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Aging and Retirement

Background Document: Quantitative Evaluation Framework for Retirement Benefit Systems

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Quantitative Evaluation Framework for Retirement Benefit Systems

AUTHOR Rowland Davis

SPONSOR Retirement Section Research Committee

Acknowledgments

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CONTENTS

Introduction

Retirement benefits can be delivered through a wide variety of arrangements, including traditional defined benefit (DB) or defined contribution (DC) plans, as well as hybrid designs. Many new retirement arrangements are now being proposed, often with the idea that a shared-risk system might be more efficient in delivering benefits within a target range and with a sustainable range of long-term sponsor cost. The Society of Actuaries (SOA) is actively engaged in supporting efforts to explore such alternative designs and has identified the benefit of a quantitative evaluation (QE) framework that will facilitate the direct comparison of one proposal to another proposal, and to the more traditional DB and DC structures as benchmarks. This report summarizes work to date on a framework that would provide:

- A set of well-defined metrics that could be used for each retirement system structure or design
- Specific methods that could be used for the calculations
- Specific assumptions that could be used for the calculations

This framework was developed from 2016 through 2018 as part a research project sponsored by the SOA, led by Rowland Davis and overseen by a Project Oversight Group that included both actuaries and other retirement experts. The work is an extension of the earlier SOA Retirement 20/20 initiative, and development and refinement of the QE framework will continue as part of a new Retirement Plan Innovation (RPI) initiative led by Barbara Sanders.

The purpose of this report is to provide documentation of the extensive work completed to date on the framework and for the benefit of practitioners in this area.

Please note the underlying model referred to in this document is not currently available as a software tool.

The author and oversight group for this report thought it useful at this stage of the process to educate readers and document the model concepts that have been developed for the framework.

In addition, readers are encouraged to suggest refinements to the model concepts and overall framework that they would find useful.

Further material on the framework as part of the RPI initiative will be shared upon completion.

Separation of Accumulation and Payout Phases

Any retirement system includes both an accumulation phase (where benefits are accrued and assets are accumulated and invested to support the payouts that commence at retirement) and a payout phase (where accumulated assets are converted to some form of payout stream). This QE framework is predicated on the concept that accumulation structures and payout structures are fundamentally separable, such that any accumulation structure may be combined with any payout structure to create a complete retirement system. Because of this feature, the framework provides specific metrics (and supporting analysis) for each of these two separable parts of any system.

We recognize that some retirement systems integrate the accumulation and payout phases (e.g., a single investment fund is used, and benefit or cost adjustments may be made for both active and retired participants based on the overall funded status), but this framework assumes there is always an appropriate way to de-couple the two components—at least for an initial analysis. Absent this de-coupled analysis, there may be some possibility of risk being shifted from actives to retirees, or vice versa. A de-coupled analysis will clarify the possible nature of these risk shifts. If needed, additional analysis can be done that illustrates the combined functioning of the accumulation and payout components.

Since the primary goal of this framework is to facilitate comparisons on a consistent basis for various retirement system structures, the metrics are developed within a highly standardized model, using well-defined sample employees, calculation methods and assumptions (both demographic and economic). The framework is based on a stochastic simulation process, as this is the best way to properly quantify the various risk and reward metrics that are appropriate for an adequate analysis.

Basic Structure: Accumulation Phase

For the accumulation phase, the metrics focus primarily on the range of benefits provided at the point of retirement and the range of possible costs for the sponsor. At a basic level, the accumulation phase is a completely scalable entity, in that the level of benefits for any structure (inclusive of a specified investment strategy) can be scaled up or down simply by adjusting the contribution inputs. To facilitate comparisons, the QE framework uses a standard scale, with total contributions (employee, plus expected sponsor) assumed to be equal to 10% of pay over the active career.[1] The analysis can then focus on the expected level of benefits produced from this contribution, and the range of uncertainty for both the benefits and the sponsor cost. The Figure 1 through 4 illustrate this with metrics determined for:

- A defined benefit plan where the benefit is set at the level that can be supported by a 10% of pay expected cost, with benefits payable as a lump sum at retirement and then converted to a lifetime annuity using a standardized set of market priced annuity values,[2] and an investment strategy of 70% risky assets/30% fixed income assets
- A traditional defined contribution plan with total contributions of 10% of pay, and with the accumulated fund at retirement converted to a lifetime annuity using the same standardized set of market priced annuity values, and an investment strategy of 70% risky assets/30% fixed income assets.

The key benefit metrics are the average replacement ratio (RR) across all simulated scenarios and the average RR in the worst quintile of simulated outcomes, often referred to as a "tail risk estimate." The latter metric is generally used as one of the key risk metrics in the analysis of any plan.

Figures 1 and 2 summarize only the most important metrics developed for each type of plan.

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[1] In addition to being a round number, the 10% of pay contribution is deemed a reasonable choice for two reasons: (1) current levels of total contributions (employee + employer) into U.S. 401(k) plans for private employers are about 10% of pay (in Vanguard 2015 data for participating employees, the median rate is 8.8% and the average rate is 9.5%), and (2) for the benchmark employee used in our framework, a 10% of pay contribution into a standard DC plan using a typical target date investment fund over the full career produces a total replacement rate (annuitized plan benefit, plus Social Security) that will generally (i.e., with a probability greater than 50%) exceed 70% of final pay, which can be viewed as something of a minimal target to maintain the pre-retirement standard of living for a median income worker.

[2] Note that converting the lump-sum accumulation using market priced annuity values leads to benefit uncertainty for DB benefits, due to interest rate risk at the time of retirement. In traditional DB plan structures, this risk is most often eliminated for participants (and retained by the sponsor) through the use of a fixed price annuity conversion factor as the basis for the payout phase.

Figure 1
Most Important Metrics Developed for DB Benchmarks

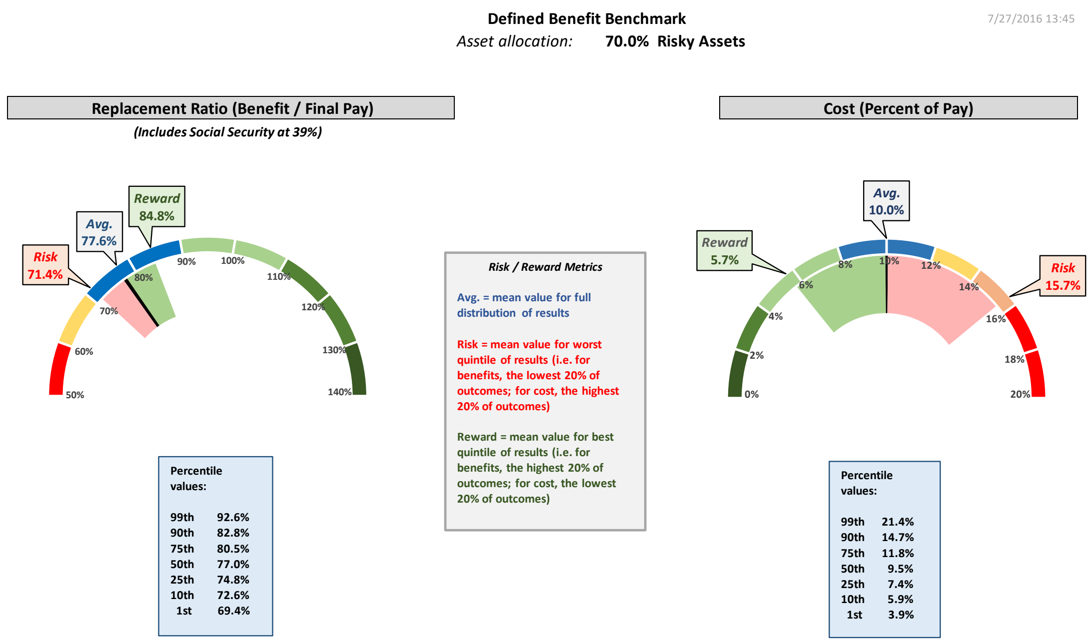
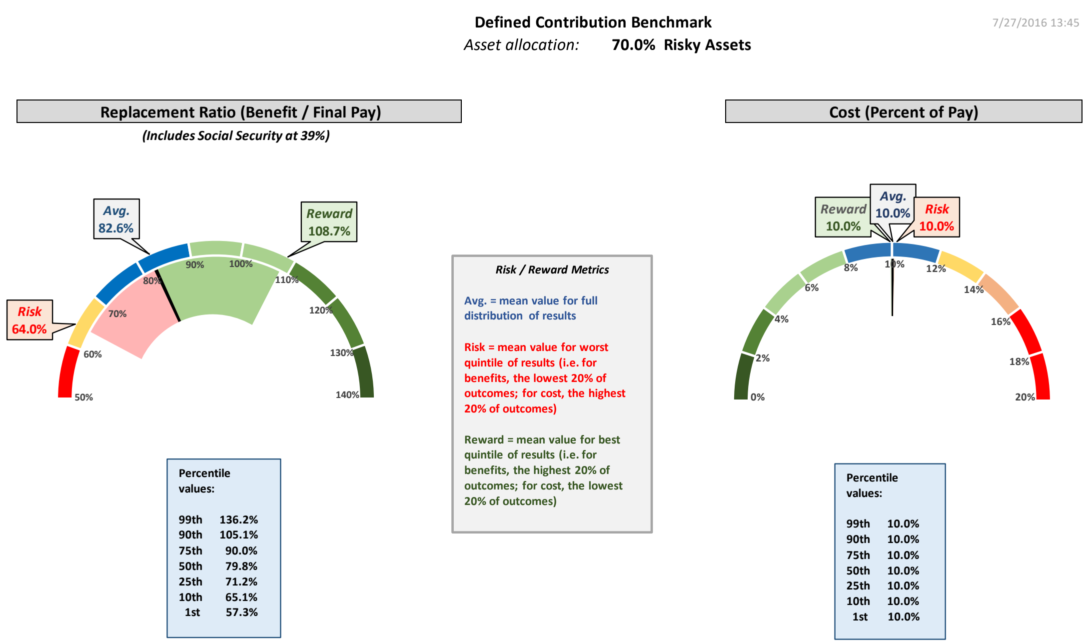


Figure 2
Most Important Metrics Developed for DC Benchmarks

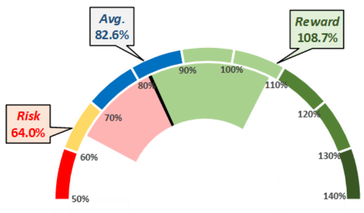


Figures 3 and 4 show the complete set of metrics used for these selected benchmark DC and DB plans. These metrics are explained in more detail in Appendix A.

Figure 3
All DC Metrics Developed

Defined Contribution Benchmark 8/5/2016 12:39
Asset allocation: **70.0% Risky Assets**
(modeled with baseline version of risky asset simulations)

Replacement Ratio (Benefit / Final Pay)
(Includes Social Security at 39%)



Percentile values:

99th	136.2%
90th	105.1%
75th	90.0%
50th	79.8%
25th	71.2%
10th	65.1%
1st	57.3%

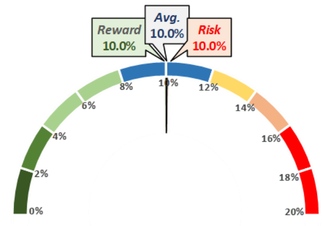
Risk / Reward Metrics

Avg. = mean value for full distribution of results

Risk = mean value for worst quintile of results (i.e. for benefits, the lowest 20% of outcomes; for cost, the highest 20% of outcomes)

Reward = mean value for best quintile of results (i.e. for benefits, the highest 20% of outcomes; for cost, the lowest 20% of outcomes)

Cost (Percent of Pay)



Percentile values:

99th	10.0%
90th	10.0%
75th	10.0%
50th	10.0%
25th	10.0%
10th	10.0%
1st	10.0%

Other Metrics

Benefit Shortfall Risk

Replacement Ratio Target:	Shortfall Probability
70%+	22.3%
60%+	3.7%

Benefits by Career Pattern

Turnover assumption = Baseline / medium
Plan: Defined Contribution

Average replacement ratio:	*# Employers*	*Weight*	*Soc. Sec.*	*Plan Ben.*	*Total*
Full career with single employer	1	40%	39.0%	43.6%	82.6%
Multiple employers over career	3	60%	39.0%	43.6%	82.6%
Blended average			39.0%	43.6%	82.6%

Stress Index for Accumulation Path

Measures reflect all years during career where account, or accrued benefit, experiences an investment-related loss, averaged over all scenarios.

	Loss Frequency	*Average Loss (% pay)*	*Cummulative Career Losses (% pay)*	*Index*
Best / smoothest possible path	0.0%	0.0%	0.0%	0.0
(i.e. no losses, such as DC w/ cash or SV investments)				
Result for DC w/100% fixed income (core style)	18.7%	-5.6%	-38.4%	0.9
Result for this plan	26.3%	-24.4%	-228.5%	5.1
Result for DC w/ typical TDF (90/50)	27.0%	-22.6%	-219.1%	4.9
Worst / most volatile possible path	30.0%	-41.7%	-444.0%	10.0
(i.e. DC plan w/ 100% risk asset allocation)				

Adjusted Cost for a 70% Repl. Ratio Target:

Cost to achieve a 70%+ replacement ratio, with a specified level of confidence.

Confidence target:	*Average Cost (% pay)*	*Cost Risk Metric (% pay)*
50% confidence	7.6%	7.6%
70% confidence	9.2%	9.2%
90% confidence	11.9%	11.9%

Assumptions

	Baseline assumption	***Adjustment***	***Adjusted assumption***
Price inflation	2.5%	0.0%	2.5%
Real wage growth	0.5%	0.0%	0.5%
Nominal wage growth	3.0%	0.0%	3.0%
Real yield on 10-yr Treas	1.8%	0.0%	1.8%
Nominal yield on 10-yr Treas	4.3%	0.0%	4.3%
Credit/duration spread for for "Core Fixed Income"	0.2%	0.0%	0.2%
Nominal "Core Fixed Income" returns	4.5%	0.0%	4.5%
Risk premium for risky assets	3.5%	0.0%	3.5%
Nominal risky asset returns	8.0%	0.0%	8.0%
(gross, long-term compounded)			

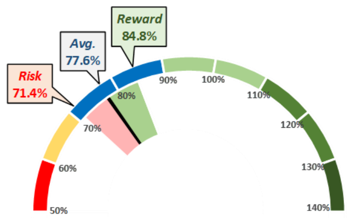
Figure 4
All DB Metrics Developed

Defined Benefit Benchmark 7/17/2016 13:34

Asset allocation: **70.0% Risky Assets**

Replacement Ratio (Benefit / Final Pay)

(Includes Social Security at 39%)



Percentile values:

99th	92.6%
90th	82.8%
75th	80.5%
50th	77.0%
25th	74.8%
10th	72.6%
1st	69.4%

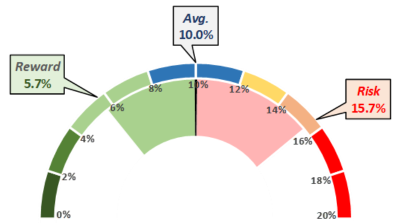
Risk / Reward Metrics

Avg. = mean value for full distribution of results

Risk = mean value for worst quintile of results (i.e. for benefits, the lowest 20% of outcomes; for cost, the highest 20% of outcomes)

Reward = mean value for best quintile of results (i.e. for benefits, the highest 20% of outcomes; for cost, the lowest 20% of outcomes)

Cost (Percent of Pay)



Percentile values:

99th	21.4%
90th	14.7%
75th	11.8%
50th	9.5%
25th	7.4%
10th	5.9%
1st	3.9%

Other Metrics

Benefit Shortfall Risk

Replacement Ratio Target:	Shortfall Probability
70%+	2.4%
60%+	0.0%

Benefits by Career Pattern

Turnover assumption = Baseline / medium
Plan: Traditional final pay

Average replacement ratio:	*# Employers*	*Weight*	*Soc. Sec.*	*Plan Ben.*	*Total*
Full career with single employer	1	40%	39.0%	45.5%	84.5%
Multiple employers over career	3	60%	39.0%	33.9%	72.9%
Blended average			39.0%	38.6%	77.6%

Stress Index for Accumulation Path

Measures reflect all years during career where account, or accrued benefit, experiences an investment-related loss, averaged over all scenarios.

