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SUBTASK 4.10 FINAL REPORT

IN-DEPTH TECHNICAL REVIEW OF SE-PIMS AND THE ME-PIMS MODELS

IN-DEPTH TECHNICAL REVIEW OF THE PENSION BENEFIT GUARANTY CORPORATION'S MULTIEMPLOYER AND SINGLE-EMPLOYER PENSION MODELS

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Contents

Introduction

In July 2015, the Social Security Administration (SSA) engaged the FTI Consulting team (FTI) to conduct an 18-month, in-depth technical review of the Pension Benefit Guaranty Corporation's (PBGC) single-employer (SE) and multiemployer (ME) Pension Insurance Modeling System (PIMS). Task 4 of the Statement of Work (SOW) consists of ten subtasks required for this in depth review - nine specific areas of review and a final report.[1] Three of the subtask reports were due at the end of each of the six-, 12- and 18-month periods (with approved extensions). This Subtask 4.10 final report consolidates the prior work and is comprised of:

- An executive summary giving an overview and synopsis of the preceding nine subtask reports;
- A summary and prioritization of our recommendations and suggestions for improving the models;[2] and
- The nine in-depth technical review documents from the preceding subtasks.

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[1] Social Security Administration, Evaluation of the Pension Benefit Guaranty Corporation's Pension Models, Description/Specification/Work Statement, page 14.

[2] Full citations relating to the conclusions in this report are provided in the included nine subtask reports.

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Actuarial Certification

While the authors and contributors to this report, including the nine subtask reports contained herein, are comprised of actuaries, economists and IT professionals, we note that the actuaries (i.e., identified with the MAAA credential) are members of the American Academy of Actuaries and collectively meet the Qualification Standards of the American Academy of Actuaries to render the opinions contained herein that are actuarial in nature.

Executive Summary and Overview

PIMS is a complex and in many ways elegant set of interrelated economic/financial models whose purpose is to provide insight as to PBGC's future liabilities, based on "…measures of the historical volatility of key factors…" affecting those liabilities, "…in particular interest rates, stock market returns, and corporate bankruptcy rates."[3] Those models, in turn, are based on bodies of knowledge and economic circumstances that are continuously evolving. Hence, there is a need to periodically reevaluate PIMS, along with the *amount* of past history properly assumed to provide reliable guidance. Relatedly (and as noted by Prof. Brown), one should also consider the need to temper historical probabilities with judgments, based on the best data available, as to the implications of changed circumstances with respect to both the solvency of plan sponsors (in the case of SE plans) and the future number of active plan participants (in the case of ME plans). Of those changed circumstances, globalization, automation and changes in industry regulation figure most prominently, and all of those forces have quite uneven effects across industries.

Many of our recommendations with respect to the substance of PIMS – as distinct from its management, and the communication of its output – flow directly from the foregoing considerations. For example, industry-specific trends in the number of covered workers are more germane to forecasting the solvency of ME plans than the economy-wide average currently employed.

In regard to our recommendations as to PIMS management and the communication of its output, a key issue is the system's already complex and operationally burdensome character. Notwithstanding notable improvements in recent years, that complexity, along with systemically inadequate documentation, continue to impede both the updating of PIMS in a technical sense and full and clear disclosure of its output, including the relationship of that output to other elements of the financial forecasting process.   Insufficient transparency can also conceal flaws in models such as PIMS, or lead to misinterpretation of their output.

While touched upon in our reports, two issues of a more substantive nature merit fuller study: (a) the desirability of replacing and/or supplementing PIMS with stress-testing scenarios of the kind employed by major banks, and/or market-based assessments of the risk to PBGC's portfolio; and (b) the desirable extent of system modifications and/or enhancements given the attendant costs. While our scope of work did not include the estimation of those costs (or, for that matter, the extent to which the agency's budget might accommodate such expenditures), cost-benefit calculations are clearly a prerequisite to pursuing select PIMS upgrades.

We have prioritized our recommendations ("1" –"3" from highest to lowest for the major) with consideration given both to likely impact on PIMS's projections and (but for the budgetary considerations noted above) relative ease of implementation. In reaching what, given our scope of work, must necessarily be only tentative estimates of likely impact and implementation requirements, FTI has relied upon its understanding of PIMS and the economic, financial and actuarial relationships influencing its output; our experience in economic, financial and actuarial modeling generally, as well as associated data processing and systems implementations; and the findings of the numerous research studies cited in other of our subtask reports.

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[3] "What Is PIMS?" April 27, 2011, page 1, http://www.pbgc.gov/documents/PIMS-Overview-2011.pdf.

Priority rankings for each recommendation are provided in the "Summary of Major Recommendations" table which follows, that summary also having as sub-headings the titles of the subtasks collectively comprising our assignment.   Both those titles and their order reflect a carefully thought-out approach to evaluating PIMS from a combined economic, actuarial and data-processing standpoint.

Next, in the main body of this report, the full text of each recommendation is sorted first by priority level (that is, all Priority 1 recommendations are grouped together, followed by all Priority 2's, etc.). However, within those priority groupings, recommendations follow the (logical) order of related subtasks.

The authors wish to emphasize that, subject to manpower and other constraints, PBGC staff have for some time been working to strengthen PIMS and related protocols along lines congruent with many of our proposals. We hope that our work will materially further that effort, and thank them for their help in providing information and review of draft conclusions during this quite ambitious review project.

Summary of Major Recommendations (Priority Levels 1-3)

Below we provide a list of our major recommendations, in order of subtask, further ranked by order of importance.

	Modeling of Macroeconomic Variables (Subtask 4.1)	Priority Level
(1)	To forecast wages and salaries, instead of the current approach, use the long-term trend in the SSA's Average Wage Index (AWI).	1
(2)	Consider unionization trends more fully, through modification of the weights assigned to alternative future outcomes, modification of plan sampling, or use of industry-specific trends in the number of covered employees.	1
(3)	Liability forecasting for both ME and SE plans should give additional consideration to the following factors, in addition to industry-specific trends in the number of covered employees: (a) long-term industry import pressure; (b) long-term trend in industry automation; and (c) industry regulatory changes.	1
(4)	To forecast *plan stock returns*, consider using a model that incorporates: (a) the time-varying nature of return distribution parameters (expected stock returns, volatility, and correlation with other asset classes, particularly bonds); (b) fat tails; and (c) different economic regimes. Also consider modeling returns at monthly or quarterly frequency, should budgets allow.	1
(5)	To forecast *plan bond returns*, consider using a mean-reverting model with a deterministic time trend. Also consider a random walk model for real interest rates, similar to that implemented in 2014 for nominal rates; modeling rates at monthly or quarterly frequency; and reflection of the impact of term structure on interest rates.	1
(6)	In addition to employing the *discount rate* currently used to present-value plan obligations, consider employing a rate based on the term structure of Treasury bonds or Government Agency Security interest rates.	1
	Simulation of Plan Sponsors and Plan Viability (Subtask 4.2)	
(7)	Establish a definitive and fully documented set of rules for selecting the sample of plans to be run through PIMS, insofar as is practical reflecting the conclusions reached through industry-focused analyses.	1
(8)	Periodically test sample representativeness in terms of key solvency-related attributes, such as the ratio of active to inactive plan participants, or trends in same.	1
(9)	With respect to the modeling of MPRA-related benefit suspensions and partitions, PIMS modifications should continue to be based on Treasury's considerations in approving benefit adjustments.	1

Summary of Major Recommendations, continued

(10)	Because PIMS is unable to fully separate its wage growth assumption and the benefit accrual rate for salary-related plans, calculation of the ratios of Normal Cost to payroll and active head count is recommended.	2
(11)	With regard to ME plans, prospective calibration only applies to percent-of-contribution (POC) plans. PBGC should explore ways of calibrating prospective factors for other types of plans.	2
(12)	Use of additional asset allocation information in SE- and ME-PIMS would provide a better forward-looking indicator of asset performance.	2
(13)	If feasible, de-risking trends should be incorporated in SE-PIMS. This could be done by adjusting pension plans' asset allocations and PBGC's premium collections.	3
	Modeling of Sponsor Failure Risk and PBGC Plan Administration (Subtask 4.3)	
(14)	PBGC should attempt to incorporate the time-varying nature of coefficients in its bankruptcy modeling.	1
(15)	The sample of firms used to estimate the bankruptcy equation should be enlarged and updated, insofar as budgets allow.	1
(16)	More market-based variables should be included in the bankruptcy model.	2
(17)	PBGC should also consider use of a GARCH (1,1) process to forecast firm-level predictor variables, instead of the AR(1) process currently used.	2
(18)	PBGC currently uses in-sample goodness of fit measures to evaluate the usefulness of competing bankruptcy model specifications. We recommend carving out a hold-out sample, to evaluate such specifications on an out-of-sample basis.	2
(19)	Determine whether inter-industry contagion of financial distress can be better forecast by a Cox proportional hazard model with a time-varying baseline hazard function dependent on macro variables and firm interconnectedness.	2
(20)	Simulate the roughly coincident bankruptcy of many firms in a given industry (i.e., determine their bankruptcy risk based on shared industry shocks).	2
	The Stochastic Modeling Process (Subtask 4.4)	
(21)	To better reflect systematic risk in the simulated distribution of financial outcomes, consider simulating a greater number of economic scenarios.	1

