

CP 312 Model Solutions

March 2026

1. 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
- (2c) Describe, apply, and evaluate model *efficiency* 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

Sources:

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

The Modeling Platform on Economic Scenario Generators

Modeling in Life Insurance & Management Perspective Chapter 7 (Sec 7.2 Ex-post Validation: Back-testing)

1. Continued

Actuarial Modeling Systems: Adding Value with Model Validation, Nov 2017

Commentary on Question:

Commentary listed underneath question component.

Solution:

- (a)
- (i) Interpret results in the context of ULSG based on the GPV reserve distribution summaries using the summary statistics table and the Scenario GPV Reserve graph.
 - (ii) Evaluate the most effective and least effective calibration procedure to capture the low-interest rate persistence and tail risk.

Commentary on Question:

Candidate performance was mixed on this question. For part (i), candidates generally did well. For part (ii), some candidates struggled to distinguish between calibration procedures and downstream modeling or risk measurement techniques. Full credit was awarded to responses that clearly identified stochastic or low-interest-rate calibration as the most effective approach and deterministic as the least effective approach.

- (i) The GPV reserve distribution shows that while the average reserve is negative, indicating asset sufficiency in most scenarios, the distribution exhibits significant tail risk, as evidenced by a large positive CTE-98. The deterioration from the average to CTE-70 and then to CTE-98 reflects increasing reserve strain under adverse interest-rate paths. This pattern is consistent with ULSG products, where long-duration secondary guarantees are highly sensitive to prolonged low interest rates, causing liabilities to emerge only in extreme scenarios rather than on average.
- (ii) The most effective calibration approach is a stochastic ESG with scenario sufficiency and tail testing, as it can generate persistent low-rate paths and adequately populate the extreme left tail relevant for ULSG guarantees. Properly calibrated mean reversion and volatility allow rates to remain low for extended periods while still reflecting long-term uncertainty. In contrast, deterministic benchmark scenarios are least effective because they lack volatility, path dependency, and probabilistic tail structure, and therefore cannot reliably capture the conditions under which ULSG guarantees become in-the-money.

1. Continued

- (b)
- (i) List two advantages and two disadvantages of a one-factor Hull-White model in projecting interest rates for this ULSG block.
 - (ii) Recommend modeling practices that help maintain consistency across economic scenarios when projecting dynamic models of secondary guarantees within a ULSG block. Justify your answer.

Commentary on Question:

Candidate performance was mixed on this question. For part i), many candidates did well. Full credit was awarded to responses that clearly identified two relevant advantages such as simplicity and smooth scenario generation, along with two disadvantages tied to ULSG modeling. For part ii), some candidates struggled to identify the specific types of testing that should be performed, full credit was awarded to responses that specifically recommended in-sample testing, path testing or validation under prolonged low-interest-rate scenarios.

- (i)
- Advantages:
- Simple and computationally efficient
 - Ability to produce smooth interest-rate paths that fit the initial term structure
- Disadvantages:
- Cannot capture yield-curve shape changes
 - May understate persistence and tail risk in prolonged low-rate environments, which is problematic for the path-dependent secondary guarantees in ULSG
- (ii) Internal consistency across economic scenarios can be maintained through in-sample single-path testing, where all model components—benefit triggers, policy behavior, cash flows, and reserves—are validated under known economic paths. In particular, extreme low-rate paths should produce expected behavioral responses, reserve inflection points, and the emergence of guarantee floors. These practices ensure that dynamic interactions within the ULSG model evolve coherently rather than producing internally inconsistent results.

1. Continued

- (c) With respect to stress testing of a ULSG product:
- (i) Evaluate the suitability of using the Academy Interest Rate Generator (AIRG).
 - (ii) Recommend the components to be included in the calibration of the model. Justify your answer.

Commentary on Question:

Candidate performance was mixed on this question. For part i), some candidates struggled to discuss AIRG's strengths in tail analysis, full credit was awarded to responses that clearly explained that AIRG is a real-world generator suitable for reserve, capital and stress testing purposes, but insufficient on its own for market consistent pricing valuation. For part ii), partial credit was awarded to responses that only mentioned interest rates, equity returns, inflation, mortality, or lapse without explaining why they matter for ULSG tail risk.

