

ERM-INV Model Solutions

Spring 2021

1. Learning Objectives:

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:

- (1c) Identify and analyze specific risks faced by an organization, including but not limited to: financial, environmental, operational, legal, reputational and strategic risks.
- (4c) Demonstrate the use of controls for retained and residual risks.
- (4h) Demonstrate possible risk management strategies for non-financial risks.
- (4i) Choose appropriate techniques to measure, model and manage various financial and non-financial risks faced by an organization.

Sources:

Financial Enterprise Risk Management, Sweeting, 2011, Ch. 8 Risk Identification
Data Quality is the Biggest Challenge by Moody
Internal Controls Toolkit by Christine H. Doxey, Chapter 1 pp. 11-17, 27-35
ERM-131-18: Leveraging COSO Across The Three Lines of Defense
ERM-130-18: AAA Model Governance Practice Note

Commentary on Question:

This question was intending to test candidates' ability to identify and analyze various risks faced by an organization and test their understanding of different approaches available for an entity to manage risks and their applications.

Candidates were expected to demonstrate knowledge of controls for retained risks and choose appropriate techniques to manage various risks faced by an organization.

The most significant theme in candidates struggling was by simply restating the background information given in the problem. Those who scored high were able to expand on that information and draw conclusions from it.

1. Continued

Solution:

(a) The VP is concerned that hiring DEF will increase ABC's operational risk.

(i) Explain why each of the following operational risks could increase.

- People Risk
- Reputational Risk

(ii) Explain how the new system could improve data quality.

Commentary on Question:

Subpart (i)

Most candidates received about half of the potential credit. Multiple valid explanations were given across all submissions; however, the majority could have given more in terms of quantity of potential responses.

Subpart (ii)

Most candidates received anywhere from half to full credit. Those who scored lower did so because they were simply restating the background information that was given in the question, without taking it a step further to explain how it would actually improve the quality of the data.

(i) **People Risk**

People risk will increase for ABC given they are working with an external company, whose employees may have a lack of formal training or knowledge around ABC's specific industry.

Additionally, ABC has no control over the hiring/firing practices or ethical standards of DEF.

Consulting an external company for such a large project may cause concern for ABC employees in regard to the need for their continued employment, or at least the need to learn a new system.

Given there is disagreement amongst ABC's senior management on whether to undertake this project, there is the possibility that taking on the project (or not taking it on) may result in turnover at the senior management level.

Reputational Risk

When transferring client data between companies, there always exists the possibility of a data breach, which would cause concern and possible loss of ABC's customer data and resulting business.

1. Continued

ABC's inability to develop a system in-house may cause a signaling effect to their clients and the market that they are not as strong of a reinsurance company as was previously believed.

Were any senior management to leave due to the disagreement surrounding this project, this would reflect poorly on client's view of ABC's ability to make decisions internally.

Lastly, the reputation of DEF is important given that ABC is placing business confidence in them – any negative events relating to DEF would reflect poorly on ABC as well.

- (ii) By unifying all of the existing separate systems and geographies, data will be in a consistent format to streamline the data validation process and improve data reliability.

ABC's client data will now be complete and uniform, which will allow them to compare and analyze client data in the aggregate, across all clients and geographies, which is currently not an easy or even possible process.

The new system will allow all data to exist in a larger volume dataset which is assisted by new technology and the addition of big data. These new practices will further improve the potential of big data or improved technologies to highlight unknown data issues and improve the potential analysis and business insights.

Under a consistent process within one system for all clients, additional time will be available for the data validation and audit process. This will decrease some of the existing data and model risk, giving ABC more confidence in its business processes.

- (b) If DEF is hired, the VP will organize a steering committee consisting of key internal stakeholders.
 - (i) List and explain the steps that need to be taken by the steering committee to ensure an effective development process for the new system.
 - (ii) Propose three review and testing procedures that ABC can adopt to validate the new system.

1. Continued

Commentary on Question:

Subpart (i)

The majority of candidates either received either approximately half of the potential credit or all of the potential credit. Those who scored better not only identified more steps in the process, but also explained them well and tied them to the context of ABC and the new system, as opposed to generic steps in an implementation process.

Subpart (ii)

Almost all candidates received at least half credit. Many candidates focused on matching data output/results and less on overall system governance. Those who scored higher did a better job of providing context around the proposed testing procedures.

- (i) The steering committee should take the following steps to ensure an effective development process:
 - Outline the existing processes under all current systems to identify the necessary changes for DEF to implement a single unified system.
 - Specify key dates and deadlines to ensure the project can be completed as necessary within the two-year time period.
 - Monitor the system development: define and enforce regular checkpoints between ABC and DEF to ensure that the project is moving as expected.
 - Organize a team to test and validate the new system – the testing team should consist of representation of all critical business units and functions, to ensure that all data requirements are met, and that the platform is functioning as intended via robust testing.
 - Following testing and validation, define final approval standards of the final system before implementation.
 - Validate that documentation and ongoing controls are in place. Though DEF is immediately responsible for maintaining the system, there needs to be working knowledge of it within ABC and an existing contingency plan given that ABC is ultimately responsible to its customers, while DEF is not.
 - Institute a collaborative training program between ABC and DEF employees to ensure effective implementation.

- (ii) Historical backtesting testing: ensure that the aggregate output and results from the new system match selected aggregate results of all combined prior legacy systems. This should be validated for actual historical data at specified points in time, spanning multiple years of actual historical data.

1. Continued

Parallel seriatim testing: ensure that the new system matches expectation and calculations in prior legacy systems in all critical intermediate steps in addition to in the aggregate. Ensure that logic and output match not only historical situations but also unique and extreme data points that have not happened but that could realistically occur.

Model documentation and governance: appropriate and sufficient documentation of the new system and the associated testing and validation procedures should be created and maintained into the future. Robust validation standards should be created and assigned to specific parties, with appropriate segregation of duties to ensure multiple Change controls for future updates should be established in accordance with the level of testing put into place at the initial implementation.

- (c) You are asked to design and implement an internal control framework for ABC to effectively manage the risk of hiring DEF and implementing the new system.

Recommend four controls to be adopted in your design. Justify your answer.

Commentary on Question:

Many of the candidates received substantial credit on this part. While there were many possible answers here, several candidates focused on specific system access restrictions and results testing without addressing the larger picture that a full internal control framework would likely need established.

1. First line of defense: managers and employees of ABC should have a clear understanding of their responsibilities relating to the project. Managers and business owners need to hold their teams accountable to the risk inherent in such a large project. Clear authority needs to be outlined and internal controls such as the segregation of duties relating to the project should be established whenever possible.
2. Second line of defense: adjacent business units that are not directly related to ABC's core business model also need to support senior management in providing risk protection surrounding the implementation of the new system. Examples of this would include Risk Management, who should be thoroughly vetting DEF as a business partner, and Compliance, who should ensure that all elements of the agreement between ABC and DEF abide by legal standards.