	Loss Frequency	*Average Loss (% pay)*	*Cummulative Career Losses (% pay)*	*Index*
Best / smoothest possible path	0.0%	0.0%	0.0%	0.0
(i.e. no losses, such as DC w/ cash or SV investments)				
Result for DC w/100% fixed income (core style)	18.7%	-5.6%	-38.4%	0.9
Result for this plan	0.0%	0.0%	0.0%	0.0
Result for DC w/ typical TDF (90/50)	26.3%	-24.4%	-228.5%	5.1
Worst / most volatile possible path	30.0%	-41.7%	-444.0%	10.0
(i.e. DC plan w/ 100% risk asset allocation)				

Adjusted Cost for a 70% Repl. Ratio Target:

Cost to achieve a 70%+ replacement ratio, with a specified level of confidence.

Confidence target:	*Average Cost (% pay)*	*Cost Risk Metric (% pay)*
50% confidence	8.4%	13.1%
70% confidence	8.9%	14.0%
90% confidence	9.5%	14.8%

Assumptions

	Baseline assumption	*Adjustment*	*Adjusted assumption*
Price inflation	2.5%	0.0%	2.5%
Real wage growth	0.5%	0.0%	0.0%
Nominal wage growth	3.0%	0.0%	3.0%
Real yield on 10-yr Treas	1.8%	0.0%	0.0%
Nominal yield on 10-yr Treas	4.3%	0.0%	4.3%
Credit/duration spread for for "Core Fixed Income"	0.2%	0.0%	0.0%
Nominal "Core Fixed Income" returns	4.5%	0.0%	4.5%
Risk premium for risky assets	3.5%	0.0%	0.0%
Nominal risky asset returns	8.0%	0.0%	8.0%
(gross, long-term compounded)			

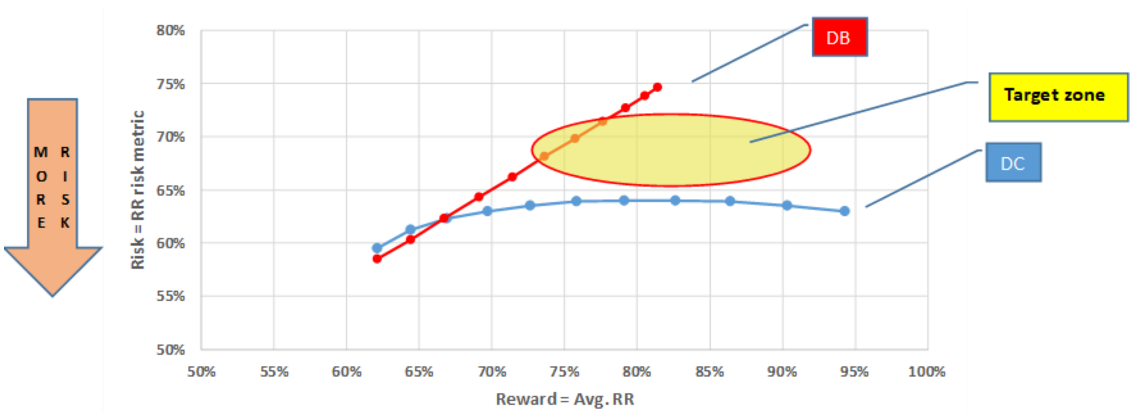
If a proposed accumulation design includes the potential for different levels of investment risk, the metrics should be tested, at a minimum, for each of three different levels of investment risk, based on allocations to risky assets of 70%, 50% and 30%. Additional investment strategies (e.g., a target date strategy for a defined contribution plan) can then be added, as needed, for comparative purposes.

For certain types of accumulation structures, some additional analysis may be required, such as:

- Where the accrual of benefits is not uniform across the career (e.g., a traditional final pay DB plan, with a back-loaded accrual pattern), the metrics should be developed under the assumption of a full career under a single plan, as well as for a career that is broken into separate fragments under different plans. These results will then be blended to create the final set of metrics. The detailed methodology is described in Appendix L.
- Where the accumulation structure includes intergenerational risk sharing (e.g., a collective DC plan, or certain DB plans with a variable benefit structure), the metrics should be developed for various age cohorts, to illustrate how the results might differ between early cohorts and later cohorts.
- Where benefit adjustments depend on actual investment and economic outcomes but retain some degree of flexibility (e.g., board discretion), then the metrics may need to be shown with more than one illustrative pattern of decision-making assumptions, or rules.

For the QE framework, a complete set of benchmark results have been determined for standard DC and standard DB plans, covering the full range of investment risk (from 0% to 100% allocation to risky assets, in 10% steps). When plotted graphically, the replacement ratio benchmark values help to identify a risk-sharing "space" (i.e., the target zone where the results from any risk-sharing plan design should plot). The Figure 5 uses the average RR value and the RR risk metric (i.e., a tail risk estimate; see Appendix L).

Figure 5
Target Zone for Results



The most basic risk-sharing design is a simple combination of a standard DC plan with a standard DB plan (combo DC + DB plan). In fact, for any set of risk-sharing results that show up in the risk-sharing target zone, the QE framework can be used to reverse engineer one specific combo DC + DB plan that has the same set of results. We refer to this as the equivalent combo DC + DB plan.

Figure 6 illustrates this with a sample set of results where the average RR is 80% and the RR risk metric is 70%.

Figure 6
Sample Results; RR = 80%, RR risk metric = 70%

For this example, the equivalent combo plan has a DC weight of 45% and a DB weight of 55%, both using a 71% allocation to risk assets. This equivalent combo plan can then be used as a benchmark for the evaluation of any other risk-sharing plan that might produce the same RR metrics. The evaluation process will involve looking at the other metrics, especially the cost risk metric, for both the risk-sharing plan under review and for its equivalent combo DC + DB plan. The comparison will indicate whether the risk-sharing plan under review is cost efficient, at least relative to its simple equivalent combo plan.

The use of benchmark DC, DB and combo DC + DB values to frame the risk-sharing space is more fully explained in Appendices B through E. The evaluation process is illustrated in Appendix F for a specific cash balance plan design that uses a participating form of credit rate, and a more complete evaluation study is included in Appendix G for the broader family of participating cash balance designs.

Basic Structure: Payout Phase

For the payout phase, the primary focus is to show how benefits are distributed across the period of retirement, with separate metrics for income payments and for death benefits, and with the range of uncertainty shown for all of these. We again start from a standardized point, in this case based on an accumulation amount at retirement equal to the final balance after 37 years of contributing 10% of pay each year and investing in a typical target date fund (TDF). These standard starting values are different for each scenario in the stochastic simulation, and they are consistent with the accumulation phase model. On average, the starting balance equals 7.2 times final pay, with a standard deviation of 2.8 times final pay. The specifications for any payout phase design will determine how the balance is converted into a year-by-year pattern of income payments and death benefit payments for each scenario in the stochastic simulation. We first establish a set of baseline payout values for each year, using a fixed-price annuity conversion factor.[3] (A fixed-price annuity is used here because it represents the lowest risk option from the participant's point of view, since all mortality risk, investment risk and interest rate risk is taken on by the provider, who will be exposed to cost risk from these factors.) Then, for any other payout phase design, we take the ratio of each resulting income payout to the corresponding baseline value, for each year after retirement. These ratios become the basic raw material for analysis of payout benefits with a set of standardized metrics. If there is any cost risk to the sponsor/provider (e.g., any fixed-price annuity) then the cost risk is also quantified and the potential range of gains and losses is shown.

There are many metrics included in the standard payout phase analysis and these are described in Appendix A. To illustrate, we show the complete set of metrics for three sample payout arrangements:

- A market-priced insured annuity, priced for each scenario at interest rates linked to the simulated values prevailing at retirement for (1) the 10-year Treasury yield, (2) the shape of the yield curve, and (3) the spread for high quality corporate bonds, and with a 5% load for expenses, contingencies and profits. The annuity includes a 2.5% fixed COLA and a 15-year certain period (as a proxy for death benefits under a cash refund feature). See Figure 7.

[3] Specifically, we use a lifetime annuity priced at 5.85% interest, which is the expected return for a portfolio invested with a 30% allocation to risk assets. The annuity includes a full consumer price index (CPI) cost-of-living adjustment (COLA) (priced at an assumed 2.5% rate) and no death benefits. The cost risk for the provider is shown in Figure 8.

- Distributions taken under the simple “4% rule” (initial payout equal to 4% of the accumulated balance, with subsequent payments adjusted for actual inflation) with 50% of the assets allocated to risky assets. See Figure 8.
- The fixed-price annuity approach used to establish the baseline payout values, as described earlier. Since this arrangement creates cost risk to the sponsor/provider, the set of metrics includes analysis of the range of cost variation that may result from potential gains and losses. See Figure 9.

Figure 7
Insured Annuity Payout Phase Analytics

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Description of payout method being analyzed:

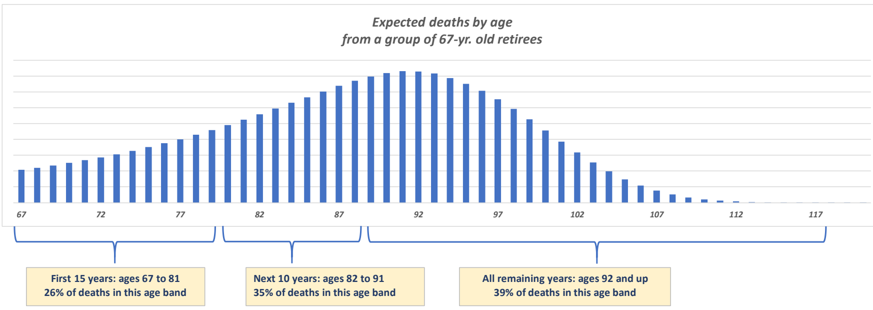
Allocation of distribution (by percent of initial balance)

Immediate annuity -- insurance company	100%
Immediate annuity -- fixed rate in-plan	0%
Longevity insurance	0%
Longevity bridge fund (LBF)	
Balance to "Structured Withdrawal Plan" (SWP)	%

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*
Yes	2.5%	5%	Stochastic market rates

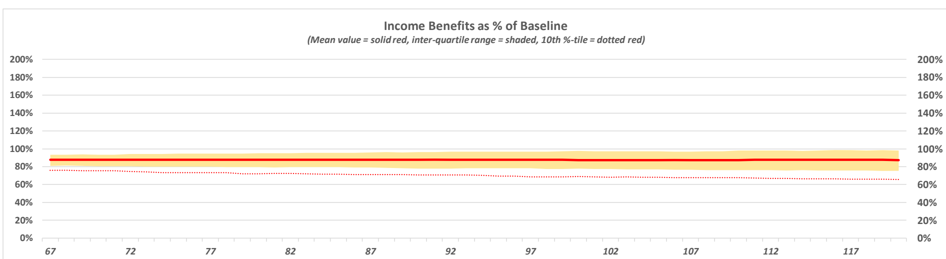
SWP alloc. to risk assets		*SWP alloc. to TIPS*		*SWP methodology (see parameters for details):*
50%	*at 67*	0%	*at 67*	*X% Rule is used for all years*
50%	*at 70*	0%	*at 70*	
50%	*at 75*	0%	*at 75*	
50%	*at 80*	0%	*at 80*	
50%	*at 85+*	0%	*at 85+*	

Age groupings used in analysis:

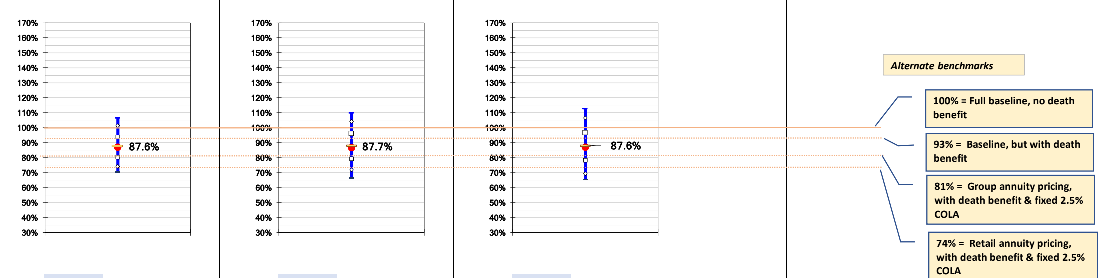


Range of income benefits as percent of baseline*:

*"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.45%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.*



First 15 years: ages 67 to 81	Next 10 years: ages 82 to 91	All remaining years: ages 92 and up



%tile	First 15 years: ages 67 to 81	%tile	Next 10 years: ages 82 to 91	%tile	All remaining years: ages 92 and up
95%	106.4%	95%	109.8%	95%	112.5%
90%	101.2%	90%	104.3%	90%	106.4%
75%	93.9%	75%	95.9%	75%	96.5%
50%	87.0%	50%	86.7%	50%	86.9%
25%	80.3%	25%	79.1%	25%	78.2%
10%	74.1%	10%	71.7%	10%	69.3%
5%	70.7%	5%	66.4%	5%	65.4%
Mean	87.6%	Mean	87.7%	Mean	87.6%

Sensitivity to initial age 67 conditions:

Initial interest rate at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	100.0%	100.4%	100.8%
Medium (avg. 20th to 80th percentile)	86.8%	86.7%	86.6%
Low (avg. lowest quintile)	77.7%	77.7%	77.3%

Expected inflation at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	96.3%	96.3%	96.5%
Medium (avg. 20th to 80th percentile)	86.5%	86.7%	86.7%
Low (avg. lowest quintile)	82.3%	82.1%	81.4%

Figure 7, continued
Insured Annuity Payout Phase Analytics

Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

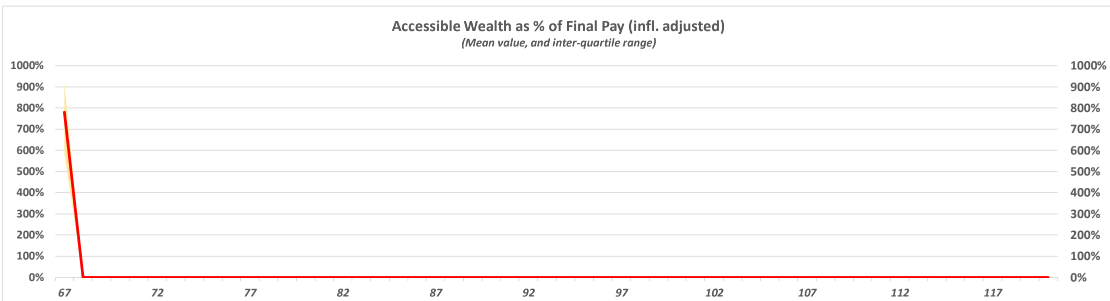
	------------- Shortfall risk (using 3-yr. avg.) ----------------		------------- Failure rate at: ----------------				
	First 15 yrs. (Ages 67 to 81)	**Next 10 yrs. (Ages 82 to 91)**	**Age 90**	**Age 95**	**Age 100**	**Age 105**	**Age 110**
			---------- Survival probability ----------				
60% of baseline	**0.6%**	**1.7%**	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	**0.0%**	**0.1%**					
40% of baseline	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
30% of baseline	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	**Next 10 yrs. (82 to 91)**	**Next 10 yrs. (92 to 101)**
Decline by 10+ percent	**2.4%**	**2.5%**	**2.9%**
Decline by 15+ percent	**0.2%**	**0.3%**	**0.6%**
Decline by 20+ percent	**0.0%**	**0.0%**	**0.0%**
Decline by 25+ percent	**0.0%**	**0.0%**	**0.0%**

Level of accessible wealth as percent of final pay (inflation adjusted)

(Note that the age 67 value is before the purchase of any annuities.)



