ACTEX Learning

CFE 101
Enterprise Risk Management Study Manual

1st Edition

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An SOA Exam

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NOTES

Thank you for purchasing the ACTEX CFE 101 Study Manual.

Actuaries have practiced risk management for centuries. Yet it was not until recently that the actuarial profession (and indeed, the financial services industry) began to focus on risk in the context of the entire enterprise. Commercial banks started the shift a decade or so before the insurance industry, although some of their early efforts would be more aptly described as management of portfolio risk rather than enterprise risk.

The Society of Actuaries introduced the ERM exam into its syllabus in 2012. The syllabus has undergone considerable change over the last few years. This is reflective of the changes in the practice and new emerging research in what is a relatively young field. In addition, the financial crisis of 2008-2009 has spurred numerous changes in the regulatory and rating agencies perspective on risk management. The SOA has endeavored to include current publications and research in place of older papers as appropriate.

One consequence of the dynamic state of the practice and the multitude of papers included in the syllabus is a considerable amount of overlap and duplication in content. In some cases the duplication serves to fill in background for the principle subject of the paper, and in other cases it is simply the result of a different author offering his or her own perspective. In producing these study guides we have reduced some duplication but more often tended towards keeping close to the content as presented by each author.

These study guides attempt to capture the key essence of the syllabus in a considerably compressed form. They are not, however, a substitute for the original syllabus material. We recommend you start with a thorough reading of each syllabus resource before reading the corresponding guide. Our intent is for the guides to serve as an efficient means of subsequent review and overview of the entire syllabus.

Finally, I welcome any comments, observations or recommendations for improvement to this Manual.

Godspeed with your preparation for the exam.

Zafar Rashid

FSA, MAAA, CERA

ERM Exam – Core Readings – Fall 2025

Table of Contents

A) Topic 1: Enterprise Risk Management Foundations

Learning Objectives

The candidate will understand the foundation of ERM be able to apply them to organizations.

Learning Outcomes

The Candidate will be able to:

1. Fundamentals of ERM
    a) Describe the concept of ERM, the drivers behind it and the resulting value to organizations
2. The Internal Environment
    a) Recommend an appropriate risk management framework for an organization
    b) Analyze the ERM roles and responsibilities of the people within an organization and how the different groups can collaborate effectively
    c) Demonstrate an understanding of governance issues, such as agency, compliance, and legal risks and the need for audit and market conduct compliance activities
    d) Evaluate the elements and structure of a successful risk management function
3. The External Environment
    a) Examine the impact of the external environment on an organization's ability to achieve its objectives

Resources

B) Topic 2: Risk Analysis and Evaluation

Learning Objectives

The candidate will understand the types of risks faced by an entity and be able to identify and assess these risks.

Learning Outcomes

The Candidate will be able to:

1. Risk Identification
    a) Identify specific risks faced by an organization
    b) Detect emerging risks
    c) Determine an appropriate monitoring mechanism for emerging risks
2. Risk Assessment
    a) Determine the implication of risks on the balance sheet and income statement
    b) Describe the properties and limitations of common risk measures (e.g., VaR and TVaR)
    c) Demonstrate risk aggregation techniques that illustrate the concept of risk diversification
    d) Demonstrate the use of scenario analysis and stress testing in the measurement of risks
    e) Demonstrate the use of techniques to assess risk accumulations and compounding risks
    f) Demonstrate an understanding of model risk
    g) Propose an appropriate modelling technique that meets organizational needs to analyze risks
    h) Analyze risks that are not easily quantifiable, such as operational, environmental and contagion-related risks

Resources

C) Topic 3: Embedding ERM into Decision-Making

Learning Objectives

The candidate will understand how an organization can articulate its approach to risk and how to assess risk and return trade-offs. The candidate will understand the approaches for managing risk. The candidate will understand different concepts of risk capital, risk measures in capital assessment and techniques to allocate risk capital once aggregated.

Learning Outcomes

The Candidate will be able to:

1. Making Decisions
    a) Describe how an organization can articulate its approach to risk using risk appetite and risk limits
    b) Assess the risk and return trade-offs for decisions (e.g. those targeting changes in the organization's risk profiles)
2. Responding to Risks
    a) 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
    b) Demonstrate the use of controls in an organizational process
    c) Demonstrate how derivatives or similar methods may be used to manage or reduce risk
    d) Demonstrate how reinsurance or similar methods may be used to manage or reduce risk
    e) Analyze how ALM and similar risk strategies can be used to manage or reduce risk in an organization
    f) Demonstrate possible techniques for managing non-financial risks
3. Risk Capital
    a) Explain how to develop a capital model for a hypothetical organization
    b) Demonstrate a conceptual understanding of economic measures of value and capital requirements (e.g., EVA, embedded value, economic capital, regulatory measures, and accounting measures) and their uses in decision-making processes
    c) Apply risk measures (such as VaR and TVaR) and demonstrate how to use them in value and capital assessment
    d) Demonstrate the use of techniques to allocate risk once aggregated
    e) Propose techniques of attributing the "cost" of risk/capital strategies to business units in order to gauge performance (e.g. returns on marginal capital)

Resources

- Financial Enterprise Risk Management, Sweeting, Paul, 2nd Edition, 2017
    - Ch. 16: Responses to Risk..... C-1

Quantitative Enterprise Risk Management
Chapter 3: Risk Measures

Reviewer's note: *This is a new resource for 2024. It describes the risk measures most commonly used for the analysis of risk, including VaR and Expected Shortfall (ES). The numerical examples are very explanatory/*

I. Introduction

A. Risk measures are needed to assess potential losses from risk outcomes and assess adequacy of risk capital

B. Steps involved include:

1. Identify a suitable distribution of losses to model
2. Model using Monte Carlo simulations or empirical distributions or parametric distributions
3. Assess the downside outcomes and capital adequacy

C. The risk loadings in the premium can be a function of the expected loss, or the standard deviation of losses, or the variance of losses

II. Risk Measures for Capital Requirements

A. Value at Risk (VaR) at a specific probability level α:

1. There is a α% probability that the VaR will not be exceeded
2. $Q_\alpha = \min(Q: Pr\lfloor L \le Q \rfloor \ge \alpha)$
3. Pr $[L \le Q_\alpha]$= α, or, equivalently $Q_\alpha = F_L^{-1}(\alpha)$

B. Expected Shortfall:

1. ES_α is the expected loss of the losses in the (1- α) part of the loss distribution
2. $ES_\alpha = \frac{1}{1-\alpha}\int_\alpha^1 Q_v\, dv = \mathrm{E}(L|L > Q_\alpha)$
3. $ES_\alpha = \frac{(\beta^l - \alpha)\, Q_\alpha + (1-\beta^l)\, E\left[L \middle| L > Q_\alpha\right]}{1-\alpha}$

C. Other observations

1. ES_0 is the mean
2. Q_0 is the minimum loss
3. $Q_{50\%}$ is the median loss
4. The graphs in Figure 3.4 (not reproduced here) are very explanatory

III. Coherent Risk Measures

A. The 4 Criteria for the Coherence 0f a Risk Measure f

1. Translation Invariance
   a. $f(X+c) = f(X) + c$, for any non-random c
2. Positive Homogeneity
   a. $f(\lambda X) = \lambda f(X)$, for any non-random $\lambda > 0$
3. Subadditivity
   a. $f(X+Y) \le f(X) + f(Y)$ for two random losses X and Y
4. Monotonicity
   a. $Pr\left[X \le Y\right] = 1$, then $f(X) \le f(Y)$

