Pension Insurance Modeling System (PIMS) Single-Employer Model

Peer Review

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Executive Summary

1. Summary of the peer review assessment performed

The Moving Ahead for Progress in the 21st Century Act (MAP-21) requires PBGC to contract with a capable agency or organization that is independent of PBGC to conduct annual peer reviews of Single Employer (SE) Pension Insurance Modeling System (PIMS) and Multi-Employer (ME) PIMS.

The current review scope covers a comprehensive peer review of SE PIMS and ME PIMS and particularly focuses on the high-level conceptual soundness and governance review of inputs, methodology and assumptions, operations, functionality and performance and a review of the completeness of documentation for these models. In addition to recommendations from this review, the objective of the review is also to provide PBGC with best practices on model governance.

PBGC is currently in the process of modernizing the current SE PIMS model with a new version referred to as Transformational PIMS (TPIMS). While this peer review is performed on the legacy SE PIMS model, any recommendations from the review will inform improvements to the current PIMS models and future TPIMS development.

This document covers the review of SE PIMS. The review of ME PIMS is covered in a separate document.

2. Peer review observations and recommendations

While the current review is focused on legacy PIMS models, the following table summarizes the observations and associated recommendations that were identified for PRAD to consider for TPIMS.

TABLE 0-1: PEER REVIEW RECOMMENDATIONS

ID	Section, Sub-section	Observations and recommendations	Priority [1]
R01	**Section:** Conceptual framework - data **Sub-section:** Data input: plan database **Related chapter:** 2.2	**Observation:** The current field names in the plan data are not easily comprehensible for a user who is not familiar with the PIMS model **Recommendation:** Rename data fields using an intuitive naming convention to enhance the transparency of the plan data	Low
R02	**Section:** Conceptual framework - data **Sub-section:** Data input: variable selection	**Observation:** The inflation rate is derived from the nominal interest rate by adjusting a real interest rate component. While the nominal interest is modeled stochastically, the real interest rate variable used in the model is assumed to be an input parameter and is fixed across all simulation periods. This might lead to the outcomes being less sensitive to interest rate changes	Low

	Related chapter: 2.2	**Recommendation:** Perform an impact assessment through sensitivity analysis to understand the materiality of this variable. Further, investigate the feasibility of stochastic approach for real interest rate modeling to reflect the interest rate changes	
R03	**Section:** Conceptual framework - data **Sub-section:** Data input: variable selection **Related chapter:** 2.2	**Observation:** The yield on corporate bond is equal to the treasury bond yield plus a spread that reverts, over the projection period, from its starting point of a fixed spread of 110 basis points. **Recommendation:** While the approach of modeling corporate yield using a spread over the treasury yield is common, stochastic modeling of the spread can be considered to capture the actual movement of corporate bond in the real world.	Low
R04	**Section:** Conceptual framework - methodology **Sub-section:** Assumptions **Related chapter:** 2.4	**Observation:** Currently, there is no formal process defined where assumptions are reviewed, challenged, and updated as appropriate on a periodic basis. Potentially several of the SE plan behavior assumptions (e.g., benefit improvements, etc.) and capital market assumptions (e.g., asset allocation correlation between Treasury yield and equity returns, have not been updated in the recent past **Recommendation:** Establish a systematic assumption review process to review the assumptions on a periodic basis and sufficiently document the review process that potentially includes materiality, sensitivity testing, and changes to assumptions used in the SE model	Medium
R05	**Section:** Conceptual framework - methodology **Sub-section:** Demographic selection process **Related chapter:** 2.5	**Observation:** The demographic weighting process is mostly manual and iteratively performed until the total liability of the sample plans matches with the total liability of all plans in any segment. The manual iterative process could potentially introduce operational errors **Recommendation:** Explore automated weighting process to improve the accuracy of the results	Low
R06	**Section:** Conceptual framework - methodology **Sub-section:** Bankruptcy probability calculation **Related chapter:** 2.5	**Observation:** The recalibration process in the bankruptcy probability calculation currently normalizes the bankruptcy rate of the largest outliers with the mean of the market estimate of bankruptcy risk for their class of bonds. This is a non-conservative approach that can potentially underestimate the claim liabilities **Recommendation:** Perform a sensitivity analysis to assess the impact of these outliers and explore more conservative approach to recalibrate the bankruptcy probability to minimize the mismatch between credit rating and bankruptcy probability	Low

R07	**Section:** Conceptual framework - methodology **Sub-section:** Economic scenario generation (ESG) **Related chapter:** 2.5	**Observation:** Parts of the current review process for the generated scenarios is manual through spot checks **Recommendation:** The manual review process could be reassessed to understand if automated process might be more reasonable. However, given there will be a new in-house ESG in Python, limited reassessment might be needed for the current ESG	Low
R08	**Section:** Conceptual framework - methodology **Sub-section:** PBGC cashflow simulation **Related chapter:** 2.5	**Observation:** PIMS does not model PBGC's asset allocation during the transition period of the terminated plans, which could result in an imprecise estimation of PBGC's surplus **Recommendation:** Consideration could be given to refining the asset allocation calculation during the transition period of the terminated plans in future version of PIMS	Low
R09	**Section:** Conceptual framework - methodology **Sub-section:** Post-processing **Related chapter:** 2.5	**Observation:** Although the post-processing tool offers a comprehensive view of the model outputs, it provides limited transparency in the calculation process, making it challenging to review the outputs thoroughly without clear instructions on how to navigate the workbook. **Recommendation:** Perform regular clean up or review of the post-processing to ensure it is user-friendly	Low
R10	**Section:** Assessment of operations: use **Sub-section:** Use **Related chapter:** 3.1	**Observation:** The SE-PIMS model is currently being used appropriately as each model user has specific responsibilities regarding the model and the assignment of responsibilities is clear. However, there is a lack of formally established roles and responsibilities at each phase of model development. **Recommendation:** The adoption of a roles and responsibilities matrix at each stage of model development can be considered	Low
R11	**Section:** Assessment of operations: use **Sub-section:** Result generation **Related chapter:** 3.1	**Observation:** Some of the post-processing / aggregation is still performed in Excel and/or SAS and a manual process is used to copy/paste the values from either another Excel workbooks or SAS output files. Further, the governance around model parameters update can be potentially enhanced **Recommendation:** The following recommendations could be considered to enhance the existing process to generate results: • Combining post-processing files from multiple sources to streamline the process	Medium

		• Fine-tuning model parameters to ensure the accuracy of the model outputs	
R12	**Section:** Assessment of operations: use **Sub-section:** Model use governance **Related chapter:** 3.1	**Observation:** PIMS models have multiple uses and multiple users of the model. A use attestation process is critical to ensure that the model is not used for unapproved/unlisted uses **Recommendation:** Consider establish a formalized model attestation process for use and creating formal documentation to track open model related issues	Low
R13	**Section:** Assessment of operations: implementation **Sub-section:** Model verification **Related chapter:** 3.2	**Observation:** PIMS model implementations are highly complex and the current training programs in place can potentially be improved. Further, given the materiality of the models, an end-to-end replication of critical components is important to ensure the accuracy of the implementation **Recommendation:** The following enhancements could be considered to enhance the implementation process: • Establishing a systematic training program on model implementation and a formal documentation on model implementation procedures • Integrating the key calculation logic in the existing replicating process	Low
R14	**Section:** Assessment of functionality and performance **Sub-section:** Economic scenario generator **Related chapter:** 4.1	**Observation:** The following observations have been noted based on the assessment of the current ESG • The existing ESG uses a core model with two variables being fully stochastically generated: the yield on 30-year Treasury bonds and the return on the S&P 500 stock index • A few economic variables are stochastically projected in the current ESG (e.g., inflation, plan investment returns, corporate bond yield, discount rate) but there are no industry segmented variables being projected • The current approach to model treasury yield eliminates the possibility of rates going below zero • The current approach to model equity return is using risk premium as excess returns over treasury yield, which limits the model's ability to capture varying relationship throughout the economic cycle • The current correlation between stock and Treasury bond returns is weakly positive (0.209) • The current approach to model long-term corporate rate uses a fixed spread of 110 basis points over the Treasury yield plus	Medium

		• The values for the nominal stock return parameters were originally based on a study done in 2008 and they only capture the period from 1973 to 2007 **Recommendation:** The following recommendations could be considered to enhance the ESG functionality as the new ESG being developed in the T-PIMS model: • Incorporate additional factors such as GDP, unemployment rate, etc., to model core variables • Consider industry segmented variables in the ESG • Explore approach to allow possible negative treasury yields • Explore approach to simulate equity return independently • Recalibrate the correlation between treasury bond yield and equity return with the latest data to ensure the correlation factor reflect market observations • Consider dynamic correlation between stock and treasury yield • Explore stochastic modeling of spread over Treasury yield • Explore more frequent parameter calibration	
R15	**Section:** Assessment of functionality and performance **Sub-section:** Sensitivity analysis **Related chapter:** 4.2	**Observation:** PBGC currently performs sensitivity analysis of changes in discount rate of increase and decrease of 50 basis points and changes in assumed plan de-risking activity in the Projection Report In addition to the sensitivity analysis currently disclosed by PBGC, other sensitivity analyses observed in the industry and would further enhance the analytics of the SE model include the following: • Wider range of changes in discount rate (i.e., +/- 100 and 200 bps) in sensitivity analysis • Sensitivity analysis around mortality improvement, changes in premium structure and bankruptcy probability of plan sponsors **Recommendation:** Consider expanding its sensitivity analysis to further enhance analytics of the SE PIMS model	Medium
R16	**Section:** Assessment of functionality and performance **Sub-section:** Stress testing **Related chapter:** 4.3	**Observation:** PBGC currently uses one illustrative stress test scenario with a market downturn and elevated rates of bankruptcy in the Projection Report Examples of stress scenarios utilized in the industry that would further enhance the analytics of the SE model include interest rate changes, liquidity crunch, pandemic, and geopolitical changes. **Recommendation:** Consider additional stress test scenarios to further enhance the analytics of the model	Low
R17	**Section:** Assessment of	**Observation:** Currently, there is no formal process defined for back testing of the SE-PIMS.	Low

	functionality and performance **Sub-section:** Back testing **Related chapter:** 4.4	Considering the challenges of performing the back testing given the constant changing in model parameters, data sources, and frequent changes in pension regulation and policies, special considerations and techniques may be required for SE PIMS model, such as implementing a component-based back testing approach and potentially a macro-overlay to incorporate external changes in back testing **Recommendation:** Consider performing back testing and define and justify the performance metrics to support analysis of modeled vs. actual variance and identify potential model risks.	
R18	**Section:** Assessment of documentation **Sub-section:** Model documentation **Related chapter:** 5.1	**Observation:** The documentation of the SE-PIMS model is appropriate to be used as a model functional documentation, offering a comprehensive view of the model's construction, key assumptions, and utilized variables during the development process. However. while the current documentation is appropriate, there exist potential areas of improvement **Recommendation:** The following enhancements could be considered to enhance the model documentation: • Incorporating the rationale behind methodological choices • Establishing a repository of model assumptions • Clearly articulating all model limitations • Regularly updating information	Low
R19	**Section:** Assessment of documentation **Sub-section:** Governance on model documentation **Related chapter:** 5.2	**Observation:** Key governance procedures on model documentation have been observed in the SE PIMS model, including procedures on management changes, version controls, continuous enhancement, and regulatory compliance **Recommendation:** Given the current absence of explicit governance regarding the documentation around model limitation, it becomes important to incorporate appropriate and comprehensive disclosures within the model deliverables to mitigate any instances of misuse, misinterpretation, or misrepresentation	Low