Death benefits paid as percent of total payments

	First 15 yrs. (67 to 81)	**Next 10 yrs. (82 to 91)**	**All remaining yrs. (92 and up)**
%tile			
95%	**10.7%**	**0.0%**	**0.0%**
75%	**10.7%**	**0.0%**	**0.0%**
50%	**10.7%**	**0.0%**	**0.0%**
25%	**10.7%**	**0.0%**	**0.0%**
5%	**10.7%**	**0.0%**	**0.0%**
Mean	**10.7%**	**0.0%**	**0.0%**

Cost risk to sponsor for any fixed price annuities (cost spread as % of pay over career)

	------------- Change in cost as % of pay --------------	
	For "Baseline"	**For selected payout parameters**
%tile		
95%	**1.7%**	**0.0%**
75%	**0.4%**	**0.0%**
50%	**-0.4%**	**0.0%**
25%	**-1.1%**	**0.0%**
5%	**-2.2%**	**0.0%**
Mean	**-0.3%**	**0.0%**

Figure 8
4% Rule Payout Phase Analytics

12/5/2018 17:18

Description of payout method being analyzed:

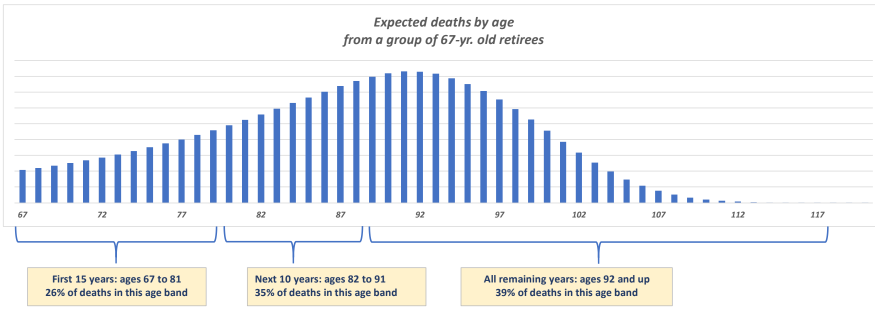
Allocation of distribution (by percent of initial balance)

Immediate annuity -- insurance company	0%
Immediate annuity -- fixed rate in-plan	0%
Longevity insurance	0%
Longevity bridge fund (LBF)	
Balance to "Structured Withdrawal Plan" (SWP)	100%

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*

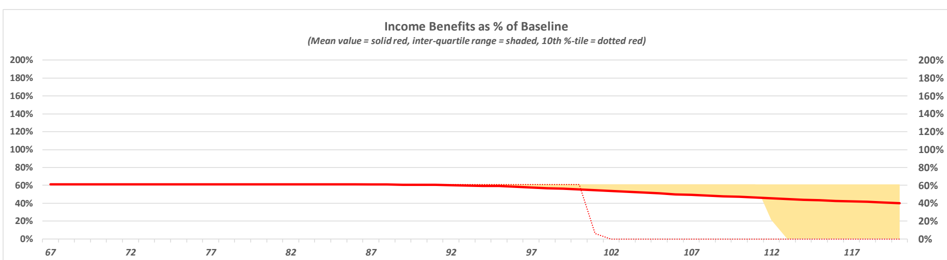
SWP alloc. to risk assets		*SWP alloc. to TIPS*		*SWP methodology (see parameters for details):*
50%	*at 67*	0%	*at 67*	*X% Rule is used for all years*
50%	*at 70*	0%	*at 70*	
50%	*at 75*	0%	*at 75*	
50%	*at 80*	0%	*at 80*	
50%	*at 85+*	0%	*at 85+*	

Age groupings used in analysis:

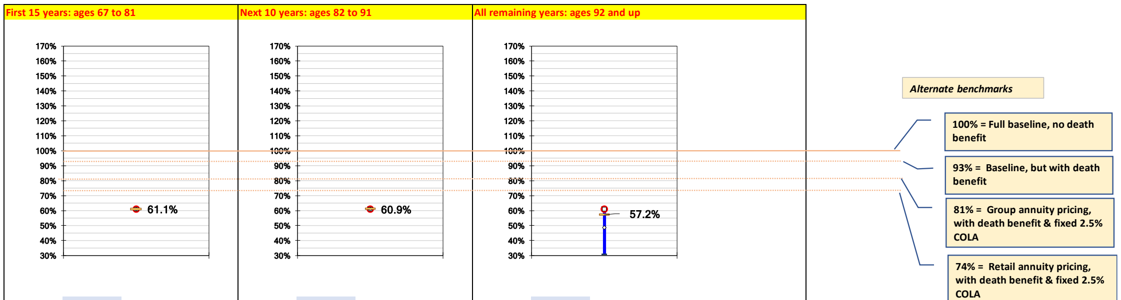


Range of income benefits as percent of baseline*:

"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.45%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.



First 15 years: ages 67 to 81	Next 10 years: ages 82 to 91	All remaining years: ages 92 and up



%tile	Ages 67 to 81	%tile	Ages 82 to 91	%tile	Ages 92 and up
95%	61.1%	95%	61.1%	95%	61.1%
90%	61.1%	90%	61.1%	90%	61.1%
75%	61.1%	75%	61.1%	75%	61.1%
50%	61.1%	50%	61.1%	50%	61.1%
25%	61.1%	25%	61.1%	25%	60.9%
10%	61.1%	10%	61.1%	10%	48.6%
5%	61.1%	5%	61.1%	5%	30.8%
Mean	61.1%	Mean	60.9%	Mean	57.2%

Sensitivity to initial age 67 conditions:

Initial interest rate at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	61.1%	60.9%	58.3%
Medium (avg. 20th to 80th percentile)	61.1%	60.9%	57.3%
Low (avg. lowest quintile)	61.1%	60.7%	55.9%

Expected inflation at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	61.1%	60.9%	57.8%
Medium (avg. 20th to 80th percentile)	61.1%	60.9%	57.2%
Low (avg. lowest quintile)	61.1%	60.9%	56.7%

Figure 8, continued
4% Rule Payout Phase Analytics

Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

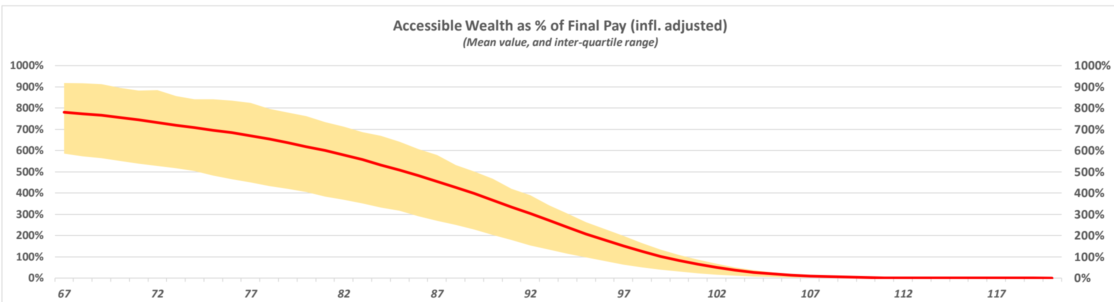
	Shortfall risk (using 3-yr. avg.)		Failure rate at:				
	First 15 yrs. (Ages 67 to 81)	Next 10 yrs. (Ages 82 to 91)	Age 90	Age 95	Age 100	Age 105	Age 110
			Survival probability				
60% of baseline	0.0%	0.4%	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	0.0%	0.3%					
40% of baseline	0.0%	0.2%	0.7%	3.0%	9.3%	17.0%	22.8%
30% of baseline	0.0%	0.2%	0.7%	3.0%	9.0%	16.4%	22.8%

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	Next 10 yrs. (92 to 101)
Decline by 10+ percent	0.0%	0.3%	5.0%
Decline by 15+ percent	0.0%	0.3%	4.9%
Decline by 20+ percent	0.0%	0.3%	4.7%
Decline by 25+ percent	0.0%	0.3%	4.7%

Level of accessible wealth as percent of final pay (inflation adjusted)

(Note that the age 67 value is before the purchase of any annuities.)



Death benefits paid as percent of total payments

%tile	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	All remaining yrs. (92 and up)
95%	41.7%	74.5%	91.6%
75%	36.2%	66.2%	85.6%
50%	32.7%	59.7%	79.0%
25%	29.2%	50.4%	65.0%
5%	24.4%	34.3%	28.2%
Mean	32.9%	57.5%	72.1%

Cost risk to sponsor for any fixed price annuities (cost spread as % of pay over career)

	Change in cost as % of pay	
%tile	For "Baseline"	For selected payout parameters
95%	1.7%	0.0%
75%	0.4%	0.0%
50%	-0.4%	0.0%
25%	-1.1%	0.0%
5%	-2.2%	0.0%
Mean	-0.3%	0.0%

Figure 9
Baseline Fixed-Price Annuity Payout Phase Analytics

12/5/2018 17:24

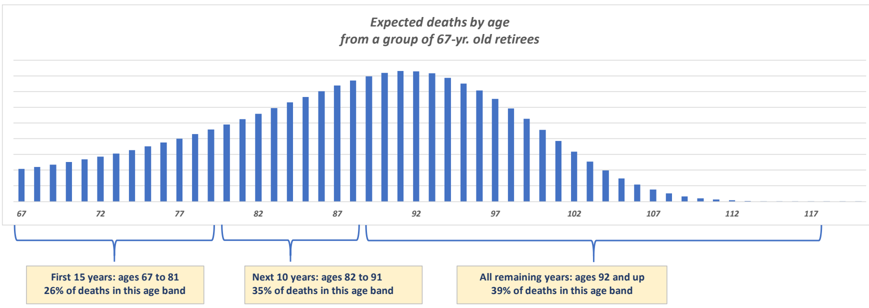
Description of payout method being analyzed:

Allocation of distribution (by percent of initial balance)	
Immediate annuity -- insurance company	0%
Immediate annuity -- fixed rate in-plan	100%
Longevity insurance	0%
Longevity bridge fund (LBF)	
Balance to "Structured Withdrawal Plan" (SWP)	%

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*
No	CPI	None	Expected return with 30% risk asset alloc. = 5.45%

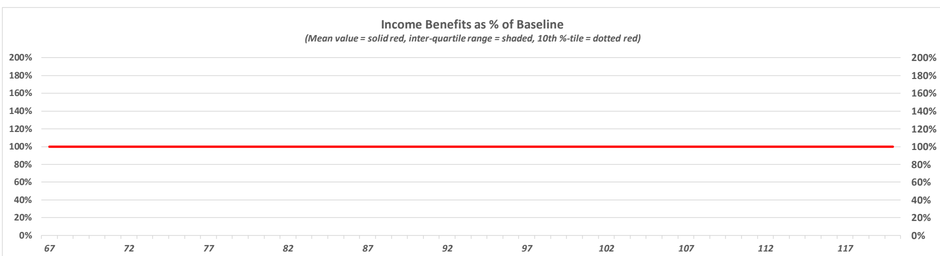
SWP alloc. to risk assets		*SWP alloc. to TIPS*		*SWP methodology (see parameters for details):*
50%	*at 67*	0%	*at 67*	*X% Rule is used for all years*
50%	*at 70*	0%	*at 70*	
50%	*at 75*	0%	*at 75*	
50%	*at 80*	0%	*at 80*	
50%	*at 85+*	0%	*at 85+*	

Age groupings used in analysis:

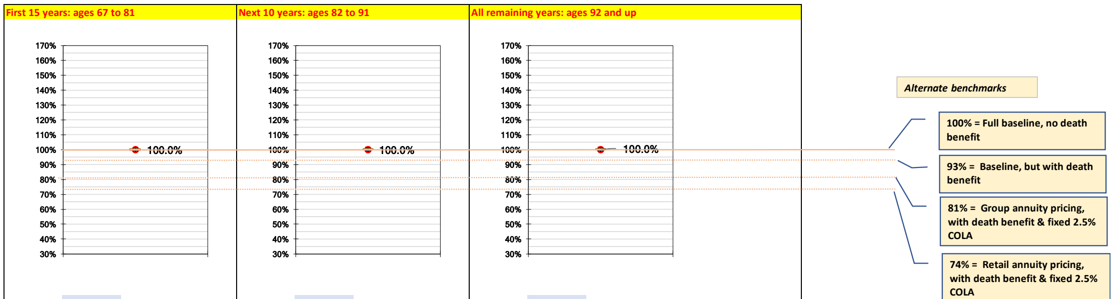


Range of income benefits as percent of baseline*:

"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.45%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.



First 15 years: ages 67 to 81	Next 10 years: ages 82 to 91	All remaining years: ages 92 and up



%tile	First 15 years: ages 67 to 81	%tile	Next 10 years: ages 82 to 91	%tile	All remaining years: ages 92 and up
95%	100.0%	95%	100.0%	95%	100.0%
90%	100.0%	90%	100.0%	90%	100.0%
75%	100.0%	75%	100.0%	75%	100.0%
50%	100.0%	50%	100.0%	50%	100.0%
25%	100.0%	25%	100.0%	25%	100.0%
10%	100.0%	10%	100.0%	10%	100.0%
5%	100.0%	5%	100.0%	5%	100.0%
Mean	100.0%	Mean	100.0%	Mean	100.0%

Sensitivity to initial age 67 conditions:

Initial interest rate at age 67:	Mean	Mean	Mean
High (avg. highest quintile)	100.0%	100.0%	100.0%
Medium (avg. 20th to 80th percentile)	100.0%	100.0%	100.0%
Low (avg. lowest quintile)	100.0%	100.0%	100.0%

Expected inflation at age 67:	Mean	Mean	Mean
High (avg. highest quintile)	100.0%	100.0%	100.0%
Medium (avg. 20th to 80th percentile)	100.0%	100.0%	100.0%
Low (avg. lowest quintile)	100.0%	100.0%	100.0%

Figure 9, continued
Baseline Fixed-Price Annuity Payout Phase Analytics

Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

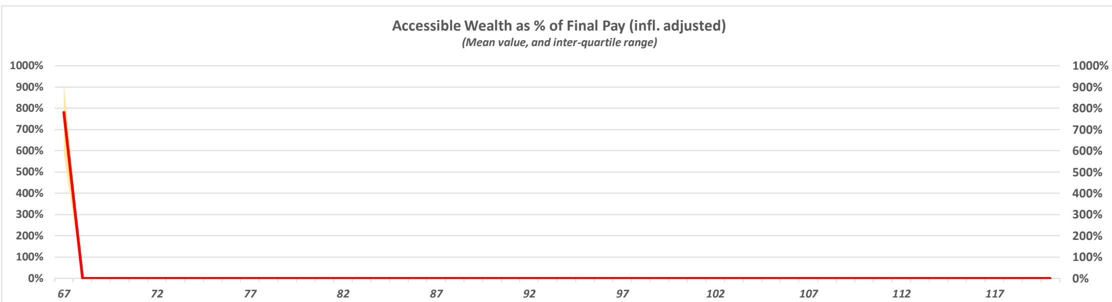
	Shortfall risk (using 3-yr. avg.) First 15 yrs. (Ages 67 to 81)	Next 10 yrs. (Ages 82 to 91)	Failure rate at: Age 90	Age 95	Age 100	Age 105	Age 110
			Survival probability				
60% of baseline	**0.0%**	**0.0%**	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	**0.0%**	**0.0%**					
40% of baseline	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
30% of baseline	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	Next 10 yrs. (92 to 101)
Decline by 10+ percent	**0.0%**	**0.0%**	**0.0%**
Decline by 15+ percent	**0.0%**	**0.0%**	**0.0%**
Decline by 20+ percent	**0.0%**	**0.0%**	**0.0%**
Decline by 25+ percent	**0.0%**	**0.0%**	**0.0%**

Level of accessible wealth as percent of final pay (inflation adjusted)

(Note that the age 67 value is before the purchase of any annuities.)