B. Both VaR and ES meet the four criteria for coherence

IV. Estimating Risk Measures Using Monte Carlo Simulation

A. Monte Carlo simulation is used to generate a large number of simulations of the loss variable L

1. These simulations are ordered from the smallest to the largest
2. This is assumed to be the true underlying distribution of L

B. Estimating VaR by interpolating between successive values of L_j

1. $Q_{95\%} \approx (0.05)\, L_{(950)} + (0.95)\, L_{(951)}$

C. Estimating ES_α

1. $\widehat{ES}_\alpha = \frac{1}{N(1-\alpha)} \sum_{j=N\alpha+1}^{N} L_{(j)}$

V. Quantifying Uncertainty in VaR and ES Estimates

A. Standard Errors for Monte Carlo Estimates of VaR

1. Method 1:
   a. Use order statistics from the simulation to interpolate Q_α for ${}_\alpha VaR$
2. Method 2:
   a. Repeat the simulations many times and take the mean L_α of the multiple simulations

B. Standard Errors for Monte Carlo Estimates of ES

C. Uncertainty for Analytic Risk Measures

VI. Other Measures of Risk

A. Other measures of risk include:

1. Portfolio variance or standard deviation
2. Semi-variance (variance of the downside scenarios) estimated by the sample semi-variance
   a. Semi-variance is $\sigma_{sv}^2 = \left[E\left(max\left(0, X-\mu_x\right)^2\right)\right]$
   b. Sample semi-variance is $s_{xv}^2 = \sum_{t=1}^{n} \frac{\left(max\left(x_i - \bar{x}, 0\right)^2\right)}{n-1}$
3. Threshold semi-variance
   a. $\sigma_{xv,\tau}^2 = E\left[(max(0, X-\tau))^2\right]$ for the threshold parameter τ
4. Downside semi-variance
   a. $\sigma_{xv,\tau}^2 = E\left[(min(0, Y-\tau))^2\right]$
5. Downside semi-standard deviation is $\sqrt{\sigma_{xv,\tau}^2}$

Quantitative Enterprise Risk Management
Chapter 10: Economic Scenario Generators

Reviewer's note: *This is a new resource for 2024. It is a good overview of the types of ESG models commonly used and the considerations in selecting them.*

I. Introduction

A. An ESG is a multivariate model of economic indicators used for risk measurement and management
1. In addition to the economic indicators, non-economic time series (e.g. Weather data) may be needed

II. Considerations for the ESG

A. What will the model be used for?
1. For pricing purposes, the performance of the ESG in the middle of the distribution is important
2. For risk analysis and measurement the performance in the tails is crucial

B. The time step
1. Models calibrated to small time steps so not work well for long term horizons
2. Monthly time steps may be more appropriate for long term analysis

C. Horizon
1. Longer horizon analysis needs more focus on the extremes of the distribution

D. Availability of Data to Calibrate the Model
1. If data available is limited, the results of the model must be viewed with caution
2. Ideally, the data series should be twice as long as the projection horizon
3. Long data series suffer from the possibility of obsolescence of older data

E. Dependency Modeling
1. Dependency can be modeled simultaneously with the individual series
2. Alternatively, copula methods can be used
3. In some cases, modeling dependency among separate data series may not improve the model fit

F. Tail Behavior and Fit
   a. Model fitting to the extreme outcomes can be critical for some model applications
2. Data scarcity is always an issue when trying to calibrate models for tail outcomes

G. Materiality
1. The complexity of the model in both the middle and extremes of the distribution should depend on the intended use of the model

H. In-House or Vendor?
1. Vendor purchased models may need some customization

I. Univariate or Multivariate?
1. Model purpose should guide the choice of whether univariate or multivariate modeling is appropriate

J. Deterministic or Stochastic
1. Models for economic variables are often Monte Carlo simulation based
2. Deterministic models (used for scenario and stress testing) may suffice for some applications

K. Real-world or Risk-neutral?
1. Risk-neutral or Q-measure models are appropriate for pricing and market-consistent valuation
2. Real-world or P-measure models are appropriate for risk measurement and management

III. Economic Scenario Generator Design

A. ESGs are multivariate models of economic series intended for use in stochastic simulation
1. ESG models have been developed for both P and Q measures

B. Two common approaches to developing ESGs are:
1. Cascade models (e.g. Wilkie model) develop dependencies that feed through one or two key series
   a. Wilkie model is a P-measure model useful for long horizon modeling
2. Vector Autoregression models
   a. Sherris and Zhang (2009) is an example of a complex model for 11 economic variables

IV. Model Fitting and Robustness (using standard time series methods)

A. Stationary and Structural Breaks
1. ESGs are usually required to be weakly stationary
   a. A univariate time series is weakly stationary if the mean and autocovariance do not vary over time
   b. A multivariate series is weakly stationary if the individual univariate series are weakly stationary and the cross-covariances do not vary
2. Structural breaks in the data can create problems in fitting models, especially for long term models

B. Parameter Uncertainty
1. Non-stationary data and structural shifts also increase the uncertainty of parameter estimation
2. Some parameters can be fitted to different time periods than others
   a. This can result in inconsistencies in the model

C. Forecasting with ESGs
1. Risk of treating the ESG as a "black box"
2. More variables in an ESG can make it suitable for more applications but may make it less accurate for forecasting some individual series
3. For some risk management analyses a multivariate ESG is necessary
4. The time steps used (including discrete vs continuous) should be appropriate for the intended use of the model

Quantitative Enterprise Risk Management
Chapter 14: Model Risk and Governance

Reviewer's note: *This is a new resource for 2024. It is an overview of best practices in the management and governance of quantitative models from development to implementation to use.*

I. Introduction

A. Federal Reserve defines model risk as the potential for adverse consequences from incorrect or misused model outputs and reports
   1. It is a form of operational risk for the enterprise
   2. Model may be flawed in its design or implementation
   3. Models may also be used inappropriately or for the wrong purpose

II. Model Risk

A. Defective Model Risk
   1. Model specification errors – Incorrect mathematical algorithms or the numerical methods used
   2. Model implementation errors – Errors in programming the model specifications
   3. A model that was performing well may be rendered inappropriate due to structural shifts in markets
   4. Spreadsheet errors are especially difficult to detect and correct
   5. Model parameters may be inappropriate due to insufficient data to calibrate it
      a. Can test a variety of parameters, and/or add a margin of safety to the parameters
   6. User errors, including input and keyboard errors
      a. Mitigate by appropriate checks and balances and reconciling results with previous results
   7. Data quality – cleaning and validation of data is a crucial mitigation
   8. Models used by different business units for the same purpose may be inconsistent with each other

B. Defective Model Application Risk (Right model for one purpose may be wrong for another)
   1. Users must fully understand the model and allow for the limitations/weaknesses of the model
   2. Relationships among model parameters can shift quickly – over reliance on model results is risky
   3. Failure to heed model results when they conflict with users biases
   4. Concentration risk occurs when the same model is used by different business units

III. Model Lifecycle

Figure 14.1 in the text illustrates the complete model management cycle

A. Initial Model Proposal
   1. Identify the purpose and risks to be modeled and select the features of the model that are critical
   2. Identify proposed model users and assure that the models are consistent across all business units
   3. Identify and recruit the required expertise to develop and operate the model

B. Model development
   1. Time step and horizon must be appropriate for the range of uses for the model
   2. Data used should be credible and relevant
   3. Model should be validated and tested for goodness of fit
   4. Monte Carlo simulation models results should include uncertainty metrics such as standard errors
   5. Benchmark model specifications and documentation with industry best practices
   6. Model should comply with sensible constraints
   7. Weaknesses and limitations of the model should be documented
   8. End-users of the model should understand its documentation and appropriate uses
   9. Model reports should be available in a timely fashion and integrated in the risk management decision-making