Summary of Major Recommendations, continued

(22)	To better reflect idiosyncratic risk, consider allowing the size and number of sampled "partner" firms in a given funded ratio stratum to vary.	1
(23)	To better reflect idiosyncratic risk, also consider increasing the number of sampled firms. For firms not sampled, instead of using the present partner firm system, consider using a "replicating" portfolio.	1
(24)	Supplement PIMS with a stress-testing module to compute potential liabilities under easily understood adverse scenarios. Relatedly, identify scenarios giving rise to large liabilities and compare those conditions to stress scenarios giving rise to similar liabilities.	1
(25)	The linkage of economy-level, industry-level, and firm-level error components in PIMS entails variances and correlations that should be furthered reviewed.	2
(26)	Two areas of linkage are systematically important for modeling the pension insurance system: asset-liability modeling and underfunding-bankruptcy modeling. An effort should be made to more fully reflect possible interactions in these areas.	2
(27)	Update PIMS documentation to properly describe the claim examination process in PIMS, in the event of bankruptcy.	3
	PIMS Documentation (Subtask 4.5)	
(28)	Merge PIMS' "Input Data Structure" and "Data Dictionary" into a single document describing the entire PIMS input data structure and how to access the Database Manager, including full process flow charts and detailed descriptions of each table and parameter contained, and update this document as necessary.	2
(29)	Develop a formal yearly review plan for all PIMS documentation to assure conformity with the evolving PIMS application.	2
(30)	In the PIMS User Guide, provide step-by-step instructions on how to run a PIMS projection, including a description of required Statistical Analysis Software (SAS) scripts.	2
	Evaluation of the Coding of the Models (Subtask 4.6)	
(31)	Provide an addendum to the PIMS 2010 Guide and other documentation to reflect FTI's Algorithm Implementation Review Findings.	1
(32)	Update documentation to reflect methodologies and parameters which appear in the SAS code or as comments in PIMS C++ code.	1
(33)	Implement specific code optimization recommendations (details in main text).	2

Summary of Major Recommendations, continued

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(34)	Utilize industry best practices for system documentation when designing and implementing future versions of PIMS.	2
(35)	Refrain from using hard-coded values within the code for values that are not static.	3
	The Model Development Process (Subtask 4.7)	
(36)	Formally track bug fixes and enhancements to PIMS by leveraging the existing change control ticketing application and workflow used for other General Support Systems at PBGC.	1
(37)	Documentation to support release management and system integration testing should be enhanced so that an independent reviewer is able to determine what changes are included in the release, what system integration testing was performed, and who provided formal approval for migration to production.	1
(38)	Ad hoc report requests requiring changes to the PIMS code should be part of the change management process, even if those changes are not implemented in the next release.	2
	Internal Consistency and Ease of Implementation of Modifications to PIMS (Subtask 4.8)	
(39)	Update quality assurance procedures to explicitly require a comparison with previously communicated results and act as a consistency check.	2
(40)	Update the quality assurance manual for ad hoc requests, to require that, where necessary, communications back to the requestor comply with Actuarial Standards of Practice Number 41, Actuarial Communications.	2
(41)	Appropriately account for potential policy lever changes in future system designs that facilitate and implement design features flexibly.	2
(42)	Appropriately capture institutional knowledge documentation at the functional level, such as documentation on the structure of PIMS code and process memos on how to review PIMS results.	3
	Presentation of Model Output (Subtask 4.9)	
(43)	Eliminate inconsistencies in the PIMS 2010 System Guide.	2
(44)	Provide a full explanation of the purpose of the Projections Report.	3
(45)	In the Projections Report, more fully describe the main drivers of uncertainty and extreme losses.	3

Priority 1 Recommendations

To forecast wages and salaries, instead of the current approach, use the long-term trend in the Social Security Administration's Average Wage Index (AWI).

Currently, insured plan participants' wages and salaries, a key determinant of plan obligations, are forecast to grow in such a manner as to reflect both productivity increases and increases in the cost of living (inflation), with assumptions with respect to future values of both of those variables taken from OASDI Trustees Reports. However, recent research and related economic trends indicate that the current approach may lead to overstated wage and salary forecasts, as the approach does not fully account for such factors as technological change causing the substitution of capital for low-skilled labor and the integration of labor markets worldwide attendant to globalization. Indeed, after adjusting for changes in the CPI-U, average hourly earnings in the United States are no higher than they were 45 years ago, a result inconsistent with the assumption that they grow sufficiently to compensate workers for both increases in labor productivity (which more than doubled over the period) and a six-fold increase in the cost of living. Indeed, the long-term stagnation, if not decline, in average real wages in this country has been the subject of extensive study.

An alternative approach to wage forecasting based the *Average Wage Index* (AWI) employed by the SSA for determining cost-of-living adjustments is in our view far preferable, both because the AWI is based on actual employee earnings, and, relatedly, because its long-term trend is relatively stable, so that future values can be forecast with greater accuracy (Chart 1).

Chart 1
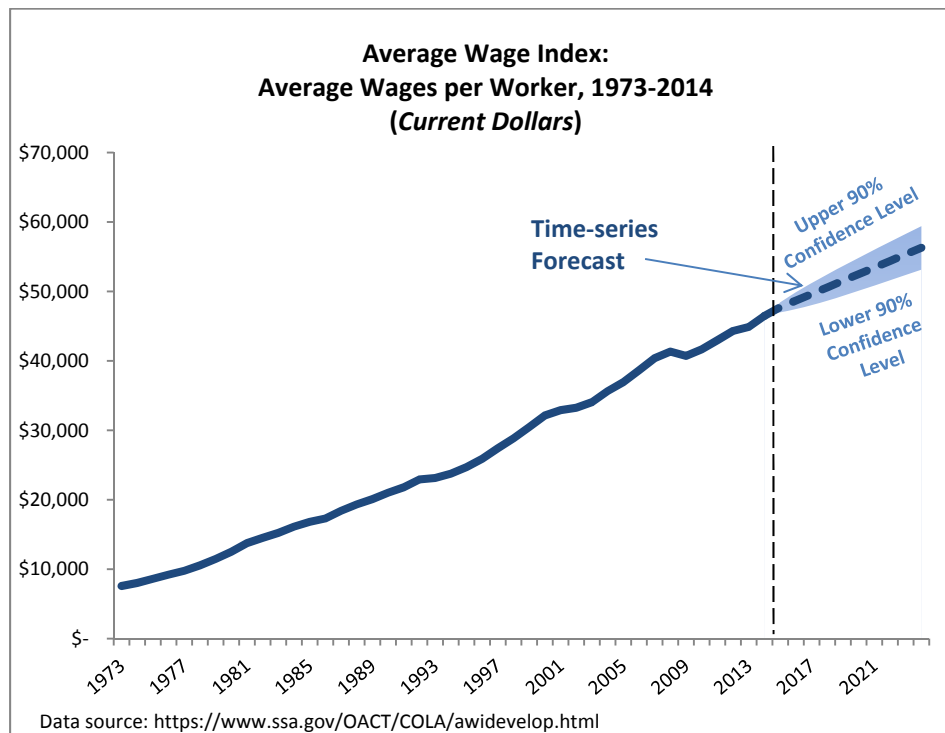
The extent of the difference in wage and salary forecasts as between a productivity-plus-inflation method, on the one hand, and a simpler AWI-based method, on the other, can be seen through this example: *Escalating the 1973 value of the AWI ($7580) by (a) the increase in the CPI-U between that*
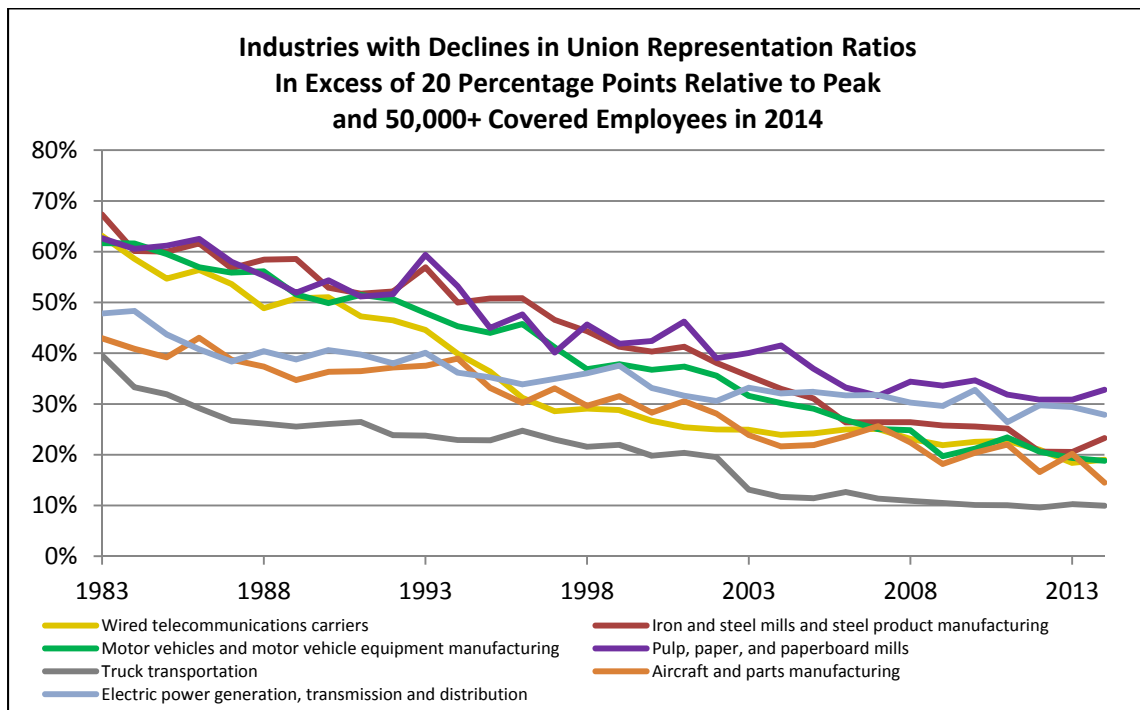
year and 2014 (439%) and, in addition, (b) the increase in labor productivity over the same period (115%), yields an expected AWI of $87,928 in 2014, as contrasted to an actual $46,482. Furthermore, even if the method were conceptually sound, separately forecasting the assumed components of a future wage increase would tend to compound the errors inherent in each constituent forecast.