Death benefits paid as percent of total payments

%tile	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	All remaining yrs. (92 and up)
95%	**0.0%**	**0.0%**	**0.0%**
75%	**0.0%**	**0.0%**	**0.0%**
50%	**0.0%**	**0.0%**	**0.0%**
25%	**0.0%**	**0.0%**	**0.0%**
5%	**0.0%**	**0.0%**	**0.0%**
Mean	**0.0%**	**0.0%**	**0.0%**

Cost risk to sponsor for any fixed price annuities (cost spread as % of pay over career)

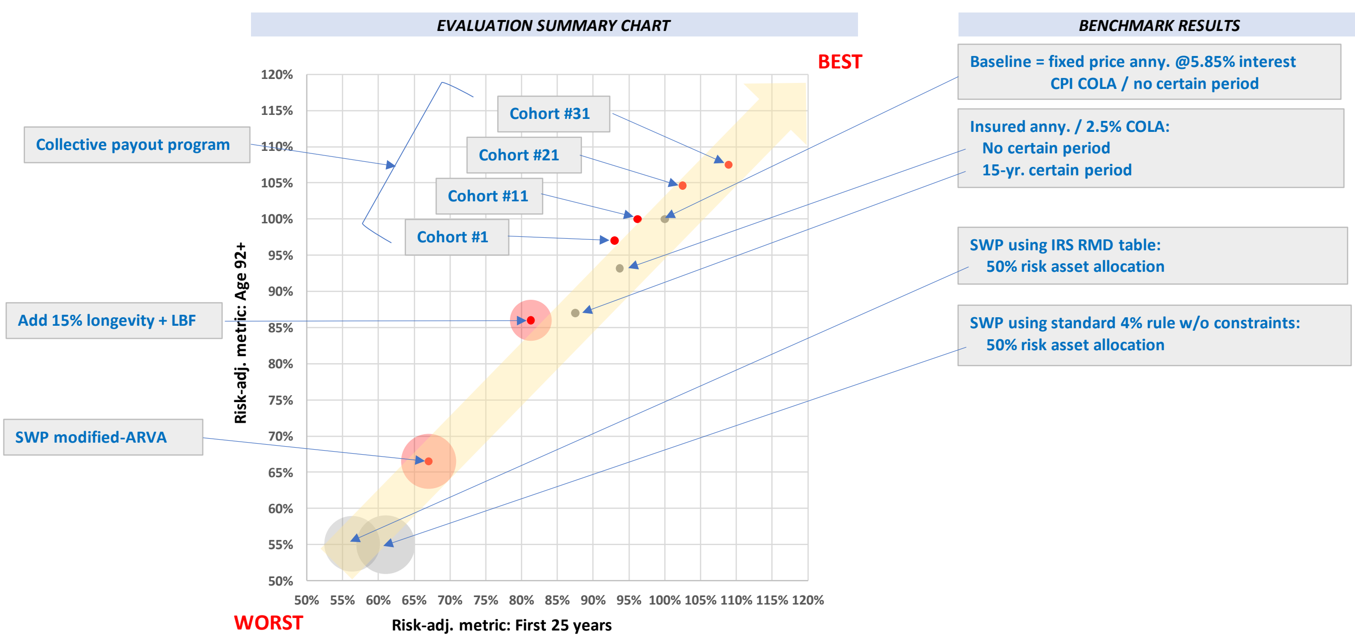
%tile	Change in cost as % of pay: For "Baseline"	For selected payout parameters
95%	**1.7%**	**2.1%**
75%	**0.4%**	**0.8%**
50%	**-0.4%**	**0.0%**
25%	**-1.1%**	**-0.7%**
5%	**-2.2%**	**-1.8%**
Mean	**-0.3%**	**0.1%**

For the evaluation of any payout phase design, we can use a graph that plots results for the income payout ratio values (i.e., ratio to the baseline fixed-price annuity income payouts) using selected risk and reward metrics. Figure 10 is the most useful, and we show the three payout arrangements just described (which are used as standard benchmarks in the payout phase evaluation process), plus several more that have been analyzed so far using the payout model:[4]

- A structured withdrawal plan (SWP), which is in the family of withdrawal arrangements known as annually re-calculated virtual annuities (ARVA). See Appendix H for more details.
- The SWP-modified ARVA that integrates a longevity annuity purchased with 15% of the accumulation balance and uses a longevity bridge fund to integrate the early payouts with the deferred payouts from the longevity annuity. See Appendix I for more details.
- A collective payout program where mortality and investment risk are mitigated with an intergenerational risk-sharing arrangement. See Appendix J for more details.

The horizontal axis measures how well a method provides income for the first 25 years after retirement and the vertical axis measures how well a method provides income for the later period of retirement from age 92 on. (Appendix A explains the specifics for the metrics.) The best methods will do well for both periods, and they will plot more toward the upper right corner of the graph, while less effective methods will plot more toward the lower left corner. For each payout method, the size of the circle is a measure of liquidity at age 85 (a simple point plot indicates no liquidity), and the results plotted here show the trade-off between maintaining liquidity and providing income over a lifetime.

Figure 10
Income Payout Phase Results



[4] The model for the payout phase of the QE framework includes a complete set of parameters that can be used to structure a wide range of withdrawal rules and to integrate full or partial annuitization with insured products, both immediate annuities and deferred longevity annuities.

Table 1 shows additional metrics for the designs shown in Figure 10.

Table 1
Additional Income Payout Phase Results

RESULTS FOR ALL SCENARIOS:			--- Ben Metric*---			--- Failure rate*** at age ---			--- Volatility Metric**** ---		
	Risk asset %	*Smoothing param.*	*1st 25 yrs*	*After 25*	*Age 85 liquidity***	*90*	*95*	*100*	*1st 15 yrs*	*Next 10 yrs*	*After 25 yrs*
Standard 4% rule	**50%**	**NA**	**61.0%**	**55.0%**	**508%**	**0.7%**	**3.0%**	**9.3%**	**0.0%**	**0.3%**	**5.0%**
ARVA-type SWP only	**50%**	**+5% , -4%**	**67.0%**	**66.5%**	**452%**	**1.3%**	**1.7%**	**4.9%**	**13.6%**	**9.0%**	**22.4%**
SWP/LBF + 15.0% longevity(max)	**80%**	**+7% , -4%**	**81.3%**	**86.0%**	**258%**	**0.0%**	**0.1%**	**0.1%**	**8.4%**	**6.5%**	**4.8%**
Insured annuity w/ 2.5% COLA & 15-yr.CP	**NA**	**NA**	**87.5%**	**87.0%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**2.4%**	**2.5%**	**2.9%**
Collective payout program:	**35%**	**NA**									
Cohort #1			**93.0%**	**97.0%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**5.4%**	**13.3%**	**27.5%**
Cohort #11			**96.2%**	**100.0%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**11.2%**	**25.4%**	**35.9%**
Cohort #21			**102.5%**	**104.6%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**21.8%**	**34.8%**	**40.4%**
Cohort #31			**108.9%**	**107.5%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**29.5%**	**39.3%**	**42.2%**

** Benefit metric = risk adjusted average of [benefits / base benefits], where base benefits are from low-risk fixed-price annuity (5.85% interest).*
*** Accessible wealth at age 85 as % of final pay, adjusted for inflation.*
**** Probability that benefit falls below 40% of baseline benefit.*
***** Probablity that average benefit over rolling 3-yr period is more than 10% lower than prior 3-yr period.*
For collective program, the volatility is based on total benefit (base+bonus). Volatility for base only would be nil.

Assumptions

Demographic

We use a benchmark employee (or age cohort, for collective structures) with a current age of 30 at the start of the accumulation period and with assumed retirement at age 67 following a continuous 37-year period of participation, reflecting a blend of full career within a single plan and "fragmented" career with participation in several plans. The pay level and career pay progression is designed to be representative of U.S. median income levels. Similarly, for the payout phase we assume that benefits commence at a retirement age of 67 (37 years into the future). More specifics are provided in Appendix K.

Economic

A standardized set of projected economic variables is used for all calculations. The set includes 1,000 different scenarios[5] produced from a stochastic model that includes these features:

- All of the variables are created in a way that maintains the appropriate degree of linkage, or correlation, among the relevant variables (e.g., inflation and nominal interest yields).
- The scenarios are forward projections under the assumption of an economy in "equilibrium." That is, the starting point for each variable that evolves over time (e.g., inflation, interest yields) is set equal to the median value for the expected future distributions of that variable. In this way we maintain a set of scenarios that is not time sensitive (i.e., they can be used regardless of actual current market conditions when the analysis is being performed). Such an approach would not, of course, be appropriate for any analysis intended to produce a point-in-time valuation measure, or for predictive purposes—but the purpose of the quantitative evaluation framework is only to produce metrics that facilitate consistent comparisons among various retirement system structures.
- The projection period is 100 years, so it is sufficiently long for projections that involve multiple generations of age cohorts (required for certain structures with intergenerational risk sharing).
- The investment process is simplified to reflect a particular allocation between "risky assets" (intended to be representative of a global equity index fund), and fixed income assets (intended to be representative of a broad fixed income index fund).
- For the "risky asset" projected rates of return, two alternative models are used. Both models produce identical long-term median return outcomes—only the shape of the distributions change. One model uses a simple assumption of log-normal distributions for future wealth. The second model,[6] which we use as our baseline model, incorporates two special features:
    - Fat tails for more downside risk exposure over shorter time periods, and
    - Long-term mean reversion for more compact return distributions over longer time periods.
- The assumptions for median outcomes, and the volatility of outcomes, are intended to be representative of common practice and relevant historical experience. While users may differ somewhat in their opinion of the "best" values to use, it is important to remember that the purpose of the framework is to facilitate consistent comparisons. For selected variables, an option exists to shift the distributions so that a different median outcome can be produced, but this is only for purposes of additional sensitivity analysis. The basic comparative metrics (and the benchmark results already available from the SOA website) reflect the baseline set of assumptions. Appendix L contains more detail. The median values for selected economic variables in the baseline set are seen in Table 2.

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[5] The set of 1,000 scenarios is of a size that allows for reasonable calculations in most software configurations, but the distributions of the variables are also sufficiently smooth to produce viable risk and reward measures for the outcomes. More technically, the stochastic process used is based on a Latin hypercube sampling methodology that creates distributions comparable to those created by about 10,000 scenarios from a standard random number generation process.

[6] More details can be found in Davis, Rowland. 2014. Simulation of Long-Term Stock Returns: Fat-Tails and Mean Reversion. In *Investment Fallacies.* Schaumburg, Illinois: Society of Actuaries. *https://www.soa.org/essays-monographs/invest-fallacies/inv-ebook-2014-davis-simulation.pdf.*

Table 2
Median Values for Selected Economic Variables in Baseline

	Baseline Assumption
Price inflation	2.50%
Real wage growth	0.50%
Nominal wage growth	3.00%
Real yield on 10-year Treasury	1.80%
Nominal yield on 10-year Treasury	4.30%
Credit/duration spread for core fixed income	0.20%
Nominal core fixed income returns	4.50%
Risk premium for risky assets	3.50%
Nominal risky asset returns	8.00%
(gross, long-term compounded)	

Appendix A: Description of Metrics

Accumulation Phase

Replacement ratio (RR) is the total retirement benefit divided by final pay at retirement. Final pay is the assumed pay rate at the point of retirement (age 67), so it equals the age 66 pay level increased by one more year of wage inflation. The total retirement benefit is the plan benefit determined by converting the age 67 accumulation amount into a lifetime income with the annuity conversion factor, plus a Social Security benefit assumed equal to 39% of final pay. Full percentile ranges and a mean value are shown for the replacement ratio. Unless otherwise specified, the RR is a blend of the results for a full single-employer career employee and for a fragmented career employee, if those values are different because of portability design features. (See Appendix K for more details.)

Replacement ratio risk metric is the average replacement rate for the worst quintile of simulated outcomes (i.e., a tail risk estimate).

Cost is the level percent of pay contribution for each separate scenario in the simulation that would result in the final accumulation value at retirement for a scenario. To facilitate comparison of benefit levels, the quantitative evaluation (QE) framework uses a standardized average contribution level of 10% of pay for all plans, so this metric will also always have an *average* value of 10% of pay, but the range of possible costs is shown, with cost above 10% (e.g., due to investment results being worse than expected on average) and below 10% (e.g., due to investment results being better than expected on average). By definition, a standard DC plan will have no variation in cost, so this metric is important for DB plans, or certain variable contribution DC arrangements, where the sponsor cost might change based on economic outcomes (investment and/or inflation).

Cost risk metric is the average cost for the worst quintile of simulated outcomes (i.e., a tail risk estimate).

Benefit shortfall risk is the probability that the replacement ratio falls below some target value, based on the simulated range of values. The QE framework uses RR target values of 70% and 60% for the shortfall metric.

Benefits by career pattern shows how the average RR is developed as a weighted average value from two components (1) for an employee with an unbroken 37-year career with a single employer, and (2) for an employee who has a fragmented career with several employers. (See Appendix K for more details.)

Stress index for accumulation path includes three measures that gauge the degree to which the employee might experience investment-related losses during the accumulation period:

- **Loss frequency** indicates the percentage of years where a loss might occur, on average
- **Average loss** indicates the average size of an annual loss, expressed as a percent of pay
- **Cumulative career losses** measures the total cumulative value of losses, on average, that occur over the entire 37-year accumulation period, expressed as a percent of pay

For each of these, the QE framework also shows values for four benchmarks:

- A DC plan with 100% allocation to cash or stable value investments over all years—the best case for a smooth accumulation process, as no investment losses are possible
- A DC plan with 100% allocation to market-priced fixed income, or bond, investments
- A DC plan with investments following a typical target date fund (TDF) strategy
- A DC plan with 100% allocation to risky assets over all years—the worst case for a volatile accumulation process

Finally, a “stress index value” is created on a scale of 0 to 10, where the best-case benchmark is assigned a value of 0 and the worst-case benchmark is assigned a value of 10. Other plans are assigned a value based on the cumulative career loss metric as a percentage of the worst-case benchmark.

Adjusted cost for a 70% replacement ratio target is a metric that allows for comparison based on a common benefit target of 70% RR, instead of looking just at benefit levels that result from the standardized 10% of pay average cost. Based on the simulated benefit levels from the model using the standard 10% average cost, we can rescale results to achieve a 70% total RR with some specified level of confidence and then determine how much the cost needs to be adjusted (from the 10% of pay standardized level) to achieve the desired benefit result. We use confidence levels of 50%, 70% and 90% and for each of these we show both the required adjusted average cost as well as the adjusted cost risk metric. (See Appendices F and G to see how these adjusted cost metrics can be used for evaluation purposes.)