1. Continued

3. Third line of defense: an internal audit function should be established if one does not already exist. This function should report above ABC's senior management, directly to the board or applicable governing body. The internal audit function should provide both broad oversight and detailed analysis on the implementation of the new system, and should work completely independent of business units that are both directly and adjacently involved in the first two lines of defense.
 4. Senior management commitment and communication: commitment from the upper levels of ABC is a key contributing factor to the success of such a sophisticated undertaking. Effective support and communication in regards to the project needs to come from the top down to successfully disseminate throughout the organization. Ensuring that a positive and strong message is sent throughout the project will support success.
- (d) Recommend whether ABC should proceed with the proposal. Justify your response.

Commentary on Question:

Almost all candidates received at least half credit, with many receiving full credit. Not only was a recommendation required, but it also needed to be justified using information drawn from the preceding parts of the problem. Those who received less credit typically failed to draw their own conclusions and instead restated the context provided in the background of the problem.

ABC should proceed with the proposal in order to remain competitive and reduce the risk of their systems becoming dysfunctional or obsolete. While partnering with DEF provides potential people and reputational risks as discussed earlier, there exists the potential for far more severe risks if ABC is unable to keep up with its competitors and begins to lose customers as a result.

Contracting with DEF to develop and implement the system will give them technological advances that they very likely will need in the future, as well as a partner to help maintain and educate them throughout implementation. Adopting a system that provides a single source of truth for their customer data will further help ABC gain insight into their business to provide potential strides in strategic planning and competitive advancement.

2. Learning Objectives:

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:

- (1a) Describe different definitions and concepts of risk.
- (1c) Identify and analyze specific risks faced by an organization, including but not limited to: financial, environmental, operational, legal, reputational and strategic risks.
- (4b) Demonstrate application of the following responses to risk, including consideration of their costs and benefits: avoidance, acceptance, reduction without transfer, and transfer to a third party.
- (4f) Demonstrate the use of tools and techniques for identifying and managing credit and counterparty risk.
- (4i) Choose appropriate techniques to measure, model and manage various financial and non-financial risks faced by an organization.

Sources:

ERM-128-17: The Breadth and Scope of the Global Reinsurance Market and the Critical Role Such Market Plays in Supporting Insurance in the United States, Ch. III, IV, and VI (LO 4)

ERM-115-13: Creating an Understanding of Special Purpose Vehicles, PWC (LO 4)

ERM-122-14: Chapter 1 of Captives and the Management of Risk, Kate Westover (LO 4)

Value-at- Risk, Third Edition, The New Benchmark for Managing Financial Risk, Jorion Ch. 13 Liquidity Risk (Except section 13.4) (LO 1)

Managing liquidity risk: Industry practices and recommendations for CROs (excluding section 4) (LO 1)

Value-at- Risk, Third Edition, The New Benchmark for Managing Financial Risk, Jorion Ch. 13 Liquidity Risk (Except section 13.4) (LO 4)

2. Continued

Commentary on Question:

This question intended to test the candidates' understanding of catastrophic mortality risk and assess the appropriateness of various risk mitigation methods for catastrophic mortality risk. The question also tests the candidates' understanding of liquidity risk, how it is quantified, and the various ways that it is experienced. Overall, candidates performed fairly well on the question, with the exception of part (d) due to candidates not using all available information to make quantitative assessments/recommendations or providing answers that were not directly relevant to the question.

Solution:

(a) ERM Life is considering the use of reinsurance to address its concerns with catastrophic mortality claims. The following reinsurance alternatives have been offered to ERM Life:

- 50% pro-rata reinsurance
- Per risk excess of loss reinsurance
- Per occurrence excess loss reinsurance
- Aggregate excess of loss reinsurance

Assess the suitability of each of these alternatives to mitigate ERM Life's catastrophe risk exposure.

Commentary on Question:

Candidates generally performed well. Several candidates confused Per Risk and Per Occurrence reinsurance and did not understand how catastrophic mortality claims would be realized (high frequency rather than high severity) which led to incorrect assessments of the reinsurance options.

- 50% pro-rata reinsurance cedes 50% of all claims, and will be the most expensive of the provided options. ERM Life will still be exposed to 50% of catastrophic mortality claims. This option is not appropriate to address ERM Life's concerns.
- Per risk excess of loss covers losses in excess of a threshold for each policy/contract. Catastrophic mortality claims would be realized as a high frequency of claims, rather than a small number of high face amount claims. This option would not be appropriate to address ERM Life's concerns.
- Per occurrence excess of loss would cover claims in excess of a threshold arising from a single event, subject to the wording of the treaty. If, for example, the treaty defined a pandemic event as a single occurrence, then this option would be appropriate to address ERM Life's concerns, and would come at a lower cost than alternative options.

2. Continued

- Aggregate excess of loss covers all losses in excess of a threshold over a given timeframe. Although this option would likely be more expensive than the alternative XoL options, this option would address ERM Life's concerns with catastrophic mortality claims.
- (b) ERM Life is also considering the following alternative risk transfer approaches to cover catastrophic mortality claims:
- Issuing a catastrophe bond sold through a dedicated Special Purpose Vehicle (SPV)
 - Participating in a self-insurance pool
 - Setting up its own captive
- (i) Describe each approach.
- (ii) Analyze the appropriateness of each approach to mitigate ERM Life's catastrophic mortality risk.

Commentary on Question:

Candidates generally performed well on this part. Candidates that did not perform well commonly made recommendations that were not specific to ERM's goals of mitigating catastrophic mortality risk, and focused on the risk financing aspects rather than the intention of risk transfer (specifically for captives, where the risk is still retained by the parent company).

Issuing a catastrophe bond sold through a dedicated Special Purpose Vehicle (SPV)

- (b i) ERM Life would sponsor an off balance sheet SPV which would issue bonds to investors. If a catastrophic event occurs, ERM Life would be able to use the invested capital to pay off claims, while investors receive coupons and the return of principal if no catastrophic event occurs.
- (b ii) This approach would be appropriate for ERM Life. It provides funding when catastrophic mortality events occur and has low counterparty risk as funds are received initially. ERM Life should consider the risks and regulatory scrutiny associated with SPVs.

Participating in a self-insurance pool

- (b i) ERM Life would participate in a pool of catastrophic claims with other insurers and would share overall claims results.
- (b ii) This approach would not be very useful as catastrophic mortality claims would likely be experienced by all insurers in the group.

2. Continued

Setting up its own captive

- (b i) ERM Life would set up a captive reinsurance company for risk financing purposes that can be based in a jurisdiction with favorable capital and/or tax treatment.
- (b ii) This would not be appropriate for mitigating catastrophic mortality claims. Captives are for risk financing, not risk transfer. If ERM Life experiences catastrophic mortality claims, they are still responsible for the claims as a captive is not bankruptcy remote.

(c) ERM Life is considering two options:

- 1st option: Liquidate 100,000 shares immediately
- 2nd option: Liquidate 20,000 shares each of the next five trading days

Describe the asset liquidity impact of each option.

Commentary on Question:

The majority of candidates answered this part of the question well and understood the tradeoffs and liquidity impacts of the two options.