1. Definition in appendix

Table 0-2: MODEL LIMITATIONS

ID	Limitation	Recommendation
ML01	**Section:** Conceptual framework - data **Sub-section:** Data input: plan database **Observation:** There is currently a one-year lag of the Form 5500 reporting, which could result in outdated plan information used in the model **Related chapter:** 2.2 – assessment of conceptual risk	Explore potential ways to minimize the lag of Form 5500 reporting
ML02	**Section:** Conceptual framework - methodology **Sub-section:** Plan cashflow simulation **Observation:** The existing plan cashflow calculation does not have the flexibility to model premium structure changes. Potential improvement to add the capability to change premium levels could be considered so the model is able to quickly calculate how premium structure changes will impact the plan level cashflows **Related chapter:** 2.5 – assessment of the governance and controls	Explore the addition of capability to change the premium levels in the model
ML03	**Section:** Conceptual framework - methodology **Sub-section:** Post-processing **Observation:** The current output from the post-processing is on the aggregated PBGC level and the model's ability to provide a segment level output is limited **Related chapter:** 2.5 – assessment of conceptual risk	Explore potential capability to present a segmented view of the projected cashflows such as plan-level projection, cashflows by scenarios, etc. to provide more transparency of the results to the users

1 Overview

1.1 Model description

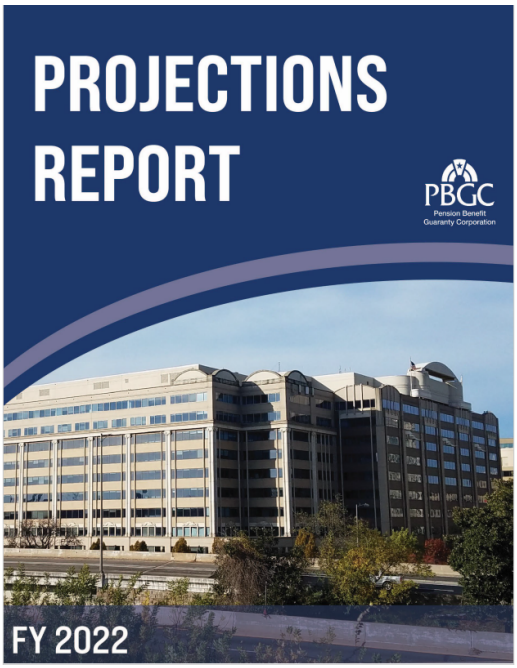
Pension Benefit Guaranty Corporation (PBGC) insures participants in private pension plans against loss of benefits in case their plan ceases to pay. PBGC employs a stochastic modeling system known as the Pension Insurance Modeling System (PIMS) to assess its future obligations and financial position each year. There are two models as part of PIMS – Single Employer (SE) PIMS model and Multi-Employer (ME) PIMS model as part of PIMS.

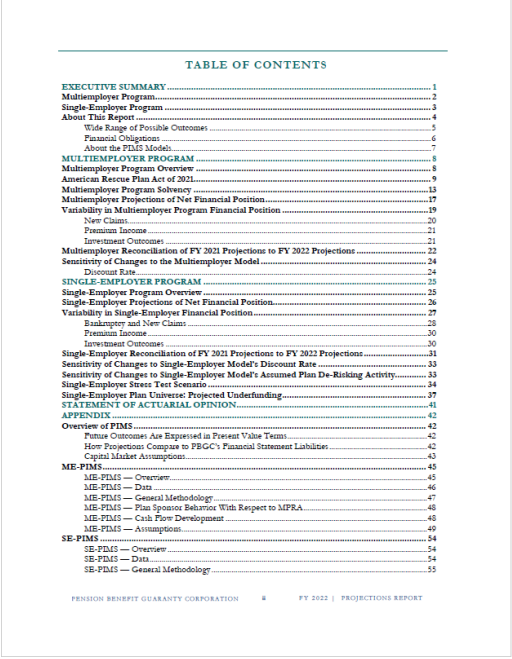
The SE-PIMS uses a sample of single-employer pension plans to model the future funding status of the universe of private sector pension plans. The model projects long-term financial outcomes by running several simulations, each modeling year-by-year changes over 20 years into the future. The SE PIMS model relies on historical data for factors such as the incidence of bankruptcy, mortality tables, stock returns, interest rates and other macroeconomic variables. This data informs the choice of parameters and assumptions used for the stochastic model's future projections that are developed based on simulated macroeconomic scenarios. The outputs of these simulations are used to create the projected financial position of PBGC for the next 10 years.

1.2 Model use and scope

There are multiple uses and outputs produced from the SE PIMS model, including:

- Projection Report: PBGC's annual Projection Report is required by the Employee Retirement Income Security Act, providing all stakeholders including the public an actuarial evaluation of the future financial status of PBGC's Multiemployer and Single-Employer Programs





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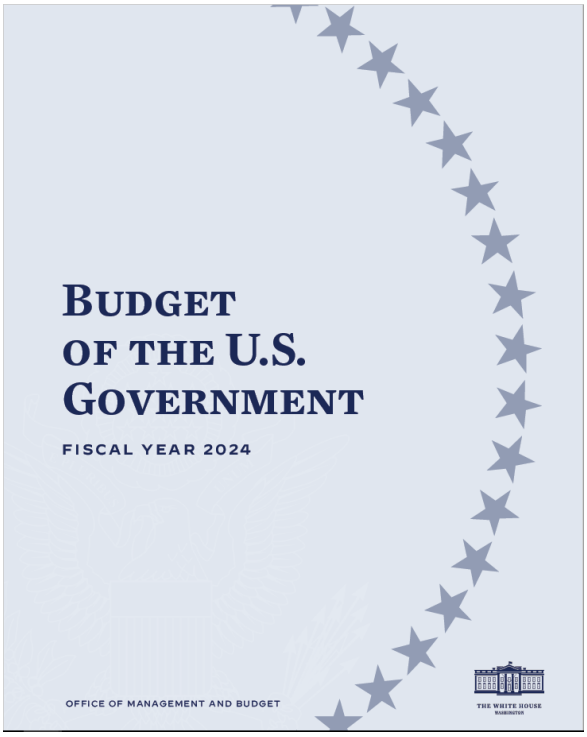
- President's budget report: The 10-year financial statement projections provide the Congress and the public the budget estimation of PBGC for the next fiscal year



- Technical assistance requests: The outputs provide the external legislative stakeholders estimates of the budgetary impact from legislative proposals. Possible examples include:
    - Changes to the premium structure
    - Changes to funding laws
    - Changes to the interest rates used to value liabilities
- Ad hoc internal PBGC analysis: The PIMS model outputs are used to generate internal reports for ad hoc PBGC analysis

1.3 Peer review approach

The peer review assessment approach for the single-employer PIMS model focuses both on the conceptual risk assessment and governance and controls assessment for each of the model components.

The table below summarizes the review approach of the conceptual framework assessment and the governance and controls assessment:

TABLE 1-1: PEER REVIEW APPROACH

Dimension	Sub-section	Conceptual risk assessment	Governance and controls assessment
1. Conceptual framework: data	Data preparation	• Assess the data quality, completeness, and appropriateness based on walkthroughs with the model users • Assess whether the sources of data inputs are appropriate • Assess data format is appropriate for each variable • Assess whether any data transformation is appropriate • Verify the data quality, completeness, and appropriateness of the input datasets with existing metrics through independent replication	• Review the evidence provided for quality controls of data inputs • Sufficient data quality controls are in place for creating the initial database from Form 5500 • Assess whether the review process to spot material data quality issues is in place, and they are addressed properly when issues are identified • Verify that robust governance is in place around the data and assumptions such as a data dictionary for SE/ME models, a summary of assumptions • Evidence of review and challenge of: ○ Variable selection in the scenario generation process with supporting evidence such as presentations or meeting minutes are available ○ If any data is shared with a vendor, assess whether controls are in place for the data delivery process and responsible parties • Assess whether proper monitoring procedures for data inputs are in place
	Variable selection	• Assess the criteria for variable selection for scenario generation and assess its appropriateness • Assess whether variables in scenarios are properly link to the risk factor of the SE plans • Assess whether the breadth of economic variables enables the model to depict full picture of the macro economy • Assess how effectively model inputs support the conceptual framework of the models	
2. Conceptual framework: methodology	Assumption	• Assess the appropriateness of plan behavior assumptions and whether additional assumptions are needed to reflect plan holder behaviors at segment level • Assess the appropriateness and completeness of capital market assumptions and whether additional assumptions are needed to reflect the economy level • Assess whether the assumption setting methodology is consistent with the models' intended purposes	• Assess the evidence of review and challenge the process to approve various methodologies (demographics sampling selection, economic scenario generation, plan cashflow simulation, bankruptcy probability) • Assess whether changes of variables/methodologies used in the SE/ME models are properly logged and proper approval is in place of changes of variables/methodologies • Review and challenge the process of methodology change management
	Demographic	• Assess whether the demographic sampling methodology is consistent with the models' intended purposes	

	selection process	• Assess the conceptual soundness of the demographic selection process • Assess whether plans are sorted based on liability ranking with the largest ~500 plans captured in the sample selection • Assess with plans getting expired, whether new plans are added into sample collection to keep total number of sample plans consistent • Assess whether total liabilities of sample plans match the total liabilities of all SE plans through weighting process	• Assess whether proper monitoring of assumptions and methodologies are in place
	Economic scenario generation	• Assess the conceptual soundness of the economic scenario generation • Assess whether the breadth of scenarios is able to cover tail events • Assess whether variables in scenarios are properly linked to the risk factor or the SE plans • Assess identification of additional market information not currently used in models that, if combined with current inputs, would enhance model effectiveness. • Assess whether the economic scenario generation is consistent with the models' intended purposes	
	Plan cashflow simulation	• Assess the conceptual soundness of the plan cashflow simulation • Assess whether the logic used to calculate the plan liabilities and assets over projection period reflect the actual experience of a potential claim • Assess whether the fundamental methodology of plan cashflow simulation is consistent with the models' intended purposes	
	PBGC cashflow simulation	• Assess the conceptual soundness of the PBGC cashflow simulation • Assess whether the logic used to calculate the PBGC cashflows over projection period reflect the PBGC's actual experience • Assess whether the fundamental methodology of plan cashflow simulation is consistent with the models' intended purposes	

	Bankruptcy probability calculation	• Assess the conceptual soundness of the bankruptcy probability calculation • Assess whether historical credit rating and default rate used in the calculation is appropriate • Assess whether the calculated bankruptcy probability capture the underlying default risk of the company • Assess whether the fundamental methodology is consistent with the models' intended purposes	
3. Operation	Use	• Review the alignment of model use with the scope and approved uses of the model • Assess whether the post-processing tool properly aggregates cashflows from the model in all scenarios to project PBGC experience • Review the format of model outputs is appropriate for different purposes	• Evaluate types of access and security controls applied to prevent unauthorized access to the SE/ME models and their supporting documents and review existing access rights on a regular basis • Assess the data output controls are in place to ensure output does not have errors and is calculated per the model requirements • Review and challenge the request process for producing model results • Evaluate how and where the results are logged and the parties that review the results on an ongoing basis • Verify model usage is consistent with approved use cases, restrictions, and limitations • Assess the existing decision-making process in place for defining, reviewing, and updating model governance procedures • Review attestation from the model users on the uses to ensure the model is used only for approved uses • Assess the tracking of progress on open model related issues and recommendations
	Implementation	• Examine whether the current practices of testing the replicability of model are sufficient • Assess whether the current review approach to identify implementation errors of the model is appropriate • Evaluate the appropriateness of the system or platform in which the	• Assess whether clear training procedures are in place • Assess whether measures are in place for knowledge retention and transfer to support maintenance and enhancement of the models

		model is embedded or implemented given the model purpose and complexity	
4. Functionality and performance		• Assess whether model captures the full range of potential outcomes for macroeconomic series, assets, liabilities, and cash flows • Assess whether additional deterministic functionality could be utilized to supplement the stochastic modeling in order to illustrate extreme tail-risk events • Assess whether model outputs do not correspond well to actual outcomes • Assess whether sufficient testing was performed to assess the accuracy and soundness of the implementation in production (e.g., back testing, reconciliation testing, user acceptance testing, etc.) • Assess whether the key deliverables (i.e., Projection Report, President's Budget, a sampling of Technical Assistance deliverables) are effective relative to their intended purposes and audience • Review the current model functionality relative to its intended purposes	• Assess whether controls are in place to ensure all appropriate scenarios are run • Assess whether the composition of subject matter expertise to support the model is appropriate • Assess whether proper monitoring procedures for functionality and performance are in place • Assess the review and challenge of model performance
5. Documentation		• Assess the comprehensiveness, readability, and consistency of model documentation • Assess if documentation is properly stored with appropriate version controls • Assess the accuracy, sufficiency, and clarity of content of the current PIMS webpage	• Assess whether the information documented is accurate, clear/understandable • Change management processes, including location of change log, version controls procedures, review and approval of change procedures • Assess whether archiving and retention controls are in place • Assess whether supporting documents and resources adequately inform users in order to avoid misuse, misinterpretation, or misrepresentation • Assess whether appropriate and sufficient disclosures exist in the model deliverables to avoid misuse, misinterpretation, or misrepresentation

2 Assessment of data and methodology

The assessment of data and methodology for the Single-Employer (SE) PIMS model is conducted along both conceptual risk and governance and controls for each component of the model. The components of the SE PIMS model are shown in the model architecture diagram in section 2.1 and the assessment is conducted for each sub-component in the model architecture diagram.