C. Model Validation
   1. Independent validation of the model is essential, including the following:
      a. Evaluating the model risk
      b. Validation of model inputs and results
      c. Documentation of model limitations to avoid misuse of the model
D. Model Approval should include an independent review of the documentation
E. Model Monitoring includes:
   1. Verifying it is still appropriate in light of changes in markets and business environment
   2. Is data used of sufficient quality?
   3. Review of updated model parameters to incorporate new data
   4. Do users understand model limitations? Is it being used for appropriate purposes?
   5. Are model results consistent with industry benchmarks?
F. Model Modification and Change Management
   1. Minor model modifications can be subject to a limited review and validation
   2. Major modifications should be subjected to the same review process as new models
   3. Decommissioned models may still be useful for some limited uses

IV. Model and Parameter Risk

A. General
   1. Risk can be mitigated by testing a range of plausible models and parameters
   2. Statistical techniques can be used to test the resulting fit to data
   3. Statistical measures such as standard error just measure sampling variability but not the appropriateness of the model for the intended use
   4. The variability of model results for changes in models or parameters indicates the level of model risk
B. Parameter Uncertainty
   1. The h-year log-return in any year is independent of the preceding or subsequent values
C. Model Uncertainty
   1. It is scalable, i.e. weekly log-returns are just the sum of the daily log-returns
D. Proxy Models
   1. As with GBM, it does not produce a good fit beyond very short term periods

V. Model Governance

A. Model governance is the process for assuring that models are developed, maintained and used consistently across the firm and consistent with its risk appetite
B. Model Inventory (a catalogue of the models in use)
   1. It should include complete documentation of each model
C. Model Materiality
   1. A model is material to the firm if:
      a. Model is involved in financially significant decisions
      b. Decisions depend on the results of the model
      c. There is significant uncertainty in the output
D. Model Ownership (the person or team responsible for model management)
   1. Access to the model for making changes should be restricted to authorized persons
   2. Users are often well suited for such a role
   3. For firm-wide models, the role can be assigned to a specialized unit

E. Internal Audit
   1. Internal Audit verify the following:
      a. Is the model risk management framework effective and consistent with the risk appetite?
      b. Are all participants compliant with the model risk management framework?
      c. Is the model inventory and documentation complete and accurate?

VI. Risk Treatment for Model Risk (Ways to mitigate)

A. Misspecification and/or coding errors avoidance depends on having strong governance processes
B. Misuse of model results can be mitigated by:
   1. Engaging users in the design of the model and subsequently training them on appropriate uses
   2. Clear communication of model results
   3. Feedback loops to identify problems
   4. Restricting use of the models for purposes other than intended
C. Idiosyncratic model errors can only be avoided by sound design practices
D. Multiple inconsistent models in use can be prevented by strong governance practices
E. Avoiding fat finger errors requires checks and constraints to be built into the interface
F. Spreadsheet errors require restricting access to formulas
G. Model and parameter uncertainty can be managed through a combination or using and recording standard errors of estimates, stress test results and use of Bayesian methods, and by incorporating some conservatism in the choice of assumptions

Identifying and Evaluating Emerging Risks

Reviewer's note: *This is a new resource for 2025. It outlines an approach to understanding and managing emerging risks.*

I. The Value of Understanding Emerging Risks

A. Emerging risks are new, not well understood, have unknown significance and impact
1. The potential probability of occurrence and the consequences are not known

B. Three major types of emerging risks are:
1. Highly uncertain risks, often arising from social or technological changes
2. Risks with a growing complexity due to a change in variability or a change in the interaction with other risks
3. Environmental or contextual changes that alter the frequency and severity of previously known risks

C. Benefits of evaluating emerging risks include:
1. Gaining competitive advantage or first-mover advantage
2. Future-proofing long term strategies and improving chances of success
3. Minimizing unwanted surprises and exploiting emerging opportunities
4. Opportunity for risk management to add value to the organization

II. Research and Discovery

A. Sources useful for identifying emerging risks include:
1. News articles, professional publications and subject matter expert opinions
2. Social and cultural changes
3. Changes in macroeconomic metrics such as the unemployment rate, etc.
4. Environmental changes such climate change
5. Emerging technologies
6. Regulatory changes

III. Evaluating the Impact of Identified Emerging Risks

A. Scenario analysis
1. Can be used to test impact, raise questions and challenge conventional thinking
2. Also, useful for testing mitigation steps and evaluate growth opportunities in the emerging environment

B. Cause-and-effect Diagrams
1. A logical and structured approach to analyzing an emerging risk
2. Table 2 in the text illustrates the approach (not reproduced here)

C. Delphi Technique
1. It is a useful technique for evolving a consensus among subject matter experts about the nature of and the plausibility of emerging risks
2. The 4-step process is described in summary in the text

D. Prioritization of the risks
1. Emerging risks can be prioritized based on 3 factors:
   a. Impact or severity
   b. Likelihood
   c. Velocity – how fast it is emerging
2. It is important to consider the interaction of emerging risks with the known risks
3. Expert opinion can also be used brainstorm appropriate mitigation or exploitation opportunities

IV. Monitoring the Risk

A. Can develop key risk indicators to monitor the risks that are identified and prioritized

B. KRI's are also useful for monitoring the emergence of the risk and prioritizing the ones with the highest velocity

V. Developing a Response Plan

A. A pre-emptive response can reduce the organization vulnerability

B. Response plan can include:

1. Changes to strategic plans or risk appetite
2. Acquisition or allocation of capital at specific entities
3. Assigning roles and responsibilities to appropriate individuals
4. Forming partnerships
5. Risk transfer and control tools

VI. Integrating Emerging Risks into the Risk Portfolio

A. Should define early-warning indicators that signal the imminence of the risk as well as thresholds that should trigger mitigation

B. Risk owners can develop these indicators and monitor them

VII. Overcoming Challenges

A. Risk management should prepare leadership for the possible mitigation steps that may be needed

1. Use examples of the impact of the risks on other organizations
2. Know when the risk intervention needs to be elevated to a higher management level
3. Ensure that appropriate interdisciplinary coordination can be brought to bear

Shaw, Smith, Spivak – Measurement and Modeling of Dependencies in Economic Capital
Chapters 3, 4, 5 and 7

Reviewer's note: *This paper, presented to the Institute of Actuaries in 2010 is wide-ranging in scope.*

I. WHY DIVERSIFICATION IS IMPORTANT

A. Economic Capital (EC)

1. It is the amount of capital needed to cover losses at a tolerance level and is dependent on the risk measure utilized, the probability threshold and the time horizon
   a. E.g. 99.5% VAR over one year
   b. Reflecting diversification effects should result in lower combined EC than the sum of the EC for each risk
   c. In some cases, one risk may have a contagion effect on other risks
   d. The diversification benefit can vary from company to company

B. Regulatory Developments

1. Basel II
   a. Created an international standard for the regulation of banks
   b. Uses 3 pillars: Minimum capital amounts, supervisory review and market discipline
   c. Covers credit risk, operational risk and market risk
2. Solvency II – a risk-based approach for determining Solvency Capital Requirement (SCR)
   a. First pillar: EC for quantifiable risks using internal models or the European Standard Formula
   b. Second pillar: Qualitative assessment of operations including risk management
   c. Third pillar: Supervisory reporting and disclosure
3. Solvency II internal model approval (IMAP) requirements
   a. Use Test: Does senior management understand the model and its limitations, perform timely computations and use the output to make decisions?
   b. Board members may also be required to have some understanding of the model methodology
   c. Statistical Quality Standards – Diversification effects must be supported by empirical analysis, expert judgement of causal relationships, or both, and should hold in extreme scenarios as well
   d. Justification for the diversification parameters is essential
   e. If external ESG's are used, their dependency modeling and calibration must be understood
4. Hedges can be used for diversifying or hedging risks
   a. Diversifiers avoid high dependence between risks
   b. Hedgers use high correlation/dependence to offset risks