The first option will have a higher asset liquidity impact as selling more shares at once will have a larger impact on the bid-ask spread and the price impact function. The second option will have a lower asset liquidity impact by spreading the sale out over 5 days, however this will expose ERM Life to volatility in the share price over the week.

(d) It has been suggested that ERM Life use liquidity-adjusted VaR (LVaR) to inform its decision on how to pay the reinsurance premium. You are given the following information for the liquidation options:

- Price impact of the 1st option: \$257,500
- Price impact of the 2nd option: \$51,500
- Asset portfolio VaR for 2nd option: \$361,623

- (i) Recommend which liquidation option ERM Life should implement in order to pay the reinsurance premium. Justify your answer.
- (ii) Describe other aspects of asset and liability liquidity risks that ERM Life should consider when entering into this transaction.
- (iii) Describe two other relevant risks that ERM Life should consider when entering into this transaction.

2. Continued

Commentary on Question:

Many candidates did not consider the required premium amount when recommending an approach for subpart (i), and thus did not provide any quantitative reasoning for their recommendation. Many of the risks provided were not relevant to the specific transaction. Other reasonable answers not shown in the solution received credit.

(d i)

The liquidity adjusted value of the position in stock company for the 2 options are:

- 1st option: $103 * 100,000 - 257,500 = \$10.04M$
- 2nd option: $103 * 100,000 - 51,500 - 361,623 = \$9.89M$

Given ERM Life needs \$10M at the end of the week to pay the reinsurance premium, they should use option 1 to ensure enough funds are available.

(d ii)

- The impact of the bid-ask spread was not considered in the above but could result in less funds being available.
- If there is a lag between covered claims being incurred and provided to ERM Life, there may be a liquidity strain when ERM Life needs to pay contract holders before the reinsurance claims are received.
- The sale of these assets may have an impact on ERM Life's ALM position.
- ERM Life will need to be able to pay future premiums for this reinsurance which could impact the availability of liquid assets.

(d iii)

- Counterparty risk: There is a risk that the reinsurer will default on its obligations in the event of a catastrophe.
- Operational risks: For example, process risks related to the administration of the reinsurance agreement.

3. Learning Objectives:

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.

Learning Outcomes:

- (1c) Identify and analyze specific risks faced by an organization, including but not limited to: financial, environmental, operational, legal, reputational and strategic risks.
- (2a) Demonstrate how each of the financial and non-financial risks faced by an organization can be amenable to quantitative analysis.
- (2c) Evaluate and select appropriate copulas as part of the process of modelling multivariate risks.
- (2e) Demonstrate the importance of the tails of distributions, tail correlations, and low frequency / high severity events, and the use of extreme value theory to analyze these situations.

Sources:

Value-at- Risk, Third Edition, The New Benchmark for Managing Financial Risk, Jorion
Ch. 18 Credit Risk Management

Quantitative Enterprise Risk Management by Mary Hardy, Chapter 7: Copulas

Commentary on Question:

This question tested candidates' general knowledge and understanding of different quantitative approaches to credit risk analysis, and the utilization of knowledge of copulas in credit risk analysis using structural models.

Solution:

- (a) There are several modeling approaches used for estimating default probabilities, including:
 - Merton's model
 - KMV Moody's
 - Models incorporating bond prices
- (i) Compare and contrast the structure and use of reduced-form models and structural models.
- (ii) Identify whether each of these models is a reduced-form model or a structural model. Justify your response.

3. Continued

Commentary on Question:

This part of the question tested candidates' knowledge of market-based default models and application of the knowledge to identify reduced-form and structural models. To receive full credit, candidates needed to explain the differences between reduced-form and structural models. In general, candidates did better on explaining/identifying structural models than reduced-form models.

(i)

Structural models model the value of an entity. Models are based on capital structure of companies.

Reduced-form models model default probability directly, for example, using bond-price yields.

(ii)

Merton and KMV models are structural model. They are based on capital structure of companies and model company values.

Models incorporating bond prices are reduced-form models, which calculate default probability directly.

- (b) Using bond prices, the credit spread of a bond can be calculated and used to estimate the expected credit loss. Thus, your colleague claims that if bond A has higher spread than bond B, bond A must have higher probability of default than bond B.

Explain whether your colleague's statement is correct.

Commentary on Question:

This part tested candidates' knowledge and understanding of the reduce-form model of using bond price (spread) to calculate probability of default. To receive full credit, candidates needed to explain that other factors, beside probability of default, may affect credit spread. Overall candidates did well on this part.

The statement is not correct.

Interest spread reflects not only credit loss risk due to default, but also other risks, for example, liquidity risk, systematic risk, etc.

3. Continued

(c) Your team has been working on a project using simulations to estimate tail credit loss of the company's portfolio. You use copulas in the simulations to capture the dependencies between credit losses on bonds in the portfolio. You are given the following information:

- The time horizon is one year.
- The returns of each bond issuer's asset portfolio are simulated assuming they follow a lognormal random walk.
- A correlation matrix of the returns of the bond issuers' assets.
- The following have already been estimated for each bond issuer: the growth rate of the asset value, the volatility of the asset value, default threshold, exposure, and loss given default.

(i) Describe the steps to simulate the asset values of the bond issuers and to calculate credit loss of your company's portfolio using a Gaussian Copula. You do not need to give any formulas.

(ii) Your other choice of copula is Student's t.

Describe how the simulation process would need to change to incorporate a Student's t copula into the simulation. You do not need to give any formula.

(iii) You run two simulations, each generating 10,000 samples – one using a Gaussian copula and the other using a Student's t copula. You then calculate the credit loss at the 99th percentile from each simulation.

Compare the VaR(99) results you would expect between the two simulations. Justify your answer.

(iv) Recommend which copula should be implemented. Justify your recommendation.

Commentary on Question:

This question tested candidates' knowledge of a simulation process involving different copulas, understanding of the differences between different copulas, and the ability of choosing an appropriate copula for a specific application and justifying the choice. To receive full credit, candidates were required to describe all the steps of simulation process in the right order and the changes in specific step(s) due to switching to a different copula. Candidates also needed to provide justifications for (iii) and (iv) to demonstrate good understanding of the real-world problem and differences between the two copulas.

3. Continued

Candidates generally did not do well in describing the correct steps of a simulation process using a copula. However, most candidates demonstrated a good understanding of tail dependence in financial crisis and were able to identify the appropriate copula for the real-world problem.

(i)

1. Create a random correlated $N(0,1)$ vector using the correlation matrix of the returns of bond issuers' assets.
2. Convert the above vector into uniform vector with Gaussian copula using standard normal distribution function.
3. Convert the vector from step #2 into marginal vector.
4. Calculate asset values of the bonds in one year using marginal vector from step 3. Bond is in default if asset value is below its default threshold. Credit loss is "Exposure times Loss Given Default".

(ii)

1. After step #1 above, convert the vector into a student's t vector.
2. Convert the student's t vector into uniform vector with student's t copula, using student's t distribution function.

(iii)

99% VaR using student's t copula is likely to be higher than that using Gaussian copula.

Student's copula has tail dependence, or extreme event (bond default) are more likely to happen simultaneously with Student's t copula.