Consider unionization trends more fully, through modification of the weights assigned to alternative future outcomes, modification of plan sampling, or use of industry-specific trends in the number of covered employees.
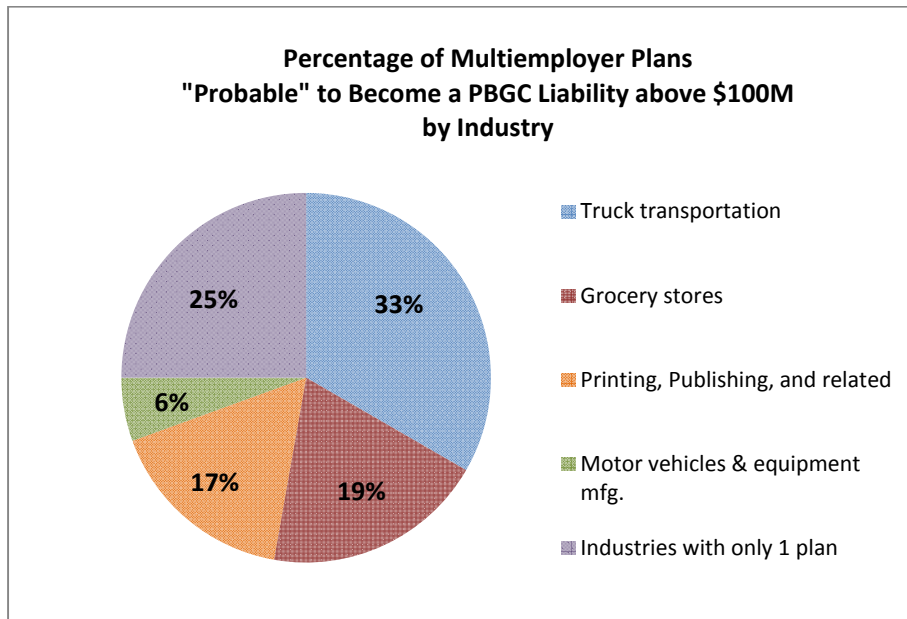
To assess the usefulness of industry trends in union representation in forecasting PBGC liabilities, FTI utilized a database constructed in 2003, and since updated annually, by Barry Hirsch (Georgia State University) and David Macpherson (Trinity University). The database includes employment and number of employees represented by unions ("union coverage") for 259 private sector industries, compiled from the monthly household Current Population Survey (CPS) using Bureau of Labor Statistics methods.

Our analysis determined that: (a) a relatively small subset of industries characterized by significant long-term declines in union representation today account for a disproportionately large share of PBGC's SE and ME program liabilities, and (b) that those same industries could have been identified as probable liability sources as early as 2001, based on trends in union representation and/or industry employment over the prior 18 years (1983-2000) (Chart 2). Indeed, but for those in the printing and publishing and retail grocery industries, nearly all the large (over $100 million) ME plans now considered to represent probable future liabilities, as well as the preponderance of those liabilities themselves, pertain to industries identifiable as "high risk" based on trends in employment and unionization level as of the Year 2000. Moreover, 75% of all such plans are accounted for by just four industries (Chart 3): truck transportation, grocery stores, printing and publishing and related, and motor vehicles and equipment.

Chart 2

Chart title: Industries with Declines in Union Representation Ratios In Excess of 20 Percentage Points Relative to Peak and 50,000+ Covered Employees in 2014

Legend:
- Wired telecommunications carriers
- Iron and steel mills and steel product manufacturing
- Motor vehicles and motor vehicle equipment manufacturing
- Pulp, paper, and paperboard mills
- Truck transportation
- Aircraft and parts manufacturing
- Electric power generation, transmission and distribution

Chart 3

**Percentage of Multiemployer Plans
"Probable" to Become a PBGC Liability above $100M
by Industry**

- Truck transportation — 33%
- Grocery stores — 19%
- Printing, Publishing, and related — 17%
- Motor vehicles & equipment mfg. — 6%
- Industries with only 1 plan — 25%

Liability forecasting for both ME and SE plans should give additional consideration to the following factors, in addition to industry-specific trends in the number of covered employees: (a) long-term industry import pressure; (b) long-term trend in industry automation; and (c) industry regulatory changes.

Chart 4, below, portrays certain key influences on pension plan viability, as well as the economic agents most immediately and directly affected by those influences. As indicated, while ultimately impacting a sponsoring union (in terms of size, bargaining power, financial condition, etc.) and its sponsored plan(s), relatively more of these influences are first felt by the employers making plan contributions. As noted above, those industries accounting for PBGC's largest liabilities – both ME and SE – have for many years been characterized by long-term declines in employment or unionization, and/or impacted with particular severity by technological, import-related, and/or regulatory events (i.e., airlines, steel, automotive, printing and publishing, grocery stores, electrical machinery and equipment, apparel, furniture and trucking). The relevance of such factors is also indicated by recent research on systematic corporate default risk, or "default clustering." In a 2012 paper, Koopman et al identify three basic sources of such clustering: (a) macroeconomic (i.e., related to general economic conditions, of the kind varied in alternative PIMS runs); (b) industry-level factors; and (c) "frailty," a residual factor. They find that macroeconomic factors account for only 30% to 60% of default risk exposure, the higher percentage applicable only to firms with investment grade ratings.

While our Subtask 4.1 report addressed technological change chiefly in the context of current wage trends, the 2016 *Economic Report of the President* and the research literature cited therein explain the employment-suppressing effects of robotics, which also should be considered, if only in a broad-gauge way, in identifying industries whose pension plans are likely to be imperiled over the next 10 to 20 years.

Chart 4

KEY ECONOMIC DETERMINANTS OF PLAN VIABILITY
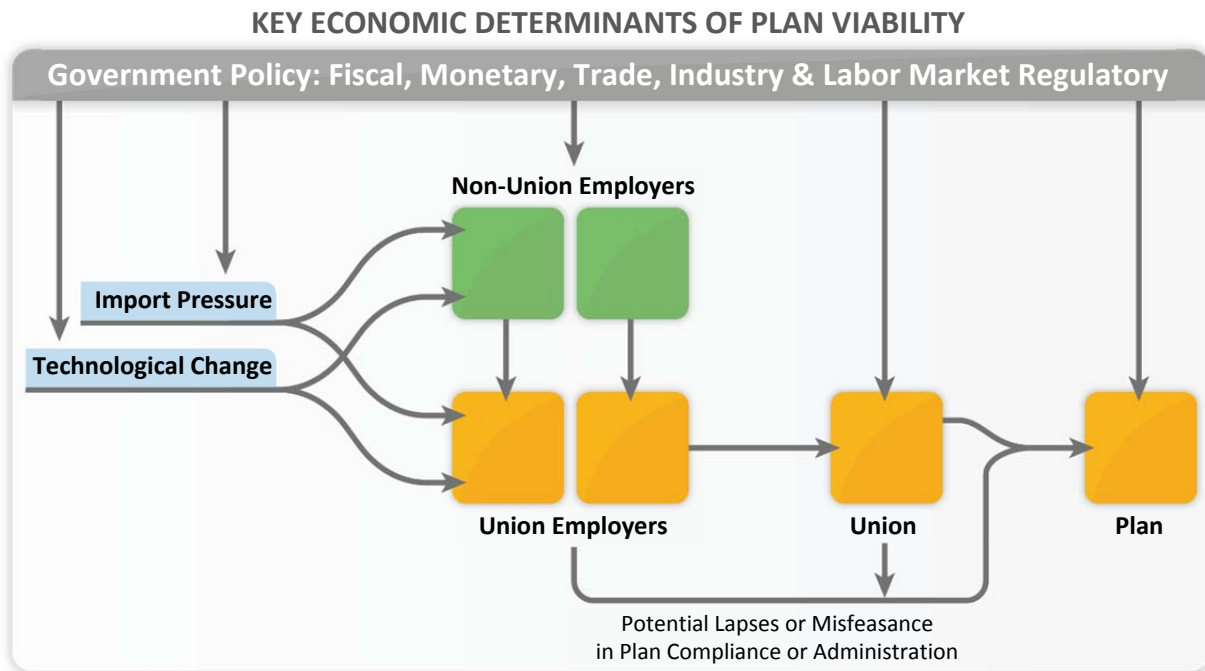
Noting, among other things, that the industries at present most prone to this form of automation are automotive, chemical, rubber, plastics, metal and food processing, the report presents data indicating that workers earning less $20 an hour as of 2010 have an 83% chance of their jobs being automated; those earning between $20 and $40, a 31% chance.

To forecast plan stock returns, consider using a model that incorporates: (a) the time-varying nature of return distribution parameters (expected stock returns, volatility, and correlation with other asset classes, particularly bonds); (b) fat tails; and (c) different economic regimes. Also consider modeling returns at monthly or quarterly frequency, should budgets allow.

In our Subtask 4.1 report, we also addressed certain properties of stock returns considered important in the academic literature, all of which have implications with respect to the forecasting of stock returns:

a. Mean reversion and momentum in returns;

b. The time-varying nature of return distribution parameters - expected stock returns, volatility and correlation (as used here and elsewhere, in the general statistical sense) of stock returns with other asset classes (*e.g.*, bond yields);

c. Fat tails – the tendency of stock returns to exhibit extreme values, particularly negative ones; and

d. Predictability of returns – the ability of certain other variables, such as the dividend-to-price ratio ("dividend yield") to forecast returns.

The extent to which stock returns exhibit these properties depends upon the time horizon, economic conditions, whether an individual security or the market as a whole is being analyzed, and the underlying economic "regime" as to macroeconomic policy, industry and labor market regulation, technology, and the conditions of international trade.

Given the purposes for which PBGC forecasts stock returns, and bearing in mind that forecasting remains inherently incapable of predicting cyclical turning points, there are several widely-accepted forecasting methods, as cited our Subtask 4.1 report, that may better reflect the influences and attributes described above. Relatedly, PBGC should consider modeling both stock returns and bond yields using monthly or quarterly data, to estimate its models based on a recent history incorporating a regulatory structure, policy regime, etc. more representative of the period PIMS is simulating.

