatory reporting

Commentary on Question:
Candidates generally did well critiquing statements a and d of this question. For statement a, candidates generally did well highlighting the need for the company to review/understand the model—but did not mention the need to disclose reliance on MYB, resulting in partial credit. In part b, some candidates accurately identified the potential for bias and the need for additional individuals to be surveyed. A significant number of candidates did identify the problem with this approach and said the practice was appropriate, receiving no credit. Candidates struggled to earn full credit on part c, with few mentioning the inadvisability of adding conservatism at the input parameter level. Many candidates received partial credit for mentioning that mortality conservatism will not reduce third-party risk. In part d, most candidates highlighted the need to consider the intended use of the model and received full credit in doing so.

A. This statement is incorrect. The company should review and understand the model to correctly use it and interpret the output. The modeling team should attempt to determine limitations of the model, which can be difficult due to vendors not wanting to disclose this information. Also, the extent to which the company relies on MYB should be disclosed.

B. This statement is incorrect. Obtaining feedback from the users of the report will likely result in asymmetric feedback and bias. Users are likely to recommend the report if the report is favorable to their work and vice versa. Individuals who don't use the report directly should also be surveyed.

6. Continued

C. This statement is incorrect. Adding conservatism to the mortality table will not address third-party risk. The company should instead review the model and mortality assumption to address third-party risk. Additionally, adding conservatism at the input parameter level is not advisable, as this contributes to opacity in the model.

D. This statement is likely incorrect. It is important for the intended purpose of the model to match the use of the model. Pricing models are not intended to be used for regulatory reporting, as they usually include market consistent assumptions while regulatory reporting models contain more conservatism.

(b) **(LO 3a)** Identify additional documentation required from MYB and your company to ensure effective model risk control.

Commentary on Question:
Most candidates received at least partial credit on this section. Many did not name the three categories of documentation explicitly. Listing the types of documentation was sufficient for full credit, though some candidates also described the documentation. Full credit was given if detailed examples of the types of underlying documentation were described. Most candidates only highlighted one or two of the three areas, resulting in partial credit.

The user guide alone is not sufficient documentation to manage model risk. Comprehensive documentation includes model development documentation, model implementation documentation and on-going model governance documentation.

Examples of each include:
Model development documentation: User Guide, How model outputs will be used, company specific assumptions
Model implementation documentation: Development tests performed by MYB, Data Dictionary, Intended Use and Limitations
Model governance documentation: Model monitoring, model and assumption change management, implement changes, reviewing changes

1. Spring 2024 ILA LAM Exam (LO 2a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

Relevant Sources:

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

CP312-103-25: Chapter 8 of Quantitative Enterprise Risk Management, Hardy, Mary and Saunders, David, 2022 (8.1-8.6)

CP312-101-25: Stochastic Modeling, Theory and Reality from an Actuarial Perspective, sections I.A, I.B-B.2, I.B.3.a, II.B-B.1.d

Commentary on Question:

The question was generally answered well by the candidates. Both correct statement and supporting points are required to receive full credits.

1. Continued

Solution:

(a) **(LO 2a)** Critique the following statements regarding stochastic modeling:

(i) *Stochastic models should only be used when it is explicitly required by a regulatory standard.*

(ii) *Real-world scenarios cannot be connected with risk-neutral scenarios due to different usage of expected cash flows and a discount rate.*

(iii)*For nested stochastic modeling, real-world scenarios and risk-neutral scenarios should be used for inner-loop and outer-loop, respectively.*

NO LONGER RELEVANT

~~(iv)*When using a random number generator, a true random number generator is more efficient than a pseudo random number generator.*~~

Commentary on Question:
Full credits are given for candidates providing reasonable support for their answers.

(i) False

a. Stochastic models can also be used to perform tail risk analysis, calculation of diversification effects, risk adjusted strategies.

(ii) False

a. Risk-adjusted cash flows are adjusted in such a way as to ensure that the expected PV of CF's between two are consistent, ~~Two scenarios can be connected via the use of deflators.~~**(This part of the answer is no longer relevant.)**

(iii)False

a. The fund returns and interest rates driving the fixed and variable account balances of the policy should be generated with real-world outer scenario. The fair-market value of liabilities under market-consistent risk-neutral inner paths must be determined at selected periods.

~~(iv)~~**NO LONGER RELEVANT** ~~False~~

~~a. It is more desirable to use Pseudo Random Number Generator (PRNG) than True Randon Number Generator (TRNG) when one is doing stochastic simulations, PRNGs are much more efficient, meaning that the amount of time required for them to generate large sets of numbers is small compared to TRNGs.~~

1. Continued

(b) NO LONGER RELEVANT

~~A Generalized Linear Model (GLM) is due for an update. The following data is provided regarding claim severity:~~

	Smoker	**Non-smoker**
Male	900	500
Female	600	400

~~The form of the GLM is:~~

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

~~Where:~~

~~β_1 = Parameter for Male~~
~~β_2 = Parameter for Female~~
~~β_3 = Parameter for Smoking Status~~

~~(i) Solve for parameters β_1, β_2 and β_3 assuming the error term is normally distributed with mean zero and variance σ^2.~~

~~(ii) Evaluate the limitations of the use of a normal error structure.~~

~~Commentary on Question~~:
~~(i)This part is generally not answered well. Full credits were granted to candidate where the formula was shown and calculated correctly. Few candidates showed final answers without description or formula and received partial credits. Partial credits were granted to candidates who described the methodology correctly but did not calculate correctly.~~
~~(ii)Most candidates could answer some limitation of using normal error structure to receive partial credits.~~

~~(i)~~
~~Y: Parameter Value~~
~~X_1: Indicator for Male~~
~~X_2: Indicator for Female~~
~~X_3: Indicator for Smoking Status where 1 for smoker and 0 for non-smoker~~

$$Y_1 = 900 = \beta_1 + 0 + \beta_3 + \varepsilon_1$$
$$Y_2 = 700 = 0 + \beta_2 + \beta_3 + \varepsilon_2$$
$$Y_3 = 500 = \beta_1 + 0 + 0 + \varepsilon_3$$
$$Y_4 = 400 = 0 + \beta_2 + 0 + \varepsilon_4$$

1. Continued

Sum of squared errors
$= \varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2 + \varepsilon_4^2$
$= (900 - \beta_1 - \beta_3)^2 + (600 - \beta_2 - \beta_3)^2 + (500 - \beta_1)^2 + (400 - \beta_2)^2$

Differentiate β_1, β_2, and β_3 and solve when setting to zero

Differentiate β_1
$\beta_1 + \beta_3 + \beta_1 = 1400$
$2\beta_1 + \beta_3 = 1400$

Differentiate β_2
$\beta_2 + \beta_3 + \beta_2 = 1000$
$2\beta_2 + \beta_3 = 1000$

Differentiate β_3
$\beta_1 + \beta_3 + \beta_2 + \beta_3 = 1500$
$\beta_1 + \beta_2 + 2\beta_3 = 1500$

Then
$\beta_1 - \beta_2 = 200$
$\beta_2 = \beta_1 - 200$
$\beta_3 = 1400 - 2\beta_1$

$\beta_1 + \beta_1 - 200 + 2(1400 - 2\beta_1) = 1500$
$-2\beta_1 = 1500 - 2600 = -1100$

Thus,
$\beta_1 = 550$
$\beta_2 = 350$
$\beta_3 = 300$

(ii)
The limitations of the use of a normal error structure:

- It is difficult to assert Normality and constant variance for response variables.
- The values for the response variable may be restricted to be positive. The assumption of Normality violates this restriction.
- The variable is a function of the mean. If the response variable is strictly non-negative then intuitively the variable of Y tends to be zero as the mean of Y tends to be zero.

1. **Continued**

(c) **(LO 2a)** Your company uses a normal distribution with constant volatility to project equity returns.

(i) Describe a drawback of using the normal distribution with constant volatility to project returns.

(ii) Recommend two possible alternatives to using constant volatility. Justify your answer.