II. CORRELATION AS THE SIMPLEST TYPE OF DEPENDENCE

A. Dependency Structures

1. Economic drivers are the risks – interest rates, mortality, etc.
2. Monetary effects are the functions of these drivers
   a. So we have a multivariate joint probability distribution and must calculate marginal distributions for each risk before we can even consider how to link them in a dependency structure
      i. Which is information in the joint distribution, not in the marginal distribution
3. Very difficult to assess dependency accurately – and errors in doing so can offset the most accurate individual capital components
4. Dependencies and Causation
   a. Dependencies – information about one risk can provide information about another

i. Example: catastrophe damages a property and that causes the stock price of the company that owns that property to fall
ii. More often, dependence reflects complex impact of macroeconomic conditions on many risks
- Inflation, interest rates, equity prices and foreign exchange rates are interrelated and affect values on both sides of the BS

iii. When the dependencies in risk factors are assessed using expert judgment, causal impacts can be taken into account
iv. Statistical approaches, on the other hand, describe correlation or dependency without determining causation

5. Dependency as a Mathematical Representation – most often described as a single number – the Pearson correlation coefficient, which is linear
   a. If one variable depends on another in a non-linear way, correlation does not adequately capture the relationship
   b. Dependency structure includes linear and non-linear dependence – so don't use "correlation" and "dependency" interchangeably

B. What Do We Mean by Dependency?

1. Dependency means there is a link between two random variables
   a. Perfect dependence means if you know one value, you know the other
   b. On the other extreme is the case where the value of one RV tells you nothing of the other
   c. Dependency does not imply a linear relationship – although it is convenient to assume so
      i. Modern Portfolio Theory uses variance-covariance matrices, based on a normal distribution
         - These assumptions have been tested by recent economic events and found to be lacking
            ◊ Correlation is linear and does not reveal the whole dependency structure
            ◊ Possible values of correlation depend on the marginal distribution of risks
            ◊ Perfectly positively/negatively dependent risks do not necessarily have a correlation of 1/-1
            ◊ Zero correlation does not imply independence
            ◊ Monotonic transformation – like the log function, change the correlation
            ◊ Correlation is only defined when variances of the risks are finite (note that heavy-tailed risks seem to have infinite variances)

C. Detailed explanations of the Pearson, Spearman and Kendall Tau correlation statistics – See pages 17 through 20 of the paper

III. RISK AGGREGATION

A. Risk Aggregation Framework

1. Dependency modeling helps us find the overall EC level
2. Assess individual risk components and then figure out how to best aggregate them
3. Multivariate distribution is useful and brings copulas into play to combine marginal distributions of single risks into a multivariate distribution

B. Risk Aggregation Methodologies – broadly

1. Simple summation – no diversification benefits, equivalent to perfect correlation
2. Fixed diversification % - Overall EC is reduced by a fixed %
3. Variance-covariance Matrix – Stand-alone capital for each risk is aggregated using a correlation matrix
4. Copulas – Monte Carlo simulation with full marginal risk distributions are joined together by a copula function to produce an aggregate distribution

5. Causal Modeling – may be used in conjunction with other methods
   a. Common risk drivers which impact risks, often non-linearly
      i. Used to capture dependencies within economic scenario generators
   b. Causal Loops
      i. A diagram that is used to understand how interrelated variables impact each other
         - Positive feedback means the two change in the same direction, negative means they change in opposite directions
         - Can be open (outputs respond to, but do not influence their inputs) or closed (outputs both respond to and influence their inputs)
         - Complexity of these diagrams means some Monte Carlo simulation is necessary

C. Best Approach – balances the following criteria:

1. Model accuracy
2. Consistent methodology
3. Numerical accuracy
4. Data availability
5. Communication ease and intuitiveness
6. Flexibility
7. Resources needed

D. Solvency II (and IMAP)– increases the importance of some criteria – like intuitiveness and communication ease of the risk aggregation framework

E. Natural Catastrophe vs. Reinsurance Credit Risk Aggregation

1. Companies use different methods or combinations
2. Example: catastrophe underwriting risk vs. reinsurance credit risk
   a. Cat UW and RI Credit risks used as separate entries in a variance-covariance matrix
      i. The correlation coefficient in the correlation matrix would reflect the dependencies between the two
   b. Could try to capture the reinsurance credit risk associated with the Cat UW risk in the Cat UW marginal distribution by adjusting the reinsurance recoveries with an appropriate dependency function
      i. May still leave some default risk unaccounted for
   c. Or perhaps more complex causal modeling

IV. VARIANCE-COVARIANCE MATRIX METHODS

A. Introduction

1. Uses pair-wise correlation matrices between risks
   a. Pair-wise Capital $=\left(\sum\sum\rho_{ij}C_iC_j\right)^{0.5}$ for i,j =1 to n, ρ_{ij} is the correlation between risks i and j *and* C_i *is the stand-alone capital for risk i*
   b. If all risks are independent (all correlations are zero),Total Capital = $(\sum C_i)^{0.5}$ i =1 to n
   c. If all correlations are 1, Total Capital = $\sum C_i$
2. Risk dimensions – risks can be combined by type of risk or organization or geographical region

B. Advantages/Disadvantages of the Variance/Covariance Matrix Approach

1. Advantages
   a. Simple, intuitive and transparent

b. Some correlations can be typical and common among companies
c. Pairwise approach facilitates the addition of new businesses, subsidiaries or risk categories
d. Easier to communicate to non-technical stakeholders

2. Disadvantages
a. Method assumes the risks are normally or elliptically distributed, which may not be the case
b. May underestimate effects of skewed distributions and does not allow for heavier correlation in the tails
c. It does not capture non-linearity and all cause/effect structures may not be properly modeled
d. Correlation matrix has to satisfy certain conditions that are often ignored
e. Correlations are very sensitive to the underlying marginal distributions
f. Reliable, viable data to base correlations is only available for a few risks, so use of expert opinion introduces subjectivity

C. Risk Granularity

1. The finer the risk classification, => lower the intra-risk diversification and => greater inter-risk diversification
2. SCR standard formula uses a set of "nested" variance-covariance matrices illustrated in Tables 3 & 4 in the text
3. Companies often use the variance-covariance approach to aggregate the results of stress tests