2.1 Description of high-level model architecture

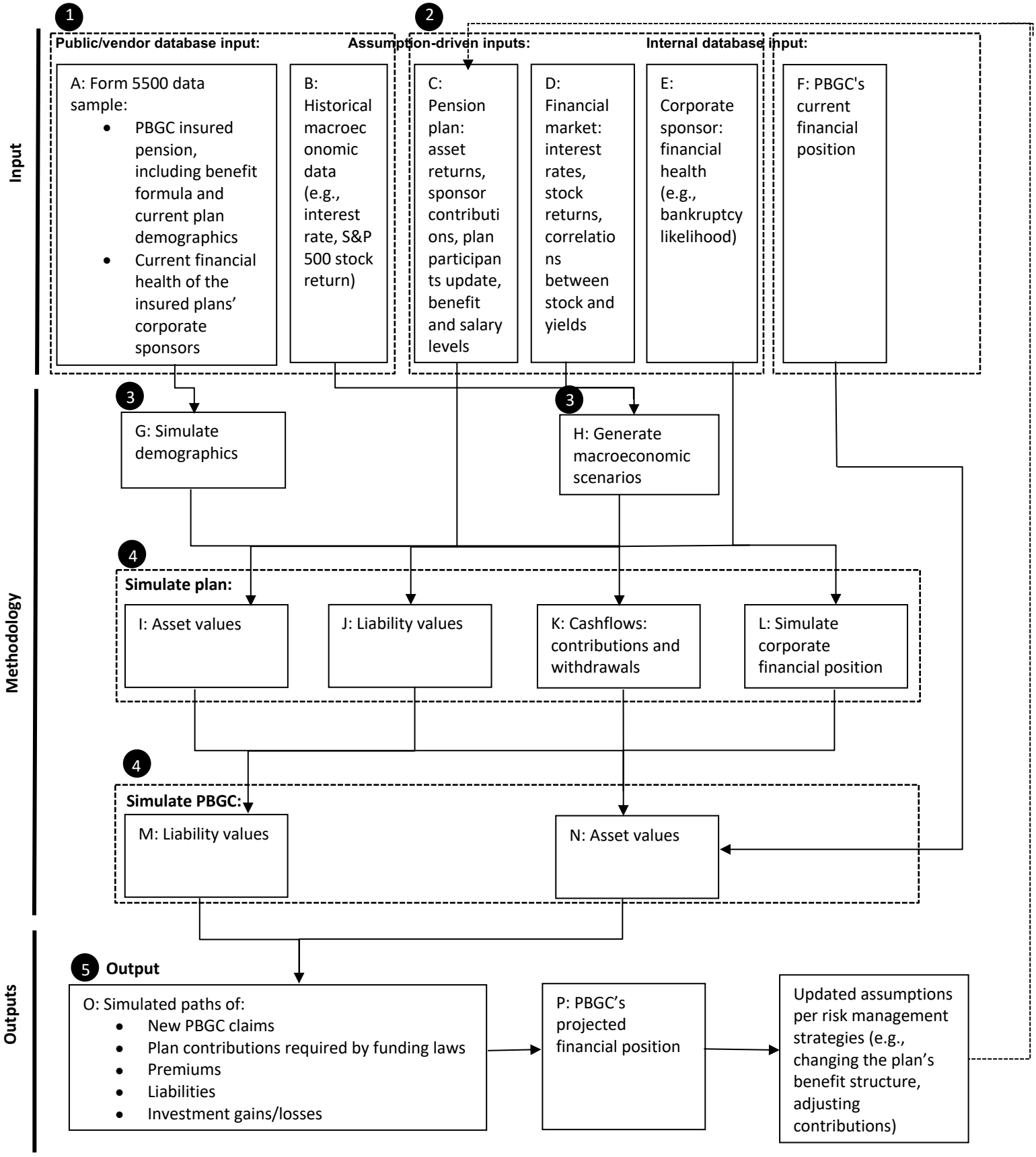
SE PIMS model employs stochastic-based simulation techniques to project long-term financial trajectories of the single-employer pension plans insured by PBGC. It begins by utilizing PBGC's net current financial position and data on the funding status of nearly 500 of the largest plans, extrapolating results for this group to represent the entire single-employer universe. The model then introduces random yearly variations to simulate economic fluctuations, producing 500 simulations to depict alternative economic paths over time. Within each simulation, the outcomes of each plan in one year serve as the starting point for the subsequent year's projections. To project future claims for a plan, the SE PIMS model simulates the likelihood of bankruptcy for plan sponsors based on projection of firm characteristics. While the main PIMS calculation computes projections at the plan level, the final projected PBGC assets and net positions are developed externally by using the target level premiums and PBGC assets projection. As shown in the model architecture diagram below, the key components of the SE PIMS model include:

- Public/vendor database input: SE PIMS pension data obtained from Form 5500 annual pension plan filings. This data includes plan liabilities, assets, participant demographics and actuarial assumptions about demographics dynamics and investment returns
- Assumption-driven inputs: SE-PIMS uses numerous assumptions to estimate the stochastic and key deterministic variables. The key segments of factors for which assumptions are used include economic variables, firm level variables, plan level variables and PBGC specific variables
- SE plan universe weighting process: SE PIMS sample is weighted to represent the full universe of PBGC-insured single employer plans. The weighted sample represents total liabilities and underfunding, and the distribution of funding levels among plans in the PBGC-insured universe based on data available as of the preceding spring.
- Economic Scenario Generator (ESG): SE PIMS model uses ESG to produce simulated scenarios based on macroeconomic variables such as future economic growth, inflation, interest rates and equity returns
- Plan simulation: A set of actuarial calculations are performed to determine the financial implications of the obligations incurred and anticipated to be incurred under a pension plan. SE-PIMS simulates contributions, premiums, and underfunding for the plans modeled. SE PIMS first calculates the expected bankruptcies with underfunded plans. SE PIMS uses an 80% funding threshold to determine whether PBGC will trustee a plan sponsor by a bankrupt firm. Based on the threshold, the SE-PIMS models the level of the claim based on the

underfunding at the time of the projected bankruptcy based on assumptions used for valuing plan terminations for the purpose of PBGC's own financial projections.

- PBGC simulation: The financial condition of PBGC is calculated annually considering changes in claims, premiums, fixed and variable expenses resulting from managing the pension insurance program, and investment gains or losses from the agency's portfolio of assets
- Outputs: SE PIMS produces a set of model outputs based on the simulations. The final projected PBGC assets and net position are developed outside of the model by scaling the premium levels to estimated target level premiums that PBGC estimates for the current fiscal year

TABLE 2-1: SINGLE-EMPLOYER PIMS MODEL DIAGRAM



2.2 Assessment of data: data preparation

The table below documents the peer reviewer's assessment of the appropriateness of the inputs for use in this model and the data preparation and quality controls around the inputs.

TABLE 2-2: ASSESSMENT OF DATA: DATA PREPARATION

Data input & source	Description and usage in model	Peer review assessment description
1A. Data input: *Plan database* ***Source:*** *Form 5500*	**Description** The plan demographics and account information for Single-employer plans **Usage in the model** The plan data is manually entered into the system and used to generate plan demographics by selecting plans based on liability amount	**Assessment of the conceptual risk** The data source for plan database is appropriate. The plan database uses Form 5500, an electronic filing for all employee benefit plans. As Form 5500 serves a disclosure document for plan participants and beneficiaries, as well as a key data source for Federal agencies, Congress, and the private sector in evaluating employee benefit, tax and economic trend and policies, it stands as an appropriate choice for plan data. The plan database includes a series of data fields to accurately depict the characteristics of the plans, including plan demographics (i.e., cohort age, cohort service, retirement age, etc.), plan cashflows (i.e., account balance, benefit payment), and plan asset cashflows (i.e., aggregate return, asset allocation among different types of assets) The current field name in the data plan is difficult to understand even though there is a data dictionary. Consistent and intuitive naming convention could be adopted to give more transparency of field name. An observation has been identified in this regard [R01] Further, there is currently a one-year lag in the Form 5500 reporting, which could result in outdated plan information used in the model. Potential ways to minimize the lag of Form 5500 reporting could be assessed. A model limitation has been identified in this regard [ML01] **Assessment of the governance and controls** Sufficient data quality controls are in place for creating the initial database from Form 5500. The manual entry process is done by third-party contractor and there is rigorous review process done by the third-party contractor to examine the accuracy of the data entered, including error log during the reconciliation process, flagging fields with pre-defined criteria. After data is received by PRAD, there is another data scrubbing process done by PRAD team member to ensure data quality (i.e., confirm large year-over-year changes) There is sufficient governance in place around the database given there is a series of automated tool for quality control purposes and a well-documented data dictionary is available for the PIMS models
1F. Data input: *PBGC*	**Description** PBGC's current financial position as the starting	**Assessment of the conceptual risk**

current financial position ***Source:*** *PBGC's annual report*	point of the projection for PBGC's cashflows **Usage in the model** The PBGC current financial position is used as the starting point of PBGC's cashflow projection	The data source and data quality of PBGC's financial position is found to be appropriate as the data is directly extracted from PBGC's annual report **Assessment of the governance and controls** Sufficient data quality controls are in place for using PBGC starting financial position. The process to extract PBGC current financial position is automated in Excel to minimize human errors. PRAD team members also check the accuracy of the file path associated with the annual report, which is the data source of the PBGC financial position There is sufficient governance in place around the PBGC current financial position given that checks are performed within the automated tool to extract the financial numbers

2.3 Assessment of data: variable selection

The table below documents the peer reviewer's assessment of the appropriateness of the variable selection for use in the scenario generation process including the assessment of the conceptual risk of the economic variable based on the model development document supporting the use of PIMS model and the assessment of the governance of controls of the economic variable based on the model development document supporting the use of PIMS model and key insights from model user interviews.