(iv)

Recommend Student's t copula. The simulation is for VaR calculation, so having no tail dependence with Gaussian copula may understate tail risk. In a financial crisis (tail event), financial correlations typically increase.

4. Learning Objectives:

2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.
3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.
4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:

- (2a) Demonstrate how each of the financial and non-financial risks faced by an organization can be amenable to quantitative analysis.
- (2d) Demonstrate the use of scenario analysis and stress testing in the measurement of current and emerging risks.
- (2g) Evaluate and select appropriate models to handle diverse risks, including models that use a stochastic approach.
- (3b) Analyze quantitative financial and non-financial data using appropriate statistical methods to assist in quantifying risk.
- (3c) Analyze risks that are not easily quantifiable, such as liquidity, operational, and environmental risks.
- (4d) Demonstrate how derivatives, synthetic securities, and financial contracting may be used to reduce risk within a static or dynamic hedging program.
- (4f) Demonstrate the use of tools and techniques for identifying and managing credit and counterparty risk.
- (4i) Choose appropriate techniques to measure, model and manage various financial and non-financial risks faced by an organization.

Sources:

Financial Enterprise Risk Management, Sweeting, 2011, Ch. 14 Quantifying Particular Risks

Value-at- Risk, Third Edition, The New Benchmark for Managing Financial Risk, Jorion
Ch. 12 Monte Carlo Methods

Managing Investment Portfolios, Maginn, John L. & Tuttle, Donald L., 3rd Edition, 2007
Ch. 9: Risk Management (section 5)

4. Continued

Financial Enterprise Risk Management, Sweeting, 2011 Ch. 16 Responses to Risk
ERM-120-14: IAA Note on Stress Testing and Scenario Analysis (pp. 1-6 and 14-17 and
19-25)

Commentary on Question:

This question tests candidates' ability to model and mitigate counterparty risk in a nontraditional setting by using GAM, an auto company in the case study, as its subject. The last part of this question requires candidates to use information from the case study to design a stress scenario that applies to this company.

Solution:

- (a)
- (i) Assess the appropriateness of using the Merton model to measure the solvency of companies A and B.
 - (ii) Propose one alternative method GAM could use to measure the solvency of its supplier. Justify your proposal.
 - (iii) Demonstrate that Company B is preferable to Company A, as of December 31, 2020, using the Merton model. Show all work.

Commentary on Question:

This part of the question asked candidates to demonstrate knowledge of weaknesses and strengths of the Merton model for credit risk, as well as knowing at least one other model for assessing credit risk. Candidates could argue for or against the appropriateness of the Merton model in subpart (i), as there are aspects of this specific situation that are relevant. There were various correct answers for subpart (ii), with the justification of the use of the alternative to the Merton model being the most important.

In general, candidates were able to address all three subparts of this question fairly well; however, there were some issues with people showing all their work on subpart (iii). Some candidates copied and pasted the formula and/or table given at the beginning of the problem and then replaced variables with the appropriate numerals, which led to full credit.

- (i) This model works best when used for large borrowers with liquid and frequently traded equity stock, since an accurate number for the volatility of the corporate equity is needed to model the default. This is true for both companies A and B.
Though this is not assessing credit risk for a bond held by GAM, GAM is at risk if the supplier defaults. The Merton model gives a probability for the companies defaulting, so GAM could use this to pick the firm with lower probability of default.

4. Continued

(ii) One could use the KMV model, which measures a “distance to default” based on firm’s asset value, volatility, and debt structure. This model uses similar assumptions as the Merton model, so necessary information should be available for use. The output represents the number of standard deviations the firm value is from default, instead of the actual default probability. The model assumes that the price of the equity can be regarded as a call option on the underlying assets of the firm.

(iii)

$$\Pr(X_T \leq B) = \Phi \left(\frac{\ln \left(\frac{B}{X_0} \right) - \left(r_x - \frac{\sigma_x^2}{2} \right) T}{\sigma_x \sqrt{T}} \right)$$

Company	X_0 = Total Asset Value (in millions)	r_x = Expected Growth Rate	σ_x = Volatility of Growth Rate	B = Total Amount of Company's Borrowing (in millions)	T = Time of Lump Sum Payment of Company's Debt
A	\$5,000	5%	35%	\$1,000	5 years from today
B	\$8,000	7%	25%	\$2,000	5 years from today

Firm A:

$$\begin{aligned} \Pr(X_T \leq 1000) &= \Phi \left(\frac{\ln \left(\frac{1000}{5000} \right) - \left(.05 - \frac{.35^2}{2} \right) 5}{.35\sqrt{5}} \right) = \Phi(-1.98) \\ &= .0239 \end{aligned}$$

Firm B:

$$\begin{aligned} \Pr(X_T \leq 2000) &= \Phi \left(\frac{\ln \left(\frac{2000}{8000} \right) - \left(.07 - \frac{.25^2}{2} \right) 5}{.25\sqrt{5}} \right) = \Phi(-2.83) \\ &= .0023 \end{aligned}$$

So, the probability of default for firm B is less than that of firm A.

4. Continued

- (b) GAM's management is concerned with the cost of lithium which heavily influences the price of the batteries and, therefore, the overall production cost of BEVs. Caerus has determined that lithium prices can be described using geometric Brownian motion.
- (i) Describe a process for using Monte Carlo simulation to calculate VaR(99) for lithium prices over the next n years.
- (ii) Explain how the volatility of battery prices could be mitigated using:
- A forward contract on lithium
 - A futures contract on lithium
- (iii) Recommend whether GAM should use a forward or a futures contract for lithium to hedge against battery price volatility. Justify your recommendation.

Commentary on Question:

This part of the question focused on price volatility for lithium, looking at ways to model and measure the potential volatility as well as use of forwards or futures for mitigating the price volatility. Most candidates were able to address all parts of this problem. Some candidates confused forwards with futures. In subpart (iii), some candidates used the information from the case study that lithium futures were new to the exchange, but this observation was not required for full credit. For subpart (iii), either choice could be supported given the information, and the justification of the choice was the point of that subpart.

- (i)
1. To calculate VaR, you need several simulated values to approximate the distribution of lithium prices at the target horizon.
 2. To do this, you will need to generate a sequence of random (from a random number generator) or pseudorandom numbers ϵ_1 to ϵ_n , from which prices are computed as $S_{(t+1)}$, $S_{(t+2)}$... $S_{(t+n)}$.
 3. Next, using the stochastic process from the analyst, calculate the value of the lithium price at the target horizon n .
 4. Repeat this process a large amount of times (e.g. 1000) to get a simulated distribution. This gives you distribution values $F(T,1)$ to $F(T,1000)$.
 5. Sort the values and find the 99th percentile. Subtract the mean if you are computing VaR relative to the mean.

4. Continued

(ii)

1. **Forward:** GAM could enter into a forward contract with a lithium supplier. In this contract, GAM will agree to buy a fixed amount of an asset (in this case, lithium) for a fixed price at some point in the future. This will eliminate any price uncertainty, because the price and delivery amount will be locked in at issue. However, the amount and timing must be determined at issue, and is not flexible to changes. The actual delivery of lithium is part of this contract.