- (i) The Academy Interest Rate Generator (AIRG) is suitable for real-world ULSG pricing and capital analysis, as it models Treasury rates and asset returns with mean reversion and fat-tail behavior. However, it is not appropriate for market-consistent valuation, and any pricing or risk management work requiring fair values or Greeks must use a separate risk-neutral model. In addition, AIRG guidance emphasizes the need for large scenario counts to stabilize tail measures such as CTE, which is critical for evaluating ULSG guarantee activation.
 - (ii) Model calibration should include persistent low-interest-rate scenarios to capture the risk of guarantees becoming in-the-money, along with validation of equity and bond fund return properties such as volatility, skewness, and fat left tails. Volatility parameters should be tailored to reflect shocks that increase lapse-supported risk, and scenarios should be validated against historical stress periods such as Japan and 2008. Sufficient left-tail scenarios are required to support CTE-based capital calculations.
- (d)
- (i) Construct a governance framework that ensures ongoing appropriateness and oversight of key modeling assumptions for the ULSG block.
 - (ii) Propose a model change control process for this ULSG block as the Experience Studies team is proposing implementing a new lapse assumption next year. Justify your answer.

1. Continued

Commentary on Question:

Most candidates did well on this question.

- (i) An effective governance framework should define clear ownership, periodic review of assumptions, documented model limitations, and escalation thresholds when results materially change. The framework should explicitly distinguish real-world versus market-consistent uses, enforce scenario sufficiency standards for tail risk, and require regular validation of AIRG assumptions given the sensitivity of ULSG guarantees to adverse paths. This ensures ongoing appropriateness and oversight of key modeling assumptions.
- (ii) A formal model change control process should include a documented change request, quantitative impact analysis on reserves, pricing, and capital, independent testing and peer review, and full documentation with version control. Final implementation should require sign-off from actuarial, finance, and risk functions to ensure the lapse assumption change is appropriate, well-understood, and consistent with governance standards.

2. 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.
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:

- (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
- (1d) Describe, apply, and evaluate model *efficiency* techniques
- (3b) Describe, compare and evaluate organizational structures for model governance, including controls, roles, and responsibilities

Sources:

Considerations Regarding Dynamic Lapses in Actuarial Modeling, AAA

Ch 1-3, 6 of Metamodelling for variable Annuities, Gan and Valdez

Model Risk Management, American Academy of Actuaries, May 2019

Commentary on Question:

Commentary listed underneath question component.

Solution:

- (a) The chief actuary is interested in adding a dynamic lapse assumption to the model.

Assess the suitability of using dynamic lapse assumption for this variable annuity product, based on how each of the three given characteristics may impact the dynamic lapse assumption.

Commentary on Question:

Candidates generally did well on this question. Full credit was awarded to responses that clearly differentiated GMDB from GMAB, explained how guaranteed moneyiness affects lapse behavior, and discussed the practical challenges of modeling investment options.

2. Continued

On both a GMDB and GMAB, the level of lapses are determined by the moneyness of each feature.

GMDB:

- The moneyness of a GMDB is similar to a GMAB. That is, the guarantee is in the money if the fund falls below the GMDB value.
- However, a GMDB only pays out if the policyholder dies, and therefore the impact on the decision to lapse depends also on the health of the policyholder and whether the death benefit is of value to them
- Therefore, the dynamic lapse impact of the GMDB is dependent on:
 - Fund growth / market conditions (moneyness)
 - Mortality rate of the policyholder
 - Anti-selective forces based on the health of the policyholder
- Since the company cannot underwrite the policyholder after it is issued, it is very difficult to accurately determine the dynamic lapse impact of a GMDB.