D. Simpler Variants

1. Simple Simulation
a. Advantages
i. Conservative
ii. Computationally simple and easy to communicate
iii. No data on correlations required
b. Disadvantages
i. Ignores interactions between risks
ii. Over-stated capital = > higher cost of capital
2. Fixed Diversification %
a. Advantages
i. Data and computational simplicity
ii. Some recognition of diversification effects
iii. Easy to communicate

b. Disadvantages
i. Ignores interactions between risks
ii. Not sensitive to changes in underlying exposures
iii. Does not capture non-linearity
3. Parameterization
a. Three approaches
i. Empirical estimation based on historical data
ii. Use expert opinion or industry benchmarks
iii. Use ranking approach (Low/Medium/High)
b. Using Historical Data – Considerations include:
i. Choice of data series or index
ii. Data frequency and time span
iii. Data weightings (more weight for recent data?)
iv. Treatment of data outliers and data gaps

v. Prospective expectations of data correlations and trends
vi. Data quality – Completeness, accuracy and consistency

c. Using Expert Judgement or Industry Benchmarks
   i. May be necessary if internal data is not available
   ii. Should be based on consensus of various disciplines
   iii. It is subjective but an essential oversight, especially for prospective expectations
   iv. Reliance on expert judgement will vary considerably by type of risk
d. Using Risk Rankings – (Zero/Low/Medium/High)
   i. Rankings may be based on prior studies or experience
   ii. Generally, not the preferred approach
e. Pages 44 – 48 in the text show examples of estimation that are worth studying
f. Variance-Covariance Matrix Cross-terms
   i. A common approach used is a large correlation matrix reflecting geography and risk
   ii. Especially useful if a Gaussian or t copula is used to model dependencies
   iii. The text on pages 49 – 51 show an example of this that is worth studying
g. Positive Semi-Definite Matrices
   i. The positive semi-definite property of a correlation matrix implies that the variances of the weighted sum of the correlation matrix's elements are nonnegative. This property is crucial for ensuring that the correlation matrix does not yield negative variances, which would lead to incorrect variance calculations. The positive semi-definite property is a necessary condition for the correlation matrix to be positive semi-definite, which is essential for the validity of the correlation analysis.
   ii. This property is crucial because it ensures that the correlation matrix does not yield negative variances, which would lead to the calculation of negative correlation values.
   iii. Failing this requirement could result in the total EC being greater than the undiversified EC
   iv. The Gaussian or t copula approach will not work if the matrix fails the PSD requirement
h. Elliptical Distributions
   i. These are symmetric distributions in one dimension where all linear combinations of coefficients produce distributions with the same shape
   ii. With elliptical distributions, risks can be aggregated in a closed form
   iii. The correlation matrix for an elliptical distribution is: $R_{ij} = \frac{V_{ij}}{\sqrt{V_{ii}}\sqrt{V_{jj}}}$ where V is the scale matrix for the elliptical distribution
   iv. The correlation formula for the capital aggregation is:

$$ECAP = \sqrt{\sum_{i=1}^{p}\sum_{j=1}^{p} R_{ij} C_i C_j}$$

How CEO's Can Mitigate Compounding Risks

Reviewer's note: *This is a new resource for 2025. It proposes an approach to the management of risks that can have a compounding impact on the company.*

I. Introduction

A. Corporations face a multitude of risks that can interact in ways that are difficult to predict and manage
1. The cumulative effect of these risks can be an existential threat to the company
2. A failure of management to address and mitigate such risks is usually insufficient foresight rather than willful ignorance or negligence

II. Three types of compounding risks

A. Compounding risks have two common features
1. Their characteristics are distinct from the underlying risks
2. They have different likelihood and severity impact than the underlying risks

B. The 3 categories of compounding risks are:
1. Connected risks are seemingly unrelated risks that are in fact linked and can impact different parts of the business simultaneously
2. Cumulative risks are risks that build over time to trigger a major shock
   a. The trigger point may be just another small event in a series of events
   b. Often the second and third order effects of the events is ignored before the trigger point
3. Novel risks are multiple known risks combining to create an unexpected new risk with distinct characteristics
   a. Often long term in nature
   b. E.g. Climate change, geopolitical tensions, technological disruption, etc.

III. How to address compounding risks

A. Four steps the CEO can take to manage compounding risks
1. Strengthen risk management governance
   a. Broaden the risk scenarios to include compounding risks
   b. Establish accountability among senior executives for management of such risks
   c. Establish early warning signals to monitor development of these (long-term) risks
2. Run "premortems" (scenarios) on managing risks
   a. Develop scenarios to cover the full range of compounding risks
   b. Evaluate impacts over multiple time horizons
3. Use a horizon planning approach
   a. Compounding risks often build slowly and reach a trigger point in a long term horizon
   b. Three broad horizons can be:
      i. Managing and protecting the core business
      ii. Nurturing emerging businesses
      iii. Creating entirely new businesses
4. Make big strategic bets that address long term risks
   a. These could fundamentally change the company trajectory
   b. Such strategic bets should address the multiple threats that could occur in confluence
5. Avoids the incentive for managers to manipulate accounting earnings

Western Australian Public Sector Financial Statements –
Tool 1 Example: Risk Analysis for Financial Statements

Reviewer's note: *This is a new resource for 2025.*

I. Purpose

A. To establish the analysis needed for each financial statement line
1. To assist in the prioritization of resources
2. To assure sufficient controls are in place to mitigate risk of material misstatement

B. Should adopt best practices for appropriate risk assessment including:
1. A regular cycle of reviewing line item risks
2. Standard format and analysis of each line item
3. Reporting to appropriate governance committees

II. Risk Assessment Steps

A. Step 1: Specify high-level objectives and sub-objectives such as:
1. (High-level) "Prepare reliable financial statements in accordance with accounting regulation"
2. (Sub-objective) "Property, plant & equipment recorded with valuation financial statement assertions"

B. Step 2: Conduct financial reporting risk assessment
1. Decide which financial reporting risk factors are most appropriate for the entity and the weighting for each factor
2. Include both quantitative and qualitative factors
3. Apply risk ratings to each factor consistent with the risk management framework
4. The table on pages 2,3 and 4 of the paper contains examples of the type of risk factors, ratings and the appropriate analysis for each. It is already in summary form and not reproduce here, but merits a careful review.

C. Step 3: Conduct a residual risk assessment (including preventive and detective controls)
1. Preventive controls: Pre month-end assurance framework designed to prevent, identify an correct errors before the general ledger closes
   a. Best practices include controls for system access, security, procurement, payment of invoices, receipting and a segregation of duties
   b. Framework should include executive endorsement of journals above a certain size and CFO endorsement of the largest journals and those affecting equity
   c. Pre month-end assurance process should include:
      i. A reasonableness review of financial statements
      ii. Substantive testing of large or unusual items
      iii. Testing where the change from previous values exceeds certain $ or % thresholds
      iv. Reasonableness relative to other items and external benchmarks
      v. Correction of material errors prior to closing the general ledger
2. Detective controls: Post month-end assurance framework (including account reconciliations and analytics)
   a. Finance team should review and reconcile all accounts and:
      i. Adopt a cycle for reconciliation, analysis and testing accounts based on risk level
      ii. Conduct a risk assessment of all accounts to assign a risk rating
      iii. Use a standard format for analysis of each account
      iv. Prioritize reconciliations based on risk level and variance thresholds
      v. Assign separate preparer and reviewer for each account

vi. Review the risk assessment and controls where the nature, materiality or risk profile has changed
vii. Identify opportunities for redesigning and streamlining compliance without impacting effectiveness of controls

b. Based on the above, assign an overall residual risk rating for each financial statement item
i. The table on page 6 of the paper has an example of such an assessment and is worth studying

D. Step 4: Summarize risk ratings and key actions taken or required

1. Determine required treatments with regard to the risk appetite
2. Review and update the assessments as the business or the nature of risk changes
3. Present the assessments in a summary table form to the audit committee and other governance bodies
4. Use a standardized risk and control matrix to present the results

Milliman – Economic Capital Modeling: Practical Considerations

Reviewer's note*: Very practical guide, although it is difficult to teach this material, which is better learned through hands-on experience. Pay particular attention to the examples at the end of the paper. The appendix contains a detailed recitation of risks.*

I. Introduction

A. Interpretation of economic capital varies – used to value a business or manage risk in a business
   1. Measure/optimize capital resources already existent in a business
   2. Determine capital required by a business to meet risks inherent in its liabilities and operations
      a. Required EC – what you need; available EC – what you have

B. EC analysis being used more to facilitate strategic management decisions
   1. Basel II requirements in banking, Solvency II in insurance, IAIS
   2. Used to calculate cost of capital for embedded capital calcs

C. Methods of EC calculation still differ among companies – decisions to be made
   1. What type and scope of risks to consider?
   2. How to measure risks and what is the right probability of ruin to accept?
   3. What decisions should be involved in developing an EC model?