Commentary on Question:
(i) The candidate should describe that economic variables have fatter tails and a stronger central peak to receive full credits. Partial credits were granted to candidates to answer fatter tails or stronger central peak only.
(ii) This part is generally done well by the candidates. Most candidates provided two (different) alternative methods with descriptions to receive full credits.

(i)
The actual variability of most economic variables is better characterized by a distribution with both fatter tails and a stronger central peak than the Normal bell-shaped curve.

(ii)
Stochastic Volatility
The Normal distribution is still used, but the volatility parameter is made to follow its own mean-reverting stochastic process over time. When the volatility is lower than average in the scenario, values clump toward the center of the distribution. When the volatility is higher than average, relatively more tail values are generated. Overall, the ultimate distribution has longer tails and a stronger central peak.

NO LONGER RELEVANT
~~Regime Switching~~
~~The Normal distribution is still used but the model switches between two regimes, which are characterized by different sets of parameter values for both the volatility and the mean. There is a high-volatility regime and a low-volatility regime, typically with different mean values. Switching between regimes results in an ultimate blended distribution that can have longer tails and a stronger central peak.~~

Different Underlying Distribution

The Normal distribution is abandoned as a model of variability within each time step. A different distribution that has longer tails is used instead. There are many choices for such a distribution.

GARCH

GARCH is a discrete time model with time-varying volatility. The GARCH model incorporates stochastic volatility and volatility clustering.

5. Spring 2024 ILA LAM Exam (LO 2a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

Relevant Sources:

Economic Scenario Generators: A Practical Guide, SOA, Jul 2016, Ch. 1, 2, 4.1-4.3, 5, 6, 7.1-7.3, 8

Commentary on Question:

Commentary listed underneath question component.

Solution:

(a) **(LO 2a)** Critique the following statements:

A. *Interest rate modeling is not as complex as stock price modeling as the term structure of interest rates only requires modeling a single variable.*

B. *It is not sufficient to treat the risk-free rate as a fixed parameter. An ESG that is being used for the management of variable annuity risk would need to include model dynamics that capture the path wise features of interest rates.*

C. *Arbitrage-free models are a necessary requirement when one wants to apply an ESG to real-world scenarios. If the scenarios are not arbitrage-free, then one cannot consistently price derivatives.*

D. *Only risk-neutral scenarios are used for hedging variable annuities.*

5. Continued

Commentary on Question:
This question tested the candidate' knowledge of interest rate and stock price modeling under real-world and risk neutral scenarios. Candidates generally performed well across all four parts.

A) Not correct - Interest rate modeling is more complex than stock price modeling. The reason is that the term structure of interest rates requires modeling a curve rather than a single variable, and the no-arbitrage principle constrains the possible outcomes.
B) Correct - The path-wise nature of interest rates and equity market returns are important considerations in hedging risks associated with underwriting investment guarantees.
C) Partially Correct - If ESG models are applied in real-world modeling contexts, then these models should be able to capture return behavior and market dynamics but do not necessarily have to be technically arbitrage-free. Arbitrage-free models are a necessary requirement when one wants to apply an ESG to risk-neutral pricing problems. If the scenarios are not arbitrage-free, then one cannot consistently price derivatives.
D) Not correct - Hedging of variable annuities is a standard example in which real-world and risk-neutral scenarios are applied together. The real-world simulation is used to assess the overall risk of the variable annuity book and to measure the effectiveness of the hedging strategy. Since the liabilities associated with the variable annuity book are complicated, closed-form formulas are not available, and risk-neutral scenarios must be used to price the variable annuity book at each node of the real-world simulation.

(b) **(LO 2a)** Describe the purpose of establishing Stylized Facts prior to the development of the ESG.

Commentary on Question:
This question tested the candidates' knowledge of stylized facts. To receive full credit, candidates were required to demonstrate an understanding of stylized facts and clearly indicate reasons for establishing stylized facts prior to the development of the ESG. A common mistake was to list benefits of stylized facts but neglect to mention how they are used in the development of the ESG.

Stylized facts refer to generalized interpretations of empirical findings that provide a basis for consistent understanding of markets or economic drivers across a wide range of instruments, markets and time periods. Stylized facts are important in guiding the design of an ESG in that they help establish and prioritize the properties that the ESG model must have to be useful for a given application. Detailed knowledge of these dynamics is essential for setting ESG model calibration targets and understanding strengths and weaknesses of various ESG model frameworks.

5. Continued

(c) **(LO 2a)** Management is not convinced about the use of an ESG and recommends using analytical solutions which do not require intensive computation.

Critique management's recommendation.

Commentary on Question:
Candidates were required to specifically address the recommendation and justify their position. Many candidates neglected to directly respond to the recommendation and instead simply listed benefits of using an ESG.

Management's recommendation is not reasonable. While utilizing an analytical solution can save time and resources, they can present many limitations.

Impediments and limitations to analytical solutions:

- An underlying distribution must be identified and this is often unknown or unknowable.
- The problem involves the use of complex joint distributions.
- Discontinuities must be incorporated into the analysis.
- Results require translation or mapping to the desired output.
- Multiperiod projections are required.

Given the complex nature of a variable annuity product and substantial amount of tail risk embedded in potential GMxBs, I recommend that the company continue to utilize an ESG.

NO LONGER RELEVANT

~~(d) Calculate the risk neutral probability of the account value increasing by 8% in a given year.~~

~~**Commentary on Question**:~~
~~*This question required candidates to demonstrate how to correctly use the risk neutral probability formula. Candidates generally did well on this question with the most common mistake being to confuse the probability of an up-move with the probability of a down move.*~~

- ~~S(0) = 10000~~
- ~~S(1)u = 10800~~
- ~~S(1)d = 9200~~
- ~~R = 3%~~
- ~~Prob(Up) + Prob(Down) = 1~~
- ~~S(0) * exp(r) = Prob(Up) * S(1)u + Prob(Down) * S(1)d~~
- ~~10000 * exp(.03) = Prob(Up) * 10800 + (1- Prob(Up)) * 9200~~
- ~~Prob(Up) = 69.03%~~

5. Continued

(e) State if the following concepts are illustrated in the model used in part (d). Justify your answer.

(i) Replication

(ii) No-arbitrage assumption

(iii) Risk neutral probability distribution

(iv) Dynamic hedging

Commentary on Question:
Candidates were required to identify that all 4 concepts are illustrated in the risk neutral model presented in part (d). Candidates did well on parts (ii) and (iii) but struggled with (i) and (iv)

(i) Replication is illustrated in the model. Replication is the process of finding a portfolio that exactly replicates the option payoff. I.e. the market value of the replicating portfolio at maturity exactly matches the option payoff at maturity whatever the outcome of the asset. The model in part (d) replicates an option payoff through a portfolio of risky and risk-free assets.

(ii) No-arbitrage is illustrated in the model. The no-arbitrage assumption states that 2 identical cash flows must have the same value. As illustrated by the model in part (d), the portfolio and option have the same payout. By definition, risk neutral models must adhere to an arbitrage free assumption.

(iii) Risk neutral probability distribution is illustrated in the model. Under the risk-neutral framework, the model is indifferent between two investment choices that have the same expected payoff. These investment choices will always have the same price as evident in the model in part (d).

(iv) Dynamic Hedging is illustrated in the model. Dynamic hedging involves investing and rebalancing in risky and risk-free assets to meet potential GMxB liabilities at future points in time. In the model in part (d) a combination of risky and risk-free assets can be combined to meet the liability of the guarantee.

3. Fall 2024 CFE FD Exam (LO 2b)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(2b) Describe, apply, and evaluate model validation techniques

Relevant Sources:

CP312-108-25: Chapter 15 of Measuring Market Risk, Dowd, Kevin, 2nd Edition, 2005

Case Study - Darwin

Commentary on Question:

This question tests the candidate's ability to construct and interpret backtests, transformations, and their results. To perform well, candidates needed to not only know the various methods, but also their purpose and how to interpret their results. Candidates generally did poorly on this question.