To forecast plan bond returns, consider using a mean-reverting model with a deterministic time trend. Also consider a random walk model for real interest rates, similar to that implemented in 2014 for nominal interest rates; modeling rates at monthly or quarterly frequency; and reflection of the impact of term structure on interest rates.

Apart from stock returns, PIMS currently employs four economy-level variables: (a) 30-year Treasury rates, both real and nominal; (b) the yield on corporate bonds; and (c) inflation. Of these, PIMS itself currently models only the nominal yield on 30-year Treasuries. The real rate of interest is an externally-sourced input to PIMS, and the yield on corporate bonds is modeled as the forecast 30-year bond yield plus one percent, multiplied by a proportional increase factor. The inflation rate is inferred from the 30-year nominal yield and the real interest rate input.

Treasury bond yields: To forecast 30-year nominal yields on Treasuries, PIMS models the natural logarithm of interest rates. This model assumes that the change in the 30-year nominal yield in a given year is independent of the yield realized in prior years, and determined as a random realization. While this assumption is consistent with certain research, real long-term interest rates have in fact been declining over the long term. Further, they have also been highly volatile over the last five years.

Those findings, as well as others discussed in our Subtask 4.1 report, suggest that PBGC should consider modeling both the long-term real interest rate and the long-term nominal rate. Based on our review of the literature, with respect to both, we suggest considering a mean reversion model in combination with a deterministic trend. Also meriting consideration is a simpler random walk model, because, given the high persistence in real interest rates, the random walk may also suffice over the PBGC projection horizon. The final choice of a model is an empirical question.

Further, as suggested for stock returns, PBGC should consider modeling both real and nominal long-term interest rates at monthly or quarterly frequency if feasible, so that the models can be reliably estimated using a recent history incorporating a regulatory structure, policy regime, and economic data more representative of the period PIMS is simulating.

Corporate bond yields: PIMS determines a forecast corporate bond yield by adding a fixed spread to forecast Treasury bond yields, assuming that that spread does not vary with economic conditions. However, as the 2008 financial crisis demonstrated, credit spreads do vary with the state of economy, tending to increase during recessions. Further, credit spreads also vary with term structure. Currently, PIMS does not appear to model either of these properties, and PBGC might consider incorporating them.

In addition to employing the discount rate currently used to present value plan obligations, consider employing a rate based on the term structure of Treasury bonds or Government Agency Security interest rates.

PBGC's current practice is to discount the future benefit payment obligations of the pension plans that it has taken over to a present value. The agency uses a survey provided by the American Council of Life Insurers to determine currently available annuity rates, calculating the effective discount rate embedded in those rates. For the year ended Sept. 30, 2015, this rate was 2.86%.

From an economic viewpoint, both fundamental principles and market practice indicate that the discounting of future cash flows take into account two components: (a) the time value of money (the risk-free component); and (b) the risk of not receiving full and timely payments (the credit risk component). While the latter factor may be an appropriate one to consider by a hypothetical purchaser of (for example) PBGC debt obligations, in our view, it is inappropriate for PBGC itself to include a credit risk factor in the discount rate applied to its own best estimate (or estimates) of its future obligations. By doing so, it is, in a sense, disavowing some portion of those obligations, as well as presenting a picture of its financial condition that could be misleading to those unfamiliar with the details of its discount rate calculations and assumptions. Hence our recommendation that, in addition to its current reporting method, PBGC also reports its liabilities based on a discount rate corresponding to the risk-free rate of interest – more specifically, on the basis of the yield curves for U.S. Treasury securities, perhaps adjusted upward somewhat to allow for the uniquely high liquidity of such securities.

We would also underscore the importance of estimating appropriate risk-free rates and credit spreads based on: (a) contemporaneous, forward-looking data; and (b) data derived from financial instruments of maturities corresponding to the time frames of PBGC's various future obligations.

With regard to the former, reliance on historical data risks introducing significant, even substantial, errors, since such data reflect past economic, social, and political realities of limited relevance to future developments in the marketplace. For example, a calculation based on the historical average of the 10-year U.S. Treasury Note over the 1970-2000 period introduces an approximate 46.7% error in discounting an annual stream of cash flows over a 30-year time frame.

With respect to the choice of appropriate financial instruments, reliance on data (e.g., average yields or, worse yet, average historical yields) based on instruments of maturities that do not correspond to the time frames of the PBGC's future obligations is also bound to introduce significant, even substantial, error. That is because the U.S. Treasuries yield curve is not flat, different time horizons being associated with different yields.

Establish a definitive and fully documented set of rules for selecting the sample of plans to be run through PIMS, insofar as is practical reflecting the conclusions reached through industry-focused analyses.

For clear practical reasons (cost considerations and/or data availability), the sample of ME plans run through PIMS in FY 2014 totaled 284 across all plan categories, out of a total of roughly 1,400, and was not randomly drawn. The sample did not include plans representing a potentially large portion (the obverse of "more than half") of PBGC's ME plan exposure, based on several-year-old Form 5500 filings – themselves, at least in some cases, of questionable reliability. Which is not to say that we advocate evaluation of all ME plans, or even a majority, but rather consideration of the desirability of adding plans of significant size in industries particularly vulnerable to the economic forces cited earlier.
Perhaps more fundamentally, with respect to all plans run through PIMS:

(a) Sample plans are now replaced when, "…information for the specific plan and/or sponsor is not available or [the] plan is terminated."

(b) The sample may also be modified pursuant to judgments by PBGC staff, as in 2015, when plans projected to be MPRA-eligible were added.

(c) The original sample of non-booked plans (modified only pursuant to the above) was specified years ago by individuals presently unavailable for comment, nor is PBGC in possession of any documentation that might shed light on the selection method employed.

Given the judgmental character of the plan sampling methods employed by both the MWG and PBGC, the relative lack of documentation of the process by which the PBGC's sample was drawn is of some concern.

Periodically test sample representativeness in terms of key solvency-related attributes, such as the ratio of active to inactive plan participants, or trends in same.

To the extent that such attributes differ as between the sample of plans run through PIMS and the full population of insured plans, the sample cannot be used to reliably generalize about the solvency of the population. Indeed, particularly in the case of sampling procedures entailing ad hoc judgements and the exclusion of cases due to insufficient information, confirmation of sample representativeness in terms of key variables of interest is standard procedure. Should significant disparities be found, there are often means to correct for them, even where large gaps in data exist.

With respect to the modeling of MPRA-related benefit suspensions and partitions, PIMS modifications should continue to be based on Treasury's considerations in approving benefit adjustments.

At the time of our report (Subtask 4.2) addressing this issue, 10 multiemployer funds had submitted proposals to reduce accrued benefits under MPRA. Central States Teamsters' and Road Carrier Local 707's submission had been denied, Teamsters Local 469 Pension Plan had withdrawn its application, and the other seven (including a fund that submitted a request, withdrew it, and resubmitted it) were under review.

Because MPRA is a recent law, and there is little experience thus far, it is not surprising that PIMS can only account for MPRA with probabilities as to what will ultimately happen to MPRA-eligible plans. We expect PIMS would be modified to reflect additional information as it becomes available. For example, in the FY 2015 Projections Report, revised MPRA assumptions resulted in a substantial change to PBGC's ME plan deficit.

Therefore, we recommend that the PIMS modifications continue to be made based on Treasury's criteria for approving MPRA applications – for example, using a lower investment return assumption when performing MPRA-related projections, if appropriate.

PBGC should attempt to incorporate the time-varying nature of coefficients in bankruptcy modeling.

Studies have found that the relationship between predictor variables and probability of bankruptcy for a firm varies both with macroeconomic conditions and industry. As Brown et al. note in their 2013 review of PIMS, "A relatively simple way to circumvent this problem is to divide the sample based on factors

believed to drive time variation in the coefficients." For example, one could divide the sample by business cycle regimes – contraction and expansion – and, within each regime, by industry (e.g., finance, utility, manufacturing, etc.; high- or low union representation; or other potentially salient features).

Such an approach should be feasible, as PIMS already has a feature permitting the use of up to 10 distinct bankruptcy equations based on firm size. Further, it is an approach consistent with the regime-based modeling recommended for forecasting stock returns and interest rates. Depending upon the simulated regime and the industry of the firm being analyzed, PIMS would select an appropriate equation to predict probability of bankruptcy.

The sample of firms used to estimate the bankruptcy equation should be enlarged and updated, insofar as budgets allow.

PIMS bankruptcy model is currently estimated using data from the Compustat database for firms sponsoring defined benefit plans over the sample period 1980 to 1997, with minimum employment of 500 in their earliest observation. Therefore, the data used to estimate the model is quite old and the model should be re-estimated using more recent data. As Brown et al noted in 2013, "There is a range of data concerns [with respect to the model]. For example, the process for updating parameter estimates based on new data has been inconsistent and inadequate. Conversations with PBGC staff confirm that the model has not been re-estimated in many years and thus, in all likelihood, the model parameters likely differ from today's best available estimates."

To better reflect systematic risk in the simulated distribution of financial outcomes, consider simulating a greater number of economic scenarios.

One key aspect of PBGC's stochastic modeling is the number of economic scenarios needed to adequately simulate the entire distribution of two key variables with economy-wide ("systematic") effects – stock returns and interest rates. In this connection, it is helpful to consider private insurers' approach for determining their Solvency Capital Requirements ("SCR"s). Global insurers often determine SCR at a 99.5% confidence interval, which implies that one would need about 10,000 economic scenarios to arrive at an appropriate error rate.

Therefore, we recommend that PBGC consider increasing the number of simulated economic scenarios run in PIMS. Indeed, PBGC staff inform us that their goal is to run 10,000 scenarios, and that they will try to meet that goal in the redesign of PIMS. To reach that goal, PBGC might also consider alternative simulation approaches such as Least Squares Monte Carlo Simulation ("LSMC"), which could considerably increase number of economic scenarios to better capture all possible future economic outcomes, including "fat tail" events such as the steel and airline bankruptcies.