GMAB:

- The moneyness of the GMAB is directly linked to market performance.
- Dynamic lapse curve is usually a half U shape, where total lapse is close to zero when guarantees are deep in the money (market rates are much lower than credited rates)
- Since the product has been sold for many years, there is ample data to determine the dynamic lapse impact of the GMAB

Large number of investment options:

- Dynamic lapse is correlated with the moneyness of financial guarantees. The large number of investment options makes it very difficult to accurately project the moneyness of these guarantees in the future
- Simplifying assumptions based on macro-level market data (e.g. S&P 500) may provide a useful model in aggregate but not necessarily on a seriatim level.

- (b) The chief actuary is considering using a set of 10,000 economic scenarios as part of the valuation model but is concerned about the amount of time needed to calculate the reserves. You have been presented with several different approaches to increase computational efficiency on this block of business.

Evaluate the appropriateness of each approach specified below:

- (i) Scenario Reduction
- (ii) Inforce Compression

2. Continued

- (iii) Increase computing power (more computers)
- (iv) Simplify the valuation model

Commentary on Question:

Candidate performance was mixed on this question. For part (i) and (ii), some candidates were unable to explain the trade-off between computational efficiency and loss of accuracy. Most candidates did well on part (iii) and (iv).

(i) Scenario Reduction

- Pros:
 - Focuses on most significant scenarios
 - Generally easy to implement. Scenario ranking and random sampling are very easy to understand
 - No impact on actual inforce data used
- Cons:
 - Given the wide selection of investment options, it can be difficult to choose a representative sample of policies to use for calibrating the scenario ranking / distance
 - Random sampling only provides a good estimate in aggregate, with potentially large errors on the valuation of individual policies
 - Scenario ranking does not provide a reduction if we are only calculating CTE0, since that requires an average of all scenarios

(ii) Inforce Compression

- Pros:
 - May provide larger gains by reducing total inforce by a larger factor. (It can make sense to cluster 500k policies into 100 nodes, but it does not make sense to reduce 10k scenarios down to 20.)
 - Uses optimization techniques which allow arbitrary metrics in the objective function, so that the compressed inforce has the desired properties mimicking the full inforce
 - Hierarchical k-means allows for a “moderate” number of clusters (a few hundred), which improves upon other methods (e.g. k-means) which are less efficient at this cluster size.
- Cons:
 - Inforce data is compromised; calculations on the compressed inforce gives no information on the fair market value of individual policies
 - Replicated Stratified Sampling is useful for sensitivity runs but requires a full run (no savings) for the baseline
 - Objective function (and other metrics used to measure goodness of fit) may be difficult to define, calling into question the accuracy of the valuation using the compressed inforce

2. Continued

- (iii) Increase computing power
 - Pros:
 - Straightforward to implement
 - No loss of information or approximation, exact result
 - Easily auditable
 - Cons:
 - Expensive
 - For large datasets with many scenarios, this solution may not provide sufficient reduction in time.
 - Not scalable
- (iv) Simplifying the valuation model
 - Pros:
 - Easy to explain; does not require complex mathematical algorithms
 - Based on actuarial judgement
 - Cons:
 - Run-time savings difficult to estimate; may not provide much savings
 - Oversimplification could lead to flawed models which does not capture all the properties of the inforce portfolio
- (c) Several tasks are required for model governance during the new model's implementation:
 - Peer review the quarterly reserve calculation that is reported on the company's financial statements
 - Calculate the regulatory capital requirements of the company
 - Prepare responses to audit challenges
 - Develop the policy for frequency of performing experience studies and updating mortality and lapse assumptions
 - Reconcile the inforce data used in the valuation model to the administrative system.

Identify the line of defense each of the above task falls under using the “three lines of defense” model risk management framework.

Commentary on Question:

Most candidates did well on this question. Full credit was awarded to responses that correctly identified the line of defense for each activity and clearly explained the rationale based on the responsibilities of model owners, risk oversight, and internal audit.