There was a defect found in the graph to be interpreted in part c(iii). Individual results were reviewed. Candidates were given full credit for that part of the question so that no candidate was penalized for the issue on the exam. For purposes of training, sample answers are included below to assist in future exam study.

Solution:

(a) **(LO 2b)**

(i) Describe the two bases for statistical backtests that can be used to assess the adequacy of the risk models.

(ii) Identify an advantage, in addition to ease of application, and a disadvantage for each basis in part (i).

Commentary on Question:

Many candidates were familiar with one basis for statistical backtests, but few were familiar with two. For full marks for part (ii), candidates only needed to name one advantage and disadvantage for each basis, but multiple correct answers are included below for reference.

(i) Statistical backtests can be:

- Based on the frequency of exceedances
- Based on the distribution of exceedances or P/L

3. Fall 2024 Continued

Statistical backtests based on frequency of exceedances focuses on the probability of the first exceedance happening in time T, or on the probability that the # of observed frequency of tail losses ties with the expected # in the model.

Statistical backtests based on distribution of exceedances or P/L focuses on the distribution of the observations making a good fit (based on tests of distribution of equality) with the assumed distribution of the exceedances or P/L of the model.

(ii) For statistical backtests based on frequency of exceedances:

- Advantages
  - Only need limited information both in terms of data volume and parameters
  - Useful when long runs of data are not available
  - Intuitive, easy to explain
- Disadvantages
  - Throws away information on temporal pattern of exceedances which would have allowed tests for iid (independently and identically distributed). This is important for applicability of tests.
  - Throws away information on size of exceedances, which could lead to accepting "bad" models because the frequency is low even though the forecasts of size of losses are very poor.
  - Does not provide context for model failure, such as abnormal situations (e.g., natural disaster or market crash)

For statistical backtests based on distribution of exceedances or P/L:

- Advantages
  - Allows comparison of P/L observations to forecasts that are parametric and/or change every day.
  - Allows the application of statistical tools to identify possible sources of model failure.
- Disadvantages
  - Need larger volume of data or leads to unreliable results
  - Need to apply a number of tests to ensure reliability of results even under plausible circumstances.
  - Often assumes normal distribution which does not capture fatter tails of financial risks

3. Fall 2024 Continued

(b) **(LO 2b)**

(i) Construct a backtesting chart based on the Excel data.

(ii) Interpret the results in the context of Darwin's VA hedging program.

Commentary on Question:
Some candidates did not know which components to include in the backtesting chart. Many candidates did not know how to interpret the results.

(i) See solution in Excel.

(ii) There is a relatively large # of negative exceedances (10) as compared to 5 positive exceedances (double), and these negative exceedances are a lot greater in size than those of the positive exceedances. This could signify where (what market conditions) the model issues are.

There are also some sharp movements in the observations which could suggest changes in volatility in the market risks and/or convexity in the liability are not captured by the hedging program.

These likely point to inadequacy of Darwin hedging only Delta and half rho, which are not hedging the volatility of the market and capturing the convexity of the liability profile at the tails. This is made worse by the basis risk from many of Darwin's more popular funds that are likely moving faster than the market.

(c) **(LO 2b)**

(i) Explain the Transformations, their purpose, and application.

(ii) Transform the data to populate the two charts provided in the Excel tab CFEFD F24 Q3c.

(iii) Interpret the results of the Transformations for Darwin Life.

Commentary on Question:
For full marks on part (i), candidates needed to explain the purpose and application of the Rosenblatt and Berkowitz transformations as opposed to transformations in general. For part (ii), candidates generally performed well. For part (iii), candidates needed to recall that the Rosenblatt transformation should show a uniform distribution and the Berkowitz transformation should show a normal distribution, but, more importantly, be able to analyze what it means if they do not show a uniform/normal distribution and why.

3. Fall 2024 Continued

(i) The Rosenblatt Transformation transforms the observed data into their forecast cumulative probability values. In doing so, it is essentially comparing the observed data to forecasts based on the risk model. It is used to check whether the forecast P/L distribution conforms to the distribution of actual observed values. This would then indicate whether the risk model distribution fits the observed data or the model needs to be changed.

Since Darwin's risk model assumes that P/L is normally distributed, the transformation is into normal cdf (cumulative distribution function) values. Under the assumption of normal distribution, these cdf values should be distributed as standard uniform.

The Berkowitz Transformation transforms the Rosenblatt Transformed data into standard normal. This allows the use of statistical tools, such as t-tests, variance analysis correlations, etc. to identify the source of model failure.

(ii) See solution in Excel.

(iii) The resulting Rosenblatt transformation chart does not show a uniform distribution and has a heavy preponderance in the lowest percentile. This would be consistent with a distribution that has much fatter tails than a normal distribution.

This could imply that Darwin's risk models need to reflect market conditions more in the tail that can happen more often (i.e., risk condition distribution itself should have fatter tails). Or, it could imply that the forecast P/L is not adequately capturing the effect on P/L of market conditions already reflected in the tails, i.e. that the hedging is inadequate.

Since the Rosenblatt transformation is already showing non-normality, the Berkowitz transformation becomes unnecessary for this iteration. If Darwin changes its model to reflect the fatter tails, and the resulting Rosenblatt transformation shows a uniform distribution, then this next transformation can be very useful.

The Berkowitz Transformation chart does support the finding under the Rosenblatt transformation of non-normality in the observations. It has a negative skew and a positive kurtosis, longer and heavier on the negative side.

3. Spring 2024 CFE FD Exam (LO 2b)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(2b) Describe, apply, and evaluate model validation techniques

Relevant Sources:

CP312-108-25: Chapter 15 of Measuring Market Risk, Dowd, Kevin, 2nd Edition, 2005

Commentary on Question:

The candidates mostly did well on part ~~a and~~ b; but many failed to complete part c, such as the normal PDF calculation and recognizing the hypothesis. The graders understood that part c had good amount of calculations; and awarded partial credit for many candidates.

~~*For part a, some candidates did not understand the P/L calculation.*~~

Solution:

~~(a) **(LO 4a, ab)**~~

~~(i) Assess Emily's suggestion to use the investment department data.~~

~~(ii) Recommend two methods to address the issue with data accuracy.~~

3. Spring 2024 Continued

~~(i) Her suggestion is correct~~
~~As this task is for risk management purpose, P/L data reflecting underlying volatility rather than accounting prudence is more important.~~

~~(ii) Clean the P/L data to reflect end-of-day market positions.~~
~~Use hypothetical P/L data obtained by revaluing trading position from one day to next.~~

(a) **(LO 2b)**

(i) Describe the purpose of back-testing in this context.

~~(ii) Explain which CRISP-DM stage the back testing procedure belongs to.~~

(i) The risk prediction model must be validated before being used to predict return in the future. This involves applying a quantitative method to judge whether the actual investment P/L data are consistent with the proposed model assumption.

~~(ii) Modelling phase.~~
~~It involves validating the model assumption and parameter of the predictive model.~~

(b) **(LO 2b)**

(i) Perform the Rosenblatt Transformation on the data provided in Excel tab Q3_c. Show your work.

(ii) Determine if the null hypothesis can be accepted. Justify your answer.

See attached spreadsheet for model solutions.

1. Fall 2023 CFE FD Exam (LOs 2a, 2b)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

(2b) Describe, apply, and evaluate model validation techniques

Relevant Sources:
CP312-108-25: Chapter 15 of Measuring Market Risk, Dowd, Kevin, 2nd Edition, 2005

CP312-107-25: A Financially Justifiable and Practically Implementable Approach to Coherent Stress Testing

Commentary on Question:
Candidates generally did well on this question. This question was testing the applications of stress testing and back testing. Candidates who did very well were familiar with evaluate (rather than describe) and interpret (rather than calculate).

Solution:

(a) **(LO 2a)** Describe two benefits and two difficulties of stress testing.

Commentary on Question:
Candidates generally did very well on this question.

Benefits of stress testing:

1. ~~Helps identify an institution's breaking point in order to develop risk mitigation to protect against.~~ It should lend itself to the identification and implementation of hedging or corrective actions.
2. ~~Highlights dependences on correlation assumptions, and evaluate what happens if "normal" correlations break down and all markets move against the institution~~ It should cover 'severe but plausible' scenarios and reflect events which have not necessarily occurred in the past.