To better reflect idiosyncratic risk, consider allowing the size and number of sampled "partner" firms in a given funded ratio stratum to vary.

In PIMS simulations, sampled firms are categorized into different strata based on the funded ratio of the largest plan a firm sponsors. Within a given funded ratio stratum, PIMS uses the partner firm methodology to simulate the economic performance of all firms (and net liabilities associated with their insured plans) in that stratum, each partner being a scaled-down (20%) copy of the associated "source firm" and that firm's plan. The number of partner firms is chosen such that the distribution of liabilities of all firms (sources and their partners) in the sample approximates the distribution of plan liabilities by funding status in the insured universe.

Instead of the trial and error method currently used to determine the number of partners assigned to each source firm, we recommend PBGC consider developing a statistical criterion to accomplish the same objective. For example, one could use a linear programming approach that satisfies constraints imposed by the three distributions PBGC uses for calibration purposes.

Thus, because idiosyncratic (firm-specific) risk varies across industries, PBGC could allow the size and number of partner firms within a funded ratio stratum to vary to better reflect such differences. This approach can be readily implemented, since PIMS has size and number of partner firms as parameters.

To better reflect idiosyncratic risk, also consider increasing the number of sampled firms. For firms not sampled, instead of using the present partner firm system, consider using a replicating portfolio.

Irrespective of whether PBGC increases sample size or not, PBGC should consider developing a replicating portfolio for plans not included in its simulation sample. For, example, Lucas (2013) notes:

> An alternative [to the partner firm system] would be to directly model key aspects and correlations of the drivers of liabilities, default rates, and underfunding for smaller firms, relying on available data for those types of firms and setting parameters to match historical outcomes in terms of default correlations, probabilities, funding levels, and so forth.

Major insurers and banks with portfolios of assets and liabilities just as complex as the one PIMS simulates often use a replicating portfolio in simulating the performance of assets that cannot be directly modeled. We recommend that PBGC review methods used by banks and insurers, and related literature, to assess the desirability of alternatives to the current partner firm system.

Supplement PIMS with a stress-testing module to compute potential liabilities under easily understood adverse scenarios. Relatedly, identify scenarios giving rise to large liabilities and compare those conditions to stress scenarios giving rise to similar liabilities.

Irrespective of the simulation approach PBGC finally adopts, it would have to deal with a complex system, which can be difficult to explain to policy makers. It should therefore consider supplementing PIMS with some stress test scenarios. Scenarios replicating economic conditions during the Great Depression or the 2008 financial crisis are easily understood and the sources of the liabilities that PBGC might have to assume under such adverse scenarios can be easily identified, if not publicly disclosed.

To develop adverse scenarios, PBGC could start with a review of those developed by large US banks under guidance of the Federal Reserve Bank. These scenarios are available in banks' financial disclosures as well as in various documents submitted to the Fed. Another example can be found in the Society of Actuary's Blue Ribbon Panel Report on Public Pension Plan Funding regarding pre-defined stress-testing scenarios. Of course, PBGC would need to supplement such scenarios with additional inputs, such as stress in certain industries posing especially high insolvency risk.

PIMS already has the capability to use simple pre-defined scenarios. A stress testing module could build on that to incorporate all parameters required a full stress scenario. For example, stress testing may involve modeling yield curves or contagion. The results of these exercises should be included in PBGC's Projections Reports, and/or provided on the agency's website.

Provide an addendum to the PIMS 2010 Guide and other documentation to reflect FTI's Algorithm Implementation Review Findings.

There are inconsistencies between PIMS code and certain parts of the PIMS 2010 Guide and other documentation because the latter are no longer current. PBGC should provide an addendum to the PIMS 2010 Guide and other documents to include the following at a minimum:

    a.   New legislative actions that are reflected in PIMS coding, but not in the respective documentation (e.g., the funding interest rate stabilization provision of MAP-21 and HATFA, and the provisions of MPRA). Fuller description of the modeling methodology and assumptions should also be provided, and obsolete material deleted.

    b.   The updates due to "Verification and Quantification of Buck's Recommended Changes, 2014" should be noted in the document describing key difference between SE and ME plan modeling.

    c.   Calculations that are performed on PIMS output (i.e., not as part of PIMS C++ code) should be noted (e.g., the adjustment to PBGC variable premiums).

    d.   Parameters that are updated more frequently than the documentation should be noted (e.g., real interest rate (currently 0.64% versus 1.48% in the PIMS 2010 Guide) and productivity (currently 1.65% versus 1.07% in the PIMS 2010 Guide)).

    e.   Program features or parameters that are not being used should be noted (e.g., the implementation of parameter uncertainty).

Update documentation to reflect methodologies and parameters which appear in the SAS code or as comments in PIMS C++ code.

Certain methodologies and parameters that appear in the SAS code or as comments in PIMS C++ code should also be noted in PIMS documentation:

    a.   The ultimate corporate bond yield spread is 1.1% over the Treasury yield.

    b.   The spread of PBGC's annuity purchase rate over Treasury yield is 30% of the corporate bond yield spread (i.e., 30% of 1.1%, or 0.33% percent).

    c.   106% of the corporate bond yield is used as a proxy for the third segment rate.

    d.   The salary merit increase scale is imputed from current age/service/salary distributions.

    e.   For calibration purposes, PIMS assumes base wage rates increase by 3% per year.

    f.   With respect to benefits valued, PIMS models different retirement eligibilities, early retirement reduction, supplemental benefits and social security integration levels.

Formally track bug fixes and enhancements to PIMS by leveraging the existing change control ticketing application and workflow used for other General Support Systems at the agency.

At present, there is no formal process to capture bug fixes and enhancements to PIMS. All change requests are submitted through email or captured during meetings and tracked in spreadsheets. Based on a review of those spreadsheets, it is difficult for an outside party to determine which changes had been implemented, were in process, or had not yet started in development. Until a change is actually selected for development, minimal information is provided regarding the amount of effort and priority

assigned to it. Absent formal tracking, it is more difficult to report on development efforts, assign accountability for changes, and enforce change management controls. Additionally, ad hoc report requests that require changes to the PIMS code are not included on the spreadsheet tracker.

Further, the process to identify and select the enhancements and bug fixes to be implemented in each new PIMS release is not formally documented. While there are meetings between the Director of PRAD, the development contractor (Lynchval), and the Division Manager of the Pension Insurance Modeling Division to evaluate and debate potential changes, there is no formal assessment or rationale documented for why certain changes were selected above others. Additionally, it was not evident from our review that all relevant stakeholders (e.g., OMB) are engaged in the evaluation of changes for a specific release, or if recommendations from other reports were considered for implementation. While documentation to support the requirements, development, and testing performed for each individual change to PIMS is robust and clear, documentation to support the release management process is not as well defined, and FTI found it difficult to independently trace an individual change to the corresponding release. We were also unable to fully trace the system integration testing performed and approval for migration to production.

Finally, changes to PIMS SAS code do not fall within the PIMS change management process. SAS is used for preprocessing of data and assumptions and also to analyze output. Unauthorized changes to SAS code could impact the model inputs and/or outputs, and therefore should be included in the change management process so that they are appropriately tested and approved.

Documentation to support PIMS release management and system integration testing should be enhanced so that an independent reviewer is able to determine what changes are included in the release, what system integration testing was performed, and who provided formal approval for migration to production.

An important goal of any change management process is to rapidly meet evolving business requirements while minimizing the possibility of service disruption. Based on FTI's interviews and evaluation of evidence provided, actual documentation to support individual changes to PIMS, including requirements, testing, and approval, was consistent with best practices. However, the documentation to support release management, system integration testing, and approval for migration to production was inconsistent.

It is considered a best practice to leverage change management software or ticketing systems to enforce a systematic approach to implementing changes. Indeed, most software products have customizable workflows, automated email notification, designated approval, and reporting capabilities, enabling management to better understand the status of changes, and accountability for each change, facilitating a clear, transparent approval process. These tools also support documentation repositories that can be backed up so that key information related to changes is not lost.

Many organizations also conduct formal risk assessments for key systems or models on at least an annual basis. This includes the reports of the Trustees of the Social Security and Medicare programs, which regularly undergo external reviews and provide documentation related to demographic assumptions, economic assumptions, long range and short range projections. These risk assessments formally analyze market, economic, IT, and regulatory issues that could impact the model as well as the organization's plans to address each, and are typically documented in strategic plans presented to management and/or public reports.

Priority 2 Recommendations

Because PIMS is unable to fully separate its wage growth assumption and the benefit accrual rate for salary-related plans, calculation of the ratios of Normal Cost to payroll and active head count is recommended.

Generally speaking, the actuarial calculation of a required pension contribution is the sum of the actuarially-computed Normal Cost and the amortizations required under IRC §412. For SE plans, the level and pattern of Normal Costs directly impact the calculation of cash contributions into a pension plan, as outlined in IRC §430. For ME plans, Normal Costs are an important component of the fund's Minimum Funding Standard Account ("FSA"). The growth of a plan's liabilities over time is a function of its Normal Costs and benefit payments. Each year, the plan's "Accrued Liability" reflects the Accrued Liability in the prior year, increased by the prior year's Normal Cost and interest, and reduced by benefits that were paid during the previous year. However, a plan's benefit payments also reduce its assets, and so do not have a direct impact on its "unfunded" liabilities (the difference between the plan's liabilities and its assets). Thus, the pattern of Normal Costs has a greater impact on the calculation of a plan's required contributions than on projected benefit payments.

An ideal calibration of calculated values to reported values in core actuarial calculations would separate the benefit accrual rate from the wage growth rate and size of the covered active population. Assuming the benefit accrual rate is constant over the forecast period, the wage growth rate and the size of the covered population are exogenous variables driving the long-term trend of Normal Costs. However, this result is difficult to achieve in practice, because actuarial assumptions are often intertwined with the level of benefit accruals, as is the case for PIMS. Given that, it may be beneficial for PBGC to calculate the ratio of Normal Cost to payroll and the ratio of Normal Cost to active head count, while holding the interest rate constant.