2. **Future:** GAM could take a long position on a lithium future in an exchange, where a broker will find a counterparty willing to take the short position. The contract is regularly marked-to-market, so if the price of lithium increases, GAM would receive payments and if it dropped, GAM would have to make payments to the short position. If needed, GAM could buy more futures or close out a futures position if they needed to adjust volume. Delivery dates are standardized as are futures amounts, and does not usually involve actual delivery of the commodity.

(iii)

GAM should enter into a forward contract with a lithium supplier. Forwards are flexible with regards to timing and volume, and would involve the actual delivery of the lithium. GAM could tailor a forward contract to the exact amount they need at a specific time. Futures would not allow such flexibility, leading to basis risk.

Forwards do have counterparty risk, as the supplier could default on the contract and not deliver the specified volume at the specified time. GAM could require collateral to reduce this risk.

(c) In response to the board meeting described in section 1.9 of the Case Study, your team has been asked to perform scenario analysis regarding GAM's strategy.

(i) Explain why using a synthetic scenario for the analysis would be more beneficial than a historical scenario in this situation.

(ii) Design a company-specific synthetic stress scenario that could be applied to the situation where GAM remains in the PCV market. Support your answer using evidence from the Case Study.

Commentary on Question:

For this problem, most candidates were able to address subpart (i) but some had difficulty in designing a company specific stress scenario for subpart (ii). There were many possible stress scenarios for subpart (ii), and we were looking for details in a stress scenario that were based on risks in the case study section 1.9. In some cases, candidates presented an upside scenario as opposed to a stress scenario.

4. Continued

- (i) Historical scenarios are based on experience over an observation period triggered by a certain historical event. Since historical circumstances will inevitably be different from the current or future situation, scenario adjustments will likely need to be applied. This would be the case for modeling the emergence of the new BEV market.
Given that the emerging BEV market is a new development, retrofitting a similar historical scenario with all relevant information could be difficult. If a synthetic scenario was used, it could be tailored specifically to GAM.

- (ii) New government regulation affecting PCVs: suppose China bans the sale of PCVs in 5 years, and key U.S. markets tighten emissions and fuel economy standards with fines for vehicles that don't comply.
GAM would be directly impacted by increased government regulation of the PCV market, and 85% of its sales come from China and the U.S. If the BEV market develops, the government could further discourage the manufacturing and use of PCVs by posing even stricter regulations on emission and fuel economy standards.
This could increase production costs for GAM because PCVs would have to be made to be more efficient, or GAM could face penalties and fines. GAM could estimate the increased cost of continuing to make these vehicles in this situation, and ultimately estimate the impact on its profitability. This might eventually drive them out of the PCV market and push them towards solely making BEVs.

5. Learning Objectives:

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
2. The candidate will understand the concepts of risk modeling and be able to evaluate and understand the importance of risk models.
3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.
5. The candidate will understand the concept of economic capital, risk measures in capital assessment and techniques to allocate the cost of risks within business units.

Learning Outcomes:

- (1c) Identify and analyze specific risks faced by an organization, including but not limited to: financial, environmental, operational, legal, reputational and strategic risks.
- (2a) Demonstrate how each of the financial and non-financial risks faced by an organization can be amenable to quantitative analysis.
- (2d) Demonstrate the use of scenario analysis and stress testing in the measurement of current and emerging risks.
- (4e) Determine an appropriate choice of mitigation strategy for a given situation, which balances benefits with inherent costs (including exposure to moral hazard, credit, basis and other risks).
- (4h) Demonstrate possible risk management strategies for non-financial risks.
- (5b) Apply risk measures and demonstrate how to use them in value and capital assessment.

Sources:

ERM-107-12: Strategic Risk Management Practice, Anderson and Schroder, 2010 Ch. 7
Strategic Risk Analysis

Emerging Risks and Enterprise Risk Management (pp. 2-6)

Embedding Cyber Risk in Risk Management: An Insurer's Perspective (pp.12 -15 of
Cybersecurity: Impact on Insurance Business and Operations)

Risk Appetite: Linkage with Strategic Planning Report

SOA Monograph- A New Approach to Managing Operational Risk -Chapter 8

5. Continued

Commentary on Question:

This question tests candidates' understanding of risk assessment, specifically for risks that are not easily quantifiable in the Energy Industry and Energetix from the Case Study. The candidate is expected to know details on Strategic Risk Analysis, Cybersecurity Risk, and the candidate should be able to evaluate Risk Appetite statements.

Solution:

- (a) Your initial task requires assessing key emerging risks that are relevant to Energetix.
- (i) Describe the process of environmental scanning as part of an emerging risk review.
- (ii) Explain how a balanced environmental scanning approach could be used by Energetix to assess the potential emerging risks related to:
- Regulatory change
 - Cybersecurity threats

Commentary on Question:

Candidates provided reasonable general process in (i), but many provided limited explanations on how to balance that process with or what they might do as a consultant assessing these risks for Energetix in (ii).

- (i) One approach to environmental scanning is to consider first the general macro-level environment, then consider the issues specific to the Energy Industry, as done by Caerus in the case study, and finally look within the company operations and strategic plan.

There are 4 Modes of scanning that could be used:

- Formal Search
- Conditional viewing
- Informal Search
- Undirected Search

The company should develop a common emerging risk vocabulary to facilitate internal communication of risk-handling activities to improve the ability to process information to optimize current activities as well as scanning for new emerging trends.

5. Continued

Environmental scanning is an ongoing process, so risks are catalogued, allowing the company to follow them as they develop. The frequency and attentiveness of reviews are based on the company's risk profile and complexity.

- (ii) A balanced approach is important to manage costs and information. Too much focus on undirected viewing might result in huge costs, information overload and not least a lack of focus. On the other hand, while more cost-efficient, conditional viewing and formal search might result in a too-narrow scanning of the environment and might miss out on fundamental changes.
 - For regulatory changes, Energetix could do more conditional viewing for information focused on specific sources. For example, one of their state regulators has already mandated a transition to renewable energy, so Energetix should monitor other state regulatory bodies for similar proposals or legislative bills, in addition to monitoring the rates that state utility commissions allow utilities to charge. They could balance this with a periodic unconditional viewing approach to try to uncover information they may not have thought about beforehand, such as climate research to see what sorts of regulatory changes climate activists might lobby government to enact.
 - For cybersecurity threats, Energetix does not appear to have expertise here, as their main technology is focused on physical production and delivery of energy, not information technology. Therefore, they should consider starting with informal or undirected scanning to look broadly at global and industry trends in cybersecurity or leverage the Caerus engagement to determine key risk indicators the company could establish to provide a formal risk assessment of their current workforce, processes and technology which they can routinely monitor and update.
- (b) You plan to coordinate scenario planning for key risks across Energetix's various subsidiaries. Caerus has identified key risk factors related to the Energy Utility Industry, and you have elaborated major themes that characterize plausible developments as follows:
 1. Regulatory changes related to the environment and the potential impact of global climate change
 2. Operational activities that impact the reputation or financial condition of the company.