2. Continued

First line of defense:

- Peer review the quarterly reserve calculation that is reported on the company's financial statements (assessment of model validity)
- Calculate the regulatory capital requirements of the company (implementation of model)
- Prepare responses to audit challenges (maintaining model documentation)
- Reconcile the inforce data used in the valuation model to the administrative system (assessment of model validity)

Second line of defense:

- Develop the policy for frequency of performing experience studies and updating mortality and lapse assumptions (development of policies for model risk management)

3. 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.
- (1d) Describe, apply, and evaluate model *efficiency* techniques

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
- (1d) Describe, apply, and evaluate model *efficiency* 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

Sources:

Long-Term Actuarial Models Part II (Tim's Book & Excel Workbook), Chapter 3
Principle-Based Projections and Nested Methods (incl. Sec 3.1 to 3.2)

Long-Term Actuarial Models Part II (Tim's Book & Excel Workbook), Chapter 6
Secondary Guarantee Universal Life

CP312-102-25: Heavy Models, Light Models and Proxy Models Chapters 1-5

ASOP 56: Modeling Dec 2019, pp1-9

Commentary on Question:

Commentary listed underneath question component.

Solution:

- (a) Contrast the $t=0$ projections methodology and the outer-inner loop nested projections methodology.

3. Continued

Commentary on Question:

Most candidates did well on this question.

$t=0$ projections utilize static valuation assumptions, whereas nested outer-inner loop projections incorporate valuation assumptions that evolve at future re-valuation dates. While nested loops provide greater dynamism, they are significantly more runtime-intensive and complex than $t=0$ projections

- (b) Critique the following statements:
- A. *Proxy models are distinctive from other models because they approximate reality.*
 - B. *The proxy model with the most accurate output should be selected.*
 - C. *Proxy models help solve the problem of modeling demand overtaking computational power.*
 - D. *Modeling no excess lapses on ULSG is a reasonable assumption.*
 - E. *Modeling higher long-term lapse rates on ULSG once the AV reaches 0 would decrease projected earnings.*
 - F. *Low interest rate scenarios lengthen the amount of time for the secondary guarantee to become in-the-money.*

Commentary on Question:

Candidates did very well on this question.

- A. False. In general, all models approximate reality. The distinction is that proxy models model other models. They are approximations of other, more complex models (heavy models).
- B. False. We should balance accuracy with complexity when selecting a model. Other considerations beyond accuracy might include implementation costs, runtime length and costs, and how intuitive the model is.
- C. True. While computational power has increased dramatically in recent years, demand for information and analysis has increased even quicker. Proxy models are used to bridge the gap between model demand and technology.

3. Continued

- D. True. ULSG is a protection product more so than an accumulation product, so it is reasonable to assume that lapses are insensitive to interest rates (no excess lapses).
 - E. False. Once the AV reaches 0, ULSG profits typically flip to a pattern of losses. Modeling higher long-term lapses would thus increase projected earnings rather than decrease (i.e., ULSG is lapse-supported).
 - F. False. In a lower interest rate environment, credited rates are lower, meaning the AV reaches 0 quicker than in a higher interest rate environment. When the AV is 0, the secondary guarantee is in-the-money. Thus, lower interest rate scenarios shorten the amount of time for the secondary guarantee to become in-the-money.
- (c)
- (i) Calculate the $t=0$ projection's gross premium reserve on December 31, 2028.
 - (ii) Calculate the inner-loop projection's gross premium reserve on December 31, 2028.
 - (iii) Explain the impact on the projected profit margin if BOS Life were to use the $t=0$ values for this product rather than the inner-loop values.

Commentary on Question:

Candidate performance was mixed on this question. For parts (i) and (ii), many candidates performed well, while some struggled to apply the correct GPR formula. Full credit was awarded to responses that correctly calculated the net cash flows and appropriately applied the discounting method using the portfolio rate. For part (iii), some candidates struggled with the direction of the impact. Partial credit was awarded to responses that lacked a clear justification.

- (i) See Excel file.
- (ii) See Excel file.
- (iii) If we use the $t=0$ method, we will under-state the gross premium reserve relative to the inner-loop method (since GPV reserve for $t=0$ method < GPV reserve for inner-loop method). This means our earnings will be higher using the $t=0$ values, so profit margin will be higher compared to using the inner-loop values.

3. Continued

- (d) Describe four considerations for validating ULSG proxy model output based on guidance from *ASOP 56, Modeling*.

Commentary on Question:

Candidates generally did well on this question.