FTI calculated those ratios on a PIMS output file and observed their forecast trends. While the ratios vary, after accounting for discount rates, the overall average ratio appears reasonable but for the final average salary formula, for which the ratios in Year 10 are lower than expected. Thus, we recommend that PBGC monitor these ratios, and adjust its wage growth assumption as appropriate.

With regard to ME plans, prospective calibration only applies to percent-of-contribution (POC) plans. PBGC should explore ways of calibrating prospective factors for other types of plans.

FTI found that in the case of a large number of ME plans, prospective calibration factors failed to calibrate (in the CAB output file). PBGC has indicated that those factors are calibrated only for percent-of-contribution plans. PBGC should explore ways of calibrating prospective factors for other types of ME plans. Nevertheless, aggregate Normal Cost is within five percent of the aggregate reported Normal Cost, which we find to be reasonable.

Use of additional asset allocation information in SE- and ME-PIMS would provide a better forward-looking indicator of asset performance.

PIMS's current practice of modeling plan assets as made up only of stocks and bonds is inconsistent with the asset allocation of typical pension funds, which allocate funds across a much wider range of assets, including international stocks and bonds, real estate, commodities, agriculture, private equity and hedge funds. Thus, in his 2013 review of PIMS, Geczy notes, "…pension plans insured by the PBGC have

potentially drastically different allocations (implying vastly different effective capital market assumptions) than the PIMS system contemplates."

The additional asset classes cited above have very different risk-return profiles than stocks and bonds. Thus, we recommend that PBGC consider additional asset class benchmarks when modeling plan asset returns. Brown et al (2013) note that PBGC staff is "…currently working on a plan to use the detailed asset allocation data available in the Form 5500 data to do additional work in this area." We encourage them to continue this effort.

More market-based variables should be included in PBGC's bankruptcy model.

The variables in PIMS bankruptcy model are chiefly accounting-based; however, the distribution of accounting ratios changes over time. Further, as authorities on this topic have pointed out, accounting statements present past performance of a firm and may or may not be informative in predicting the future; conservatism and historical cost accounting mean that the true asset values may be very different from the recorded book values; and accounting numbers are subject to interpretation by management. Also, as noted by Hillegeist et al (2004), because accounting statements are prepared on a going-concern basis, they are, by design, of limited usefulness in predicting bankruptcy. Therefore, we recommend that PBGC include additional market-based variables in its bankruptcy model, and, in our Subtask 4.3 report, cite several established approaches.

PBGC should also consider use of a GARCH (1,1) process to forecast firm-level bankruptcy predictor variables, instead of the AR(1) process currently used.

Given the strong evidence of heteroscedasticity (different variances among regression disturbance terms) in PBGC's bankruptcy model, a Garch (1,1) time series regression model, which explicitly adjusts for that fact, might prove a useful alternative approach. Garch (1,1) is commonly used to model time variation in regression disturbances.

PBGC currently uses in-sample goodness of fit measures to evaluate the usefulness of competing bankruptcy model specifications. We recommend carving out a hold-out sample, to evaluate such specifications on an out-of-sample basis.

PBGC currently evaluates its bankruptcy model by comparing average predicted rates of default for all firms with a given bond rating to actually observed default rates for those firms over the model's estimation period of 1980 to 1997. In other words PIMS essentially uses in-sample validation. However, since PBGC uses its bankruptcy model to make out-of-sample forecasts, we recommend it consider developing a new model by evaluating the current model's performance on an out-of-sample basis. This can be easily implemented by expanding the database currently used for bankruptcy modeling and dividing the new database into an estimation sample and a hold-out sample.

In this context, there are several ways to evaluate competing model specifications. Two common measures of *in-sample* goodness of fit are: (a) percent correctly predicted; and (b) the McFadden Pseudo r-Squared statistic. Shumway (2001) provides a variant of the percent-correctly-predicted measure for assessing *out-of-sample* model performance. Other means of evaluating out-of-sample forecasts have been devised by Chava and Jarrow (2004), among others.

Determine whether inter-industry contagion of financial distress can be better forecast by a Cox proportional hazard model ("CPHM") with a time-varying baseline hazard function dependent on macro variables and firm interconnectedness.

A CPHM can be thought of as a two-part model, entailing: (a) a common component describing how economy-wide bankruptcy risk evolves through time ("baseline hazard"); and (b) another component basing bankruptcy risk on firm-specific factors. (See Nam et al (2008), as cited below.) And as Brown et al (2013) note:

> Hillegeist, et al. (2004) use the number of bankruptcies within the past year (relative to the number of firms in the sample) as the baseline hazard, and show that this increases the predictive power of the model. Nam et al. (2008) use change in interest rates and exchange rate volatility to model the baseline hazard and find that these are important for modeling bankruptcy in Korean data. These papers suggest a way that PBGC may be able to capture macroeconomic trends and/or bankruptcy contagion effects – by using macroeconomic variables to establish the baseline hazard rate.

Simulate the roughly coincident bankruptcy of many firms in a given industry (i.e., determine their bankruptcy risk based on shared industry shocks).

In a PIMS simulation, forecast bankruptcies for each "partner" firm (i.e., those treated as similar in terms of all salient features to those sponsoring the sampled plans run through PIMS) are generated randomly and independently. However, PIMS can be modified to consider bankruptcies of firms in tandem. For example, in a simulation cycle, PIMS could make a random draw from the same distribution it used to generate industry-specific shocks, then use that given shock to predict bankruptcy for all the firms in a given industry found to be particularly vulnerable (given their firm-level characteristics) in that cycle, instead of making a separate random draw for each firm.

We recognize that evaluation of all such proposals would require PBGC to invest time and other resources, but given that bankruptcy modeling is at the core of SE-PIMS, it may well be worth such investment. Further, given the need to regularly update the bankruptcy model, we recommend that PBGC set aside annual funds for updates and either assign dedicated internal staff to the exercise or use outsourced assistance, if deemed necessary.

The linkage of economy-level, industry-level, and firm-level error components in PIMS entails variances and correlations that should be furthered reviewed.

Variances and correlations for the interest rate and stock return in the economy error components in PIMS 2010 Guide appear different from those used in generating macroeconomic scenarios, as documented in the 2014 Projections Report. PBGC should footnote that the actual errors for the interest rates and stock returns derived from the macroeconomic scenarios should be used.

For the equity-to-debt ratio and cash flow-to-asset ratios, the variance of the firm error components is much larger than the variance of the economy error components or the industry error components. If PBGC continues to use the current modeling approach, it should determine whether these variances and correlations have changed significantly, especially after the 2008 financial crisis.

Some correlations may produce offsetting effects on bankruptcy probability. For example, Table 5-2 in the PIMS 2010 Guide shows that stock returns are positively correlated with equity-to-debt ratios, but negatively correlated with cash flow-to-asset ratios. When the stock return is low, the equity-to-debt ratio will be lower, but the cash flow-to-asset ratio will be higher, having offsetting impacts on bankruptcy probability. It is expected that low stock returns should correlate with increased bankruptcy probability, but it is unclear if the correlation in PIMS's economy error components will produce the expected results. Therefore, we recommend that PBGC review these correlations in relation to their impact on bankruptcy probabilities.

Two areas of linkage are systematically important for modeling the pension insurance system: asset-liability modeling and underfunding-bankruptcy modeling. An effort should be made to more fully reflect possible interactions these areas.

Currently PIMS does not reflect all the interactions in these two areas. While its assumptions are internally consistent, substantial work may be required to maintain consistency if PIMS were modified to implement some of FTI's recommendations.

For example, if a yield curve is used instead of a single long-term interest rate, then care must be taken that the fixed-income returns, or more generally the returns of liability-hedging assets, move in a way that is consistent with the movement of the yield curve. This involves complexity not currently modeled in PIMS. Similarly, if bankruptcy modeling is updated to more fully reflect contagion, care must be taken to ensure that asset return modeling is updated, and different economic regimes incorporated.

Merge PIMS "Input Data Structure" and "Data Dictionary" into a single document describing the entire PIMS input data structure and how to access the Database Manager, including full process flow charts and detailed descriptions of each table and parameter contained, and update this document as necessary.

The purpose of the Pension Insurance Modeling System (PIMS) Input Data Structure vFY09.1 and PIMS Data Dictionary is to provide the user with a description of all input tables and parameters that are used in the PIMS model and how they relate to each other. Due to the interrelated nature of the two documents, we evaluated them together.

The Input Data Structure document provides a single-page flow chart showing how each input table is related to all the others. The flow chart provides the name and a minimal description of each table. We found that this document would be useful for an experienced user of PIMS, but of lesser value to a new user, absent the information in the Data Dictionary. In addition, we found that this document had not been revised since 2009. Without a current description of the PIMS model input data structure, we were unable to evaluate the accuracy of this document in relation to the current model.

The Data Dictionary provided to us comprised over 100 separate HTML documents, each of which provided the name, a short description, and the source of each parameter. The descriptions provided varied in detail, sometimes providing the possible input values for a parameter and sometimes not. Here again, we found that the dictionary could be useful for an experienced PIMS user but would prove confusing and/or unhelpful for a new PIMS user due to the lack of detailed description of each table and parameter contained. Normally this would not be considered a significant issue. However, the missing information is not included in other documents, and as such should be included here.
While the current PIMS input database is now nominally accessible with the PIMS Database Manager, FTI was not provided with any tool or functionality with that name, nor any documentation regarding its operation, and were therefore unable to evaluate the accuracy of the Data Dictionary.

Based on our review, we therefore recommend, inter alia, that PBGC combine the Input Data Structure and Data Dictionary to create one comprehensive document describing the entire PIMS input data structure with appropriate process flow charts, and regularly update the document.