1. Fall 2023 Continued

Difficulties of stress testing:

1. Computational problems. ~~It is important to push the underlying risk factors rather than the individual prices by any particular multiple. This can be expensive, and there is a limit on how frequently they can be carried out~~. Realistic scenarios can only shock a relatively small number of salient risk factors, but the realistic portfolios of asset managers are affected by 0 prices. The problem then arises of how one can propagate the scenario-generated shocks from the relatively small number of risk factors stressed 'by hand' in the construction of the stress scenario to the multitude of prices that affect the value of a portfolio.
2. Stress tests do not give any indication of likelihood, so the importance of the results need to be judged. ~~A scenario that would drive the institution into insolvency may or may not be meaningful, depending on the underlying probability.~~ A subjective element in stress testing is probably inevitable, and arguably to be welcomed; however, an unstructured assignments of shocks and probabilities to risk factors and asset prices is unlikely to satisfy elementary financial and logical requirements of consistency. In other words, when security prices are more or less arbitrarily shocked following intuition and 'hunches', there is no guarantee that the resulting prices should reflect any feasible set of 'fair' compensations for the exposures to the underlying risk factors — and in general they will not.

(b) **(LO 2a)** Recommend a specific stress-testing approach that addresses the CRO's concerns. Justify your recommendation.

Commentary on Question:
Candidates generally did very well on this question.

~~Mechanical stress testing (such as Maximum Loss Optimization, Factor Push, or CrashMetrics) is recommended.~~

~~The CRO is specifically looking to understand the worst-case losses, which mechanical stress testing addresses. Breaking points can be identified through mechanical stress testing in a way that scenario testing would not accomplish. Scenario testing historical scenarios would not necessarily identify the breaking point or worst-case scenario for the company.~~

A Bayesian–net approach is best suited to produce coherent scenarios. The use of Bayesian nets is recommended for stress testing over other competing approaches because assigning the joint probabilities of complex shocks to a number of macro factors in a logically coherent manner is easiest under this approach.

1. Fall 2023 Continued

~~(c) Your manager has recommended the use of Value at Risk (VaR) as opposed to stress testing to gauge the risks to the company in crisis situations.~~

~~Evaluate your manager's recommendation.~~

~~**Commentary on Question**:~~
~~*Candidates who did well on this question were able to identify how Value at Risk is not ideal specifically with regards to crisis situations. Many candidates discussed Value at Risk as a general concept but did not address how it performs in a crisis situation, or how it compares to stress testing in such a situation.*~~

~~Value at Risk as the better risk measure is an outdated concept. It is no longer viewed as a respectable risk measure, and stress testing is now widely regarded as the better risk measure.~~

~~Breakdowns in "normal" correlation relationships: In crises, correlations often swing to extreme values, and losses can be much greater than suggested by VaR estimates based on "normal" correlation assumptions.~~

~~Concentration risks: Stress tests can reveal a much larger exposure to a single risk factor than intended, considering the unusual conditions of a crisis, which VaR can overlook because they tend to not pay much attention to crisis conditions.~~

~~Macroeconomic risks: Stress tests are better suited for gauging our exposure to macro-economic factors.~~

(~~d~~c) **(LO 2b)**

(i) Describe one advantage and one disadvantage of a Basic Frequency Backtest.

(ii) Interpret the results of the Backtest from the table above.

Commentary on Question:
Candidates generally performed well on part (i) but did not do well on part (ii). While many candidates were familiar with how to set up the Basic Frequency Backtest formula calculation, not all candidates interpreted the results of it.

Full credit was awarded for candidates who identified that while the observations were in excess of expected at both the upper and lower risk bounds, the observations were plausible at the upper risk bound, and not plausible at the lower risk bound, based on the results of the backtest.

1. Fall 2023 Continued

(i) An advantage of Basic Frequency Backtesting is that it does not require a great deal of information. A disadvantage is that it throw away information on the sizes of tail losses predicted by risk forecasting models (in other words, a "bad" risk model will pass a frequency test if it generates an acceptably accurate frequency of exceedances, even if its forecasts of losses larger than VaR are very poor).

(ii) With n=600, p = α = .05 at the Upper Risk Bound and p = 1-α = 1-.95 = .05 at the Lower Risk Bound, n*p = 30 exceptions expected outside of both Upper and Lower Risk Bounds. Therefore, both the Upper and Lower Risk Bounds have observations in excess of the amount expected.

For the Upper Risk Bound, 36 observations is plausible, using the binom.dist fuction in Excel: =1-BINOM.DIST(36-1 , 600 , 0.05 , 1) = 15.15%.

Since this is greater than the 5% confidence interval, the number of exceedances is plausible, indicating that the risk measure on the right tail is probably not too low.

For the Lower Risk Bound, 40 observations is not plausible, using the binom.dist fuction in Excel: =1-BINOM.DIST(40-1 , 600 , 0.05 , 1) = 4.2%.

Since this is less than the 5% confidence interval, the number of exceedances is not plausible, indicating that the risk measure on the left tail is probably too low.

5. Spring 2023 CFE FD Exam ((LOs 1d, 2c)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(1d) Describe, apply, and evaluate model efficiency techniques

(2c) Describe, apply, and evaluate model efficiency techniques

Relevant Sources:

CP312-102-25 Heavy Models, Light Models and Proxy Models Ch. 1-5

Commentary on Question:

This question was looking to test a general understanding of proxy models and their behaviors when compared to heavy models. Candidates generally had a good understanding of the purpose of proxy models, but struggled to demonstrate an understanding of the application, specifically with regard to scenario accuracy as it pertains to solvency capital requirements.

Solution:

(a) **(LO 1d, 2c)** Describe one advantage and one disadvantage of stochastic models.

Advantage: Stochastic models are detailed and thorough.

Disadvantage: Stochastic models are relatively slow. The number of scenarios that can be run in one valuation exercise are limited by computational power.

(b) **(LO 1d, 2c)**

(i) Compare and contrast the three proxy formulas across the following:

I. Formula structure
II. Regression versus interpolation
III. Optimization

(ii) Recommend a proxy formula that will satisfy management's preference. Justify your recommendation.

(i) Replicating Polynomials:
- Determining Formula Structure: Choice and number of nomials
- Regression, Interpolation or Both: Both Possible
- Optimized Components, Whole, or Both: Both Possible

Replicating Portfolios:
- Determining Formula Structure: Choice of assets
- Regression, Interpolation or Both: Regression
- Optimized Components, Whole, or Both: Optimized Whole

Commutation Functions:
- Determining Formula Structure: Choice and number of commutators
- Regression, Interpolation or Both: Both Possible
- Optimized Components, Whole, or Both: Optimized Whole

(ii) Replicating Polynomial proxy formula is recommended. This is the only proxy formula being considered that can be optimized at the component level, which is management's preference. Replicating Portfolios and Commutation Functions can only be optimized at the whole formula level.

(c) **(LO 1d, 2c)** Your manager, the head of ERM, says, "A proxy model mimics the key behaviors in the heavy model, so we can rely on all the results of your proxy model at the scenario level going forward."

Critique your manager's statement.

Commentary on Question:
Candidates generally performed fairly on this question. Most candidates recognized that a good proxy model does in fact mimic the key behaviors of a heavy model, but are not necessarily accurate at the scenario level. Candidates who received full points on this question recognized that the purpose of the proxy model is to calculate solvency capital requirements, which relies on accuracy at the left tail, and scenario accuracy is not a requirement in this calculation.

A good proxy model does mimic the key behaviors of a heavy model, but the loss in complexity is accompanied by a loss in the ability to reproduce some of the other behaviors, as a proxy model is a less complex version of a heavy model. Key behaviors may just be related to the models purpose (e.g., capturing a certain portion of the distribution of results, such as the tail or expected value).