1. Compare projected proxy model output against historical actual ULSG experience.
2. Compare proxy model output to output from an alternative model, such as an existing ULSG heavy model.
3. Evaluate whether the proxy model output applied to hold-out data is consistent with proxy model output developed without the hold-out data.
4. Run sensitivity tests on model inputs such as interest scenarios or secondary guarantee assumptions to test that changes in output are consistent with expectations given changes in the input.

4. 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

Sources:

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

CP312-105-25: Ch. 9: Measuring & Marking Counterparty Risk

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

Ch 1-3, 6 of Metamodelling for variable Annuities, Gan and Valdez

Commentary on Question:

Commentary listed underneath question component.

Solution:

- (a)
 - (i) Discuss the reasons for using a nested stochastic model in this case.
 - (ii) Describe the calibration process of market-consistent ESG models and parametrization of real-world ESG models.

Commentary on Question:

Candidates performed was mixed on this question. For part (i), most candidates did well. For part (ii), some candidates struggled to provide a complete step-by-step process for both market-consistent calibration and real-world parametrization.

- (i) A nested stochastic model is required for variable annuity guarantees because their valuation must be done under multiple uncertain future economic states.

The outer loop of the simulation generates real-world economic scenarios to project the insurer's overall financial position over time.

4. Continued

Within each time step of every outer loop scenario, thousands of inner loop simulations are run under a risk-neutral measure to price the complex, path-dependent embedded options and guarantees.

This process is essential for calculating a fair market value for these guarantees at future points in time, a task that a single set of risk-neutral projections cannot accomplish.

- (ii) Market-Consistent Calibration Process:
1. Estimate Model Parameters
 2. Calculate prices of traded options
 3. Compare calculated values with traded values
 4. Adjust parameters

Real-World Parametrization Process:

1. Estimate Model Parameters
2. Run simulation
3. Compare simulated statistics with stylized facts
4. Adjust parameters

- (b) Critique the following proposals to improve the model's runtime.
- (i) Implement scenario ranking by running the first 5% of the policies through the full model, ordered the results and then run the rest of the policies through the worst 300 scenarios.
 - (ii) Implement importance sampling without running the full 1000 scenarios by ordering the scenarios based on the year 2 equity rate, choosing 100 from the first third, 100 from the second third and 100 from the last third, and taking the mean of those results.
 - (iii) Implement random sampling by running policies through the same 300 random scenarios to approximate the results for the 1000 scenarios.

Commentary on Question:

Most candidates did well on this question. Full credit was awarded to responses that clearly identified at least two flaws in each proposed approach, acknowledged where the approach could be useful, and provided practical corrections.

4. Continued

(i) Scenario Ranking

Scenario ranking does include running a random subset of policies through the full 1000 scenarios and ordering the results to determine which scenarios can be run to determine which scenarios need to be run.

But this process is more suitable for calculating CTEs (conditional tail expectations) that only use a certain number of scenarios (CTE70 would use the worst 300 scenarios).

Because we need the overall average, the worst 300 would not be representative.

(ii) Importance Sampling

Importance sampling does involve ranking the scenarios based on some aspect of the underlying scenario and then selecting scenarios from different buckets of results as described.

But the year 2 equity rate would not be predictive of full scenario results. We would need to calculate an equity accumulation factor further along in the scenario duration.

Importance sampling also does not take equal amounts of scenarios from the different buckets. Instead, bad scenarios are sampled more heavily with reduced weights and good scenarios are chosen less heavily with increased weights.

Importance sampling is also better suited for CTEs.

(iii) Random Sampling

The description given for random sampling is not correct.

In random sampling, a different sample of scenarios is chosen for each policy.

This makes the individual results not comparably accurate, but the total fair market value of the portfolio is close.

This is the best option of the three when it comes to calculating the total fair market value (average of all scenarios).

- (c) The number of inner loop scenarios has been reduced from 1000 to 250. However, this scenario reduction led to significant variation in fair value calculations from period to period, even with minor underlying market assumption changes.

Propose a variance-reduction method that uses a correlated, analytically tractable variable to stabilize results without increasing the number of simulations. Justify your answer.