Develop a formal yearly review plan for all PIMS documentation to assure conformity with the evolving PIMS application.

Creating and maintaining system documentation is critical to understanding the end-to-end lifecycle of an application. System documentation includes user manuals related to running the application and information on application infrastructure. From a user's perspective, task-based documentation rather than descriptions of product features are generally preferred, as learning efficiency is an important goal.

Documentation is also critical for the maintenance of an application, including any potential future updates or changes. Information on the architecture of the application, such as operating system, source code programming language, and database structure is critical. Such documentation should include a technical overview, an entity relationship diagram, end-to-end process flow (see above), and a source code manual. For applications that have periodic changes to source code, outlining the path of the program execution is critical for anyone who may be asked to make a change to the logic. Equally critical is the completeness and accuracy of commentary in source code.

Therefore, a policy should exist within PBGC to periodically review and assess system documentation on at least an annual basis. Updates should be made to reflect any system changes or enhancements made since the prior review.

In the PIMS User Guide, provide step-by-step instructions on how to run a PIMS projection, including a description of required SAS scripts.

The purpose of the Pension Insurance Modeling System "User Guide for PIMS SOA 'Core' (vFY09.1)" (User Guide) is to provide PIMS users with detailed instructions regarding all of the functionality within the PIMS application. FTI evaluated this document for both accuracy relative to the application and efficacy in providing the information necessary for potential users to navigate and understand the application. Overall, we found it to be outdated, having been issued in 2010, and, relatedly, in many instances inaccurate. More specifically:

1. Some sections refer to functions that no longer exist in the PIMS application, such as:
    - Administrator functions referred to in Section 5;
    - Several of the "Tools" described in Section 4;
    - Appendices A, B and C, describing how to make updates to the data using FoxPro.

2. Some sections indicate the migration of some features to a new PIMS Database Manager function, yet we did not receive a copy of the Database Manager or any associated documentation for this new application.

3. Some sections contain minor inaccuracies in the descriptions of functions/forms in current PIMS applications (e.g., incorrect field names/descriptions and outdated screenshots of specific application forms).

4. Some functions contained in the application are not described in the User Guide (e.g., User Guide lacks a description of the "Single Scenario" tab on the Run Projection form).

Further, the Guide is missing information on some portions of the PIMS functionality which could lead to confusion for new users (e.g., an error message occurs prior to each PIMS run that, according to PBGC staff, can be ignored). Nor do any of the Guide's major sections contain detailed, step-by-step instructions on how to run a PIMS projection. (The quick start guide contains step-by-step instructions for specific tasks, but does not indicate how a user would run a projection from start to finish (e.g., reviewing the final PIMS output)).

For those and other reasons, we recommend that PBGC:

1. Update the User Guide to accurately reflect the current version of the PIMS application;

2. Restructure it to provide step-by-step instructions detailing how to run a PIMS projection; and

3. Develop a formal yearly review plan for the Guide to ensure that it remains accurate as the PIMS application is updated.

Implement specific code optimization recommendations.

Code optimization for a program as large and complex as PIMS would require a stand-alone project, as the most effective optimization begins with algorithm design. However, during our code review, we identified several items for which post-algorithm changes should improve performance, particularly when performing large numbers of runs. These changes will be most beneficial when applied to functions which are called multiple times; however, the gains would be small in comparison to algorithm improvements.

1. Loop Optimization: When using counters in loops, it is faster to compare to zero than to compare two numbers.

2. Specialized Functions: Complex programs are a balancing act between optimizing for performance versus reusability. Re-using standardized functions makes maintenance easier but often results in performance sacrifices. When a particular function is called multiple times by a loop, the code will run faster if the loop is moved into the function with values passed to it.

3. Array Merge: Often, array values are initialized one item at a time via a loop. As of C++11 this operation can be replaced by the STD::COPY which will result in performance improvements for some compilers.

4. Array Pointers: Use of pointers for array manipulation can improve performance improvements.

Utilize industry best practices for system documentation when designing and implementing future versions of PIMS.

As with any large programming task, in-the-code comments and documentation within the PIMS models are important tools for the ongoing maintenance and updating of the model. These comments have taken on even greater importance due to the lack of formalized system documentation. Lynchval's programs have done an excellent job maintaining version history notes in the comment sections of the coding modules. However, additional description of some of the variables is necessary given the lack of documentation elsewhere.

Further, some functions simply have placeholders for the missing documentation. For example:

```
//=Desc: Array error handling redirecter. Calls general error handler.
//
// Called by:???
```

Although comments are frequent throughout the source code, they are generally minimal. Comments with more robust context would be invaluable, particularly when referencing unique cases such as special run settings. Microsoft's guide to programming best practices[4] recommends using "…complete sentences when writing comments. Comments should clarify the code, not add ambiguity." It further suggests that "…comments {be used] to explain the intent of the code. They should not serve as inline translations of the code." Few of the comments in the PIMS source code are complete sentences, and many appear to be direct translations of the code as opposed to contextual explanations.

Although a major undertaking, we believe that PBGC should consider rewriting the PIMS program from scratch rather than modifying the legacy code, which would result in improved performance and reduced maintenance costs (due to code reduction). However, we have not made this a priority recommendation given possible budgetary restrictions.

Ad hoc report requests that require changes to the PIMS code should be part of the change management process, even if those changes are not implemented in the next release.

PIMS code can also be changed pursuant to an ad hoc report request, typically coming from Congress, the OMB, or the White House. The request will frequently ask for an analysis leveraging assumptions or specifications of law other than those used in the prior year's Projections Report. Updates to assumptions may require changes to the code; however, because these requests will not affect the production environment, they do not entail a formal Software Change Request form. When responding to an ad hoc request, a member of PRAD or PBGC's programming contractor check out the copy of the appropriate PIMS code into the Quality Assurance environment and work on the request. Once the response is completed, the results are reviewed by the Director of PRAD and Division Manager of the Pension Insurance Modeling Division before being provided to the requestor. The documentation of the request, code updates, and results are maintained on an internal PBGC network folder in the event they receive a similar request in the future.

However, changes to SAS code (used for preprocessing of data and assumptions and also for analyzing output) do not fall within the PIMS change management process. Unauthorized changes could impact

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[4] Coding Techniques and Programming Practices, https://msdn.microsoft.com/en-us/library/aa260844(v=vs.60).aspx.

model inputs and/or outputs and therefore should be included in the change management process so that they are appropriately tested and approved.

Update quality assurance procedures to explicitly require a comparison with previously communicated results and act as a consistency check.

With respect to assessing the consistency of PIMS results relative to previous model runs, we recommend that, in the quality assurance manual for the annual PIMS update and ad hoc requests, the reviewer be explicitly required to compare current results with previously communicated results as part of the reasonableness check.

Update the quality assurance manual for ad hoc requests, to require that, where necessary, communications back to the requestor satisfy Actuarial Standard of Practice Number 41, Actuarial Communications.

If the responses to ad hoc requests are actuarial opinions issued by qualified actuaries, they should observe the relevant Actuarial Standards of Practice. The elements of such communication include identification of the responsible actuary, reference to applicable actuarial assumptions and methods, and the extent to which the subject work can be relied upon. Such information is not only useful for communicating actuarial results, but also useful for documenting the review of the consistency and reasonableness of results.

Appropriately account for potential policy lever changes in future system designs that facilitate and implement design features flexibly.

The reconciliation and sensitivity analyses currently performed by PBGC are useful in assessing the consistency of the results relative to those from prior model runs, in light of policy lever changes introduced; however, professional judgment on the part of actuaries and economists is still needed. Because policy changes often impact different elements of the pension insurance system simultaneously, expert advice is needed as to how policy changes impact different items both separately and in combination. For example, a change to ERISA funding rules may impact the plan funded status, potential PBGC claims, PBGC premium collection and bankruptcy probability, and net effects of these various impacts is not apt to be obvious. Thus, future system designs should reflect the best expert opinion as to the mechanism by which policy changes affect the financial condition of insured plans.

Eliminate inconsistencies in the PIMS 2010 System Guide.

Certain bankruptcy model coefficients as most recently estimated (in September 2009 – see PIMS 2010 Guide, Table 6-6) bear reversed signs (e.g., negative to positive) as compared to those reported earlier (2010 Guide, Table 6-4), and are also inconsistent with relevant economic and financial theory. We were told that the apparent inconsistency is due to the fact that the results reported in Table 6-6 are for a model that predicts probability of a firm *not* going bankrupt (*i.e.*, 1 – probability of bankruptcy). PBGC staff agree that the results reported in Table 6-6 need to be updated. Further, PBGC reports t-statistics for the coefficients in Table 6-4 but not in Table 6-6, making it difficult to determine whether the coefficient estimates that were statistically significant in Table 6-4 continue to remain so in Table 6-6.

Therefore, we recommend that PBGC update the results reported in Table 6-6 of the Guide (or a successor document) so that reported coefficients are for the equation used to model the probability of bankruptcy, as is done in Table 6-4, and also report the t-statistics of the coefficients in Table 6-6.

Priority 3 Recommendations

If feasible, de-risking trends should be incorporated in SE-PIMS. This could be done by adjusting pension plans' asset allocations and PBGC's premium collections.
For SE plans, recent de-risking by plan sponsors tends to reduce PBGC's risk exposure; however, ME plan sponsors have not implemented de-risking as often as SE plan sponsors. Further, it is not clear how much ME plan trustee decisions can affect either sponsor contributions or benefit levels, since both are determined through collective bargaining.

De-risking activities include a shift in asset allocation toward bonds and long duration bonds; dynamic asset allocation based on funded status (also known as a glide path or journey plan); and pension risk transfer via lump sum offering, buy-in or buy-out.

In assessing whether PIMS should model plan sponsors' de-risking activities, we observed that:

- Such strategies should not materially change the level of pension underfunding. In pension risk transfer, the assets needed to transfer the liability to a third party usually exceed the funding target or the accounting Projected Benefit Obligation (PBO) of the liability. Therefore, the funded status measured on the funding or accounting basis may decline initially. However, companies usually increase their cash contributions to maintain funded ratio targets.