5. Spring 2023 Continued

Not all proxy models are accurate at the scenario level, but are still useful in capital management in creating a proxy full distribution from which percentile results can be drawn. A model does not need to be accurate at the scenario level for it to provide an accurate description of the capital distribution/accurate assessment of required capital.

(d) **(LO 1d, 2c)**

(i) Calculate the 1-in-200 VaR of the calibration scenarios. Show your work.

(ii) Calculate the 95th Percentile Error of the proxy model. Show your work.

(i) The 1-in-200 VaR is the calibration model result of the 5th scenario of the 1,000 scenarios, ranked from smallest to largest. The 5th smallest result is -42MM.

(ii) The 95th Percentile Error of the proxy model is the ratio of (1) the difference between the VaR(95) for the proxy model vs the calibration model, and (2) the absolute value of the VaR(95) of the calibration model.

VaR(95) Scenario = 1000 * (1 - 95%) = 50th scenario

VaR(95) Calibration = 50th scenario of heavy model results ranked from smallest to largest, or -4.4727MM
VaR(95) Proxy = 50th scenario of proxy model results ranked from smallest to largest, or -4.4754MM
Difference = -4.4754M – -4.4727MM = -0.0027MM
95th Percentile Error = -0.0027MM / absolute value of -4.4727MM = -0.06%

(e) **(LO 1d, 2c)** Assess the appropriateness of the fit of the proxy model.

Commentary on Question:
Candidates generally performed poorly on this question. Candidates who did well recognized that the proxy model was intended to determine solvency capital requirements, which is a left-tail calculation, specifically at the VaR(99.5) level, however any reasonable quantitative justification was given full points. Candidates who did well on this question also recognized that a proxy model must be ranked before comparing to the heavy model when determining appropriateness of the fit of the proxy model, as a proxy model will not mimic the heavy model on a scenario level. There was no single right answer required to attain full points.

5. Spring 2023 Continued

The purpose of the proxy model is to calculate the solvency capital requirements, so the fit of the proxy model should be examined at the left tail when determining the appropriateness of the fit of the proxy model.

The right tail is not a good fit. The proxy model produces an error of over 20% in the upper 10% of the results. However, the right tail is not a consideration for the solvency capital calculation, and this does not mean the proxy model is not a good fit.

At the 99.5th percentile, the proxy model produces an error of only 0.04%, which is quite small, so it is a good fit for the purpose of mimicking a solvency capital model.

	Calibration in $MM	Proxy In $MM	Error in $MM	Error as a %	Scenario Selected	Percentile
VaR(99.5)	(42.007)	(41.990)	0.017	0.04%	5	99.5%
VaR(10)	52.342	66.447	14.105	26.95%	900	10.0%

~~(f)~~

~~(i) Calculate the Combined Non-Linearity Surface of the stress test. Show your work.~~

~~(ii) Determine the number of heavy lift calculations required to calibrate the formulas of each of the potential risk factor pairings. Show your work.~~

~~(i) The non-linearity surface is equal to the difference of the combined stress test impact and the sum of the individual parts.~~

~~5 + 2 + 4 + 2.5 + Non-Linearity Surface = 15~~

~~13.5 + Non-Linearity Surface = 15~~

~~Non-Linearity Surface = 1.5~~

~~(ii) For n risks, there are n * (n-1) / 2 risk pairings~~

~~There are 4 coefficients to determine (c1, c2, c3, and c4)~~

5. Spring 2023 Continued

There are 4 risks (interest rate, mortality, lapse, and credit spread), so there are 4 * 3 / 2 = 6 risk pairings

6 risk pairings * 4 coefficients = 24 heavy life calculations needed to calibrate the formulas

8. Spring 2023 CFE FD Exam (LO 2b)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(2b) Describe, apply, and evaluate model validation techniques

Relevant Sources:

CP312-108-25: Chapter 15 of Measuring Market Risk, Dowd, Kevin, 2nd Edition, 2005

Commentary on Question:

Commentary listed underneath question component.

Solution:

~~(a) Identify two distinctive features that need to be considered in selecting a suitable stochastic process to model interest rates.~~

~~**Commentary on Question**:~~

~~*Candidates are expected to touch on both stylized factors and term structure to receive full credits. Many candidates answered two of the stylized factors and received half credit.*~~

~~The types of processes should ideally cover the following stylized factors:~~
~~Interest rates are random / stochastic~~
~~Interest rates should be non-negative~~
~~Interest rates are mean reverting~~

~~Additionally, the term structure has to be considered, as most fixed income instruments have payments that occur at regular intervals~~

8. Spring 2023 Continued

(b) **(LO 4a, 4b)** Identify two data quality issues indicated by the data summary report provided in Excel.

Commentary on Question:
In general, Candidates did well in this part of the question. Missing values is easy to identify in the ABT provided, irregular cardinality and outliers may not be that obvious. However, candidates are expected to look for these issues therefore should be able to at least discuss that there is a possibility of the data containing outliers and irregular cardinality.

Missing Values:
There are missing values in 3 of the features selected: Competitor rates average, Credited rate not considering GMIR and Remaining time to annuitization.
Out of these, the % of missing values in competitor rates average and remaining time to annuitization are reasonably low. Further investigations in to the distribution of values would be needed to understand whether there are underlying issues with the data in these fields, but the % of missing values do not appear to be a problem.
The % of missing values in credited rate (not considering GMIR) is high. However, the rule of thumb as a threshold for missing values to be problematic is 60%, and the % of missing values in this feature is less than 60%. Further analysis on the distribution of data and undertsanding the reason behind missing values would be needed before determining the usability of this data.

Irregular Cardinality:
Cardinality refers to the number of distinct values present for a feature. A data quality issue arises if the cardinality for a feature is ""irregular"". i.e. does not match what we would expect.
From the ABT, it appears that the cardinality for credited rate is very low. The cardinality of this feature is 67 when the market data (10yr UST rates and S&P Index) to which the credited rate is tied has a cardinality of 120. It may be due to the missing values. Further investigations in to the underlying data is required to confirm whether this would be potential problem and whether this feature would be usable.

Outliers:
Outliers are values that lie far away from the central tendency of a feature.
From the ABT, it appears that the Benefit Base feature may have outliers. The gap between the maximum and the third quartile is much higher than the gaps between the other quartiles. The data appears to be valid, as there are no invalid values as outliers (e.g.: negative values) that show up in the ABT. However further analysis of the underlying data would be required to identify the outliers and investigate the reasons for outliers.

8. Spring 2023 Continued

(c) Describe two pros and two cons of using stress testing for this model.

Commentary on Question:
Candidates are expected to describe two pros and two cons in the list below to receive full credit. Most candidates received partial credits on this part.

Stress Testing:
Pros
- Since stress tests are usually unlikely, the data used to estimate VaR will not reveal much information about them. If the stress events are rare, they are likely to fall in the VaR tail region and VaR does not provide any information about the region beyond the value.
- Assumptions that help value non-linear positions in normal times might not be appropriate in stress situations, so a stress test could reveal more than a second-order approximation VaR.
- Stress tests are useful in identifying the consequences of volatility
- Can highlight dependence on correlation assumptions

Cons
- Not straightforward
- Dependent on chosen scenarios and hence on the judgment and experience of the people carrying out the test
- Difficulties in working through scenarios in a consistent and sensible way
- Can run into computational problems
- If risk tolerance is 90% VaR, then you need to make sure that your stress test is sufficient to move the more extreme tail results (likely, but not a given)

(d) (**LO 2b)**

(i) Compare the two models based on backtesting results.

(ii) Recommend the best model to use. Justify your recommendation.

Commentary on Question:
Candidates did poorly on this past of the question. Partial credits were granted to candidates attempted to calculate p-value and use that to derive a conclusion instead of QPS.

(i) For the company model:
n = 1,000
p = (1-α) = 0.10
Expected number of losses = 100
x (number of exceedances) = 122
QPS = 0.2152

8. Spring 2023 Continued

QPS with expected number of losses =0.1800

The model performs worse than a model that generates expected number of exceedances.