4. Continued

Commentary on Question:

Candidates performed poorly on this question. A common error was recommending antithetic variates simply because they use correlated random numbers such as u and $1-u$. Full credit was awarded to responses that correctly identified the control variate method, explained that it requires a correlated variable with a known analytical value, described the mechanism, and showed why the standard error of the control variate estimator is lower.

Use the control variate method/technique.

Choose $g(u)$ with high correlation to guarantee payoff $f(u)$ and has analytical solution (e.g., account value, Black-Scholes option value).

The first step is to calculate the estimates of $f(u)$ and $g(u)$ based on the same set of random numbers. The second step is to obtain the price of $g(u)$ from the closed-form solution. Thus, the final estimate of $f(u)$ equals $f^*(u) - g^*(u) + g(u)$ where f^* and g^* are the estimates obtained from the first step.

The standard error of the control variate estimator is $(1 / \sqrt{N}) * \text{Stdev}(f(u) - g(u))$ which is smaller than the standard error of the crude MC estimate.

- (d) In the previous quarter, the counterparty on an interest rate swap used to hedge the fair value GLWB liability defaulted. This highlighted a limitation of the model, as the counterparty risk has not historically been factored in the projection. You are given the following average risk-neutral projection results for default exposure on a block of hedges with a single counterparty:

Trade	Notional Amount	Year 0	1	2	3	4	5
A	1,000,000	0.89%	-1.26%	0.47%	-0.51%	0.76%	0.23%
B	1,000,000	-0.44%	0.44%	-1.06%	1.82%	-1.51%	0.00%
C	1,000,000	-0.85%	-0.30%	-0.89%	1.14%	-0.98%	1.90%
D	1,000,000	0.88%	0.73%	0.25%	0.42%	0.84%	-0.79%
E	1,000,000	-1.80%	0.47%	-0.73%	-1.38%	1.49%	1.13%

- (i) (1 point) Calculate the annual exposure to this counterparty with netting.
- (ii) (2 points) Calculate the net reduction in market value to the counterparty due to default losses, assuming:
- $i = 0.07$
 - the expected loss rate is 25bp in all years

4. Continued

Commentary on Question:

Candidate performance was mixed on this question. For part (i), many candidates did very well. Full credit was awarded for responses providing the correct formula. For part (ii), some candidates struggled to construct the correct measurement. Full credit was awarded for responses providing the correct formula, which was graded independently of the response in part (i).

(i) See Excel file.

(ii) See Excel file.

5. Learning Objectives:

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 - Model risk management
 - Model validation
 - Model maintenance and change management
 - Model and model governance documentation and disclosures

Sources:

Long-Term Actuarial Models Part II (Tim's Book & Excel Workbook), Chapter 1 Introduction to Modelling (excluding Section 1.5)

Long-Term Actuarial Models Part II (Tim's Book & Excel Workbook), Chapter 11 Long Term Health Products – focus on IDI (incl. up to Section 11.5)

The Importance of Centralization of Actuarial Modeling Functions, Part 2: DevOps – The Path to Actuarial Modernization and Consolidation, The Modeling Platform, Apr 2020

Commentary on Question:

Commentary listed underneath question component.

5. Continued

Solution:

- (a) You are asked to implement a multi-state first principles model for the IDI business.

Evaluate the advantages and disadvantages of the model.

Commentary on Question:

Candidates generally performed well on this question. Candidates who received full credit described at least two advantages and at least two disadvantages.