5. Continued

- (i) Describe a relevant scenario, specific to Energetix, for each theme.
- (ii) Outline the remaining steps in the scenario planning process.
- (iii) Provide a relevant example for each step identified in (ii) using one of your scenarios from (i).

Commentary on Question:

Most candidates provided reasonable scenarios. For the operational activities, though cybersecurity was mentioned in parts (a) and (c) of this question, there were other relevant examples for Energetix from the case study, such as infrastructure maintenance, nuclear waste disposal, or labor unions. Many candidates recognized the stem as steps 1 and 2 of the scenario planning process in ERM-107-12, with subpart (i) as step 3, and so put variations of steps 4 and 5 (or sometimes all 5 steps) in subpart (ii). For those who missed subpart (ii), but gave reasonable, relevant examples to their own steps in subpart (iii), partial credit was given.

- (i)
 - 1. From the case study, “Last year, the state regulator for one of the EUI companies mandated that, within the next 20 years, 50% of all electricity in that state must be generated from renewable resources such as wind or solar energy.” A plausible scenario for Energetix to consider is if all states or all EUI subsidiaries are required to meet this mandate.
 - 2. Part of Energetix’s EUI has a significant financial commitment to disposal of nuclear fuel due to the Nuclear Waste Policy Act (NWPA). A plausible scenario for Energetix to consider is the uncertainties with respect to the cost and long-term availability of disposal sites for spent nuclear fuel and other radioactive waste, either by increasing base costs in their operating plan or modeling significant fines or penalties for failure to comply appropriately.
- (ii)
 - Step 4: Evaluate the impact of key strategic risk factors in the scenarios and assess capacity for corporate responsiveness
 - Step 5: Formulate new strategic alternatives, and evaluate them in the different scenarios
- (iii) For this part, referencing the Regulatory changes scenario:
 - Step 4:
 - 1. Perform a sensitivity test on current projections, increasing costs for production or acquisition of renewable energy sources up to 50% over next 20 years. Consider impacts of 50% in 10 years, or 100% in 30-40 years.

5. Continued

2. Assess whether Energetix can maintain profitability under the investment in renewables: Is there adequate capital to fund the investments or does Energetix need to consider strategic alternatives?

Step 5:

1. Consider a strategic arrangement between the EUI and CR subdivisions or a new counterparty for EUI to facilitate the energy acquisition or share the costs / capital. The case study states “EUI companies also complete projections under various scenarios to test what actions would be needed if one or more counterparties failed to provide the contractual amount of energy”, so these should be easy for Energetix to test.
 2. Reevaluate the scenarios/sensitivities in Step 4 under each of these alternatives to assess which to advocate or pursue to senior management.
- (c) The Energetix Board has developed a new qualitative risk appetite statement for cybersecurity risk as follows:

“Any material damage to Energetix’s reputation or interruption of business from a cybersecurity event is unacceptable.”

The Energetix CRO wants more specific limits and has asked you to help establish a quantitative risk appetite statement for cybersecurity risk.

- (i) Identify the challenges with translating a qualitative statement into a quantitative one for cybersecurity risk.
- (ii) Energetix initially proposes a quantitative risk appetite statement, as follows:

“The company cannot lose more than 20 percent of value in a cybersecurity event.”

Propose a modification to the above statement incorporating each of the following:

- Energetix’s current balance sheet and income statement
- Historical experience in data breaches and operational failures.

Explain your reasoning.

5. Continued

- (iii) Recommend two enhancements that Energetix could implement to support compliance with the cybersecurity risk appetite statement that you proposed in (ii). Justify your response.

Commentary on Question:

Candidates stated reasonable modifications in subpart (ii) and enhancements in subpart (iii), but in both places many failed to provide sufficient explanation or justification for them, especially ignoring the specifics to Energetix current situation and financials. Full credit was given in subpart (ii) if the explanations of what modifications should be done were sufficient but there was no “re-statement” of the risk appetite either for each item separately or both together, since that was not specifically requested.

- (i) A quantitative risk appetite statement for cyber risk requires experience data, expert opinions and sophisticated (fuzzy) modeling to incorporate a changing environment. There are issues with:
- Agreement on what constitutes a cybersecurity event and defining “material damage”
 - Gathering and analyzing internal and industry data on operational risks, in general, and cyber risks specifically
 - Difficulty assigning frequency / severity probabilities to historical events or providing plausible hypothetical scenarios to test.
- (ii) I propose: “The company cannot lose more than 20 percent of the annual pre-tax income in the event of a 1-in-100 year cybersecurity incident.”

The quantitative statement needs to provide specifics on what “value” and what determines an “event”. For the value, 20% of pre-tax income is more reasonable than 20% of equity or surplus, which would be nearly 6 times the annual income, likely too much “material damage” for a single event. To define the “event”, available experience on data breaches in the industry can be used to help calibrate the quantitative part of the model and set a 1-in-100 1-year loss or series of related losses. To enhance the data, including other company and industry operational losses in the modeling is reasonable, as the chance of cyber risk can also be roughly estimated as the percentage for noncyber operational risk multiplied by the relative extremity of cyber risk compared to noncyber operational risk.

5. Continued

- (iii) Energetix should implement Key Risk Indicators for cyber risk in order to strengthen the governance of the risk. Possible KRIs include the number of system breakdowns per month, number of users with access to key sensitive data, the level of risk awareness measured by the training that has been taken by employees and the average length of time before a cyberattack is detected. If these KRIs are tied to manager scorecards, the company will benefit from encouraging continued and consistent appropriate risk/return decisions, while at the same time providing metrics that can adjust according to the company's situation and the evolving environment.

Energetix should also consider cyber insurance to offset some of the losses that would occur in a cybersecurity event. This would mean having a cyber insurance company reimburse losses as specified in a contract for a 1-in-100 year event's financial impacts. Energetix should still maintain KRI monitoring because cybersecurity risk is contagious: there is counterparty risk introduced as an incident can happen across several firms at one time, increasing the likelihood that the cyber insurance company defaults on its obligations.

6. Learning Objectives:

1. The candidate will understand the types of risks faced by an entity and be able to identify and analyze these risks.
3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.
4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:

- (1c) Identify and analyze specific risks faced by an organization, including but not limited to: financial, environmental, operational, legal, reputational and strategic risks.
- (3c) Analyze risks that are not easily quantifiable, such as liquidity, operational, and environmental risks.
- (4c) Demonstrate the use of controls for retained and residual risks.

Sources:

National Risk Management A Practical ERM Approach for Federal Governments (Page 11-22)

Internal Controls Toolkit by Christine H. Doxey, Chapter 1 pp.11-17, 27-35

ERM-107-12: Strategic Risk Management Practice, Anderson and Schroder, 2010 Ch. 7 Strategic Risk Analysis

Commentary on Question:

This question dealt with identification of key risks, identifying mitigations and controls to manage the risks. This question showed how different sources, appearing distinct at first, can have concepts that fit together in the context of a specific company, GAM in this case.