TABLE 2-3: ASSESSMENT OF DATA: VARIABLE SELECTION

Economic variable	Description and usage in model	Peer review assessment description
1B. Nominal interest rate	**Description** In attempting to mimic economic and actuarial behavior, PIMS required a model of the long-term market interest rate, which is the yield on 30-year government bonds **Usage in the model** Nominal interest rate is used as a parameter to generate stochastic scenarios	**Assessment of the conceptual risk** The selection of nominal interest rate for modeling scenarios is appropriate with potential limitation because: • Interest rate typically is correlated to the macroeconomic trends (e.g., consumer spending, commercial lending, stock fluctuation) • Interest rate significantly affects asset values and liabilities associated with the SE plans • While the interest rate for modeling scenario is a dynamic rate changing over the projection period, the interest rate used to discount the liability cashflows for plan projection is a flat curve over the period of projection. Due to the limitation of the SE PIMS model capability, using a flat curve for discounting is considered appropriate but potential improvement on documentation of the limitation is made in "5.1 Assessment of documentation" section Furthermore, the methodology used to forecast interest rate is appropriate because: • The nominal interest rate yield is modeled as a first difference of a natural logarithm, and this is a common approach of interest rate modeling in the industry

		• The calculation also considers the disturbance term, which is assumed to be drawn from a joint normal distribution with other economy-level disturbances to reflect randomness in interest rate forecasts **Assessment of the governance and controls** Sufficient data quality controls are in place for generating the nominal interest rate given that the modeling process of economic scenarios uses an automated program in SAS, which runs the simulation of a series of economic variables and includes quality check procedures as part of the automated program
1B. Real interest rate and inflation	**Description** PIMS uses an inflation rate in making inflationary adjustments to pension benefits and other real-to-nominal conversions **Usage in the model** Real interest rate and inflation are used as a parameter to generate stochastic scenarios	**Assessment of the conceptual risk** The selection of real interest rate and inflation for modeling scenarios is appropriate because: • Real interest rate and inflation typically is correlated to the macroeconomic trends (e.g., business investment, tax policies, and interest rates) • Real interest rate and inflation is crucial to investing and can significantly reduce the value of investment returns associated with the SE plans Furthermore, the methodology used to forecast real interest rate and inflation is appropriate with potential opportunity for enhancements: • The inflation rate is derived from the nominal interest rate by adjusting a real interest rate component with log normal distribution, and this is a common approach of inflation rate modeling in the industry • While the inflation rate follows a log normal distribution, the median of the inflation rate distribution comes from the Congressional Budget Office, which is a calibrated parameter reflects analysis and expert opinion from the CBO. The peer reviewers believe the approach is appropriate given that the parameters could easily be adjusted to reflect a different view or calibrated to produce a different set of outcomes as desired • The inflation rate is derived from the nominal interest rate by adjusting a real interest rate component. While the nominal interest is modeled stochastically, the real interest rate is not a stochastic variable, but rather is assumed to be an input parameter and is fixed across all simulation periods. Similar to nominal interest rate, a stochastic approach could be considered for real interest rate modeling in T-PIMS to ensure consistency in inflation rate calculation. An observation has been identified in this regard [R02] **Assessment of the governance and controls** Sufficient data quality controls are in place for generating the real interest rate and inflation given that the modeling process of economic scenarios uses an automated program in SAS, which runs the

		simulation of a series of economic variables and includes quality check procedures as part of the automated program
1B. Stock return	**Description** The rate of return on stocks is used to determine the investment return on pension plans and PBGC's assets held in equities and changes in the plan sponsor's financial condition **Usage in the model** Stock return is used as a parameter to generate stochastic scenarios	**Assessment of the conceptual risk** The selection of stock returns for modeling scenarios is appropriate as stock returns are typically, an indicator of economic growth and can significantly affect the value of investments associated with policy plans Furthermore, the methodology used to forecast stock return is appropriate because: • Stock returns, based on the S&P 500 index, are modeled as a function of the beginning of period Treasury yield and a long-term spread parameter. The process for developing equity returns is clear and parameters are well defined. The size of the equity risk premium and the correlation between stocks and bond yields are based on standard financial theory and observed historical data • The calculation considers the disturbance term, which is assumed to be drawn from a joint normal distribution with other economy-level disturbances to reflect randomness in stock return forecasts **Assessment of the governance and controls** Sufficient data quality controls are in place for generating the stock return given that the modeling process of economic scenarios uses an automated program in SAS, which runs the simulation of a series of economic variables and includes quality check procedures as part of the automated program
1B. Corporate bond yields	**Description** Corporate bond yields are used to determine the investment return on pension plans and PBGC's assets held in non-equities hedging instruments and changes in the plan sponsor's financial condition **Usage in the model** Corporate bond yields are used as a parameter to generate stochastic scenarios	**Assessment of the conceptual risk** The selection of corporate bond yield for modeling scenarios is appropriate because: • Similar to equity market, corporate bond yields typically are an indicator of economic growth • Corporate bond yields can significantly impact the value of assets and liabilities associated with policy plan Furthermore, the methodology used to forecast corporate bond yield is appropriate with potential opportunity for enhancements: • The yield on corporate bond is equal to the treasury bond yield plus a spread that reverts, over the projection period, from its starting point of a fixed spread of 110 basis points. While the approach of modeling corporate yield using a spread over the treasury yield is common, stochastic modeling of the spread can be considered to capture the actual movement of corporate bond in the real world. An observation has been identified in this regard [R03] • Given that corporate bond spreads historically have shown a strong tendency toward mean reversion, the current assumption of reversion to a target credit spread is reasonable in normal market

		environments and serves as a rational central tendency over longer time horizon **Assessment of the governance and controls** Sufficient data quality controls are in place for generating the corporate bond yields given that the modeling process of economic scenarios uses an automated program in SAS, which runs the simulation of a series of economic variables and includes quality check procedures as part of the automated program

2.4 Assessment of methodology: assumptions

The table below documents the peer reviewer's assessment of the appropriateness of the assumptions used in the PIMS model including the assessment of the conceptual risk of the assumptions based on the model development document supporting the use of PIMS model and the assessment of the governance of controls of the assumptions based on the model development document supporting the use of PIMS model and key insights from model user interviews.

TABLE 2-4: ASSESSMENT OF METHODOLOGY: ASSUMPTIONS

Assumptions	Description and usage in model	Peer review assessment description
1C. Plan behavior assumptions	**Description** A series of plan behavior assumptions are set to project how plan related behaviors (e.g., contribution, form of payment, etc.) vary under different circumstances **Usage in the model** Plan behavior assumptions are used to model plan cashflows	**Assessment of the conceptual risk** The plan behavior assumptions are found to be appropriate given that a range of plan behaviors are considered in the model such as plan contribution, benefit improvements, etc., which reasonably depict the plan holder behavior at the segment level. For example: • **Contribution and credit balances:** Contributions are assumed to be driven by incentives such as complying with minimum funding requirements, reducing the Variable Rate Premium (VRP), and maintaining funded status at certain levels. The current approach is appropriate given that it distinguishes between five contribution strategies to five states of plan funding, which explicitly ties employer contributions to target amounts meaningful to many plan sponsors • **Benefit improvement:** For non-frozen plans, benefit multipliers are assumed to increase annually by the rate of inflation and productivity growth. The current approach is appropriate given that inflation and productivity growth are potentially the most important factors impacting benefit improvements • **Plan de-risking:** SE-PIMS was modified in recent years to model plan de-risking based on the plan's funded percentage, and the associated lump sum take-up and/or annuity purchase percentages for active, terminated vested participants and retirees **Assessment of the governance and controls** The review and challenge process to approve the plan behavior assumptions is found to be appropriate with scope for potential improvement: • PRAD team holds frequent meetings to discuss if an assumption update/change is needed and there is a group review process of any assumption changes in the PIMS model

		• Periodic peer review is also conducted by independent third parties on selected assumptions However, several of the SE plan behavior assumptions (e.g., benefit improvements etc.) have not been updated in the recent past. While some other plan behavior assumptions such as contributions have not been updated in the recent past, they have been reviewed and discussed internally. Currently, there is no formal process defined where plan behavior assumptions are reviewed, challenged, and updated as appropriate on a periodic basis. An observation has been identified in this regard [R04]
1D. Capital market assumptions	**Description** A series of economic variables are stochastically projected in PIMS (e.g. interest rate, stock return, corporate bond yield, annual wage growth) **Usage in the model** Capital market assumptions are used to model plan asset cashflows	**Assessment of the conceptual risk** The capital market assumptions are found to be appropriate given that a variety of economic variables are considered in the model such as interest rate, inflation, stock return etc., which accurately depict the stochastic movement of the macro economy. For example: • The methodology to generate interest rates, stock returns and related variables is appropriate given that they are determined by the underlying means, standard deviation, and correlation matric establish for the PIMS projection • The methodology to generate corporate bond yields and stock returns is appropriate given that they are modeled based on risk premiums plus a disturbance term to reflect randomness. Credit spreads on investment-grade corporate bonds are assumed to regress toward their historical mean with no stochastic variation **Assessment of the governance and controls** The review and challenge process to approve the capital market assumption is found to be appropriate with scope for potential improvement: • PRAD team holds frequent meetings to discuss if assumption update/change is needed and there is a group review process of any assumption changes in the PIMS model. PRAD also holds a biweekly Economist meeting where they dive into issues related to the capital market assumptions • Periodic peer review is also conducted by independent third parties on selected assumptions However, a few capital market assumptions (asset allocation, correlation between Treasury yield and equity returns, etc.) have not been updated in the recent past. Currently, there is no formal process defined where capital market assumptions are reviewed, challenged, and updated as appropriate on a periodic basis. An observation has been identified in this regard [R04]

1C. Mortality assumption	**Description** The number of deaths in a specific population over a specific period of time **Usage in the model** Mortality assumptions are used to model plan liability cashflows	**Assessment of the conceptual risk** The mortality assumptions are found to be appropriate given that the mortality table used in the model is based on mortality experience study of PBGC-insured participants, which is able to estimate the number of deaths and retirees over the projected period of the PIMS model **Assessment of the governance and controls** The review and challenge process to approve the mortality assumption is found to be appropriate given: • PRAD team holds frequent meetings to discuss if assumption update/change is needed and there is a group review process of any assumption changes in the PIMS model • Periodic peer review is also conducted by independent third parties on selected assumptions

2.5 Assessment of methodology: simulation

The table below documents the peer reviewer's assessment of the appropriateness of the methodologies used in the PIMS model including the assessment of the conceptual risk of the methodologies based on the model development document supporting the use of PIMS model and the assessment of the governance of controls of the methodologies based on the model development document supporting the use of PIMS model and key insights from model user interviews.

TABLE 2-5: ASSESSMENT OF METHODOLOGY: SIMULATIONS

Assumptions	Description and usage in model	Peer review assessment description
3G. SE plan universe selection process	**Description** The SE-PIMS sample is weighted (scaled up) to represent the full universe of PBGC-insured, single-employer plans. The weighted sample represents total liabilities and underfunding, and the distribution of funding levels among plans in the PBGC-insured universe based on data available as of the preceding spring **Usage in the model** The SE plan universe selection process selected	**Assessment of the conceptual risk** The SE plan universe selection process is found to be conceptually sound given that: • All plans are sorted based on liability ranking with the largest ~550 plans captured in the sample selection • As plans getting expired, new plans are added into sample selection to keep total number of sample plans consistent • The total liabilities of sample plans match the total liabilities of all SE plans through weighting process The SE plan universe sampling methodology is found to be consistent with the models' intended purpose since it gives an accurate representation of the total plan population by capturing plans with largest liabilities and ensuring total liabilities of the selected plans match the total liabilities of all plan universe through weighting process **Assessment of the governance and controls**

	sample plans that are fed into the model as plan data input	The review and challenge process to approve the SE plan universe selection process is found to be appropriate with scope for potential improvement • There are multiple review and reconciliation procedures conducted by both the third-party contractor and PRAD team members to ensure the database is free of errors • The weighting process is a manual process to test the weight iteratively until the total liability of the sample plans match with the total liability of all plans in any segment. The manual iterative process could potentially introduce noise and could be reassessed to understand if an automated process might be more accurate. An observation has been identified in this regard [R05] The reconciliation process is also properly logged and documented if any error is identified in the process PRAD team also holds frequent meetings to discuss if the selected demographic accurately captures the full plan universe. When issues are found, a series of meetings will be conducted to understand the materiality of the issue by using professional judgment to identify appropriate solutions. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures
1E. Bankruptcy probability calculation	**Description** Bankruptcy probability is calculated for every plan sponsor using variables such as credit rating, historical default rate. **Usage in the model** The bankruptcy probability is calculated to estimate how likely a plan sponsor will bankrupt and then result in a claim for PBGC	**Assessment of the conceptual risk** The bankruptcy probability calculation is found to be conceptually sound with scope for potential improvement given that: • The historical credit rating and default rate along with the financial and pension variables used in the calculation is appropriate and captures the underlying default risk of the company since a longitudinal file of bond ratings is collected from a database which is used to make empirical estimates of the volatility of bond ratings over time among firms that sponsor defined benefit pension plans • The recalibration process in the bankruptcy probability calculation currently normalizes the bankruptcy rate of the largest outliers with the means of the market estimate of bankruptcy risk for their class of bonds. This is a non-conservative approach that can potentially underestimate the claim liabilities. It is suggested to perform a sensitivity analysis to assess the impact of these outliers and explore a more conservative approach to recalibrate the bankruptcy probability to minimize the mismatch between credit rating and bankruptcy probability. Given there will be a new bankruptcy model in the T-PIMS development, limited reassessment might be needed for the current bankruptcy

		model. An observation has been identified in this regard [R06] The bankruptcy probability calculation is found to be consistent with the models' intended purpose since it gives an accurate estimate of how likely the sponsor is going to bankrupt and results in a claim **Assessment of the governance and controls** The review and challenge process to approve the bankruptcy probability is found to be appropriate given that bond ratings are captured through automated program to minimize manual errors PRAD team also holds frequent meetings to discuss if bankruptcy probability calculated captures the underlying default risk of the sponsor universe. PRAD also holds a biweekly Economist meeting where they dive into issues related to the bankruptcy model. When issues are found, a series of meetings will be conducted to understand the materiality of the issue by using professional judgment to identify appropriate solutions. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures
3H. Economic scenario generation	**Description** Generate a large number of stochastic scenarios with various economic variables based on historical data and market expectations **Usage in the model** The economic scenario generator produces ~500 scenarios for the PIMS model to project cashflows under different economic environments	**Assessment of the conceptual risk** The conceptual soundness and functionality of the economic scenario generation is assessed in detail in Section 4 **Assessment of the governance and controls** The review and challenge process to approve the economic scenarios is found to be appropriate with scope for potential improvement: • All generation procedures are automated in SAS, minimizing potential manual errors • Part of the review process of the generated scenarios are manual through spot checks. The manual review process could be reassessed to understand if automated process might be more reasonable. PBGC could explore a structured review process such as point-in-time validation and in-sample validation. Given there will be an in-house new ESG in python, limited reassessment might be needed for the current ESG. An observation has been identified in this regard [R07] Further, PRAD team also holds frequent meetings to discuss if economic scenarios generated can cover tail events. PRAD also holds a biweekly Economist meeting where they dive into issues related to the ESG. When issues are found, further investigation will be conducted to understand the materiality of the issue and appropriate resolution is identified. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures

4. Plan cashflow simulation	**Description** Project plan level asset and liability and calculate claims amount if the plans go bankrupt **Usage in the model** The plan cashflow simulation uses model inputs and scenarios to project plan level liability and asset cashflows	**Assessment of the conceptual risk** The plan cashflow simulation is found to be conceptually reasonable given that the logic used to calculate the plan liabilities and assets over the projection period reflects the experience of a potential claim: • Firstly, exposure and risks are considered at time zero for a single defined benefit pension plan and a one-period expected loss is derived • Secondly, risk and exposure changes over one period are considered, and the two-period expected loss from the perspective of period zero is determined • Finally, the approach is expanded to many periods The plan cashflow simulation is found to be consistent with the models' intended purpose since it reasonably reflects how a potential claim will be generated under the circumstances of sponsor bankruptcy and how the cashflow will be impacted However, the existing plan cashflow calculation has limited flexibility to model larger structural changes (e.g., premium structure change). Potential improvement to add the capability to customize the model to perform impact analysis due to premium changes is recommended for TPIMS. A model limitation has been identified in this regard [ML02] **Assessment of the governance and controls** The review and challenge process to approve plan cashflow is found to be appropriate given that the simulation is automated minimizing potential human errors Further, PRAD team holds frequent meetings to discuss if the cashflows generated accurately reflect the expected claim experience. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures
4. PBGC cashflow simulation	**Description** Projects PBGC's potential financial position by combining simulated claims with simulated paths for premiums, expenses, PBGC's investment returns, and changes in PBGC liability; that is, the present value of benefits and expenses payable pursuant to claims recognized by PBGC **Usage in the model**	**Assessment of the conceptual risk** The PBGC cashflow simulation is found to be conceptually reasonable with scope for potential improvements: • The key components of PBGC liabilities and assets are captured including the changes in claims, premiums, fixed and variable expenses resulting from managing the pension insurance program, and investment gains or losses from the asset portfolio. • PIMS does not model PBGC's asset allocation during the transition period of the terminated plans, which could result in an imprecise estimation of PBGC's surplus. Consideration could be given to refining the asset allocation calculation for terminated plans in the future version of PIMS. An observation has been identified in this regard [R08]

	The PBGC cashflow simulation uses plan-level cashflows and PBGC's current financial position to project PBGC liability and asset cashflows	The PBGC cashflow simulation is found to be consistent with the models' intended purpose since it accurately reflects how PBGC cashflows will be impacted when a sponsor bankrupts and results in a claim **Assessment of the governance and controls** The review and challenge process to approve PBGC cashflow is found to be appropriate given that the simulation is completely automated, minimizing potential human errors PRAD team holds frequent meetings to discuss if cashflows generated accurately reflect the expected PBGC experience. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures
5. Post-processing	**Description** Aggregate the plan/scenario results from the simulations to produce PBGC's stochastic net position **Usage in the model** Post-processing tool aggregates PBGC cashflows under various scenarios and create charts and tables for the Projection Report	**Assessment of the conceptual risk** The post-processing is found to be conceptually reasonable given that the process aggregates plan/scenario results from the model outputs to project PBGC financial position • PBGC assets, insolvency year, and PBGC net position will be projected using the aggregated output. • PBGC assets are projected stochastically whereas the PBGC net position are shown as percentiles Although the post-processing tool offers a comprehensive view of the model outputs, it provides limited transparency in the calculation process, making it challenging to review the outputs thoroughly without clear instructions on how to navigate the workbook. Frequent clean-up or review of the post-processing tool is recommended to ensure that it is user friendly. An observation has been identified in this regard [R09] Further, the current output from the post-processing is at the aggregated PBGC level. Potential enhancements to build capabilities to run the custom analysis of model outputs at segment level (e.g., plan-level projection, cashflows by scenarios, etc.) could be considered. A model limitation has been identified in this regard [ML03] **Assessment of the governance and controls** The review and challenge process to approve post-processing process is found to be reasonable given that the post-processing tool is completely automated, minimizing potential human errors PRAD team holds frequent meetings to discuss if charts and tables generated reflects the expected patterns over the projection period. Projection crosswalks are also conducted to show how projections change by changing input/assumptions step by step in sequential order. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures

3 Assessment of operations

The assessment of operations for the Single-Employer (SE) PIMS model is conducted along the model use and implementation dimensions as detailed in Section 3.

3.1 Assessment of operations: use

SE-PIMS is primarily used by PRAD and applicable PBGC contractors for a variety of purposes including several published reports and internal analyses. Key outputs such as the annual PBGC Projection Report provide an actuarial evaluation of PBGC's future expected operations and financial status. The SE-PIMS model is used to project long-term financial outcomes for PBGC. Projecting PBGC's financial position informs not only the PBGC's future planning, but also gives stakeholders a better understanding of the range of financial risks faced by PBGC. Given the primary goal of the SE-PIMS model is to forecast the range of Single-Employer claims for PBGC over future period, alignment of model uses to produce an actuarial evaluation of PBGC' future financial position is appropriate with the scope and approved uses of the SE-PIMS model.

Several model users and stakeholders are involved in the process to produce an actuarial evaluation of PBGC's future financial position using the SE-PIMS model. An inventory of current/former users/stakeholder, roles of users/stakeholder, and their responsibilities regarding the use of the model is included below:

Roles	Responsibilities regarding the use of the SE-PIMS model
Model developer 1	• Support data contractors update plan data from Form 5500 and perform reviews their work for SE-PIMS model • Perform selection of new plans for SE PIMS model to add into the sample plan pool based on liability ranking of the plans
Model reviewer 1	• Review and challenge the model outcomes by participating in PRAD weekly meetings and discussing model results for reasonability • Work on specific legislative impacts on the model and incorporating legislation into the model as applicable
Model developer and economist 1	• Own plan weighting process for SE model: the weighting process takes the plan data and assign weights to each of the plan so that the total weighted plan liability equals to total liability of all plan universe • Utilize the bankruptcy probability tool to calculate bankruptcy probability for each company and compare it to the credit rating and historical default rate to see if there is material discrepancy • Set and update economic assumptions and generate economic scenarios
Model developer 2	• Own parameters update of the SE model, which is a collection of data input by working with contractors, approving code changes, and approving software change requests • Run SE models to test all changes made to the SE model and compare model results prior and after the changes to see if the outcomes are reasonable

Model owner and reviewer 1	• Oversee the PIMS modeling process by reviewing results, directing assumption setting, and sign reports and help establish project plans and timelines of the overall Projection Report process
Model reviewer 2	• Review model assumptions and results in a group meeting format to assess reasonability of outputs
Model reviewer 3	• Review the model outcomes on the high level and use crosswalk to check for tracking unexpected trend or numbers • Develop the assumptions for SE model and review assumptions with the PRAD team
Model developers 3 as contractors	• Maintain and update SE model based on requirements and instructions provided by PRAD • Review and validate model results after model changes and document the mode changes
Model reviewer 4	• Review the model results at the high level and use crosswalk to check if the results are appropriate • Help develop the assumptions for SE model such as divesting and sponsor underfunding assumptions
Former model developer 1	• Handled post-processing of the PIMS model outside of the core model and check if the results are expected • Maintained and updated PIMS model to add new functionality to the model
Model owner 2	• Review PIMS model results and set assumptions and methodologies of the PIMS models • Sign off the Projection Report
Key stakeholders from Department of Labor and Employee Benefit Security Administration	• Use PIMS model reports as supporting materials for policy analysis • Approve the investment policies for PBGC based on PIMS model outputs provided
Key stakeholders from Congressional Budget Office and Joint Committee on Taxation	• Use PIMS model reports as supporting materials to estimate the impact of new legislation proposals • Use PIMS model outputs to evaluate effect of potential new tax policies
Key stakeholders from Department of Treasury	• Use PIMS model reports as supporting materials for policy analysis • Use PIMS model reports as supporting materials to review impact of new legislation and regulation
Key stakeholders from PBGC	• Approve the projection report • Review investment policy provided in the annual projection report • Review the impact of potential policy changes

Key stakeholders from PBGC	• Review the projection report • Use Technical assistance on requests regarding the model outputs

The SE-PIMS model is currently being used appropriately as each model user has specific responsibilities regarding the model and the assignment of responsibilities is clear. However, there is a lack of formally established roles and responsibilities at each phase of model development. The adoption of a roles and responsibilities matrix at each stage of model development is a common practice in the industry [R10]. Presented below is an industry-standard roles and responsibilities matrix.

Category	Model owner	Model developer	Model implementer	Model user
Model design & development	• Ensure the design and development of model occurs in line with the policy	• Provide leadership for model development activities comprising methodology, design, and prototyping	• Use the input provided from leadership	• Provide business specifications to leadership
Model implementation	• Ensure the implementation of the model occurs in line with the policy	• Provide input to model implementer	• Develop the implementation plan and ensure correct implementation	• N/A
Model monitoring & use	• Explain to model users and model output users assumptions and limitations of the model • Collect ongoing monitoring results and submit to leadership	• Propose ongoing monitoring plan	• Discuss proactively environmental changes with stakeholders	• Use the model and communicate issues to leadership • Provide ongoing monitoring data

Periodic peer review	• Ensure that the model fits its purpose • Ensure the model change is appropriate for its intended use • Ensure the model change is communicated to business leadership	• Provide the monitoring report to submit for periodic review • Provide updated model change documentation if applicable	• Provide implementation tests and controls to submit for periodic review • Provide implementation tests due to model change	• Use the model and confirms its fir for purpose • Perform the user acceptance test once model change is implemented
Monitoring of remediation	• Ensure the remediation actions are implemented within timelines	• Provide input to model implementer	• Implement the remediation action if applicable	• Understand the limitations of the model for its use
Compensating controls decisions	• Ensure the mitigation actions/compensating controls are in place for the model	• Implement the compensating controls	• N/A	• Understand the mitigation actions/compensating controls for its use
Regulatory responses	• Responsible for all regulatory requests	• Provide input for preparing the regulatory response if applicable	• Provide input for preparing the regulatory response if applicable	• N/A
Risk management	• Understand the model risk related of the model	• Understand the model risk related to the model they develop	• Understand the model risk related to the model they implement	• Understand the model risk related to the model they use

Further, the scope of work for third-party contractors is clearly defined and the review process to examine their work is reasonable.