Payout Phase

Income benefits as percent of baseline is a metric based on comparing the income benefit from a specific payout design for any year in each scenario to the income benefit from a standardized baseline payout stream. The baseline payouts are produced by converting the same starting accumulation value for each scenario to a lifetime benefit using a fixed-price annuity value for the conversion factor. The fixed-price annuity is priced at an interest rate of 5.85% (the expected return on a portfolio invested 30% in risky assets and 70% in core fixed income assets) and includes a full consumer price index (CPI) cost-of-living adjustment (COLA) (priced at an assumed 2.5% rate of inflation). The baseline benefit is intended to represent the best-case result from the participant's viewpoint, similar to results from an in-plan annuity from a DB plan with a conservative investment policy. The resulting values for the ratio of income benefits to the baseline are then summarized in several ways:

- A graph showing values for the entire payout period, with indication of the mean value, the interquartile range (i.e., range from the 25th to the 75th percentile values), and the 10th percentile value.
- Three sets of results for (1) the first 15 years of the payout period from age 67 to age 81, (2) the next 10 years of the payout period from age 82 to age 91, and (3) the remainder of the payout period from age 92 onward. For each of these, we show the mean value and the full range of percentile values. We also show values for selected benchmark payout arrangements. In these statistics, the values for each age are weighted by the number of deaths expected at each age.
- Similar to the previous point, but using only a portion of the simulation set to show the sensitivity to the initial age 67 conditions in two respects: (1) the simulated interest rate at age 67, and (2) the simulated expected inflation at age 67.
- Two critical risk and reward metrics that utilize a risk-adjusted version of the income benefit ratio results. The risk metric covers the ages from 92 onward and essentially becomes a metric for the risk of outliving resources to provide a lifetime income. The reward metric covers the first 25 years of retirement and essentially becomes a metric for the desire of a high initial benefit, to be balanced against the need for sustainability (i.e., as measured by the risk metric). The risk-adjustment process is premised on a behavioral finance risk-aversion concept applied with a frame of two fundamental goals from the retiree's perspective: (1) make the initial payout as high as possible, but (2) at a level that is also sustainable into advanced ages with a reasonably high degree of certainty. So the risk-adjustment process applies higher weights whenever the income benefit ratio falls significantly lower than the initial ratio (i.e., loss aversion will apply a "multiplier" factor to magnify a poor result), and lower weights whenever the income benefit ratio rises to a level significantly higher than the initial ratio (i.e., improved income is still rewarded, but at marginally lower rates because stability is the primary goal). Specifically, the following rules are used:
    - Use the regular unadjusted value when the ratio is between 60% and 110% of the initial ratio.
    - Give 50% credit for any excess from 110% to 120%, and no credit after 120%. So if the unadjusted income ratio at a certain age is 1.15 times the initial ratio, then the adjusted value would be 1.125 times the initial ratio. The maximum for any adjusted value will be 1.15 times the initial ratio.
    - Apply a double penalty for any shortfall below 60%. So if the unadjusted income ratio at a certain age is 0.50 times the initial ratio, then the adjusted value would be 0.40 times the initial ratio. Whenever the unadjusted ratio falls below .30 times the initial ratio, the adjusted value will be set to zero (i.e., process fails to meet goals).

Shortfall risk/"failure rate" are metrics that measure the probability that the income benefit ratios described above fall below selected values. The shortfall risk analysis is for the first 15 years and the next 10 years, while the failure rate analysis looks at specific ages from age 92 up.

Volatility risk shows probabilities for the income benefit ratio (rolling three-year average) dropping by selected percentage values.

Level of accessible wealth captures a liquidity measure, in graphic form, by showing the mean value and the interquartile range for accessible wealth at each age, expressed as a percentage of final pay (inflation adjusted).

Death benefits paid as percent of total payments shows the mean value and percentile range of death benefits paid as a percentage of total payments (income + death). The QE framework metrics focus on a sustainable lifetime income stream as the primary goal for a payout design, but death benefits still have some value. In many non-insured designs, the death benefits may not be a true target payout, but just result from the need in non-insured arrangements to maintain a "reserve" to handle worst-case outcomes (e.g., investment losses, longevity risk).

Cost risk to sponsor for any fixed price annuity shows the possible range of gains or losses that might result when a plan sponsor includes an in-plan annuity at some fixed interest rate (e.g., as is common with DB plans). The costs are shown as the cumulative simulated gain or loss during the payout period spread as a level percentage of career pay.

Appendix B: DC Plan Benchmark Values

Table 3 shows selected metrics from the DC benchmark results, for risky asset allocations from 0% to 100%.

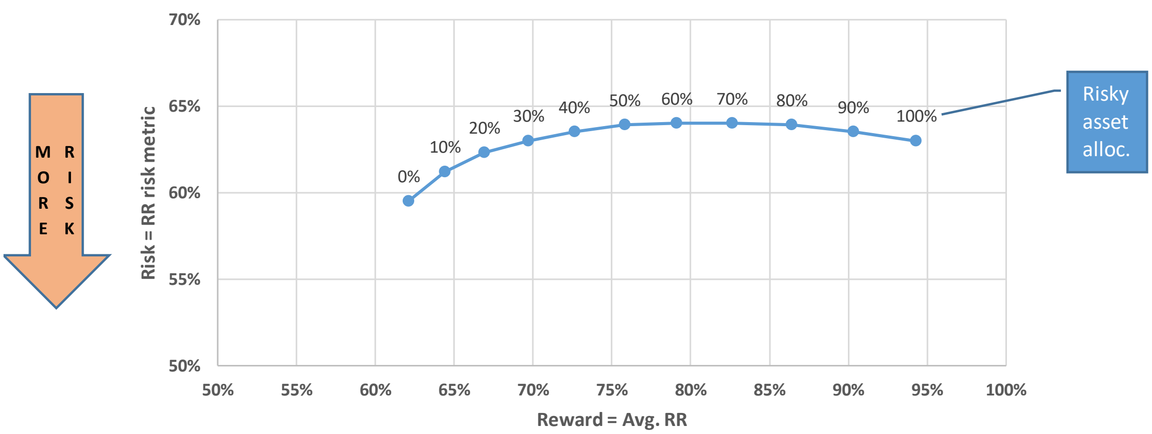
Table 3
Selected Metrics from the DC Benchmark Result

	0%	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*100%*
Repl. Ratio:											
Average	**62.1%**	**64.4%**	**66.9%**	**69.7%**	**72.6%**	**75.8%**	**79.1%**	**82.6%**	**86.4%**	**90.3%**	**94.3%**
Risk metric	**59.5%**	**61.2%**	**62.3%**	**63.0%**	**63.5%**	**63.9%**	**64.0%**	**64.0%**	**63.9%**	**63.5%**	**63.0%**
Shortfall risk (70% target)	**99.9%**	**98.1%**	**82.1%**	**57.7%**	**39.5%**	**29.7%**	**24.7%**	**22.3%**	**20.8%**	**19.7%**	**19.6%**
Path stress index	**0.9**	**0.7**	**0.9**	**1.3**	**2.0**	**2.8**	**3.9**	**5.1**	**6.6**	**8.2**	**10.0**

We can use these to do various risk-reward comparisons. Graphically, they provide a sort of "efficient frontier." In all the figures, we use the average replacement ratio as the reward metric.

For Figure 11, we use the replacement ratio risk metric to measure risk.

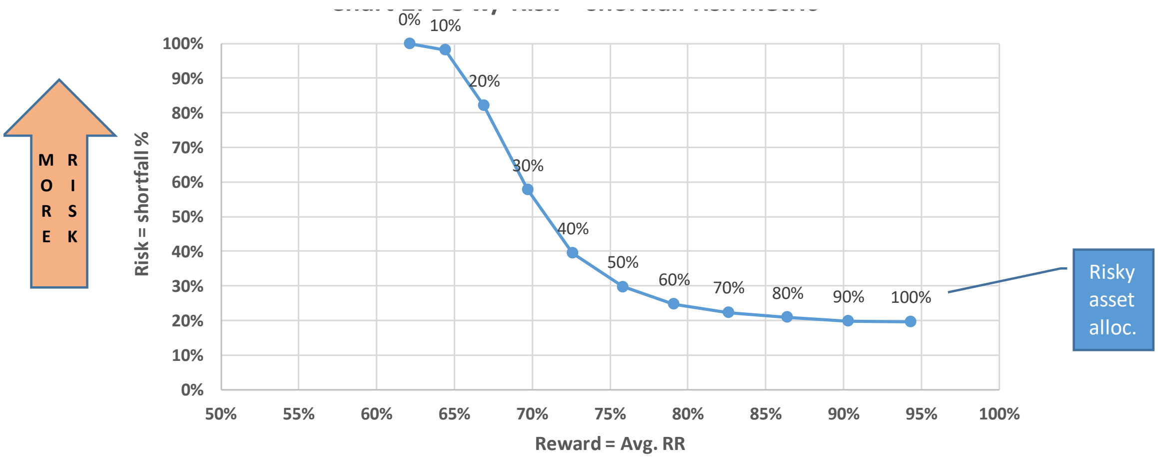
Figure 11
RR Risk Metric for DC Benchmark Result



Observations: For increased risky asset allocations up to about 50%, there is a gradual decrease in risk, along with increased reward. After 50%, additional risky asset allocation continues to improve reward (+3 to 4 percentage points for each 10% bump in allocation), but the risk flattens out, and then increases slightly. From this picture, significant risk-taking would be encouraged, with a minimum risk-asset allocation of perhaps 50%.

In the Figure 12, we measure risk using the shortfall risk metric.

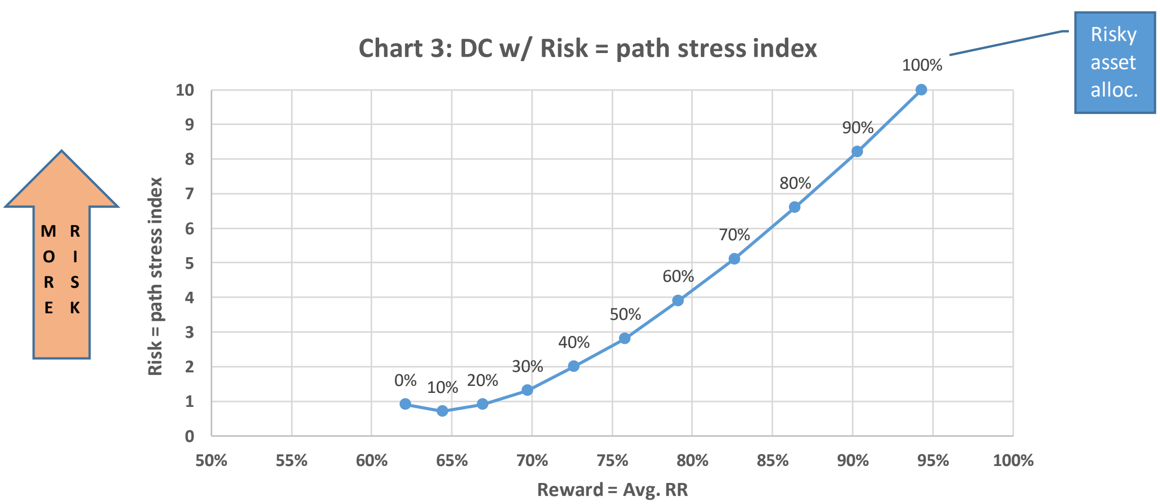
Figure 12
Shortfall Risk Metric for DC Benchmark Result



Observations: For increased risky asset allocations up to about 60 to 70%, there is a significant decrease in shortfall risk (based on a fixed 10% of pay contribution “budget”). From this picture, significant risk-taking would be encouraged—and a minimum allocation of about 60% to risky assets could be supported.

In Figure 13, we measure risk using the path stress index metric.

Figure 13
Path Stress Index for DC Benchmark Result



Observations: For increased risky asset allocations after about 30%, there is a significant increase in the path stress risk metric. From this picture we see that higher risky asset allocation creates a clear trade-off between long-term reward and the ability to tolerate a volatile path of accumulation.

Appendix C: DB Plan Benchmark Values

Table 4 shows selected metrics from the DB benchmark results, for risky asset allocations from 0% to 100%.

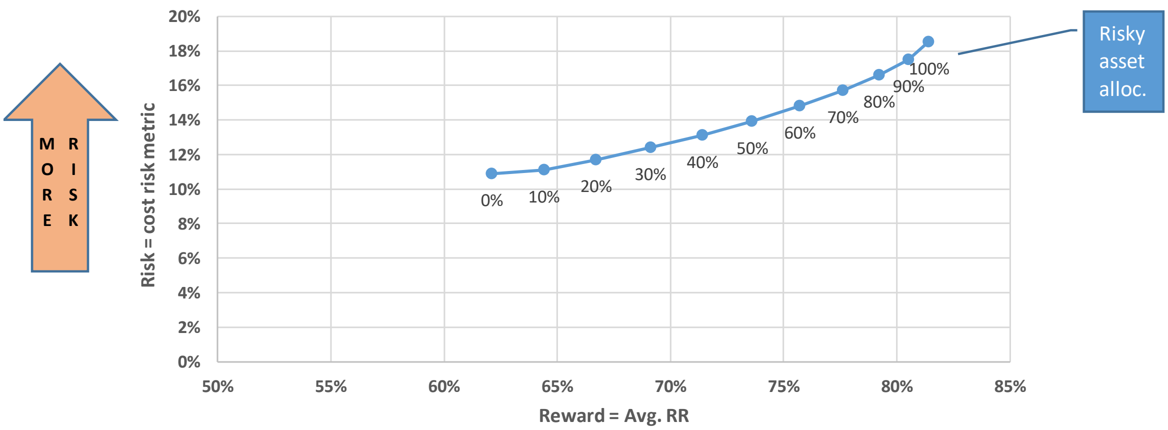
Table 4
Selected Metrics from the DB Benchmark Results

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Repl. Ratio:											
Average	62.1%	64.4%	66.7%	69.1%	71.4%	73.6%	75.7%	77.6%	79.2%	80.5%	81.4%
Risk metric	58.5%	60.3%	62.3%	64.3%	66.2%	68.1%	69.8%	71.4%	72.7%	73.8%	74.6%
Shortfall risk (70% target)	98.2%	94.9%	86.1%	64.3%	45.3%	16.0%	9.7%	2.4%	1.0%	0.2%	0.2%
Cost risk metric (% pay)	10.9%	11.1%	11.7%	12.4%	13.1%	13.9%	14.8%	15.7%	16.6%	17.5%	18.5%

We can use these to do various risk-reward comparisons. Graphically, they provide a sort of efficient frontier (EF). In all the figures, we use the average replacement ratio as the reward metric.

For Figure 14, we use the cost risk metric (i.e., average cost in the worst 20% of simulated outcomes) to measure risk.