The three main ideas of this framework as tested by this question were:

- *Review and assess strategic objectives and their relevant indicators.*
- *Review and assess key risks, their pertinence to the previous strategic objectives and the suitability of indicators to evaluate them.*
- *Review and assess relevant controls for those risks so that strategic objectives can be achieved.*

6. Continued

Candidates generally struggled with this question, with most earning less than half credit. In order to get full credit, candidates had to apply what was given in the Case Study for Giant Auto Motors (GAM) as well as Automotive Consulting (the summary of the industry and its key risks) to the information provided in the question.

Most candidates applied only limited information available to them in the Case Study.

Solution:

- (a)
- (i) Evaluate whether these objectives are the appropriate **key** strategic objectives for GAM.
 - (ii) Assess if the listed key metrics are suitable for measuring progress towards the stated objectives.

Commentary on Question:

*For (i) most responses provided limited justification as to why the objective should be viewed as a **key** strategic objective. Based on what was provided in the Case Study, candidates should have understood what the key strategic objectives were for GAM and evaluated the provided objectives to see if they were in alignment.*

For (ii) many candidates confused the “current market share of JV” with “the current % ownership in the JV”. Many candidates also confused BEVs and BEV Batteries. The 2nd and 3rd objectives were specific to the BEV Batteries, not to the BEV vehicle.

- (i) According to the company strategy, GAM is the largest auto maker in the U.S., but the objectives don’t address maintaining this but focus on expanding in China. None of the objectives specifically address the US Market, for which they are the largest manufacturer. Although for manageability it is good to limit the number of objectives to three, two of the objectives focus on the same area - batteries.

The first objective aligns to their desire to focus on China.

The second objective does not appear to be a key strategic objective. GAM wants to move into the BEV market, but this doesn’t mean they need to produce their own batteries. Is the 1 year time frame even feasible? Two years ago, it began developing its own automotive batteries for PCVs, and after two years GAM can produce enough PCV batteries to supply all of its small cars.

6. Continued

These batteries are different from BEV batteries. Does GAM currently have the funds needed to develop BEV batteries? We know there are high upfront costs to entering the BEV market and that batteries are the most expensive component of an electric vehicle.

The third objective does not appear to be a key strategic objective, as again it is focusing on BEV batteries and not BEV vehicles. Will there be a conflict of interest with their JV and providing batteries directly to the China market? The five year time frame appears more reasonable.

(ii) **Current Market Share of JV in China** (not suitable)

- We are not concerned with the market share of the JV overall, but in GAM's ownership of the JV
- Even if it focused on the % ownership in the JV, this seems to be a very generic metric and doesn't have a baseline value

Monthly reduce # of batteries that are purchased by 10% (not suitable)

- it has a baseline value, but the reducing # of batteries without context is vague.
- Simply purchasing fewer batteries doesn't mean that GAM is able to produce more batteries. What if sales shot way up?

% of BEVs (Battery Electric Vehicles) vs PCVs (not suitable)

- this doesn't really align to any of the objectives, because the metric refers to % of cars sold, but the objective is referring only to the batteries for the BEV

(b)

- (i) Evaluate whether the risks identified are appropriate for the corresponding objectives.
- (ii) Assess if the risks identified are *key* risks for GAM. Justify your response.

Commentary on Question:

Candidates struggled with this part of the question.

For (i) most candidates answered the question of whether each risk was applicable to the objective, not necessarily whether it was appropriate. Candidates would have benefitted by using this thought process: "What criteria should I use to determine if a risk is appropriate? Is what they are proposing appropriate? Is the risk defined correctly?"

6. Continued

Some candidates provided similar answers for (i) and (ii), which did not properly distinguish between the questions. For (ii), stronger responses included criteria for what would be considered a key risk for GAM, then assessed whether these risks met those criteria.

- (i) When identify key risks, you need to look at what type of risk events, defined by its originating source, would cause us to not attain our objective based on the key metric identified.

There should be more than just one risk identified for each objective.

Risk: Regulatory Changes limiting JV (appropriate)

This risk aligns with the objective, but the granularity needs to be improved.

Risk: Ability to obtain material for batteries (not appropriate)

The objective is to produce its own BEV battery within a year. More material would be needed when GAM moves into the production phase for BEV batteries than for the development phase. This risk is more appropriate for the 3rd objective.

Risk: Having the skillset in-house for continued battery improvement (not appropriate)

Being a top provider means you need to be able to supply the batteries on time and at the right price. Production generally relies on “just-in-time” processes from a global supply chain, indicating that material is a significant risk for this objective. This risk is more appropriate for the 2nd objective.

- (ii) No, the three risks listed are NOT key risks for GAM. A SWOT analysis should be done to determine the key risks, including general environmental risks, industry risks, company risks. One strategic Risk identified in the Automotive Industry is self-driving car capability, this isn't addressed at all.

Although Regulatory Change in China is a risk, China isn't their largest market.

They are addressing the battery powered vehicle risk, but battery technology is expensive, and require large upfront costs per the case study - so liquidity risk is an issue, but not mentioned.

6. Continued

(c) The following controls are suggested for the risks associated with achieving the stated objectives:

- Audit the entire production process of batteries quarterly
- Test each battery to ensure it meets the guidelines needed for all global markets in which GAM participates
- Have each order for component parts be double-checked for accuracy

Assess the effectiveness of the proposed controls for each risk when implementing a risk-based controls approach. Justify your answer.

Commentary on Question:

Most candidates received at least partial credit on this part. To receive full credit, candidates needed to opine on each of the controls for the objectives listed in aggregate. Some candidates answered this part by applying each of the controls to the three risks, effectively opining on 9 different comparisons. Maximum credit could have been achieved in either situation.

Having intensive checks would be very costly, and risk-based controls approach looks at the risks that have the most impacts. If the cost of control is greater than the benefit from the control, it is not recommended to take the control.

Audit the entire production process of batteries quarterly

- It is good to mitigate any production failures. However, quarterly full audit seems too costly. Maybe have full audit less frequently but have less comprehensive audits for particular/significant areas in production process.

Test each battery to ensure it meets the guidelines needed for all global markets in which GAM participates

- The cost of testing each battery will be intensive but testing a sample will be important. Based on the results of the same, more could be tested. The battery is the key risk in BEV, so to avoid the reputational risk and legal issues, there should be a strong control here, but not EVERY battery

Have each order for component parts be double-checked for accuracy

- Should depend on which component parts. Should be based on how material/fatal the component parts are. For example, seat belt is important, so should be given more attention. However, minor components should not be given much attention and double-checking for accuracy for each component part would be too costly without adding much benefit.

7. Learning Objectives:

4. The candidate will understand the approaches for managing risks and how an entity makes decisions about appropriate techniques.

Learning Outcomes:

- (4e) Determine an appropriate choice of mitigation strategy for a given situation, which balances benefits with inherent costs (including exposure to moral hazard, credit, basis and other risks).
- (4g) Analyze how ALM and other risk management principles can be used to establish investment policy and strategy, including asset allocation.