Assessment of existing process to generate results

The process to produce model results for the forthcoming year commences after the release of the previous Projections Report. PRAD collaborates with its contractor to establish a list of desired model enhancements for the SE-PIMS models. PRAD monitors the existing issues or desired refinements within the model, taking into account the feedback from PRAD's debriefing on the most recent Projections Report. The contractor team implements model changes, while the PRAD team performs the user acceptance testing. The existing outputs of the SE-PIMS include PBGC's net financial position, investment income, and net new claims, as well as percentile ranges. The current procedures to generate the model outputs are described below:

- PRAD generates the Statistical Analysis System (SAS) output report from analysis of data produced by SE-PIMS. The SAS output report is generated by the SAS software used to analyze the output data in accordance with the parameters set by the PRAD user. The post-processing tool that mimics the SAS post-processing routines can also be used in lieu of SAS or used to verify the SAS output. Excel templates augment the post-processing/analysis of output as needed.

- The specific PIMS Run Report Summary for each respective data-producing run is obtained. The Run Report Summary indicates unique identifiers of the run, such as the report run date, time, by which user, the run name, run identification number, the file to which the results were extracted, the source of the data, and the identification numbers for various input tables used within the PIMS run.

- PRAD staff utilizes either the SAS or post-processing output report to create Excel documents to display the resulting data in the Projections Report. This includes, but is not limited to, transfer of data to a standard set of Excel files as needed for analysis. When the Projections Report is close to completion, a Word document is linked to such Excel files via a mail merge.

The current process to produce model results is appropriate given that there is clearly defined ownership for each step of the process and an established review process to examine the reasonableness of the results. Specifically, the third-party contractor is responsible for drafting a list of desired model enhancements at the beginning of the process and making model changes accordingly based on decisions made by PBGC. There is a primary owner in PRAD of the SE-PIMS model responsible for reviewing the parameters that feed into the runs and running the models. While the output generation process is appropriate, there are potential areas of improvement as described below:

- **Governance around fine-tuning of model parameters**: Fine-tuning model parameters is an important step in producing accurate model outputs. While there is existing process in plan to review and update the parameters each year, PBGC could create a documentation that specifies what parameters have been reviewed and updated in the recent past and what parameters are planned to be reviewed in the near future [R10]

- **Combining post-processing files from multiple sources**: Some files in the post-processing and aggregation process use an automated approach to populate the model outputs from Windows explorer into an instance of Excel with values in separate cells. However, some of the post-processing / aggregation

is still performed in Excel and/or SAS. In those cases, it is a manual process to copy/paste the values from either another Excel workbook or SAS output file. With both the automated and manual population of the model outputs into the post-processing process, it could potentially lead to many individual Excel workbooks being created in the process. PBGC could consider integrating these Excel workbooks used in the post-processing process into one or multiple major files so that it is easier to implement governance and controls around the files (e.g., version control, change management, etc.) [R11]

The SE-PIMS generates aggregate output files, which are used to produce a series of charts and tables used in the Projection Report. The current process to produce the relevant charts and tables is to use Excel spreadsheet to import the raw model output, make necessary calculations to arrive at the intended results, and summarize the calculated results in chart or table format.

Assessment of the existing controls

Several controls are in place around the SE-PIMS model that mitigate the risk in the operational environment.

- **Security controls related to model access:**
    - Access to SE-PIMS is controlled through the Office of Information Technology's (OIT's) "GetIT" application request process. An appropriate PRAD staff member, as designated by the PRAD Director, approves system access.
- **Change management process and controls:**
    - The SE-PIMS programming staff is responsible for preparing a software change request and requesting changes to PIMS. Changes to programming code will be made in the development environment of PRAD. After completion, a PRAD staff member will review the changes to ensure the changes are implemented appropriately and to assess whether any other changes were made to the existing version.
    - If additional work is necessary, PRAD will inform the PIMS programming contractor. Each item raised by the PRAD staff member is resolved or otherwise addressed to the satisfaction of the PRAD staff member and appropriately documented.
    - After all of the work is complete, the updates to the code will be approved, documented, and pushed to the Quality Assurance environment of PRAD. Additional tests (e.g., running output reports) will be performed by PRAD staff to ensure that the new code will operate effectively in the Production environment. If no problems are noted, the new version will be moved to the Production environment (the PIMS programming contractor staff members have no access to the Production environment). New versions of PIMS will be deployed to Production according to the PBGC Release Management Procedures.
- **Process to log model results:**

- Different versions of the model results are organized on PRAD's P drive and SharePoint site and are reviewed internally. Each folder is named appropriately to reflect the purpose of the model run (e.g., used for internal purposes or official release of the report, or sequential changes of the model across crosswalk). The files are also labeled appropriately to reflect version controls.
- Any numbers from these excel files that are used in the Projections Report are subject to a detailed transcription process that traces every number to its root source and is reviewed by PBGC's contractor and an actuary from a different PBGC department.

- **Process to track open model related issues:**
  - A running list of potential model improvements is maintained for the SE-PIMS model and is discussed with the model owners and contractors. Each year after the Projections Report is issued, PRAD reviews this list and prioritizes the model enhancements. This is performed based on the assessed materiality of the potential changes.

The current controls in place to ensure the operational stability of the SE-PIMS model are appropriate with potential scope of improvements:

- **Establish a formalized model attestation process for use**: to ensure the SE-PIMS model is appropriately used by users, it is ideal to implement a formalized model attestation process for each use. This process should be continuously updated and maintained to ensure the model uses are appropriate and up to date. This establishes transparency and accountability in the model usage [R12]
- **Create formal documentation to track open model related issues**: while there is a running list of known issues for the SE-PIMS model, it is important to establish a continuous tracking mechanism. This involves documenting closed issues and creating a mitigation plan for open issues [R12]

3.2 Assessment of operations: implementation

Assessment of model replication and implementation

Replicating the SE-PIMS model is important for testing its accuracy and reliability and identifying errors and inconsistencies in implementation. PBGC utilizes an independent excel spreadsheet to develop claim estimates by performing actuarial roll forwards at plan level. Even though the process does not mimic the full calculation in the model, this process helps PRAD verify the claim estimates at the plan level. PBGC could also consider integrating the key calculation logic in the model into the current spreadsheet.

Further, to ensure the implementation of SE-PIMS does not contain errors, both inputs and outputs are reviewed and documented. The SE-PIMS inputs are saved in a database and each of the input parameters used for a specific run are saved in a separate file along with the standard run output. Any inputs that were changed from the prior year's version of the SE-PIMS are checked/reviewed and documented. To facilitate a review of changed

parameters, a “diff tool” such as Beyond Compare or Exam Pro Diff is used to compare SE-PIMS files. Due to file size considerations, the comparison may be performed after removing larger input tables and saved in shared location. PRAD internal review of SE-PIMS input data includes economy data, regulatory inputs, firm data, and plan data. The review typically includes the following:

- Verify correct/properly estimated historic data is entered into the SE-PIMS input data fields
- Verify correct updates were entered into the database tables
- Verify modeled values for stochastic projection were correctly entered
- Verify that the correct corporations were identified as sponsors
- Verify the modeled firm weights were correctly entered into the SE-PIMS input data fields

The SE-PIMS outputs are reviewed to ensure reasonableness. The review typically includes the following:

- The growth of liabilities over the projection period, and its distribution over the plans in the sample
- Distributions of assumed contributions among plans and across years in the projection
- Distributions of funding levels, minimum required contributions, and actuarial charges and credits
- The projection of bankruptcies and corresponding claims events
- Examination of plans with results showing strong deviation from average patterns ("outliers") to justify unusual results for specific plans where appropriate. Exceptions are noted, and corrections made, where appropriate

The current implementation of SE-PIMS model is appropriate given that there are clearly defined review procedures in place to ensure the accuracy of the data input process and the reasonableness of the outputs generated. However, given the complexity of implementation, it is important to consider the following:

- **Establish a systematic training program**: it is important to establish a systematic training process that includes industry-standard training approaches. This involves conducting in-person training sessions, with a proper trainer-to-trainee ratio, to allow for thorough coaching and the practice of new procedures. The training materials could also reflect the size and expertise of the team that uses each model. It is also important to identify stakeholders and users who need to be trained, develop tailored training content with effectiveness checks and deliver training to all applicable individuals [R13]
- **Establish formal documentation on model implementation procedures**: documenting model implementation procedures is an important part of model risk management. It is important to include detailed descriptions of the steps involved in running the SE-PIMS model with clear and concise language. Periodic reviews must also be conducted to ensure that documentation remains up to date [R13]

Assessment of implementation platform

Currently, the modeling of the projected financial cashflows for the Single-Employer program is via the SE-PIMS platform. The platform handles processing the variable inputs, calculating plan-level asset and liability calculations, and generating a series of model outputs. The existing platform in which the SE-PIMS is implemented is appropriate given it has the necessary functions to perform the required calculation and the capability to produce proper model results in a flexible and timely manner.

- SE-PIMS organizes the variable inputs into several main database tables and operates via inputs from the "Run" table. which identifies the table identification (ID) values to be used in the SE-PIMS run. The "Run" table, in turn, utilizes the tables listed above and in Appendix B for the single PIMS run. Each table further utilizes source tables by assigning appropriate identification (ID) values in fields (i.e., columns). These IDs direct SE-PIMS to the appropriate source table(s) and input data value.
- SE-PIMS generates the Statistical Analysis System (SAS) output report from analysis of data produced by PIMS. The SAS output report is generated by the SAS software used to analyze the output data in accordance with the parameters set by the PRAD user. The c# post-processing tool that mimics the SAS post-processing routines can also be used in lieu of SAS or used to verify the SAS output. Excel templates augment the post-processing/analysis of output as needed.
- The specific PIMS Run Report Summary can be obtained for each respective data-producing run. The Run Report Summary indicates unique identifiers of the run, such as the report run date, time, by which user, the run name, run identification number, the file to which the results were extracted, the source of the data, and the identification numbers for various input tables used within the PIMS run.

4 Assessment of functionality and performance

The assessment of model functionality and performance for the Single-Employer (SE) PIMS model is conducted to examine whether the SE-PIMS model is functioning consistently with its design and documentation as well as how modeled results compared to actual outcomes. Specifically, the effectiveness of the economic scenario generating process, stress testing, sensitivity analysis, and back testing is examined to assess the suitability of the modeling approach and appropriateness of judgmental aspects of the model.

4.1 Economic scenario generator

SE-PIMS model uses stochastic based simulation to project long-term financial outcomes of the single-employer pension plans PBGC insures. The model then introduces random year-by-year changes to simulate economic fluctuations, producing 500 simulations for alternate economic paths through time. In this section, an assessment of the effectiveness of the current economic scenario generator (ESG) at capturing the full range of potential outcomes, including any recommended improvements and industry best practices is covered.

The existing ESG uses a core model with two variables being fully stochastically generated: the yield on 30-year Treasury bonds and the return on the S&P 500 stock index. The Treasury bond yield is critical to SE-PIMS as it provides the foundations for the Treasury returns, cash rate and returns, and the discount rate for pension plan liability calculation. The return on the S&P 500 stock index also directly affects the projected pension plan returns and market value. All other economic variables that are projected (e.g., inflation, plan investment returns, corporate bond yields, PBGC's discount rate, etc.) are derived from those two core variables.

The Treasury bond yield follows a random walk:

$$ln(y_t) = ln(y_{t-1}) + \varepsilon_{y,t}$$

The disturbance term transitions the mean over time to a target expectation. Since the ESG chooses to model the logged 30-year Treasury yield, the possibility of negative yields is eliminated.

The equity return is modeled with the log of its spread over the Treasury yield equaling a fixed mean plus noise:

$$ln\left(1 + r_{s,t} - y_{t-1}\right) = s + \varepsilon_{s,t}$$

The risk-free rate is taken directly from the simulated Treasury yield while the equity excess return follows a lognormal distribution.