For the industry model:
n = 500
p = (1-α) = 0.10
Expected number of losses = 50
x (number of exceedances) = 54
QPS = 0.2128
QPS with expected number of losses =0.2000

(ii) The industry model performs worse than a model that generates expected number of exceedances but is still better than the company model as the QPS is less than the company model QPS. Therefore, it is recommended that the industry model be used.

~~(e) **(LO 4a, 4b)** Summarize the key points that you should highlight to the Risk Committee to help them think more broadly about using model results to make decisions.~~

~~**Commentary on Question**:~~
~~*Candidates did okay in the last part of the exam. Only partial points were granted for general acknowledgement of the risk of letting the model be the decision-maker. Additional points were granted if candidates related to qualitative considerations, assumptions, outcomes/objectives, completeness of the model.*~~

~~Is the Decision What the Model Says? No.~~

~~-Indeed, there are good reasons to challenge the outputs of the model. Collective debates around the model inputs and outputs are absolutely a must, first at the technical level and then at the political decisional level. These discussions often lead to a decision which is different from a simple reading of the direct output of the model~~

~~-'Models' outputs do not always have the same weight in decision-making. Is the model capturing the right metrics at the right level of detail?~~

~~-In strategic decisions, such as whether or not to buy a Company or an insurance portfolio, a model's outputs feed the battery of quantitative indicators under review, which are looked at in conjunction with qualitative considerations:~~

8. Spring 2023 Continued

- The assumptions used by the model should represent decision-makers' (Risk Committee) views on the future. Do they? Committee should discuss that.

- The models do one thing: they are telling a story, a simple story, understandable, with explicit shortcuts. The decision-maker's responsibility is then to pick the outcome they feels best fit what they are foreseeing vs. what the objectives are.

1. Spring 2022 CFE FD Exam (LO 3a)

Learning Objectives:

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

(3a) Describe and apply model governance best practices such as:
- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures.

Relevant Sources:

ASOP 56: Modeling, Dec 2019, pp. 1-9

Case study

1. Spring 2022 Continued

Commentary on Question:
The primary goal of this question is to examine candidates' ability to rationalize the selection and assessment of certain risk measure and capital allocation schemes and

A secondary goal of the question is to test the candidates' on the softer aspects related to capital management (i.e. model management and decision-making).

Solution:
(a) Explain one advantage and one disadvantage for each of the following with respect to Darwin's risk management:

(i) VaR(95) as the risk measure

(ii) Shapley method as the capital allocation method

Commentary on Question:
For each response in (i) *and* (ii)*, if the answer does not relate specifically to Darwin, only partial credit was awarded.*

(i) VaR(95) advantage:
- VaR aligns with Darwin's capital risk appetite statement and is easy to understand and
- It's computationally simpler than CTE (only need one point on the distribution) which is good for Darwin because the IUL products are new so this allows them to start simpler.

Var(95) disadvantage:
- Only focuses on a single point of the distribution - disregarding tail behavior. Since the IUL products are new, Darwin should want to learn more about tail behavior than a single point estimate can provide and
- Not a coherent risk measure which can cause capital to be inappropriately allocated among the products.

(ii) Shapley Method advantage:
- No scaling is required – the parts naturally add up to match the whole which allows Darwin to be efficient with its capital requirements (avoid overcapitalization).

Shapley Method disadvantage:
- It's computationally challenging which could be a problem considering the product is new and some of Darwin's systems are out of date and
- The capital allocation to non-IUL products might change depending on whether the two IUL products (IULF & IULV) are considered one product or two. Theoretically, this shouldn't impact the capital allocation to, say, Current UL, but with the Shapley method it does.

1. Spring 2022 Continued

(b) Calculate values for the 'Shapley Value Table' using the information provided for the Current UL, IULF, and IULV portfolios in Case Study section 6.7.1. Show your work.

Commentary on Question:
The calculation of Shapley values is a natural extension of the independent and marginal methods already discussed and is based on the average of the "1st in", last in" and all the intermediate "ins". Most of the candidates did not pick up the right VaR(95) [see the excel solution]. Nevertheless, partial points are awarded when the candidates processed the "1st in", "2nd on", "3rd in", and "average" correctly.

See the solution in the excel worksheet Q1-b

(c) Explain the impact of the capital allocation from your calculation in part (b) on Darwin's overhead cost allocations.

Commentary on Question:
Most of the candidate did not answer this question correctly. The primary error came from overhead allocation being affected by capital allocation.

The capital allocation will not impact Darwin's overhead cost allocation. Capital is held for future uncertainty while overhead costs are amounts that have already been incurred

An overhead allocation assigns common or indirect costs while capital is required to support the future uncertainty of a given exposure.

(d) Explain three reasons why Darwin would make strategic decisions that may disagree with the model results.

Commentary on Question:
Points will be given with valid explanations. Note: The e-mail titled 'Re: Indexed Universal Life Product' starting on page 79 of the case study is a good source to reference.

Examples of the reasons include:

- The model results may not have been analyzed under the correct scenario/proper probability level
  Justification: Aaliyah mentions that the risk metrics for the risk dashboard are yet to be decided - implying that either a higher loss VaR metric or a different metric may be better to adequately reflect the risk of offering the new IUL than what was selected for the conducted analysis

1. Spring 2022 Continued

- ~~Model results are simply one dimension of decision-making - qualitative considerations such as commercial positioning, know-how, legal issues, etc. must also be considered~~
  ~~Justification: Aaliyah mentions that Marketing wants 'to increase the interest rate floor for the fixed account and to increase the cap for the indexed account', that there are potentially 'operational issues because of the multiple investment segments' and that there has been concerns about the product's investment portfolio/interest rate risk management. All of this suggests that there are more aspects to consider about the project beyond the economic capital model results. Aaliyah also mentions not wanting to have a 'misfire' like company XYZ did.~~
- ~~The assumptions used by the model may not appropriately reflect the views of those responsible for making the decision~~
  ~~Justification: Aaliyah mentions that the model 'looks very promising in terms of both revenue and profit', but then later requests 'a more comprehensive review than usual to evaluate if the models are adequate to capture all the major risk categories and if the additional risk-taking is aligned with our risk appetite'. Aaliyah seems suspicious of the current model output and may want to approach the analysis from a different angle.~~
- ~~The decision criteria may be reach beyond the model output~~
  ~~Justification: Darwin needs to consider growing its annuity book given the growing market trend for longevity products and/or other products;~~
  ~~The model analysis was performed under a loss scenario/only with the life book -it does not consider Darwin's other LOBs or potential profit scenarios.~~

(~~e~~a) **(LO 3a)** Identify four disclosures you should include in Darwin's model documentation per the requirements of ASOP 56.

Commentary on Question:
The purpose of the question is to primarily assess the candidate's knowledge of ASOP 56 so full credit came from the ASOP 56 required list however credit was given for applicable items from ASOPs 23 and 41.

From ASOP 56's required disclosure list
- The intended purpose of the model;
- Material inconsistencies, if any, among assumptions, and known reasons for such inconsistencies;
- Unreasonable output resulting from the aggregation of assumptions, if material;
- Material limitations and known weaknesses;
- Extent of reliance on models developed by others, if any; and
- Extent of reliance on experts, if any

1. Spring 2022 Continued

From ASOP 56's additional disclosure list
- If any material assumption or method was prescribed by applicable law;
- If the actuary states reliance on other sources and thereby disclaims responsibility for any material assumption or method selected by a party other than the actuary; and
- if, in the actuary's professional judgment, the actuary has otherwise deviated materially from the guidance of this ASOP.

~~From ASOP 23's required disclosure list~~
- ~~The source(s) of the data for the model;~~
- ~~Any limitations on the use of the actuarial work product due to uncertainty about the quality of the data or other information relevant to the use of the data; and~~
- ~~Any other relevant disclosure from ASOP 23 related to data quality~~

~~From ASOP 41's Required Disclosure List~~
- ~~The intended users of the actuarial report;~~
- ~~The acknowledgement of qualification as specified in the Qualification Standards; and~~
- ~~Any other relevant disclosure from ASOP 41 related to actuarial communications~~

6. Fall 2021 CFE FD Exam (LO 1d)

Learning Objectives:

1. The candidate will understand, develop, and evaluate cash flow models for various types of long-term insurance business. The candidate will demonstrate an understanding of underlying modeling methodologies: their strengths, limitations, and applications.