II. What is EC?

A. Required EC – capital required (by economics not regulation) to support a business assuming a certain probability of default

B. Available EC – Assets less liabilities on a realistic (mark-to-market) basis
   1. Closely related to European Embedded Value (see below)

C. Can relate EC to statutory capital and market value
   1. Market capitalization =statutory assets less statutory liabilities plus value of in force plus value of goodwill
   2. Market cap also = market value of assets less (MV of liabilities plus allowance for cost of capital) plus economic franchise value
      a. MV less value in parenthesis is available EC

D. Questions to consider
   1. Scope of risks should include all material risks
   2. Probability of ruin could be tied to a certain credit rating
   3. Proper time period for assessing probability of ruin – 1 year or many years?
   4. Current in force or future business (going concern approach?

E. It is now accepted that financial strength is related not only to the value of capital but to the basis on which those values are calculated

F. IASB is moving toward fair value – market consistent values
   1. Easier to calculate for assets than liabilities

G. Makes sense to use an economic (fair value) model vs. a statutory model, but this is not universally done

III. What are the benefits of EC analysis?

A. Because capital is necessary to insulate companies against performance fluctuations and take on risk, calculating the proper figure balances the need to have enough capital to avoid insolvency but not too much capital, upon which investors require a risk return, which would drive COIs up too high

B. Ratings agencies often approach capital requirements by setting formulas based on net amount at risk, asset types, etc.
   1. Arguably, this may not appropriately reflect a company's processes and procedures for managing risk or managements strategic decisions on capital deployment

C. Shareholders and other users of financial statements need to understand a company's capital position and measure effective returns on capital

D. Regulators need to understand on a realistic basis, the level of capitalization as one of their goals is to prevent insolvencies

IV. How can EC analysis be applied?

A. International Regulatory Trends
   1. Regulators have recognized weaknesses in formulaic approaches to assessing solvency levels; to wit:
      a. No link between capital required and a the effectiveness of a company's risk management/mitigation strategies
      b. Formulas do not deal with all risks
      c. Mistaking prudent management with capital requirements obscures the actual level of solvency
      d. Formulaic approaches do not handle well changes in the environment – new product introductions, for example
      e. Benefits of diversification are not recognized
   2. The European Commission began Solvency II in 2000, hoping to correct the above
      a. So far, a draft Framework Directive has been published and is being evaluated
         i. Two levels of solvency capital defined
            - Solvency Capital Requirement (SCR) – level so that there is a 0.5% probability that assets will not be sufficient
            - Minimum Capital Requirement (MCR) – absolute minimum level of capital, below which urgent regulatory action is required
         ii. SCR could be calculated with internal models that have been validated and approved by regulator
            - Internal models will encourage insurers to measure/manage risks, be more flexible and better represent the insurer's business than rules-based standards
         iii. SCR is closely related to economic capital so Solvency II is a convergence between economic and regulatory management of insurance companies
   3. US regulators use risk-based capital (RBC), a formulaic measure, and use of internal models is progressing slowly
      a. NAIC adopted an RBC provision for VAs with MGDB, MGWD, MGAB, etc. that included internally-developed stochastic models but also a deterministic projection set by regulators
      b. Internal models for UL are being considered under principles-based valuation but regulatory capital requirements are still formulaic
   4. Canada allows internal models under a principles based approach
   5. Switzerland's Swiss Solvency Test is based on stochastic models based on principles defined by regulators

6. IAIS – international body of insurance supervisors – has developed a solvency regulatory framework
   a. Will be consistent with international financial reporting standards of IAA and IASB

B. European Embedded Value – almost all leading European life insurers have disclosed embedded value information, the weaknesses of which were uncovered by extreme market conditions of recent years
   1. CFO Forum launched European Embedded Value (EEV) principles in 2004
      a. Extends traditional embedded value techniques to include explicit valuation of options and guarantees as well as standardizing reporting standards
         i. Historical practices left wide divergence in these approaches
   2. Some companies use economic capital as the basis for the cost of capital
      a. Since economic capital considers all risks, they claim this process makes allowance for all risks even if there is no explicit margin added for non-financial risks

C. Risk-Adjusted Return on Equity or Capital (RAROE/RAROC)
   1. Different products have different risks and hence, different levels of economic capital
   2. Makes sense to measure ROE in a way that recognizes economic capital

V. What Type of Risks Should Be Considered?

A. We are dealing mainly with downside risk, not the traditional standard deviation of returns under CAPM

B. Important to consider all risks in determining economic capital – see IAA 2004 paper – A Global Framework For Insurer Solvency
   1. IAA Risk Categories
      a. Underwriting – pricing, product design, claims, policyholder behavior
      b. Credit – default, downgrade, concentration, counterparty
      c. Market – interest rate, equity & property, currency, reinvestment, concentration, ALM, off-balance sheet
      d. Operational – operational failure, strategic, catastrophes
      e. Liquidity – insufficient liquid funds to meet cash flow requirements

C. Three Key Components for Modeling – each risk type can be further broken
   1. Volatility Risk – random fluctuations in frequency/severity of contingent events
      a. Investors can diversify this away if markets are efficient but insurance markets aren't (Reviewer's note: really?)
         i. Companies may wish to recognize their exposure to volatility regardless of whether it's diversifiable – issue becomes whether investors will accept this approach
   2. Uncertainty Risk – use of the wrong model or bad assumptions – not diversifiable
   3. Extreme Events – calamity – tail risk

VI. How Should Each of Those Risks Be Measured?

A. Total risk is calculated by measuring the effect of each specific risk to a company's earnings/surplus, generally as a function of the probability distribution of losses and then aggregating individual risks as shown in VII
   1. Scenario-based model – deterministic or stochastic
      a. Risk capital is calculated by measuring the impact of specific scenarios to the distribution of loss
         i. Not stress test as scenarios cover multiple risk drivers, not a single shock

2. Static factor model – linear combination of a static risk factor times a company-specific amount
   a. RBC in the US is an example (except for C3, phase I and II)
3. Stochastic factor model
   a. Identify relevant risk drivers
   b. Find Delta (proxy for 1st derivative), Gamma (2nd derivative) or a scenario vector by doing sensitivity analysis
   c. Model joint distribution of risk drivers
   d. Resulting loss is aggregated across all risk types, leading to its stochastic distribution
      i. Find risk capital by applying a risk measure such as VaR or CTE
   e. Covariance model is a special case of stochastic factor model

B. CRO Forum study in 2004 found 8 of 13 companies surveyed used stochastic factor models while 5 used covariance models

C. Measuring risk – a brief exposition
1. Underwriting risk – mortality, morbidity and lapse
   a. Split into diversifiable (which decreases with increasing policy count) and non-diversifiable (mortality level risk and mortality trend risk) components
      i. Use binomial model to estimate volatility risk
      ii. Use methods based on company or industry experience to estimate mortality level risk
         • Don't forget catastrophe risk
   b. Surrender and lapse risk can be handled as mortality risk
   c. Risks associated with policyholder's options are dependent on economic conditions and can be measured with stochastic analysis or stress test
      i. Build model where the interaction is defined
2. Credit Risk – modeled consistent with banking standards – default, credit migration, spread and spread volatility
   a. Tools available include CreditRisk+ (Credit Suisse), CreditMetrics and KMV
      i. Explicitly model default and recovery
      ii. KMV is widely used
   b. Don't forget reinsurance default risk
3. Market Risk – can be modeled consistently with banking standards, but need to include liabilities of the insurer as well– an ALM approach
   a. Price volatility of assets also impacts liabilities
   b. Liabilities do not have a real market so MV of liabilities need to be technically derived
4. Operational Risk – not well developed methods for this risk, but include
   a. Add-on model
   b. Stochastic frequency-severity model