The core model parameters are estimated using an iterative process of running simulations using test values of core model parameters and the measuring the nominal return means, standard deviations and correlations from the simulation output. The test values are adjusted until the projection statistics match the study parameters. The values for the nominal stock return parameters were originally based on a study done for PBGC by Ibbotson Associates in 2008. The mean and standard deviation have since been slightly adjusted by PRAD using additional stock market historic data. The nominal return parameters for FY19 PIMS are:

- Mean return on stocks: 7.9%

- Stock return standard deviation: 19.8%
- Correlation between stock and treasury bond returns: 0.209

Treasury yield	Year 1	Year 5	Year 10	Year 20
25th quartile	3.18%	2.53%	2.24%	1.90%
50th quartile	3.49%	3.08%	3.03%	2.92%
75th quartile	3.86%	3.84%	4.17%	4.66%

Equity return	Year 1	Year 5	Year 10	Year 20
25th quartile	-2.55%	-4.60%	-4.29%	-6.01%
50th quartile	8.49%	7.52%	7.60%	6.10%
75th quartile	24.05%	19.61%	20.63%	20.43%

Source: 500 scenarios generated from PIMS ESG

Assessment and recommendations

It is generally expected that minimum requirements of an ESG would include the production of simulation results that reflect a relevant view of the economy and certain financial variables, the inclusion of some extreme but plausible results, and the generation of scenarios embed realistic market dynamics. The current ESG used by SE-PIMS has a sound foundation for the way the models are built and the way the variables are interrelated but potential areas for refinement are also found.

Core model approach

The core model approach provides a sound foundation to capture the economic variables of greatest importance to the risk profile of PBGC. The stochastically generated core variables with a series of derived variables are not uncommon approach to model ESG in the industry. While the core variables selected are able to capture the key risks in the capital markets, additional factors such as GDP, unemployment rate, etc., can be considered to build a comprehensive view of the macroeconomy [R13]. In addition, industry segmented variables can also be considered in the ESG to reflect how different industries will be impacted differently under the same economy scenario [R14]. The ESG should be comprehensive to include the key risks to capture segment risk factors.

The ESG has clearly defined parameters and a well-articulated calibration process and. While the process for developing the stochastic variables is clear and the parameters are well defined and logical, the following potential areas for refinement could be considered to enhance the ESG functionality as the new ESG being developed in the T-PIMS model:

- **Incorporate negative treasury yield**: the current approach to model treasury yield eliminates the possibility of rates going below zero. While it is less likely to happen, Japan and European countries have experienced negative bond yields in the past. Since treasury bond exposure accounts for a significant portion of the plan and PBGC assets, ESG must allow possible negative yields for treasury yield. [R14]

- **Simulate equity return independently**: the current approach to model equity return is using risk premium as excess returns over treasury yield. This process of stochastically projecting equity excess return based on the risk premium on top of the interest rates limits the model's ability to capture varying relationships throughout the economic cycle. Independently simulating the equity return instead of modeling a risk premium would better capture the randomness of equity market. The correlation between treasury bond and equity return would be captured by the correlation factor [R14]

- **Calibrate correlation between treasury bond yield and equity return:** the current correlation between stock and Treasury bond returns is weakly positive (0.209). While it is possible to experience a positive correlation between stock and treasury bond returns in left-tailed events, these two variables are generally observed to have negative correlation in normal market conditions. PBGC could recalibrate the correlation between treasury bond yield and equity return with the latest data to ensure the correlation factor reflect market observations [R14]

- **Assume dynamic correlation between stock and treasury bond returns:** the current correlation between stock and Treasury bond returns is using a fixed parameter of 0.209. PBGC could apply dynamic correlation between stock and treasury bond returns to mimic how correlation changes under different economic scenarios [R14]. Sample approaches may include:

    - **Jump-diffusion approach**: this approach implicitly captures dynamic correlation. Such approaches, at each time step, combine an initial Monte Carlo simulation step (diffusion) using the long-term historical correlation value followed by random shock events (jumps) to the simulated variables (i.e., yield and equity risk premium). Shock event frequency and magnitudes can be determined based on observed historical shock events.

    - **Regime-switching approach**: this approach switches between different explicit correlation values depending on the state of economy (e.g., expansion vs recession).

- **Consider stochastic modeling of spread of corporate rate over Treasury yield:** the current approach to model long-term corporate rate is the Treasury yield plus 110 basis points. If the starting point of the yield has spread different than 110 basis points, the initial spread is assumed to revert to mean. The flat spread may not be able to capture the actual movement of corporate bond in the real world. Since corporate bond exposure accounts for a significant portion of the plan assets, it is critical to reflect the impact of corporate bond in valuation of liabilities and funded status [R14]

- **Consider more frequent parameter calibration:** the values for the nominal stock return parameters were originally based on a study done in 2008 and they only capture the period from 1973 to 2007. While the process for modeling equity returns is logical, a best practice would be periodically tested to ensure the parameters remain consistent with the evolving nature of the markets. Common industry practice is to calibrate the parameters once a year [R14]

4.2 Sensitivity analysis

Sensitivity analysis helps examine how changes in key assumptions affect the SE model results and inform PBGC to take appropriate measures to mitigate associated risks. Sensitivity analysis involves applying shocks to specific variables and analyzing the impact of changes on the asset and liability projections.

Currently, PBGC performs and publicly discloses two sensitivity analysis every year.

- Changes to the discount rate: only the discount rate for calculating PBGC liability values is changed; no other related variables, such as inflation or asset returns, are changed in the sensitivity calculations. The increase and decrease of 50 basis points are applied to the discount rate, and the net financial positions post shocks are compared to that in the baseline scenario to understand the impact of the changes in discount rate.

- Changes in assumed plan de-risking activity: these de-risking actions include retiree bulk annuity purchases and voluntary standard terminations modeled by the SE-PIMS. For bulk annuity purchases, the baseline model assumes in each year there will be an 8% chance that a plan above 80% funded will undergo a bulk retiree annuity buy-out transaction to transfer 40% of its retiree liability to an insurance company. Voluntary standard terminations are modeled using parameters from an econometric analysis, based on the funded level of the plan, participant count, and whether the plan continues to offer future benefit accruals. Three sensitivity scenarios are conducted: double the assumed retiree annuity purchases only, double the assumed voluntary standard terminations only, and the combination of the previous two.

In addition to the sensitivity analysis currently disclosed by PBGC, other sensitivity analyses observed in the industry and could further enhance the analytics of the SE model include the following:

- Wider range of changes in discount rate: The +/- 50 basis point sensitivity is helpful in that it shows what the impact is for a defined change in the interest rate used for valuing PBGC's liabilities without changing other variables (e.g., the segment rates used to calculate plans' funding targets are not affected). However, rapidly raising interest rates in the past few years have demonstrated a more volatile rate movement pattern, e.g., the starting discount rate for PBGC liability moved from 0.44% in 2021 to 5.12% in 2022. PBGC could perform +/- 100bps and +/- 200bps to observe the marginal impact of cumulative interest rate movements.

- Mortality improvement: Longevity risk is a key risk in defined benefit pension programs. Therefore, PBGC could consider performing sensitivity analysis around mortality improvement.

- Changes in premium structure: the current PBGC premium structure has a risk adjustment mechanism built in (e.g., when funding level drops below certain level, the variable rate premium kicks in). However, some market participants have viewed the premium structure and premium level to have certain limitations especially around sustaining and growing define benefit pension programs. A recent academic research paper[1] suggests changes to the premium structure to better achieve PBGC's overall missions. It might be prudent to perform sensitivity analysis based on the research paper to assess how potential changes to PBGC premiums may impact the PBGC's financial position.

- Bankruptcy probability of plan sponsors: the default of plan sponsors is a key risk in the Single-Employer program. PBGC could perform sensitivity analysis around the probability of bankruptcy of plan sponsors.

PBGC may consider expanding its sensitivity analysis to continue enhancing model functionalities of the SE PIMS model [R15].

4.3 Stress testing

Most scenarios in the current SE-PIMS model project a positive position in FY2032 based on the FY2022 Project Report. As the SE-PIMS may not capture all types of extreme events that PBGC could face in the future, it is informative to consider extreme events that may pose risks to the financial health of the Single-Employer Program.

The current PBGC's illustrative stress test scenario was designed to represent a high-claims event with a market downturn and elevated rates of bankruptcy. The scenario includes a one-time 33.5% drop in equity values for PBGC and plan assets (resulting in a 20 percent reduction in the median asset return for plans in the first year of the projection) and increases in bankruptcy rates such that PBGC incurs more than $35 billion in new claims from FY2023 through FY2028. All other model assumptions and methods in SE-PIMS remain unchanged from the baseline run.

The current approach of using an illustrative stress test scenario is to evaluate how the Single-Employer Program would respond to in one adverse event, allowing PBGC to gauge the effects of the specific hypothetical adverse market condition on the program. PBGC could expand stress testing to multiple scenarios to assess PBGC's financial health under extreme macroeconomic conditions.

For narrated stress scenario analysis, besides equity market shocks, examples of stress scenarios utilized in the industry that could further enhance the analytics of the SE model include the following:

- Interest rate risk plays a significant role as it can have significant implications for the funding plan with fluctuation in interest rates. Therefore, a range of interest rate changes can be implemented in stressed scenarios instead of a single shock.
- Liquidity crunch: a situation where there is a sudden systemic shortfall in liquidity, similar to the 2008 financial crisis. This may cause a large number of pension sponsors failure to fulfill pension obligations and PBGC premiums thus resulting in an increase in bankruptcy.
- Pandemic: a global outbreak of a disease, such as the COVID-19 pandemic, affects a large number of people across multiple countries or continents, and causes increase of mortality rate, extreme volatility of capital market, rising inflation, and unexpected economic shifts.
- Geopolitical unrest: based on historical events and their subsequent impact on macroeconomics and capital market, developing scenarios that represent potential capital market volatilities and other unforeseen economic consequences.

Besides narrated stress scenarios, the leading practice employs advanced reverse scenario stress testing approach. This approach involves generating a large number of scenarios (e.g., 10,000) with built-in shocks that covers a wide range of possible adverse scenarios. Run the model through the scenarios and examine the resulting net positions. Short-list the tail scenario to develop scenario narrative to analyze potential risk factors and management risk remediation actions. This reverse stress scenario analysis can help identify the “unknown unknown” and better prepare PGBC for unforeseen risks.

PBGC could consider a variety of stressed scenarios to stress test the model by running different shocks to key risk factors to evaluate how the Single-Employer Program would respond to a variety of adverse events [R16]. PGBC could review key assumptions, e.g., default probability, under each stress scenario and adjust those assumptions according to the specific scenarios in the model projection.

4.4 Back testing

Back testing is important because it would help assess the accuracy of the SE-PIMS models, identify model weaknesses, and evaluate the effectiveness of risk management strategies.

Although PRAD has previously considered implementing back testing in past years, they have encountered challenges, partly due to evolving regulations that made comparing past projections to the current net position challenging. Additionally, modifications to the model over time can pose obstacles when attempting to run data from previous years with updated code reflecting legislative changes). The absence of formal back testing procedures may impede PRAD’s capacity to comprehensively assess the risks within the SE-PIMS model.

Back testing allows for a comparison of the SE-PIMS model’s performance against historical or comparable data sets. Three types of back testing are commonly observed in the industry for statistical and risk models:

- **In time, in sample back testing**: this is a comparison of the actual historical results there were used during the period the model is calculated to the predicted model outputs.
- In-time, out-of-sample back testing: this is a sample created setting aside, for use in back-testing, data observations from the same time period as the modeled sample.
- Out-of-time back testing: this is a sample created using observations from different time period than the in-time data (e.g., the in-time data could be from 2007 to 2015 and the out-of-time data would come from either before or after that range.

Since SE PIMS is an actuarial model, the “in time, in sample” back testing methodology is deemed most suitable for PBGC, as the other approaches are more commonly utilized for statistical or advanced analytical models. “In time, in sample” method involves comparing historical results during the period the model is calculated to the predicted outputs. However, given the complexity of the SE PIMS model and frequent legislative changes, additional considerations may be necessary to implement back testing for the SE-PIMS model [R17].