Learning Outcomes:

(1d) Describe, apply, and evaluate model efficiency techniques

Relevant Sources:

CP312-102-25 Heavy Models, Light Models and Proxy Models Ch. 1-5

Case Study: Snappy Life

Commentary on Question:

Candidates should explain and relate answers to the case study to receive the full points. The spreadsheet part of the question does not need to be explained if done correctly but will help in getting partial credits.

Solution:

(a) **(LO 1d)** Describe the following parameters.

(i) β_k

(ii) $X_k()$

(iii) $y(s)$

(iv) $r_N(s)$

Commentary on Question:

Successful candidates should be able to dissect and explain the meaning of the function

6. Fall 2021 Continued

(i) βk - the kth parameter of the proxy model to be estimated

(ii) Xk() - element of features to be included for the kth parameter

(iii) y - result produced by the heavy model. In this case this is the reserve calculated.

(iv) rN(s) - the value of the Nth risk driver for the sth observation

(b) **(LO 1d)** Explain the following considerations behind developing the proxy model for Snappy:

(i) Formula structure

(ii) Data selection

Commentary on Question:
For full credit, the answer should relate to the case study.

Formula Structure:
The key consideration for the formula structure is to construct a model that can adequately reproduce the behavior of a more complex model when subjected to variation in a number of different risk parameters. In this case, Snappy needs to create a model that can estimate reserves under stress scenarios, but faster than the current model.

Data Selection:
The key consideration for the data selection is that the sample used for calibration should be representative of the data. It should be enough to cover all cases, but not too much that it defeats the purpose of proxy modeling. Because the model needs to estimate reserves for the whole block, and the population will not change between the reserve run and the sensitivity runs, all Whole Life policies should be included to train the model.

(c) **(LO 1d)** Calibrate the parameters of the proxy model using the unweighted Least Squares method. Show your work.

Commentary on Question:
This is answered in the spreadsheet. This question does not need to be explained if done all steps correctly, but commentary will help in getting partial credits.

See Excel

6. Fall 2021 Continued

(d) **(LO 1d)**

(i) Explain four shortcomings of using this proxy model approach for required sensitivities.

(ii) Recommend two changes to your modeling process to improve its robustness. Justify your response.

Commentary on Question:
Response should surround additional work required to incorporate the proxy model into production environment. Since ABC is currently using Excel, moving valuation to a better platform should generally be a cost-effective and efficient solution.

(i) The four shortcomings of using proxy model approach to calculate sensitivities are

a. With proxy model another model is ultimately created, which brings in additional model risk. Model due diligence needs to be performed, including reviewing its design, data, assumption, intended use, results and limitation.
b. If the model is used for reporting purpose, it likely will go through vigorous balance and check, validation, consistency checks process. Principles and methods need to set out to withstand audit queries.
c. The proxy model is going to be less accurate than the full model and may need to justify and explain the difference.
d. This proxy model uses features that are directly observed from policy data and hence has limited use on sensitivity testing. One obvious shortcoming of this proxy model is the inability to test mortality and interest rate. Since the result using the heavy model relies on various assumptions coming from policyholder features, the proxy model built using the risk parameter relationships or calibration may not work if using a different set of data.

(ii) Two recommended changes to improve the robustness of the model are

a. In order for the model to be useful, it needs to be maintained and calibrated regularly. Guideline needs to be created on how to maintain and calibrate the model, including data selection process for meaningful calibration and avoid under-/over-fitting.
b. The proxy model should be used to back test with heavy model's calculation to see how accurately it would've predicted changes in reserves.

4. Fall 2020 CFE FD Exam (LOs 2a, 2b, 3a)

Learning Objectives:

2. The candidate will understand, apply, and evaluate non-cash flow and supplementary models for various types of financial business. The candidate will demonstrate an understanding of underlying methodologies: their strengths, limitations, and applications.

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

(2a) Describe, apply, and assess types of models such as the following and evaluate the appropriateness of their usage:

- Economic Scenario Generators (ESGs)
- Market Risk Models
- Other statistical models

(2b) Describe, apply, and evaluate model validation techniques

(3a) Describe and apply model governance best practices such as:
• Determining fit for purpose
• Model design and development
• Model risk management
• Model validation
• Model maintenance and change management
• Model and model governance documentation and disclosures

Relevant Sources:

CP312-108-25: Chapter 15 of Measuring Market Risk, Dowd, Kevin, 2nd Edition, 2005

CP312-109-25: Laurent, Norbert, Planchet, Chapter 7 (Sec. 7.2 only) of Modeling in Life Insurance - A Management Perspective

ASOP 56: Modeling, Dec 2019, pp. 1-9

CP312-107-25: A Financially Justifiable and Practically Implementable Approach to Coherent Stress Testing

Case Study – RPPC, Big Ben

4. Fall 2020 Continued

Commentary on Question:
The best candidates demonstrated an understanding of the application of quantitative methods with a risk management focus and an understanding of testing results and its implications.

Solution:

(a) **(LO 2b, 3a)** Recommend two improvements to RPPC's Model Risk Management Framework to strengthen the model validation process. Justify your recommendation.

Commentary on Question:
Candidates needed to identify two improvements and provide descriptions for each to receive full credit. Candidates had difficulty providing complete answers for this question. In addition to the answers listed below, graders also considered reasonable solutions specific to model validation to receive credit.

RPPC should require benchmark modeling.

Risk manager should use the benchmark model to check the performance of the proposed model.

RPPC should require independent output validation

Validate that the model output reasonably represents that is being modeled. Includes testing against historical actual results, performing statistical tests on model output to assess their reasonableness, running tests of variations on key assumptions to test against expectations, comparing model output to those of an alternative model.

4. Fall 2020 Continued

According to Section 3.6.2 ASOP 56, model output validation is required as follows:
"Model Output Validation—The actuary should validate that the model output reasonably represents that which is being modeled. Depending on the intended purpose, model output validation may include the following: a. b. c. d. e. 3.6.3 testing, where applicable, preliminary model output against historical actual results to verify that modeled output would bear a reasonable relationship to actual results over a given time period if input to the model were set to be consistent with the conditions prevailing during such period; evaluating whether the model applied to hold-out data produces model output that is reasonably consistent with model output developed without the hold-out data, as may be used for predictive models; performing statistical or analytical tests on model output to assess their reasonableness; running tests of variations on key assumptions to test that changes in the output are consistent with the expectations given the changes in the input; and comparing model output to those of an alternative model(s), where appropriate."

(b) **(LO 2a)** Critique Patel's statement.

Commentary on Question:
To receive full credit on this question, candidates are expected to comment on the validity of each item and provide explanations on each.

He is correct that stress tests on their own do not give any indication of likelihood. However, stress tests can be integrated into formal risk modelling by assigning probabilities to stress test scenarios. The resulting estimates then incorporate both traditional market risk estimates and the outcomes of stress tests, as well as the probabilities of each.

He is incorrect that stress tests have limited value.

Stress testing highlights exposures that other risk measurement approaches might easily overlook, i.e., can identify an institution's breaking point.

Stress tests can be an effective means of communicating risk information because they are easy to understand and free of any dependence on probability notions.

Stress tests can guide decision-making and setting position limits, allocating capital, and managing funding risks.

Stress testing can help firms design systems to protect against bad events.

4. Fall 2020 Continued

(c) **(LO 2a)**

(i) Critique Big Ben's stress testing.

(ii) Recommend two improvements to Big Ben's stress testing. Justify your recommendation.

Commentary on Question:
In general candidates scored well in part (i) but in part (ii) most candidates recommended points to improve general testing, but not stress testing. To receive full credit, candidates were expected to (i)identify each strength/weakness of Big Ben's model (ii)provide improvement recommendations and a brief description of its importance.