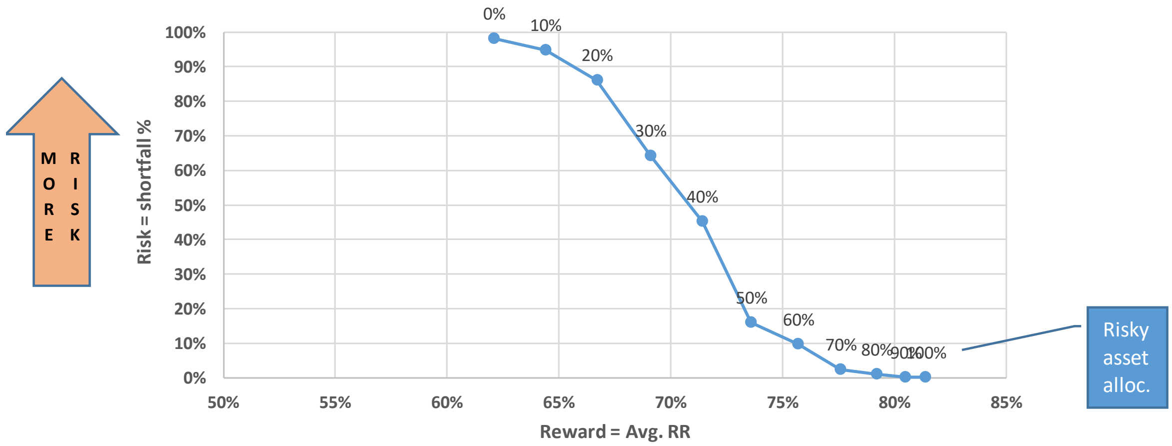
Figure 14
Cost Risk Metric for DB Benchmark Results



Observations: By definition in the framework being used, the average cost is always normalized to 10% of pay. As the risky asset allocation increases, the cost risk metric increases steadily—with no noticeable points of inflection.

In Figure 15, we measure risk using the shortfall risk metric.

Figure 15
Shortfall Risk Metric for DB Benchmark Results



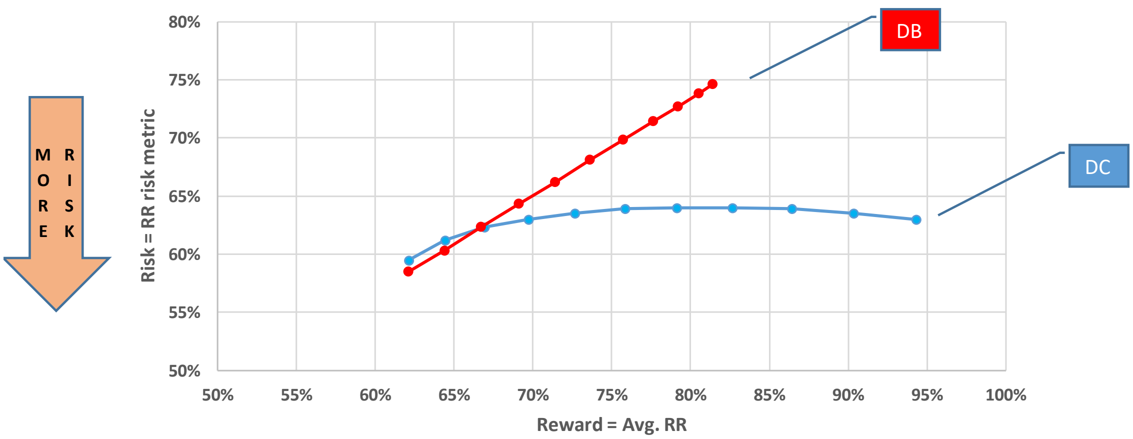
Observations: For increased risky asset allocations up to about 60 to 70%, there is a significant decrease in shortfall risk (based on a fixed 10% of pay contribution “budget”). From this picture, significant risk-taking would be encouraged—and a minimum allocation of about 60% to risky assets could be supported.

Appendix D: Comparing DC and DB Plan Results

These figures combine both DC and DB benchmark results. When any new plan design is analyzed with the QE framework metrics, the results can be plotted on these graphs to quickly gauge the risk-reward profile, relative to the familiar DC and DB benchmarks. For all the figures, we use the average replacement ratio as the reward metric.

For Figure 16, we will use the replacement ratio risk metric to measure risk.

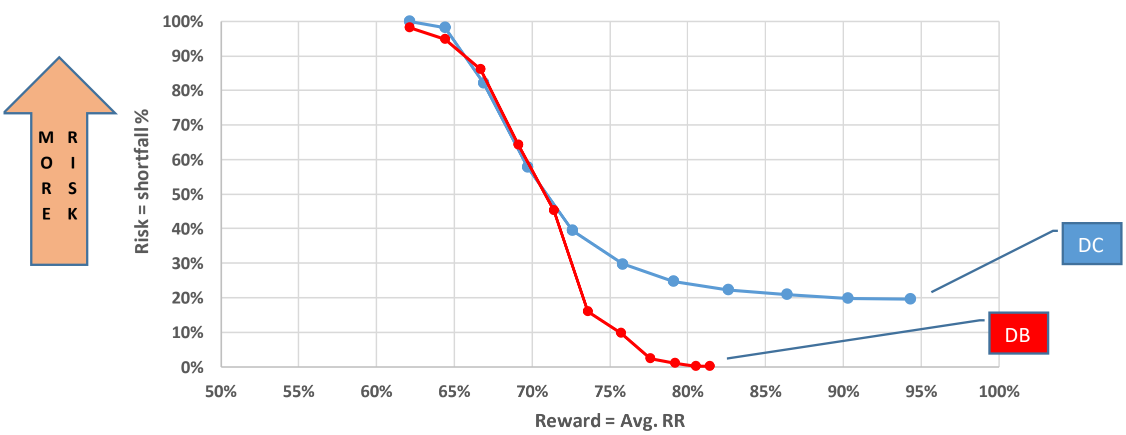
Figure 16
RR Risk Metric for DB and DC Benchmark Results



Observation: Here the DB line represents something of a low risk boundary for most accumulation plans (recall that the DB benefit risk here is all due to interest rate risk at retirement, due to annuity pricing).

In Figure 17, we measure risk using the shortfall risk metric.

Figure 17
Shortfall Risk Metric for DB and DC Benchmark Results



In Figure 18, we measure risk using the cost risk metric.

Figure 18
Cost Risk Metric for DB and DC Benchmark Results

Observation: Here the DC line represents something of a low risk boundary for most accumulation plans.

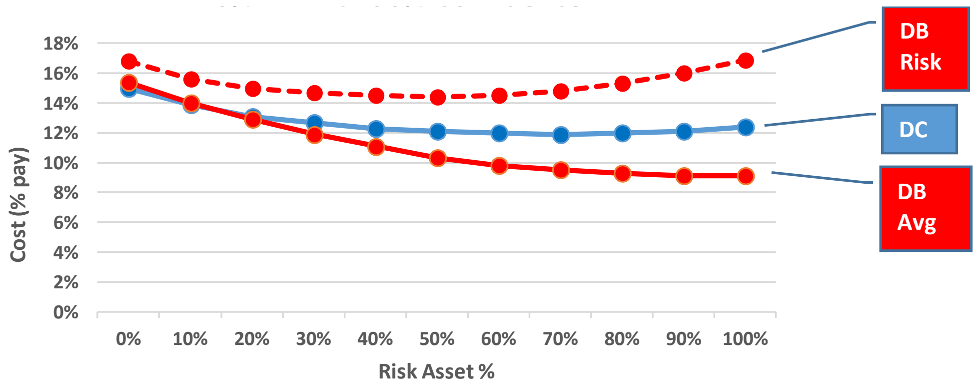
Another way to compare DC vs. DB plans is to look at the "adjusted cost" metric—which indicates the cost to achieve a 70% total replacement ratio. Table 5 shows the values from the benchmark results using three confidence levels.

Table 5
Benchmark Results from Three Confidence Levels

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
DC Plans:											
50% confidence	13.5%	12.3%	11.2%	10.3%	9.5%	8.7%	8.1%	7.6%	7.1%	6.8%	6.5%
70% confidence	14.1%	12.8%	11.9%	11.2%	10.5%	10.0%	9.5%	9.2%	8.9%	8.6%	8.5%
90% confidence	15.0%	13.9%	13.1%	12.7%	12.3%	12.1%	12.0%	11.9%	12.0%	12.1%	12.4%
DB Plans -- adj. cost avg.:											
50% confidence	13.6%	12.4%	11.3%	10.5%	9.7%	9.2%	8.7%	8.4%	8.1%	7.9%	7.8%
70% confidence	14.3%	13.0%	11.9%	11.0%	10.3%	9.7%	9.2%	8.9%	8.7%	8.6%	8.5%
90% confidence	15.4%	14.0%	12.9%	11.9%	11.1%	10.3%	9.8%	9.5%	9.3%	9.1%	9.1%
DB Plans -- adj. cost risk metric:											
50% confidence	14.8%	13.8%	13.2%	12.9%	12.8%	12.7%	12.8%	13.1%	13.4%	13.8%	14.5%
70% confidence	15.6%	14.5%	13.9%	13.6%	13.5%	13.5%	13.6%	14.0%	14.4%	15.0%	15.7%
90% confidence	16.8%	15.6%	15.0%	14.7%	14.5%	14.4%	14.5%	14.8%	15.3%	16.0%	16.9%

Figure 19 illustrates using the highest 90% confidence level.

Figure 19
DB vs. DC Cost Analysis with 70% RR with 90% Confidence



Observations: For risky asset allocations up to about 30%, the average cost to create a 70% replacement ratio (including Social Security) is very similar between DC and DB. Since DB plans have potential for above average cost outcomes, this graph would indicate a preference for DC plans at low levels of investment risk. However, for allocations above 30%, the average DB cost continues to fall, while the DC cost remains fairly flat at around 12% of pay. At these higher allocations to risk assets, there is no clear preference for either DC or DB—at least based on the cost efficiency for the accumulation phase.

Figures 20 and 21 use lower confidence levels of 70% and 50%.

Figure 20
DB vs. DC Cost Analysis with 70% RR with 70% Confidence

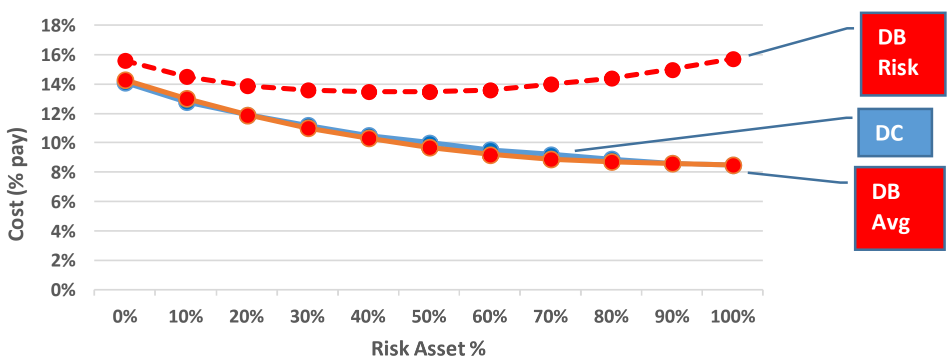
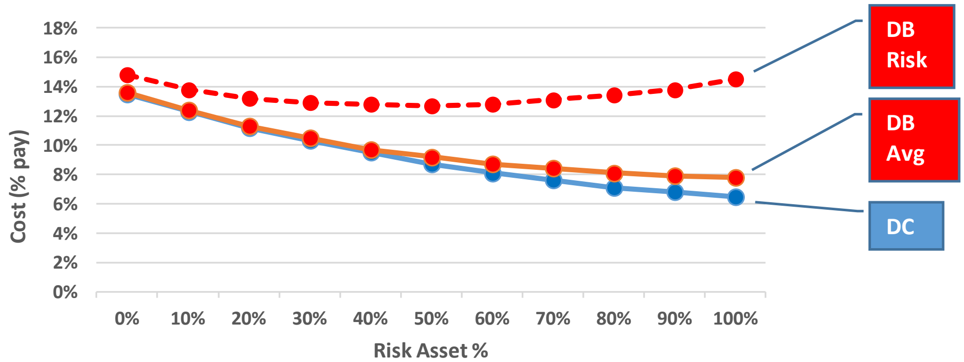


Figure 21
DB vs. DC Cost Analysis with 70% RR with 50% Confidence



Observations: As the desired confidence level is lowered, the average required cost becomes lower. But the DC cost drops more rapidly than the average DB cost, especially at higher risk-asset allocations.

Inherent in the DB structure is a path stress index of 0.0 for the participant benefits, compared with much higher path volatility for DC plans. Of course, the year-to-year cost patterns for a DB structure will also exhibit volatility, subject to the particular cost methods used for accounting and/or funding.

Appendix E: Conceptual Framework for Risk-Sharing Plans

Many ideas are being proposed to make our current retirement system more efficient and sustainable. Some of these ideas work mostly within the very important space of finding practical improvements for existing plan structures. Examples would be lower fees, reduced leakage, improved investment options, etc. These ideas deserve very serious consideration, and the QE framework provides benchmark results that offer very useful background data for some of these. But the most important goal of the QE framework is to provide a way to evaluate and compare new retirement structures, especially those that incorporate risk-sharing principles. The framework offers a consistent basis for analysis, with a special focus on risk/reward trade-offs.

The framework metrics can be used to graphically display efficient frontier spaces for the accumulation phase. This kind of EF analysis can be a very useful way to quickly evaluate new plan concepts with respect to their economic efficiency. For example, Figure 22 shows the efficient frontier for the DC and DB benchmark plans, where risk is measured by the RR risk metric, as seen in in Figure 16, overlaid with the target zone where results should show up for any new plan idea that aims toward a more efficient handling and/or sharing of benefit risk.

Figure 22
RR Risk Metric for DB and DC Benchmark Results with Target Zone

Any of the other risk metrics can also be used and new plan design concepts can be evaluated using them, as well.

Figure 23 through 25 rework Figures 17, 13 and 18, with the risk-sharing target zone indicated.