VII. What Modeling Decisions Should Inform the Analysis? Issues

A. VaR vs. Tail-VaR – the two most suitable risk measures
1. VaR assess probability of ruin at a given quantile of the probability distribution
2. Tail VaR measures both the probability and severity of losses exceeding a given quantile and is the arithmetic average of losses exceeding the quantile
   a. VaR is adequate for shareholders as once the company is bankrupted, their investment is worthless
      i. Tail VaR better for regulators because it provides info on losses to policyholder

b. Tail VaR is better for low frequency, high severity events
   i. IAA likes it better than VaR
   ii. Conditional tail expectation (CTE) is similar to Tail VaR
      - Set at the x% level, the average cost of the worst (100-x%) scenarios

B. Stochastic Analysis vs. Stress Test

1. Stochastic analysis is projecting future cash flows based on multiple scenarios for which a probability distribution is defined – it is necessary to calculate EC
2. Stress test is projecting future cash flows based on a particular scenario that could occur in an extreme environment for which the probability of the scenario is not specified
3. It follows that a stress test is indicated if no meaningful probability distribution can be determined
   a. But if the task is to calculate EC to cover losses with a certain %-tile confidence, an assumption must be made as to the probability of occurrence
      i. Just realize it is a judgment call

C. Real World (preferred) vs. Risk Neutral

1. Risk neutral technique calculates the PV of cash flows by discounting risk-adjusted future CF with risk-free rates based on multiple scenarios
   a. No arbitrage assumed and no arb opportunity assumed to exist
   b. Assumes any derivative security can be perfectly reproduced by combining other securities
   c. Theory says that the expected value of the PV of future CF based on risk-free rates and a transformed probability distribution (q-measure) = expected value of the PV of future CF based on adequate discount rates and real-world probability distribution (p-measure)
      i. Risk-adjusted cash flow then becomes the cash flow multiplied by the ratio of occurrence probability under q-measure to that under p-measure
         - It is easier to find discount rates under q-measure so that is why this is done
2. Real world technique is to calculate the PV of CF by discounting projected CF with risk discount rates based on multiple scenarios
   a. CF are not adjusted for uncertainty risk, instead the discount rate is increased above the RFR
      i. Judgment is in setting that rate
      ii. If done adequately real world and risk neutral results are the same
3. Risk neutral approach is superior because adjustments for uncertainty can be made consistent with observable market prices of securities
   a. However there are major shortcomings to the risk-neutral approach - when calculating EC:
      i. Need to define EC as the expected value of CF – if EC is defined as a certain loss at 95% confidence, then the probability distribution should be converted to have the expected value at the 95^{th} %-tile
         - Hard to figure how to use market prices to construct a risk-neutral probability distribution
      ii. Since loss is an expected value under an adequate risk-neutral probability distribution instead of the 95^{th} %-tile under a real world probability distribution, it is hard to interpret the results
   b. For those reasons, the real world technique is widely used

D. Diversification Effect

1. It is accepted that the total capital required could be less than the sum of the required capital for individual risks to the extent that these risks are independent
   a. Keep in mind that risk correlations may behave differently in extreme scenarios

i. For example, mortality rates and interest rates are thought to be uncorrelated, but in the time of a terror attack or earthquake, they may be correlated
- Can use copulas – a multivariate probability distribution function with uniform marginal distributions – to introduce dependency among risks
  ◊ Difficult to apply in practice

2. Ratings agencies have been skeptical about giving full credit for diversification and the issue of tail dependencies seems to support this stance
3. If different lines of business have non-correlated risks, then insurance groups with diverse businesses will benefit from diversification
   a. European companies have argued this point, but investors may wish to diversify their own portfolios
   b. But for capital management purposes, diversification seems reasonable
      i. Unless each entity is viewed as standalone by regulators or if there are cash flow restrictions should problems occur
      ii. CFO Forum suggested a solo entry test and a group test to sort this out

E. Time Horizon to Consider
1. Insurers tend to use either a one year(covariance model) or multiyear (balance sheet run off) horizon
   a. One year horizon tests for shocks but does not look beyond that time or measure tail loss
      i. Not adequate for VaR or CTE
      ii. But less complex and time-consuming
   b. Multiyear horizon (stochastic scenarios) can look for adequate capital throughout the period or just at the end (see f. below)
      i. Gives better sense of long term risks but does not allow for managerial action to correct issues that emerge
   c. Regulators should not take more than a year to respond to the analysis so perhaps one year horizon is preferable (10 of 13 in the CRO Forum)

F. Whether to Allow Negative Cumulative Surplus in the Middle of the Time Horizon
1. If so, recognize that REC may be understated
2. If not, is borrowing allowed and at what rate?
3. US specifies CTE(90) with no negative cumulative surplus in the middle, while Canada requires CTE(95) measured only at the end
   a. Since CTE is defined differently, no telling which is more conservative

G. Whether to Account for Future New Business
1. Yes, according to the CRO Forum - new business must not jeopardize the sufficiency of current assets
   a. Profitable business lowers the PV of liabilities, but increases required economic capital
      i. All 13 CRO benchmark companies include new business, but 11 include at most one year and none more than 4 years

VIII. Illustrative Examples

A. Deterministic Stress Test
1. What if an instantaneous shock hit – where management did not have time to respond?
2. This is very similar to tests run in UK and Switzerland
3. Business is VAs with financial guarantees and the shock is a 20% decline in equities, 5% nominal increase in volatility and a 1% decrease in short term interest rates

a. Company is bankrupted
b. Also test the impact of a hedge program, which protects the company at a small cost relative to holding enough capital to stave off bankruptcy

B. P&L Projection
1. Business is a VA with GMAB, 25 year horizon, supported by a 40/60 mix of stocks/bonds
2. Using stochastic projections and the Greeks – delta, rho, vega, quarterly P&L volatility is measured on a hedged and unhedged basis
3. CTE and VaR are calculated
4. Hedging seems effective
5. CTE requires more EC at a given confidence interval than VaR

C. Holistic VaR Aggregation
1. The two preceding examples dealt with market risk, but we can assess all risks using the same framework – market, credit, liquidity, insurance, operational and group
   a. Underwriting can be further split into mortality/longevity/morbidity, lapse, policyholder behavior and expense
2. Correlation of risks (more properly, lack of perfect correlation) is recognized and reduces required capital

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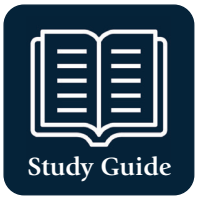

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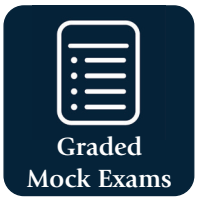

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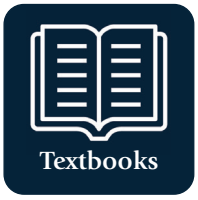