Advantages:

- Enable more accurate projections of cash flows, reserves, and capital for pricing, reporting, and financial planning
- Improve analysis comparing actual cash flows to expected cash flows
- Reflect more granularity and detailed assumption, which enables differentiation between active and disabled lives, allowing for distinct mortality, lapse, and recovery assumptions

Disadvantages:

- Introduce challenges to develop detailed assumptions that require credible and granular experience data
- Increase model complexity, which makes the model difficult to maintain
- Result in longer runtimes and higher infrastructure demands

- (b) Critique the following statements regarding IDI models:

- A. *It is unnecessary to model state transitions explicitly in an IDI first principles model, since the cash flows can be calculated directly from incidence and termination rates.*
- B. *For projection accuracy, model time step should be smaller in the early period immediately following the commencement of disability.*
- C. *Applying the same lapse rates to both active and disabled lives in an IDI model is acceptable for simplifying model calculations.*
- D. *In an IDI model, disabled lives should be grouped into monthly cohorts to properly apply duration-dependent recovery and mortality assumptions.*

5. Continued

Commentary on Question:

Candidate performance was mixed. Candidates generally did well on part A and C. For part B, some candidates were unable to address why transition rates are duration sensitive. For part D, full credit was awarded to response explaining that monthly cohort tracking helps capture high recovery and mortality rates in early disability durations.

A – False

First principles models are multi-state models that track individuals through states such as active, disabled, and recovered. Explicit modeling of state transactions is not optional; it's the mechanism by which cash flows are calculated.

B – True

Transition rates (especially recovery and mortality) are high immediately after becoming disabled. For accurate modeling, time immediately following disability is a critical factor. Many models use model time steps smaller than a month such as days or weeks.

C – False

In reality, lapses only occur on active lives and are not applicable to disabled lives. The simplification can result in crude approximations that deteriorate over time.

D – True

Mortality and recovery rates depend on the time since disability. Monthly cohort tracking ensures the dynamics are accurately captured.

- (c) ABC currently applies a single claim duration assumption for all economic environments. It recently developed an Economic Stress Indicator (ESI) based on unemployment rates, which classifies conditions into five levels. ABC's study shows that actual-to-expected claim duration ratio increases substantially under higher ESI levels.
- (i) Propose a method to incorporate the ESI into its claim duration assumptions.
 - (ii) Describe one benefit and one drawback of the proposed method in the context of disability claim forecasting.

5. Continued

Commentary on Question:

Candidate performance was mixed on this question. For part (i), some candidates struggled to describe a practical implementation method and demonstrate how the ESI directly affects projected claim duration assumptions. Most candidates did well on part (ii).

(i)

Design an approach (e.g. a lookup table or a function) that the base claim duration assumptions are scaled upward or downward depending on the ESI Level. For example, if the ESI indicates a recession, apply 150% factor to lengthen expected claim duration while applying 80% factor to reduce claim duration slightly while the economy is strong.

An alternative method is to design the model so that the ESI directly feeds into the claim duration assumption using a regression-based formula. The regression would allow the model to adjust claim duration based on ESI value under each economic scenario.

(ii)

Benefit

- The method enables the model to reflect worsening claim experience under adverse macro-economic conditions and improve reserve adequacy in stress testing.
- The model becomes more responsive to real-world economic changes, leading to more accurate reserve projections under varying stress levels.

Drawback

- The method introduces additional modeling complexity and may increase model run-time
- The method assumes the historical relationship between ESI level and claim duration is stable over time, which may not always be the case. (alternative: lack of credible historical data to support the relationship between ESI and claim duration).

5. Continued

- (d) ABC Life is considering DevOps principles to modernize its multi-state first-principles IDI model platform. Based on *The Modeling Platform* article by Bryon Robidoux (April 2020):
- (i) Describe the microservices in the context of a multi-state first-principles IDI model.
 - (ii) Explain how continuous testing can improve the reliability of the IDI model.

Commentary on Question:

Candidate performance was mixed on this question. For part (i), only a few candidates were able to connect microservices ideas and benefits directly to the IDI model context. For part (ii), candidates generally did well by demonstrating a reasonable understanding of continuous testing in the context of the IDI model.

- (i)
 - Microservices breaks the IDI model into smaller, modular components (e.g. incidence, recovery module)
 - Each modular component can be developed, tested and maintained separately
 - Microservices improve flexibility and reduce the chance of errors spreading across the entire model.
- (ii)
 - Continuous testing means automatically running small tests whenever model changes are made
 - These tests can quickly detect logic or data errors in modules like incidence or recovery
 - Continuous testing ensures the IDI model behaves as expected after updates, improving overall stability and confidence.