Figure 23
Shortfall Risk Metric for DB and DC Benchmark Results with Target Zone

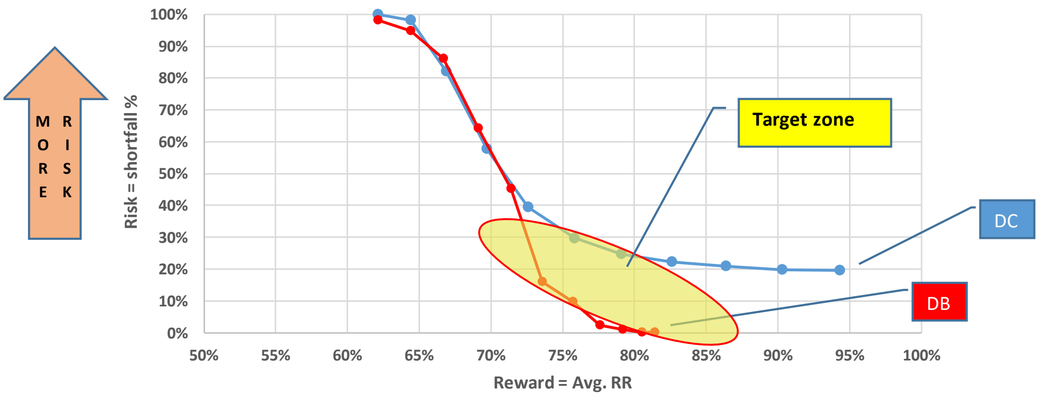


Figure 24
Path Stress Index for DC Benchmark Result with Target Zone

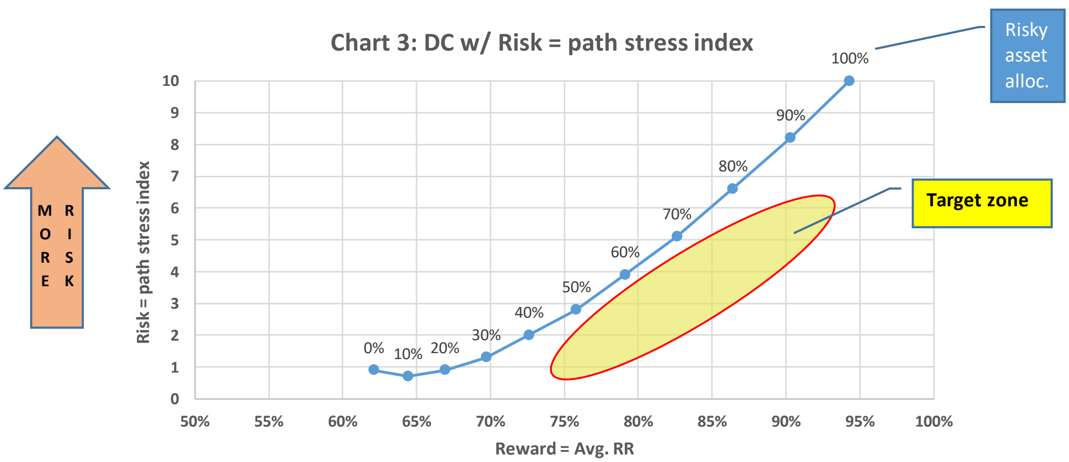
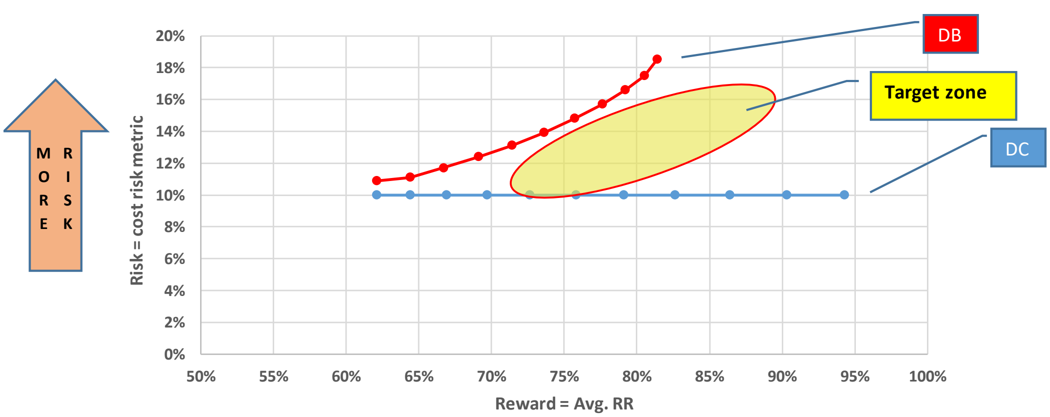


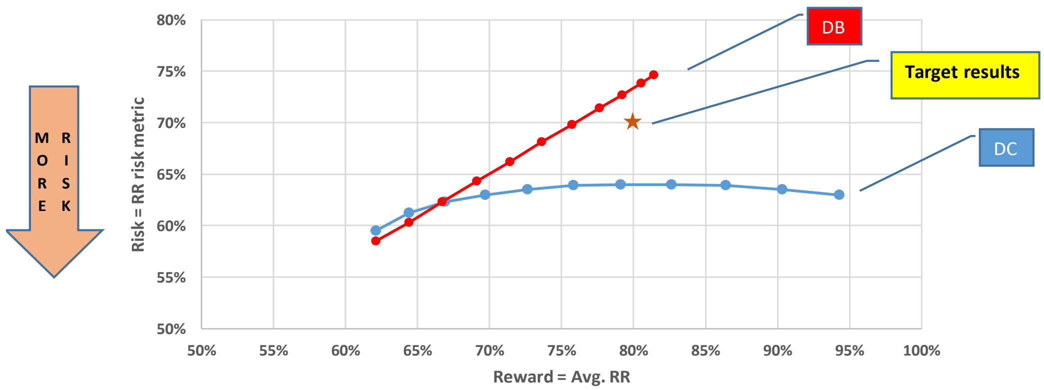
Figure 25
Cost Risk Metric for DB and DC Benchmark Results with Target Zone



Combination DC + DB Programs

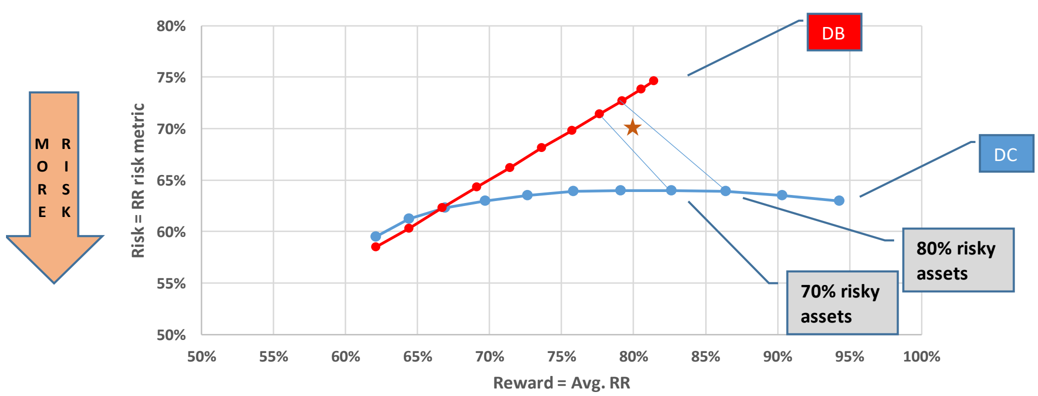
The simplest risk-sharing benefit structure is some combination of a DC plan with a DB plan. We will work through an example to show how this works. Any target results can be obtained, depending on the relative weighting for the two component plans, and on the level of investment risk. Figure 26 will take Figure 6 with any point selected in the risk-sharing target zone—for this example, we select the point with an average RR of 80%, and a RR risk metric value of 70%.

Figure 26
RR Risk Metric with Average RR of 80%, RR Risk Metric Value of 70%



The next step is to identify an investment policy range that is appropriate for meeting our target. In Figure 27, we connect the corresponding DC and DB benchmark values for each separate risky asset allocation.

Figure 27
Connected DC and DB Benchmark Values



Here we see that our target point lies in the space bounded by a 70% risky asset allocation and an 80% risky asset allocation. Next we would get the benefit risk and reward metrics for the four boundary benchmark points: DB 70%, DB 80%, DC 70% and DC 80%. An Excel workbook is intended to retrieve the required values and interpolates them. For our example, the interpolation worksheet indicates that a 45% DC + 55% DB combination (i.e., 4.5% of pay into DC plan and 5.5% target cost for DB plan) using a 71% risky asset allocation should approximate our target results. The resulting benefit risk and reward metrics for this combination DC + DB arrangement are shown in Table 6.

Table 6
Benefit Risk and Reward Metrics for Figure 27

Replacement ratio metrics for combo plan:	
Average	80.1%
Risk metric	70.2%

The importance of this ability to reverse engineer a combo DC + DB program that will meet a specified set of benefit results (i.e., an average RR level plus a RR risk metric level) is that we now have a way of creating benchmark values for the evaluation of other risk-sharing designs. This process is discussed in Appendix F.

Appendix F: Evaluation of a Sample Risk-Sharing Design

Appendix E showed how a combination DC + DB program (combo plan) can be designed for any point within the boundaries of the DC and DB efficient frontier lines, based on the replacement ratio metrics. The importance of this is that we now have benchmark designs, not only for the standard DC and standard DB plans, but also for every other point in the risk/reward space. These combo plan benchmark values are key to evaluating other risk-sharing designs. If some design proposal creates replacement ratio metrics of, for example, an average value of 78% and a risk value of 68%, then we can also get the full set of metrics for the equivalent combo plan. The proposed design will be evaluated as a favorable design (in an economic sense) if some of the other metrics (e.g., cost risk, shortfall risk, path stress index) appear to be better than those for the equivalent combo plan.

Perhaps the best single set of metrics for evaluation purposes will be the **adjusted-cost** metrics since these implicitly combine both shortfall risk and cost risk. If the proposed design does not show such economic benefits, then it could still be justified on non-economic factors (e.g., administrative efficiency, ease of understanding/communication, regulatory issues).

In this appendix, we look at a specific example of such an evaluation for a plan in the family of cash balance designs that use a "participating" credit rate which reflects some portion of actual market performance. In this plan, the interest credit rate in any year is 4% (the floor return), plus 75% of any excess returns over 4% (based on a rolling five-year average return). Employees who terminate prior to retirement only receive the 4% floor return. (This analysis is an excerpt from a more comprehensive study of this entire family of cash balance designs. The full study is included as Appendix G and is a good example of how the QE framework can be used for a very detailed evaluation of any basic design concept.)

We now evaluate the results, using the techniques discussed previously—where for each plan and asset allocation, we also create metrics for an **equivalent** combo DC + DB benchmark plan. We can then compare each of the risk metrics to the same metric for the equivalent combo DC + DB benchmark. The primary focus is on the adjusted-cost metrics, as they reflect both cost risk and shortfall risk in a single set of metrics. The **path stress index** is also important. The results are shown in Table 7 using allocations to risky assets of 30%, 50% and 70%. For example, the sample plan with a 70% risky asset allocation is equivalent to a combo DC + DB arrangement where the DC plan component has a 40% weight and the DB component has a 60% weight, and where both the DB and DC component plans have a 68% allocation to risky assets. The RR metrics for this equivalent combo arrangement are within one-tenth of a percentage point of the values for the sample plan at this level of investment risk.

In comparing the risk metrics, if they are better than the equivalent combo DC + DB plan we shade the result green, and if they are worse, we shade the result red. Essentially neutral outcomes are shaded yellow. More specifically, we use the following "shading" rules for each adjusted-cost metric value:

More than 5% lower than benchmark rate	
Between 2% to 5% lower than benchmark rate	
Within plus or minus 2% of benchmark rate	
Between 2% to 5% higher than benchmark rate	
More than 5% higher than benchmark rate	

Table 7
Comparison of Results

"Investment" Credit Rate:	Participating formula based on 5 year average return Minimum = 4.00% plus 75.0% of excess between 4.00% and 10.00% plus 75.0% of excess over 10.00%
For termination before retirement, only the minimum rate is creditied (i.e. no participation in excess returns).	

Kentucky Plan	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.3%	74.3%	79.2%
Risk metric	64.5%	67.8%	70.3%
Shortfall risk (70% target)	62.8%	20.1%	8.3%
Cost risk metric (% pay)	11.8%	12.8%	14.1%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.1%
50% confidence-risk metric	12.2%	11.6%	11.4%
70% confidence-average	11.0%	9.6%	8.7%
70% confidence-risk metric	12.9%	12.3%	12.3%
90% confidence-average	12.0%	10.7%	9.8%
90% confidence-risk metric	14.1%	13.7%	13.8%

Combo DC+DB equiv.	Risky Asset Alloc.		
	31%	*49%*	*68%*
DB plan weight:	*100%*	*55%*	*60%*
Repl. Ratio:			
Average	69.3%	74.3%	79.1%
Risk metric	64.4%	67.6%	70.4%
Shortfall risk (70% target)	64.3%	20.7%	7.0%
Cost risk metric (% pay)	12.4%	12.1%	13.3%
Path stress index	0.0	1.2	2.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.0%
50% confidence-risk metric	12.9%	10.9%	10.8%
70% confidence-average	10.9%	9.6%	8.6%
70% confidence-risk metric	13.6%	11.6%	11.5%
90% confidence-average	11.8%	10.8%	9.7%
90% confidence-risk metric	14.7%	13.0%	12.8%

Observations: From an economic point of view, these designs offer better path stress results, due to the floor crediting rate in the formula. However, the cost for this floor protection is reflected in noticeably worse results for the upside cost risk metric.

Sponsors may therefore judge this type of plan based on the perceived relative value of these two sets of quantitative outcomes, as well as the significant non-quantitative differences:

- Single plan vs. two separate plans
- Employee perception and understanding
- Ability to incorporate employee contributions
- Ability to incorporate employee choice
- Regulatory and administrative issues

Figure 28 shows the complete set of metrics for the sample plan with a 70% allocation to risky assets.

Figure 28
Complete Metrics for Sample Plan with a 70% Allocation to Risky Assets

Cash Balance Plan Results 8/10/2016 11:14

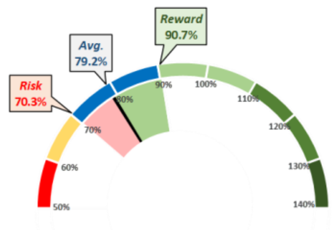
Asset allocation: **70.0% Risky Assets**

(modeled with baseline version of risky asset simulations)

Pay Credit Rate:	**12.06%**
"Investment" Credit Rate:	**Participating formula based on 5 year average return**
	Minimum = 4.00% plus 75.0% of excess between 4.00% and 10.00%
	plus 75.0% of excess over 10.00%

Replacement Ratio (Benefit / Final Pay)

(Includes Social Security at 39%)



Percentile values:

99th	101.8%
90th	88.9%
75th	83.1%
50th	77.9%
25th	74.0%
10th	70.6%
1st	66.7%

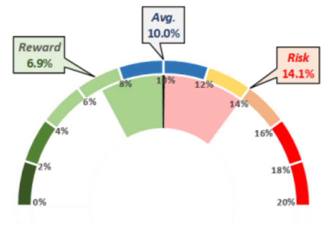
Risk / Reward Metrics

Avg. = mean value for full distribution of results

Risk = mean value for worst quintile of results (i.e. for benefits, the lowest 20% of outcomes; for cost, the highest 20% of outcomes)

Reward = mean value for best quintile of results (i.e. for benefits, the highest 20% of outcomes; for cost, the lowest 20% of outcomes)

Cost (Percent of Pay)



Percentile values:

99th	18.3%
90th	13.6%
75th	11.3%
50th	9.6%
25th	8.2%
10th	7.2%
1st	5.3%

Other Metrics

Benefit Shortfall Risk

Replacement Ratio Target:	Shortfall Probability
70%+	8.3%
60%+	0.0%

Benefits by Career Pattern

Turnover assumption = Baseline / medium

Plan: Cash Balance — No cash-out at termination — Post-term credit at min only

Average replacement ratio:	*# Employers*	*Weight*	*Soc. Sec.*	*Plan Ben.*	*Total*
Full career with single employer	1	40%	39.0%	49.4%	88.4%
Multiple employers over career	3	60%	39.0%	34.0%	73.0%
Blended average			39.0%	40.2%	79.2%

Stress Index for Accumulation Path

Measures reflect all years during career where account, or accrued benefit, experiences an investment-related loss, averaged over all scenarios.

	Loss Frequency	*Average Loss (% pay)*	*Cummulative Career Losses (% pay)*	*Index*
Best / smoothest possible path	0.0%	0.0%	0.0%	0.0
(i.e. no losses, such as DC w/ cash or SV investments)				
Result for DC w/100% fixed income (core style)	18.7%	-5.6%	-38.4%	0.9
Result for this plan	0.0%	0.0%	0.0%	0.0
Result for DC w/ typical TDF (90/50)	26.3%	-24.4%	-228.5%	5.1
Worst / most volatile possible path	30.0%	-41.7%	-444.0%	10.0
(i.e. DC plan w/ 100% risk asset allocation)				

Adjusted Cost for a 70% Repl. Ratio Target:

Cost to achieve a 70%+ replacement ratio, with a specified level of confidence.