- **Implement a component based back testing approach**: one approach is to adopt a component-based back testing approach, which involves conducting separate back testing on key components of the model, such as key assumptions, asset projections, liability projections. This would enable PBGC to assess the functionality of model components and identify any potential weakness.
    - Key assumptions: Back testing could focus on key assumptions of the SE PIMS model, including the following:
        - Sponsor bankruptcy: compare the projected sponsor bankruptcy to the actual bankruptcy occurring during the modeled period. However, back testing of this assumption may be challenging due to the infrequency of bankruptcy event.
        - Plan Contributions: compare the projected plan contributions to the actual contribution during the modeled period.
        - Mortality assumption: compare the projected mortality with the actual mortality happened during the modeled period.
    - Cashflows projections/model outputs: besides the key assumptions, potential external factors could also be examined during back testing
- **Implement a macro-overlay to incorporate changes in external factors**: When performing back testing for cash flow projection and model output, PBGC might employ a standard approach (e.g., comparing actual to model projected outputs), and subsequently overlay macro-level adjustments (e.g., adjusting aggregate model outputs) to reflect recent or anticipated external changes.
        - Changes in plan population: changes in plan population pose a challenge as plan information is refreshed annually and would not be included in past models, resulting fluctuations that are challenging to integrate into the standard back testing process. A potential solution could involve utilizing a macro-overlay to account for the impact of changes in plan populations
        - Changes in capital market: fluctuations in the capital market, including shifts in discount rates and actual equity returns, could be captured using a macro-overlay informed by pertinent sensitivity analyses
        - Sponsor bankruptcy: Given the volatility of bankruptcy occurrences, incorporating actual bankruptcy events through a macro-overlay could help bridge the variance between the model projection vs. actual bankruptcy events
        - Pension policy changes: Analyzing the impact of policy changes would necessitate further qualitative analysis by experts to comprehend how these changes would affect the model outputs

For each test, it is important to define and justify:

- The performance metrics being used to evaluate the model's performance. Examples include the following:
    - The net financial position
    - Liability/asset projections on the aggregate levels as well as selected key plans (e.g., the largest plans, select samples from different funding levels)
- The threshold of acceptable error for each test, which could consider past performance, the methodology, and the output being modeled. Once the test passes the threshold of acceptable error, further analysis could be considered to examine the cause of the additional difference
- Whether the result of the test highlights a limitation in the model, and if so, how that limitation will be mitigated

5 Assessment of documentation

The assessment of model documentation for the Single-Employer (SE) PIMS model aims to examine whether the model documentation is comprehensive, readable and consistent, while also assessing the adequacy of the existing governance around model documentation.

5.1 Assessment of model documentation

As a key component of the model lifecycle, documentation should be maintained throughout the process, covering model context, inputs, methodology, outputs and implementation. Documentation for the SE PIMS model is available for most stages of the model lifecycle. The assessment below will be conducted on the existing documentation for the SE PIMS model.

'Pension Insurance Modeling System: PIMS system description' document offers an extensive overview of the SE PIMS model. It provides detailed explanation of the SE PIMS model, including the inputs and outputs, methodological approaches, and supporting evidence along the development process of the SE PIMS model. Specifically, the document comprises seven distinct sections:

- Section 1: presents a discussion of the conceptual background for developing a simulation model of pension insurance. It describes simplified examples of how the pension insurance system operates, compares pension insurance with other types of insurance, and review theoretical studies of pension insurance
- Section 2: describes the core of the PIMS, including the variables, parameters estimates, and key relations that drive the results. Illustrative results from the model are also presented
- Section 3: explains the actuarial valuation process used in PIMS to perform the calculation to determine financial implications under a defined benefit pension plan
- Section 4: introduces the approach used to determine operations and net financial position of PBGC in PIMS
- Section 5-6: presents the fundamental methodology of modeling key variables and assumptions
- Section 7: provides a systematic overview of the simulation process, including the major components of PIMS, the data types in PIMS, simulation program flow, and output produced by PIMS

Another key document for the SE-PIMS model is *Quality Assurance Procedures for Formal PRAD Reports utilizing the PIMS*, a manual outlining policies and procedures for generating specific reports that rely on the use of the PIMS model. Additionally, it provides step-by-step instructions to run, use, monitor, and troubleshoot the SE PIMS model in a safe manner. This manual comprises eight distinct sections:

- Section 1: presents an overview of the PIMS manual, including the policy around PIMS model, the authority governing the release of PIMS reports, and roles and responsibilities for the PIMS model

- Section 2: explains the ongoing oversight and monitoring of the PIMS model
- Section 3-6: describes the procedures for reviewing PIMS inputs, outputs, Projection Report, and other uses of PIMS
- Section 7: introduces the information technology considerations regarding the PIMS model such as access to PIMS, changes made to programming code, etc.
- Section 8: explains the record retention considerations of the PIMS model

In summary, the documentation of the SE-PIMS model is reasonable to be used as a model functional documentation, offering a comprehensive view of the model's construction, key assumptions, and utilized variables during the development process. It effectively covers the essential sections such as model purpose, methodologies, outputs and limitations. Moreover, the documentation achieves clarity employing several diagrams and numerical examples to simplify the technical aspects of the SE PIMS model. Consistency in formatting is also maintained across various sections. However, while the current documentation is appropriate, there exist potential areas of improvement, as described below [R18]:

- **Incorporating the rationale behind methodological choices**: Currently, the documentation lacks presentation of the rationale behind the choices of model methodology and key assumptions. It is crucial to document the supporting evidence and reasoning behind these model elements, as it helps the audience comprehending the logic behind the model calculation
- **Establishing a repository of model assumptions**: While the documentation outlines some key assumptions, it falls short of providing a comprehensive summary of all assumptions utilized in the model. A consolidated bank of assumptions helps model users in reviewing and validating their accuracy, thereby ensuring the model's adequacy
- **Clearly articulating all model limitations**: Although the existing model documentation lists certain model limitations, not all are addressed. Clearly stating all limitations of the model documentation is suggested to keep users informed about potential constraints affecting the model results
- **Regularly updating information:** Certain information presented in the document either requires revision by PRAD or necessitates updating (e.g., fixed real interest rate being revised, asset investment options need to be updated, etc.). Frequent updates to the model documentation are suggested to ensure the accuracy of the information presented

The PIMS webpage serves as a key resource of information regarding the SE PIMS model, offering the following key resources:

- Archives of past PIMS reports: This includes Projection Reports, Five-Year Report, MPRA reports, and similar documents
- Information about PIMS: The webpage features published documentation pertaining to PIMS models, such as assumption memos, sensitivity tests, and the historical evolution of PIMS model

- PIMS peer review history: It presents a table documenting the final reports from previous PIMS peer reviews, as required by the MAP-21. These reviews are conducted by capable agencies or organizations that are independent of PBGC
- Publications: The webpage showcases past publications relevant to PIMS models or the broader pension industry

The existing PIMS webpage serves as a valuable supplementary documentation source for the PIMS models, offering a range of past PIMS reports and additional insights, such as assumption memos. The webpage effectively communicates information about the PIMS model using clear language and maintaining a consistent format. Furthermore, the information presented on the webpage is transparent and easily navigable.

5.2 Assessment of governance on model documentation

For ensuring the ongoing validity of model documentation, robust governance procedures are necessary, particularly to adapt to evolving changes of the PIMS models. Key governance procedures on model documentation observed in the SE PIMS model include (but not limited to):

- Management process: Clear procedures for updating the documentation, approval processes, and communication protocols are crucial. In the case of the PIMS model, the PRAD director holds overall accountability for documenting system changes of PIMS, ensures thorough preparation of any alterations of the PIMS documentation and oversees proper review of updated documents
- Version controls procedures: Adequate archiving and retention controls are essential to record and preserve all documentation versions. The PRAD record coordinator maintains a library of all supporting documentation, including archived versions
- Continuous enhancement: Given annual changes to the PIMS models, ongoing enhancement of documentation is vital to reflect the latest information utilized in the model. Documentation of PIMS projects displays alterations to the model, encompassing coding modifications, new parameters, data structure adjustments, and reviews of these changes. Project documentation communications primarily occur through emails, which are appropriately archived, including attachments containing relevant forms, checklists, and narratives
- Regulatory compliance of MAP-21: Ensuring documentation meets regulatory requirements and standards pertinent to model usage is important. PRAD ensures that statutory reports issued to Congress are indefinitely maintained, and all supporting documentation linked to PIMS reports must be retained for at least seven years

Although there are established governance procedures for model documentation, it's equally crucial to ensure that supporting documents and resources effectively educate model users to prevent any potential misuse, misinterpretation, or misrepresentation of the model or the model outputs [R19].

6 Assessment of the model governance

The assessment of the governance of the SE-PIMS model has been conducted within each section of the peer review. Provided below is a summarized table detailing the assessment for each component of the model along with its corresponding reference page in the report.

Section	Summary of the assessment	Page reference
Assessment of data: data preparation	**Observations:** • There is sufficient governance in place around the database given there is a series of automated tool for quality control purposes and a well-documented data dictionary is available for the PIMS models	• P19-20
As	**Observations:**	• P20-23

assessment of data: variable selection	• Sufficient data quality controls are in place for generating the variables given that the modeling process of economic scenarios uses an automated program in SAS, which runs the simulation of a series of economic variables and includes quality check procedures as part of the automated program	
Assessment of method	**Observations:** • The review and challenge process to approve the plan behavior assumptions and capital market assumption is found to be appropriate with scope for potential improvement. • Currently, there is no formal process defined where assumptions are reviewed, challenged, and updated as appropriate on a periodic basis. Potentially several of the SE plan behavior assumptions and capital market assumptions have not been updated in the recent past **Recommendations:** • Establish a systematic assumption review process to review the assumptions on a periodic basis and sufficiently document the review process that potentially includes materiality, sensitivity testing, and changes to assumptions used in the SE model	• P24-26

ology: assumptions		
Assessment of methodology: simulati	**Observations:** • The review and challenge process to approve the SE-PIMS simulation process is found to be appropriate with scope for potential improvement • PRAD team holds frequent meetings to discuss if simulation results capture the underlying risk of the plans. When issues are found, a series of meetings will be conducted to understand the materiality of the issue by using professional judgment to identify appropriate solutions. In addition, periodic peer review is also conducted by independent third parties on selected simulation procedures **Recommendations:** • Explore automated weighting process to improve the accuracy of the results. The demographic weighting process is mostly manual and iteratively performed. The manual iterative process could potentially introduce operational errors • The manual review process of the ESG could be reassessed to understand if automated process might be more reasonable. However, given there will be a new in-house ESG in Python, limited reassessment might be needed for the current ESG	• P26-30

on		
Assessment of model operations and performance	**Observations:** • The SE-PIMS model is currently being used appropriately as each model user has specific responsibilities regarding the model and the assignment of responsibilities is clear. However, there is a lack of formally established roles and responsibilities at each phase of model development • Some of the post-processing / aggregation is still performed in Excel and/or SAS and a manual process is used to copy/paste the values from either another Excel workbooks or SAS output files • PIMS models have multiple uses and multiple users of the model. A use attestation process is critical to ensure that the model is not used for unapproved/unlisted uses • PIMS model implementations are highly complex and the current training programs in place can potentially be improved. Further, given the materiality of the models, an end-to-end replication of critical components is important to ensure the accuracy of the implementation **Recommendations:** • The adoption of a roles and responsibilities matrix at each stage of model development is a common practice in the industry • Combining post-processing files from multiple sources to streamline the result generation process • Fine-tuning model parameters to ensure the accuracy of the model outputs • Consider establish a formalized model attestation process for use and creating formal documentation to track open model related issues • Establishing a systematic training program on model implementation and a formal documentation on model implementation procedures • Integrating the key calculation logic in the existing replicating process	• P30-38
Assess	**Observations:** • Key governance procedures on model documentation have been observed in the SE PIMS model, including procedures on management changes, version controls, continuous enhancement, and regulatory compliance **Recommendations:**	• P50-51

mentofmodeldocumentation	• Given the current absence of explicit governance regarding model limitation documentation, it becomes important to incorporate appropriate and comprehensive disclosures within the model deliverables to mitigate any instances of misuse, misinterpretation, or misrepresentation	

Appendix

Priority	Definition
High	The magnitude of the observation deems immediate remediation since the remediation is expected to result in significant model improvement. The observation affects the inputs, design, methodology, outputs, or use of the model materially
Medium	The magnitude of the observation is moderate and deems a timely resolution. The remediation is expected to result in moderate model improvement as it could potentially affect the structure, design, inputs, or use of one or more components of the model
Low	The magnitude of the observation is low and does not require a timely resolution, but remediation is recommended. The remediation of the observation is not expected to materially improve the model as it does not adversely affect the outcomes of the model