Sources:

ERM-617-19: Chapter 29 (pp 670-686) of Options, Futures, and Other Derivatives (INV)

Commentary on Question:

This question tested the use of options in hedging variable annuity contracts. Candidates performed reasonably well on most parts of this question, with the exception of part (c). Specific commentary is provided for each part.

Solution:

- (a) Explain why the hedging strategy needs to include options rather than only a position in the underlying stock.

Commentary on Question:

Candidates needed to recognize that the stock alone has zero gamma.

The delta of the underlying stock is 1, but the gamma of the underlying stock is 0. Therefore to make the entire portfolio gamma neutral an option which possesses a non-zero gamma is required.

7. Continued

- (b)
- (i) Explain how gamma neutrality enhances hedging effectiveness of the portfolio against the underlying price changes.
 - (ii) Determine the number of the OTM option contracts to trade to ensure the delta-gamma neutrality of the hedge.
 - (iii) Calculate the cost of the trade.

Commentary on Question:

Most candidates performed well on (i), recognizing that gamma provided nonlinear hedging. In (ii) many candidates were able to perform the calculations required to hedge the portfolio but lost some credit for not converting their answer to the number of contracts. For subpart (iii), credit was given for providing either the cost per share or cost per contract.

- (i) Delta hedging only considers the linear changes in the option price to underlying price changes. Hedging error will be produced by delta hedging due to nonlinearity changes. Gamma hedging will reduce some of this nonlinear hedging error as it measures the second order impacts of the option price to the underlying price changes.

For (ii) and (iii) refer to the Excel spreadsheet

- (c)
- (i) Describe how the delta and gamma of each option will change when the stock price drops.
 - (ii) Describe how the delta and gamma of each option will change when the volatility increases.

Commentary on Question:

Candidates struggled with this part. Not all recognized they were required to describe the change for all three options shown in the root of the question. Some answered in general terms, but this was rarely correct.

- (i) As the current ATM put will become an ITM put as price goes down, delta and gamma of the existing option will go down

The OTM call will become more OTM, therefore delta and gamma will go down

The OTM put will be less OTM. Delta will go down and gamma will go up.

7. Continued

- (ii) For the ATM put delta will remain fairly stable while gamma will decrease.

For the OTM call, both delta and gamma will increase

For the OTM put, delta will decrease while gamma will increase

- (d)
 - (i) Explain the advantages of using synthetic put options.
 - (ii) Explain why trading index futures contracts are preferred to trading the underlying stocks in the portfolio.

Commentary on Question:

Most candidates performed well on this part.

- (i) Synthetic put options allow fund managers to get strike prices and exercise dates which may not always be available in exchange-traded option markets. The option markets may also not have the liquidity to absorb trades of managers at large funds, whereas the synthetic puts will be able to.
- (ii) The transaction costs associated with trades in index futures are generally lower than those with trades in stocks, therefore future contracts are preferred.

8. Learning Objectives:

3. The candidate will understand how the risks faced by an entity can be quantified and the use of metrics to measure risk.

Learning Outcomes:

- (3a) Determine risk exposures using common risk measures (e.g., VaR and TVaR) and compare the properties and limitations of such measures.
- (3c) Analyze risks that are not easily quantifiable, such as liquidity, operational, and environmental risks.

Sources:

ERM-618-20: Chapter 9, section 6 of *Managing Investment Portfolios (INV)*

Value-at-Risk, Third Edition, *The New Benchmark for Managing Financial Risk*, Jorion
Ch. 18 Credit Risk Management (LO 1)

Commentary on Question:

The goal of this question is to test candidates' ability to measure and manage risk associated with a bond trading program.

Solution:

- (a) Describe the three key components for managing risk in a solid risk management program, from *Managing Investment Portfolios Chapter 9*.

Commentary on Question:

This part of the question specifically asks the candidate to use information from the source, which many candidates missed.

- 1) An effective risk governance model, which places overall responsibility at the senior management level, allocates resources effectively and features the appropriate separation of tasks between revenue generators and those on the control side of the business.
 - 2) Appropriate systems and technology to combine information analysis in such a way as to provide timely and accurate risk information to decision makers.
 - 3) Sufficient and suitably trained personnel to evaluate risk information and articulate it to those who need this information for the purposes of decision-making.
- (b) Michelle stated: "The risk models in SLIC have been well developed mathematically and the risk reporting and management processes have been standardized and automated. With this consistent approach, we do not need a large ERM department within SLIC."

Critique Michelle's statement using principles of effective risk management.

8. Continued

Commentary on Question:

Some candidates listed out the reasoning but without critiquing the statement. Critiques need to be explicit. Also, some candidates listed out reasoning that was unrelated to Michelle's statement, which did not receive credit.

Candidate should note that critiques can be both positive and negative.

Michelle's statement is not appropriate and shortsighted.

- Risk is measured and managed by people, not mathematical models.
- One has to question /challenge the assumptions in the mathematical models.

Michelle's statement is appropriate.

- A consistent and rigorous risk management approach will beat a constantly changing strategy.

(c)

- (i) Calculate Present Value of Expected Credit Loss (PVECL) for each bond.
- (ii) Calculate Expected Portfolio Loss for each trader's portfolio.
- (iii) Calculate Variance of Expected Losses for each trader's portfolio.
- (iv) Critique the assumption of default independence.

Commentary on Question:

Candidates did poorly on (ii) and (iii) with many of them dividing the portfolio loss by 2, while some multiplied by the price of the bonds or expected credit loss instead of the face value. The source has an example for the calculation for both the expected portfolio loss and variance of expected loss on pages 474-475 of Chapter 18 - Credit Risk Management.

Answers are slightly different if the risk-neutral probability of default are calculated and rounded comparing to the non-rounded PD. Both versions are shown in the accompanying Excel files and were eligible for full credit.

Refer to the Excel spreadsheet for (i), (ii), and (iii)

Answer for (iv)

The independence default assumption should not be used.

- Bonds are unlikely to default independently of each other.
- Typically, bonds have some correlation either within sectors or to the market.
- A dependence assumption should be used.

8. Continued

(d)

- (i) Critique this compensation design for bond traders.
- (ii) Recommend a change to the current compensation design. Justify your answer.

Commentary on Question:

Some candidates did not understand the implication of $(1 - \text{Expected Portfolio Loss}\%)$. It incentivized bond traders to be risk averse by over investing in less risky assets. The key to the question is to critique this point.

(i)

It is good that:

- A bond trader is incentivized to invest in bonds with lower expected losses for SLIC Company, since their compensation is negatively linked with expected bond losses.

However:

- The trader may become too risk-averse and choose to invest in secure bonds with extremely low expected losses (which may not be appropriate due to lower yields and/or unmatched durations) in order to get maximum pays.
- In a positive performance situation, the trader's situation does not improve from a compensation perspective with incremental bond yields (i.e. the trader is paid the same, no matter how much yields he can generate), but SLIC Company benefits from higher bond yields as a whole.

(ii)

- Incorporate bond yields (positively) and portfolio variance (negatively) into their compensation formula.
- Compensation should be measured by both risk and return.
- Model psychological and behavioral aspects of the portfolio management.
- Establish robust risk control and governance processes that compensates traders.