(i) Big Ben's stress test model is run annually, which is BAD because stress tests should be run frequently enough to ensure that results are up to date and relevant. A bank should run every week/ month

Big Ben runs one historical scenario based on 2008/2009 financial crisis, which is GOOD because historical scenarios are plausible and easily understood, but BAD because it's only one scenario. It is important to strike a balance between hypothetical plausible and historical scenarios.

Big Ben's stress scenario is calculated over a 1-year holding period.

It is important to carry out stress events on longer holding periods.

(ii) Recommendation #1: Big Ben should perform liquidity stress tests.

Distress after the Lehman failure confirms the importance of the spiral between market and funding liquidity and its fragile link to the solvency of an institution.

A stress test is very good at identifying liquidity risk factors that might not otherwise be apparent and quantifying liquidity exposures.

Liquidity effects (impacts of interest rates on collateral requirements or credit triggers, widening bid-ask spreads, increasing execution times, etc) can be quite subtle. VaR systems cannot do them justice, but they are amenable to well-designed stress tests. The information provided by liquidity stress tests can be crucial in determining how to deal with the risks concerned.

Recommendation #2: Big Ben should perform credit stress tests.

Credit risk testing is the most important area of stress testing for a bank due to its loan portfolios, and given the inherent uncertainty in predicting credit risk and the expert judgement involved. Credit risk involves assumptions on PD, LGD, and EAD which impact banks in various ways. Big Ben should perform interest rate and currency risk stress testing.

(d) **(LO 2b)**

(i) Describe two pieces of important backtesting information not provided in the above statement.

(ii) Explain how the missing information described in (i) can be a concern to Big Ben.

Commentary on Question:
The candidates were expected to identify the issues and explain each impact on Big Ben to receive full credit.

The backtest result statement does not indicate the frequency of exceedences.

If the number of tail losses is greater than expected, the risk measures are too low or there could be a problem with the VaR model.

The backtest result statement does not indicate the size of exceedences.

Model forecasts of losses larger than VaR may be very poor.

(e) **(LO 2b)**

(i) Interpret the backtesting results above.

(ii) Recommend whether further action is needed based on the results above. Justify your recommendation.

4. Fall 2020 Continued

Commentary on Question:
To receive full credit, candidates are expected to explain the Rosenblatt transformation and correctly apply the Rosenblatt transformation and determine the normal cdf is 0.8 for all observations. Very few candidates were able to relate this question to valid transformations. Candidates had difficulty with this question.

(i) Using the Rosenblatt transformation, it can be shown that the normal cdf value for all observations is ~0.80.

The Rosenblatt transformation takes each realised P/L through the relevant parameterised normal cdf function to give us the cdf value.

Under the null hypothesis that the model is adequate, the Rosenblatt transformed data are predicted to be distributed as standard uniform, U(0,1), but as shown below, all data in the sample are at 0.80.

Day	P/L	Forecast Mean	Forecast STD	Normal cdf
1	4065	3250	967	0.800333432
2	4297	2925	1629	0.800171647
3	2981	2275	838	0.800240923
4	3505	2958	650	0.799976826
5	2977	1922	1252	0.800288382

(ii) Since all the P/L data are mapped to one point under the transformation, it appears that there is a problem with the model that needs to be further investigated. The application of the Rosenblatt transformation allows us to apply distribution-equality tests to assess model adequacy. Under the null hypothesis that the model is adequate, we would expect the lowest 10% of transformed observations to fall in the region between 0 and 0.10, the next lowest 10% of observations to fall between 0.10 and 0.20, and so on.

10. Fall 2020 CFE FD Exam (LO 3a)

Learning Objectives:

3. The candidate will understand and be able to apply appropriate model governance to assess and address issues common to the development and management of models.

Learning Outcomes:

(3a) Describe and apply model governance best practices such as:
- Determining fit for purpose
- Model design and development
- Model risk management
- Model validation
- Model maintenance and change management
- Model and model governance documentation and disclosures

Relevant Sources:

ASOP 56: Modeling, Dec 2019, pp. 1-9

Commentary on Question:

Commentary listed underneath question component.

Solution:

(a) **(LO 3a)** Describe two best practices recommended in Actuarial Standard of Practice No. 56 to evaluate a predictive model.

Commentary on Question:

Candidates generally did well for this part, best practices were correctly named with reasonable description.

Model output validation: The actuary should evaluate whether the model applied to hold-out data produces model output that is reasonably consistent with model output developed without the hold-out data, as may be used for predictive models.

Model meeting the intended purpose: When evaluating a model, the actuary should confirm that, in the actuary's professional judgment, the model reasonably meets the intended purpose.

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(b) **(LO 4a, 4b)**

(i) Interpret the Recall results.

(ii) Interpret the Precision results.

(iii) Critique the CEO's statement.

Commentary on Question:
Most candidates were able to interpret the recall and precision results correctly. However, only a few candidates critiqued the CEO's comments with respect to ABC's goal of the predictive model which were time and accuracy.

(i) Recall is equivalent to true positive rate (TPR). Recall tells us how confident we can be that all instances of the target level have been found by the model. The model correctly classifies the 'Preferred' contracts 96% of the time and misclassifies them 4% of the time. The model correctly classifies the 'Standard' contracts 56% of the time and misclassifies them 44% of the time.

(ii) Precision captures how often, when a model makes a prediction, this prediction turns out to be correct. Precision tells us how confident we can be that an instance predicted to have the target level actually has the target level. When the model predicts 'Premier', it has correctly classified a 'Premier' contract as 'Premier' 88% of the time and misclassified a 'Standard' contract as 'Premier' 12% of the time. When the model predicts 'Standard', it has correctly classified a 'Standard' contract as 'Standard' 80% of the time and misclassified a 'Premier' contract as 'Standard' 20% of the time.

(iii) The CEO is incorrect. The CEO might be looking at the class accuracy which is 86%, whereas the average class accuracy of 75.7% does not meet ABC's goal of 90%. The Profit Matrix shows that misclassifying a Premier contract as Standard results in a loss of $100, which is the loss due to not getting the business. ABC will want high accuracy for both Premier and Standard classifications in order to meet the average class accuracy goal given the frequency of Premier and the cost of misclassifying Standard.

(c) **(LO 4a, 4b)** Recommend a credit review approach that meets ABC's goals. Justify your recommendation.

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Commentary on Question:
Very few candidates recommended a 2-stage model which meets both the time and accuracy goal of ABC. Credit was given to alternative responses if it showed that the model could meet ABC's goal.

A 2-stage model is recommended – 2-stage model means the premier+ and premier will be using the predictive model since both the recall and the precision results are good. The standard++, standard+ and standard class will be manually underwritten to improve its results.

This 2-stage model will satisfy ABC's goal for both time and accuracy:

Average class goal of 90%:
The recall for standard++, standard+ and standard class will be 100% if they were underwritten manually, therefore the average class accuracy of the 2-stage model is expected to be 98%=(96%+96%+100%+100%+100%)/5。

At least 50% reduction in processing time of current portfolio:
Current processing time is 161 days – 1 day each for 161 policies.

The expected processing time of the 2-stage model is 33 days (1 day each for 33 policies and instant results for the rest of the policies). Therefore, the processing time is cut by 80%.

(d) **(LO 4a, 4b)**

(i) Explain the downside to relying on stability index results.

(ii) Recommend next steps for ABC based on the stability index results. Justify your recommendation.

(i) A stability index does not directly measure the performance of a model. A high stability index may reflect a change in the underlying population rather than a change in model performance. Relying solely on a stability index can lead to models being rebuilt when it is not required.

(ii) At T1, the stability index is 0.179, which is between 0.1 and 0.25 and indicates that some change has occurred, and further investigation may be useful.

At T2, the stability index is 0.320, which is greater than 0.25 and suggests that a significant change has occurred, and corrective action is required.

~~10.~~ ~~Fall 2020 Continued~~

~~Although the high stability index reflects the change in the underlying population, it is important that ABC take corrective action because the Standard classes are growing faster than the Premier classes. The current 5-class model does not predict these classes well and the misclassification of these classes is very costly.~~