- With respect to PBGC premiums, de-risking through pension freeze or pension risk transfer will reduce the number of covered participants, and therefore the collection of flat PBGC premiums. With respect to variable-rate premium, the reduction in the volatility of pension underfunding usually means a reduction in the variable-rate premium.

- As Moody's has observed, for healthy companies, de-risking is usually credit rating neutral or positive. Therefore, it should not materially change the bankruptcy probability for such companies; and distressed companies are unlikely to take pension initiatives that will adversely impact their operating business.

Hence, our recommendation is that PBGC attempt to reflect de-risking trends in PIMS, but as a separate study initially before incorporating it into the Projections Report. Such modeling could be done by adjusting pension plans' asset allocations and PBGC's premium collections. For example, one study using Form 5500 Schedule R data showed that underfunded plans hold a four-percentage- point-more aggressive allocation than plans with a funded ratio greater than 80%. Thus, if PIMS were set up to reflect varying for asset allocations, one possible way to model the impact of de-risking is to reduce the equity allocation when the funded ratio reaches some threshold. Further, to model the impact of de-risking on PBGC premium collections for SE plans, one might reduce the head count in flat premium projections as well as in variable-rate premium cap.

Update PIMS documentation to properly describe the claim examination process in PIMS, in the event of bankruptcy.

Our review of the relevant PIMS code indicates that PIMS performs claim examinations on a plan-by-plan basis. However, the PIMS 2010 Guide states that PIMS examines a firm's plans as a unit under the assumption that a sponsor would merge under- and overfunded plans in a bankruptcy. As such, there is a discrepancy between the PIMS code and the PIMS 2010 Guide. PBGC staff in their comments informed us that PIMS 2010 Guide is incorrect and needs to be updated.

Refrain from using hard-coded values within the PIMS code for values that are not static.

FTI identified hard-coded values throughout the PIMS code. While many of these are appropriate, there are many cases where the values used could change in the future, either permanently or due to, for example, an ad hoc request. For future program changes, the PBGC should consider using values stored in a SQL server table in place of hard-coded values whenever the value may change. For example, the below code in PIMS is currently assigned static values, and would need to be manually updated every time the values changed:

```
oAct_flat_cashflow.aNewHireHeadcountDist[20] = 0.24870;
oAct_flat_cashflow.aNewHireHeadcountDist[25] = 0.16640;
oAct_flat_cashflow.aNewHireHeadcountDist[30] = 0.14240;
oAct_flat_cashflow.aNewHireHeadcountDist[35] = 0.11600;
oAct_flat_cashflow.aNewHireHeadcountDist[40] = 0.10560;
oAct_flat_cashflow.aNewHireHeadcountDist[45] = 0.08830;
oAct_flat_cashflow.aNewHireHeadcountDist[50] = 0.06580;
oAct_flat_cashflow.aNewHireHeadcountDist[55] = 0.06680;
```

Appropriately capture institutional knowledge documentation at the functional level, such as documentation on the structure of PIMS code, or process memos on how to review PIMS results.

The proper working of quality assurance procedures depends on the institutional knowledge, experience and expertise of key PBGC personnel. Appropriately capturing such knowledge should be a priority for PBGC. For example, the agency would benefit from an increased focus on documenting the methodology and rationale behind certain key PIMS algorithms, such as mass withdrawal probability and the plan sampling process. Documentation of the logic behind their creation is important for preserving institutional knowledge. Additionally, a process should be adopted to create a summary memo for all ad hoc requests. These memos should capture the original request, PIMS code change(s), results, response and any other relevant information. By using a narrative form to summarize how the ad hoc request was addressed, PBGC will be able to capture and preserve the institutional knowledge required which can then be applied to future requests or used to help train personnel moving into new roles. This is a common best practice in data science, complex modeling and analytics.

Provide a full explanation of the purpose of the Projections Report.

Based on all statutory and other references considered, as well as the authors' experience, we summarized the appropriate purpose of the PBGC Projections Report as follows:

> The Projections Report should provide relevant information that allows its readers to evaluate the financial health of PBGC's pension insurance programs. This is done through a projection of assets, liabilities, claims, and cash flows so that an evaluation can be made as to whether PBGC's pension insurance programs can pay its obligations when due.

Integral to an understanding the financial health of PBGC's insurance programs is an appreciation of their risks, implying that:

a.   Readers should be able to understand the projected financial results;

b.   Readers should be able to understand the uncertainty of the related projections;

c. Readers should be able to understand the main drivers of those uncertainties, especially in cases of extreme losses;

d. Pension professionals should be able to perform an independent evaluation of the financial health of the pension insurance programs based on the Projections Report combined with other information released by PBGC.

In the Projections Report, more fully describe the main drivers of uncertainty and extreme losses.

The 2014 Projections Report goes into some detail in discussing sources of uncertainty in the ME and SE programs. Three major sources of uncertainty are identified for the multiemployer program: (1) probability of new claims, (2) variability in the timing and amount of financial assistance payments, and (3) extent to which plans will use suspensions and partitions under MPRA. For the SE program, five sources of uncertainty are discussed: (1) the bankruptcy of plan sponsors, (2) the size of benefit payment payments and new claims, (3) projected liabilities in 2024, (4) the investment return on PBGC-trusteed assets, and (5) the amount of premium income from 2015 through 2024. However, there is little discussion of the economic and demographic forces giving rise to these uncertainties.

Apart from idiosyncratic factors impacting individual plans, there are three broad factors having immediate impact on pension insurance programs: asset returns, interest rates, and the total number of covered participants (including both active and retired) in each program. We also believe readers would benefit from a discussion of how each such factor impacts PBGC. (For example, persistently low equity returns will increase plan underfunding and cause some ME plans to be insolvent, while also accelerating the timing of financial assistance payments.)

Other Recommendations

Simulation of Plan Sponsors and Plan Viability (Subtask 4.2)

- Test the historical correlation between the incidence and/or extent of plan insolvencies, on the one hand, and materially incomplete plan Form 5500 filings, on the other.

- PBGC's inclusion of a pension plan's funding ratio in its bankruptcy model is appropriate. We recommend a test of the explanatory power of that ratio as alternatively calculated based on accounting and market values.

- Assess the benefits of measuring a firm's pension funding relative to its enterprise value, and/or modifying the debt-to-equity ratio used in the bankruptcy forecasting equation to include pension underfunding as long-term debt.

Modeling of Sponsor Failure Risk and PBGC Plan Administration (Subtask 4.3)

- PIMS models an investment policy that hedges the interest rate risk of trusteed liabilities. However, PBGC's 2014 Annual Report does not make clear whether the agency has an interest rate hedging policy for the trust fund. Therefore, PBGC should review PIMS modeling of the trust fund's investment returns to determine if it is consistent with policy.

- Determine whether removal of caps on retiree benefits materially affects forecasts.

Stochastic Modeling (Subtask 4.4)

- Conduct periodic sensitivity analyses to assess the impact of using a static simulation sample that ignores voluntary plan terminations and plan freezes and reporting the results of such analyses along with the distribution of its net financial positions.

PIMS Documentation (Subtask 4.5)

- Draft a new section in the PIMS User Guide describing the SAS scripts required to run a PIMS projection and create output for the Projections Report.

- Draft a new section in the new combined Data Structure/Data Dictionary document that describes how to access the Database Manager, and how to update tables and parameters.

Evaluation of the Coding of the Models (Subtask 4.6)

- Consider creating guidelines for the use of descriptive variables in future PIMS programming development.

- Although a major undertaking, consider rewriting the program from scratch rather than modifying the legacy code, which would result in improved performance and reduced maintenance costs (due to code reduction).

The Model Development Process (Subtask 4.7)

- Perform a periodic formal assessment of the legislative changes, economic factors, and actuarial assumptions that apply to PIMS to determine if /how they should be reflected within PIMS.

Internal Consistency and Ease of Implementation of Modifications to PIMS (Subtask 4.8)

- Track non-confidential ad hoc requests, as some previously fulfilled requests may be applicable to future requests and should be consistent with related requests.

The Presentation of Model Output (Subtask 4.9)

- Enhance documentation for completing the output from PIMS for the Projections Report.

- Explain how the distribution of outcomes is skewed by stochastic volatility of asset returns, non-normal distribution of certain variables and increased volatility and correlation at unfavorable scenarios.

- Expand explanations of the driving forces behind the uncertainties that affect projected deficits.

- Separately show the liabilities for SE plans already under PBGC control and those expected from future takeovers. For ME plans, separately show the liabilities for plans currently receiving assistance and those expected to receive it in the future.

- Break out the assets and liabilities behind projected deficits.

Subtask Reports

[Below the subtask reports will be included or linked.]

Subtask 4.1

2014 MAP-21 Peer Reviews: Evaluation of PIMS Modeling of Macroeconomic Variables

Subtask 4.2

2015 MAP-21 Peer Reviews: Evaluation of the Simulation of Plan Sponsors and Plan Viability

Subtask 4.3

2015 MAP-21 Peer Reviews: Evaluation of Modeling of Sponsor Failure Risk and PBGC Plan ...

Subtask 4.4

2015 MAP-21 Peer Reviews: Evaluation of the Stochastic Modeling Process

Subtask 4.5

2014 MAP-21 Peer Reviews: Evaluation of PIMS Documentation

Subtask 4.6

2015 MAP-21 Peer Reviews: Evaluation of the Coding of the Models

Subtask 4.7

2015 MAP-21 Peer Reviews: Evaluation of PIMS Model Development, Modification and Refinement

Subtask 4.8

2015 MAP-21 Peer Reviews: Evaluation of the Internal Consistency and Ease of Implementation ...

Subtask 4.9

2014 MAP-21 Peer Reviews: Evaluation of Model Output