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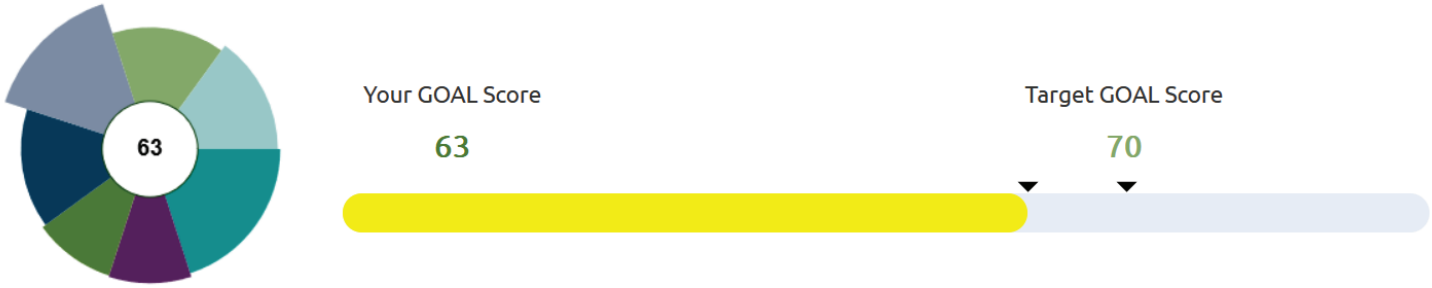

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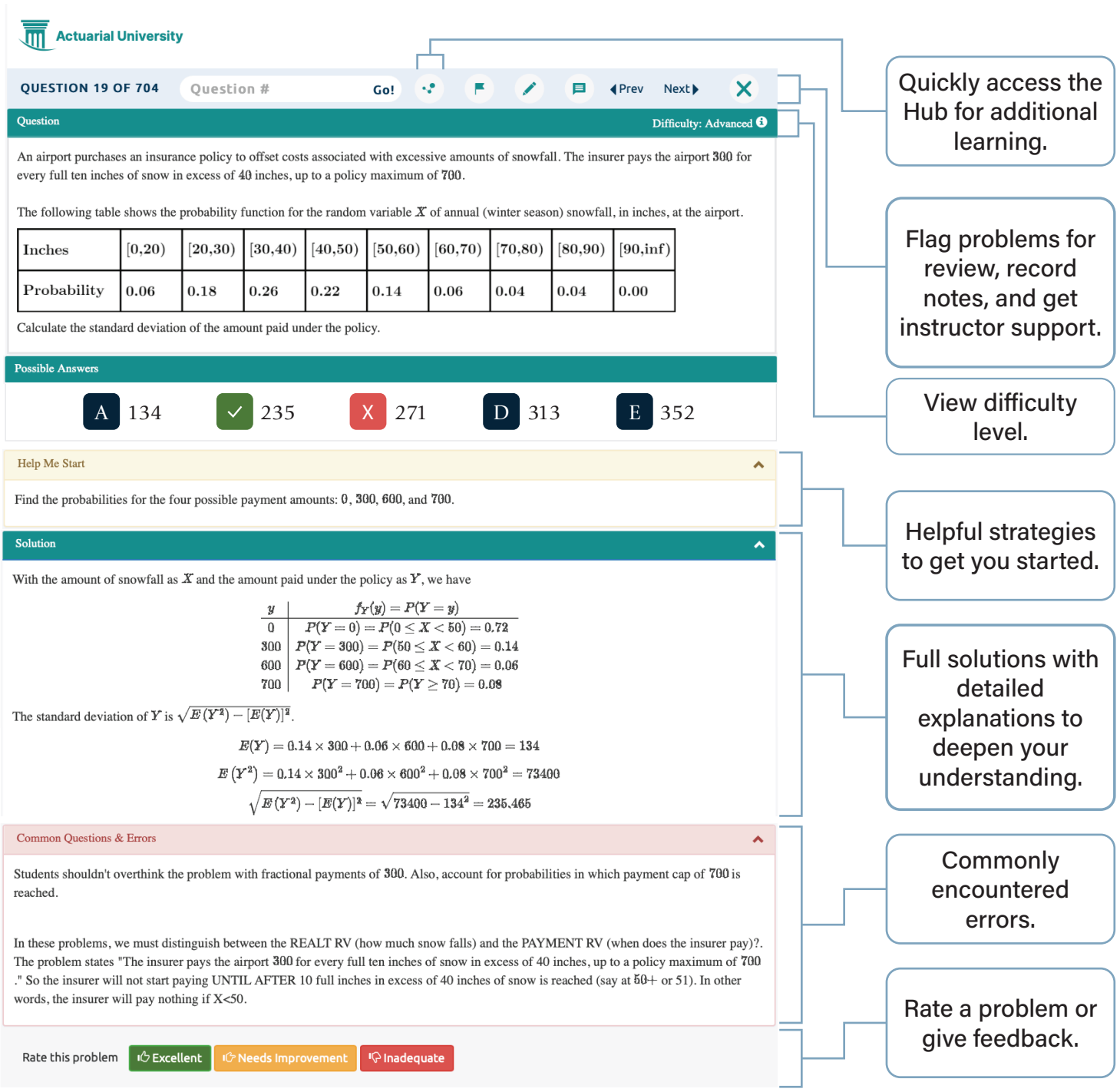

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QUESTION 19 OF 704 | Question # | Go! | Prev | Next

Question — Difficulty: Advanced

An airport purchases an insurance policy to offset costs associated with excessive amounts of snowfall. The insurer pays the airport 300 for every full ten inches of snow in excess of 40 inches, up to a policy maximum of 700.

The following table shows the probability function for the random variable X of annual (winter season) snowfall, in inches, at the airport.

Inches	[0,20)	[20,30)	[30,40)	[40,50)	[50,60)	[60,70)	[70,80)	[80,90)	[90,inf)
Probability	0.06	0.18	0.26	0.22	0.14	0.06	0.04	0.04	0.00

Calculate the standard deviation of the amount paid under the policy.

Possible Answers

A 134 ✓ 235 X 271 D 313 E 352

Help Me Start

Find the probabilities for the four possible payment amounts: 0, 300, 600, and 700.

Solution

With the amount of snowfall as X and the amount paid under the policy as Y, we have

y	$f_Y(y) = P(Y = y)$
0	$P(Y = 0) = P(0 \le X < 50) = 0.72$
300	$P(Y = 300) = P(50 \le X < 60) = 0.14$
600	$P(Y = 600) = P(60 \le X < 70) = 0.06$
700	$P(Y = 700) = P(Y \ge 70) = 0.08$

The standard deviation of Y is $\sqrt{E(Y^2) - [E(Y)]^2}$.

$$E(Y) = 0.14 \times 300 + 0.06 \times 600 + 0.08 \times 700 = 134$$

$$E(Y^2) = 0.14 \times 300^2 + 0.06 \times 600^2 + 0.08 \times 700^2 = 73400$$

$$\sqrt{E(Y^2) - [E(Y)]^2} = \sqrt{73400 - 134^2} = 235.465$$

Common Questions & Errors

Students shouldn't overthink the problem with fractional payments of 300. Also, account for probabilities in which payment cap of 700 is reached.

In these problems, we must distinguish between the REALT RV (how much snow falls) and the PAYMENT RV (when does the insurer pay)?. The problem states "The insurer pays the airport 300 for every full ten inches of snow in excess of 40 inches, up to a policy maximum of 700 ." So the insurer will not start paying UNTIL AFTER 10 full inches in excess of 40 inches of snow is reached (say at 50+ or 51). In other words, the insurer will pay nothing if X<50.

Rate this problem | Excellent | Needs Improvement | Inadequate

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