Confidence target:	*Average Cost (% pay)*	*Cost Risk Metric (% pay)*
50% confidence	8.1%	11.4%
70% confidence	8.7%	12.3%
90% confidence	9.8%	13.8%

Assumptions

	Baseline assumption	*Adjustment*	*Adjusted assumption*
Price inflation	2.5%	0.0%	2.5%
Real wage growth	0.5%	0.0%	0.5%
Nominal wage growth	3.0%	0.0%	3.0%
Real yield on 10-yr Treas	1.8%	0.0%	1.8%
Nominal yield on 10-yr Treas	4.3%	0.0%	4.3%
Credit/duration spread for for "Core Fixed Income"	0.2%	0.0%	0.2%
Nominal "Core Fixed Income" returns	4.5%	0.0%	4.5%
Risk premium for risky assets	3.5%	0.0%	3.5%
Nominal risky asset returns	8.0%	0.0%	8.0%
(gross, long-term compounded)			

Appendix G: Sample Accumulation Phase Analysis for Cash Balance Designs with Participating Credit Rate

Appendix F showed how the evaluation process works for one specific design. Here we produce the QE framework metrics for a broader range of designs that all fall within the family of cash balance plan designs which use a participating "investment" crediting rate, where the rate is derived from a formula that uses actual fund returns. Four separate designs are tested, moving from a low participation formula to higher participation formulas. For each of these, we show results for 30%, 50% and 70% allocations to risky assets in Table 8. In addition to the QE framework metrics, we show the pay credit rate (i.e., the annual "virtual contribution" credited to the cash balance account) that can be supported by the average 10% of pay contribution rate.

Table 8
Comparison of Results

CBpartic1

"Investment" Credit Rate: Participating formula based on 5 year average return
Minimum = 4.00% plus 50.0% of excess between 4.00% and 10.00%
plus 0.0% of excess over 10.00%

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.2%	74.1%	78.4%
Risk metric	64.6%	68.2%	71.6%
Shortfall risk (70% target)	63.2%	17.7%	3.9%
Cost risk metric (% pay)	11.8%	13.1%	14.7%
Supported pay credit rate	11.31%	12.29%	13.33%

CBpartic2

"Investment" Credit Rate: Participating formula based on 5 year average return
Minimum = 4.00% plus 75.0% of excess between 4.00% and 10.00%
plus 75.0% of excess over 10.00%

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.4%	74.6%	79.9%
Risk metric	64.1%	66.8%	68.7%
Shortfall risk (70% target)	61.5%	24.7%	13.2%
Cost risk metric (% pay)	11.5%	12.5%	13.6%
Supported pay credit rate	10.21%	10.21%	9.97%

CBpartic3

"Investment" Credit Rate: Participating formula based on 5 year average return
Minimum = 0.00% plus 75.0% of excess between 0.00% and 10.00%
plus 100.0% of excess over 10.00%

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.4%	74.9%	80.7%
Risk metric	63.8%	65.9%	67.1%
Shortfall risk (70% target)	59.8%	28.5%	17.4%
Cost risk metric (% pay)	11.3%	12.0%	13.0%
Supported pay credit rate	12.97%	13.18%	12.93%

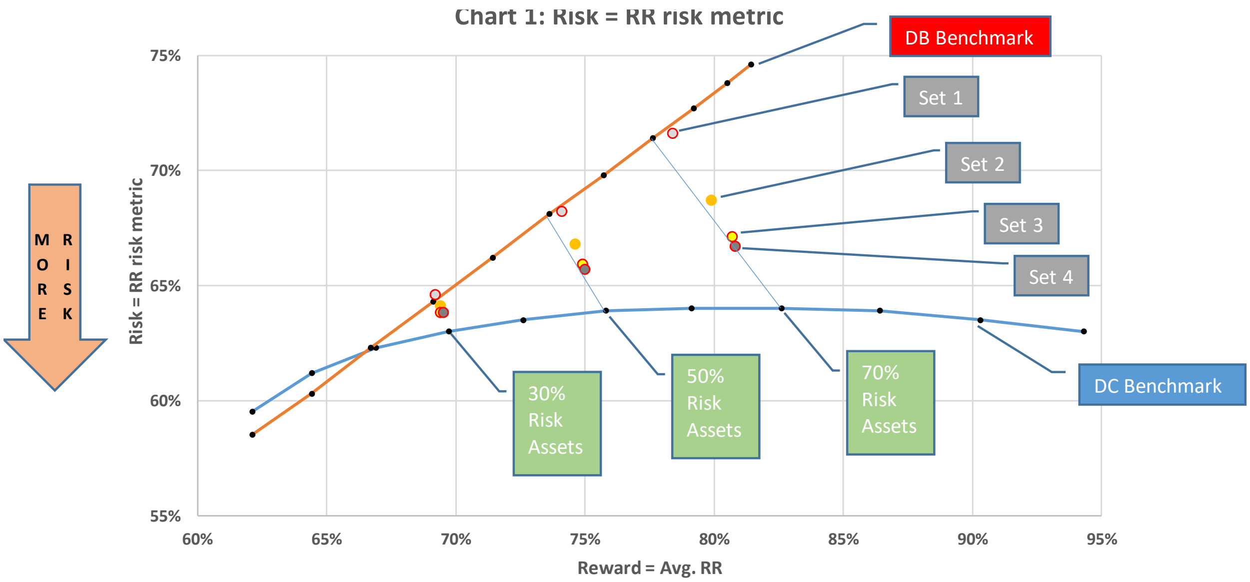
CBpartic4

"Investment" Credit Rate: Participating formula based on 3 year average return
Minimum = 0.00% plus 75.0% of excess between 0.00% and 10.00%
plus 100.0% of excess over 10.00%

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.5%	75.0%	80.8%
Risk metric	63.8%	65.7%	66.7%
Shortfall risk (70% target)	58.7%	28.2%	18.1%
Cost risk metric (% pay)	11.2%	12.0%	13.0%
Supported pay credit rate	12.75%	12.48%	11.66%

The easiest way to compare these results is to plot them into one of the efficient frontier graphs discussed in Appendix E. The four sets of results can be compared with each other, and within the context of the DC and DB benchmark results. The first one shown below in Figure 29 is a critical one, using the replacement ratio risk metric for the risk dimension.

Figure 29
Results Comparison with RR Risk Metric



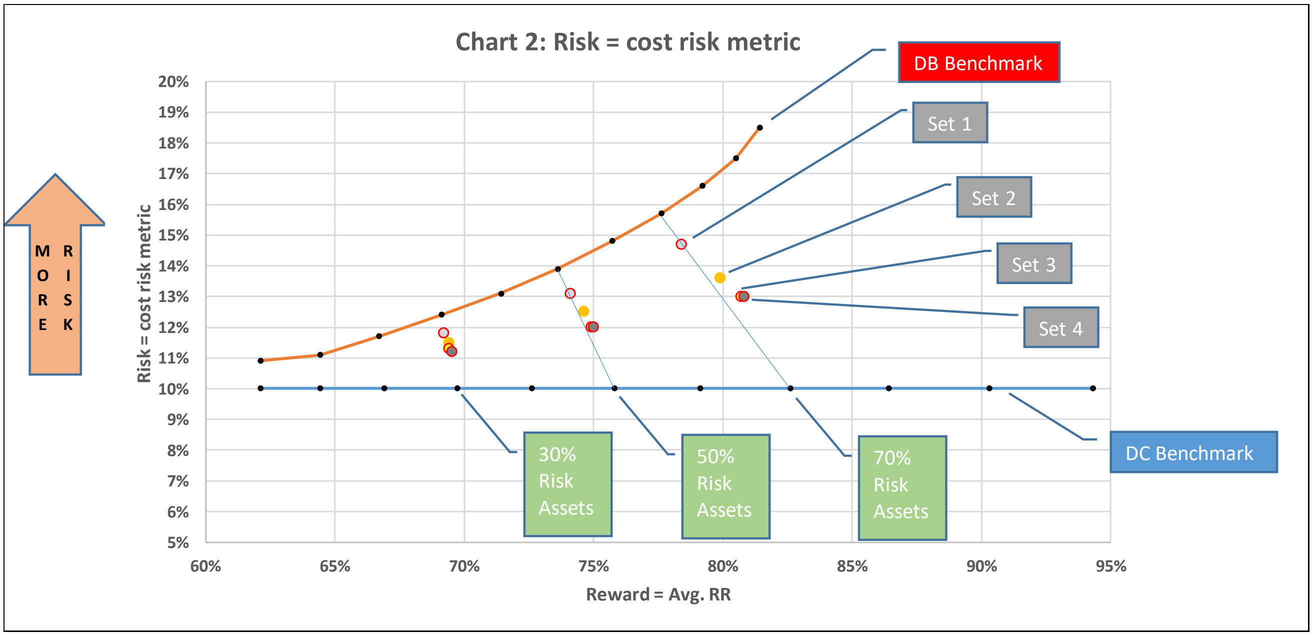
Observations: We see that visually the participating cash balance results gradually migrate from the DB benchmark line toward the DC benchmark line, as the degree of employee participation is increased. This illustrates that this type of plan is a true risk-sharing design—filling the space between DC and DB results. In fact, for any single point between the DC and DB benchmark lines, it would be possible to construct a participating cash balance design and investment policy whose results would plot at that point. Some of those designs might not be "cosmetically" attractive to participants. For example, getting close to the DC line would require that minimum interest credit values fall well below zero. But at least the door to risk sharing is open—based on the concept of partially reflecting actual fund returns, but subject to smoothing and/or constraints.

Some additional comments follow:

- Although the design used for Set 1 seems at face value to provide significant participation, in fact 50% participation within the 4% to 10% range barely moves the results off the DB line.
- Comparing Set 3 and Set 4 designs, we see that the only change is a decrease in years used for smoothing, from five years to three years. The shorter smoothing period increase the participation level.

Since the participating cash balance design is shifting some portion of investment risk from the sponsor to the participant, we predict a decrease in sponsor cost risk. In Figure 30, we see this effect when we plot results using the cost risk metric.

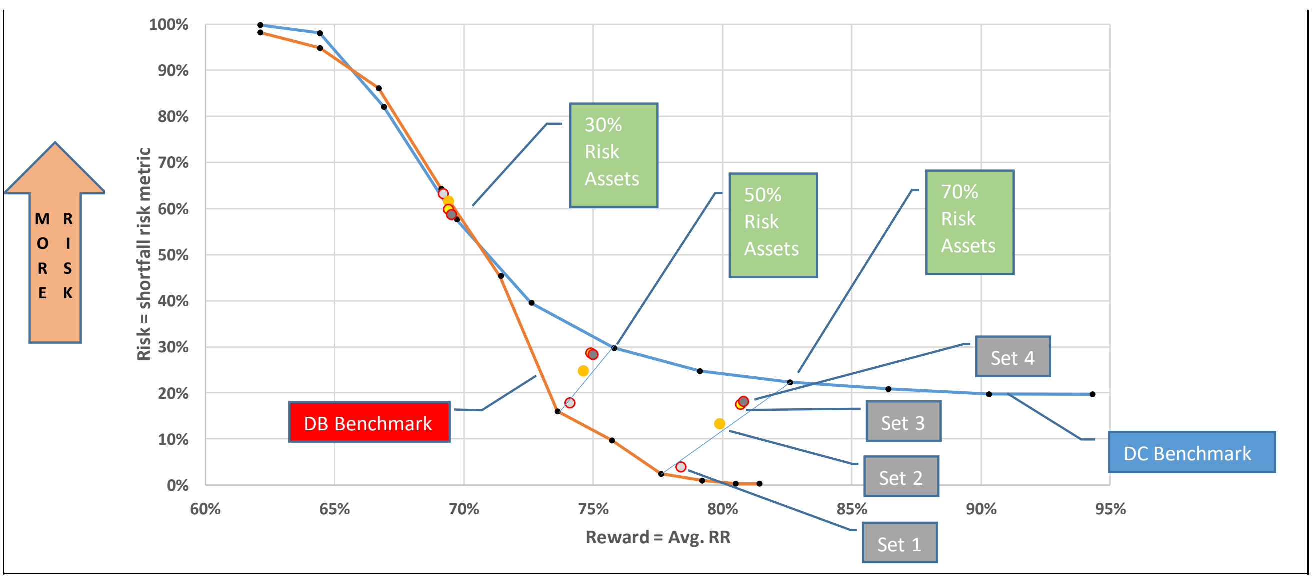
Figure 30
Results Comparison with Cost Risk Metric



Observations: The relative decrease in cost risk appears to be consistent with the increase in benefit risk. Interestingly, the introduction of even a very small amount of benefit risk in Set 1 creates more than a proportional decrease in cost risk. For Sets 2, 3 and 4, the relative shifts in risk are closer to proportional in nature.

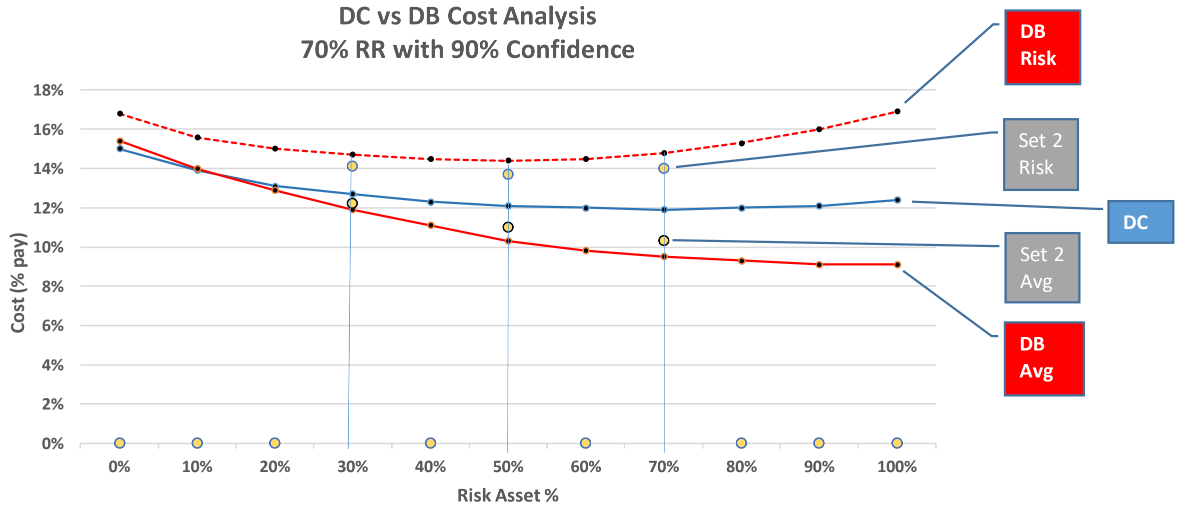
In Figure 31, we plot the results using the shortfall risk metric.

Figure 31
Results Comparison with Shortfall Risk Metric



Finally, we can plot the adjusted cost metrics that show the required cost to meet a 70% replacement ratio target with a specified level of confidence. Figure 32 shows the Set 2 design, using the highest 90% confidence level.

Figure 32
Set 2 Design with 90% Confidence



Observations: Compared with the DB benchmark cost range, the Set 2 participating cash balance design operates within a narrower range. The average cost is higher than for a DB plan, but the cost risk is lower. The higher the level of employee participation, the narrower the cost range will become. In this sense, the DC results are merely the limiting case—equivalent to a participating cash balance plan using no minimums or maximums, 100% employee participation and no smoothing.

Portability

All of the results in the previous section are based on plan designs where the cash balance account remains in the plan after an employee terminates and continues to get the participating credits. With this feature, the participating cash balance plans would have full portability of benefits—the same as for the DC benchmark plans, and for career average pay DB benchmark plans. With participating cash balance designs, however, the crediting rate following termination can be set at some fixed rate, or the account could theoretically be cashed out (as with any cash balance plan). Here we explore the impact of these alternative ways of handling post-termination benefits. For simplicity, we will use only the 70% risky asset allocation for the comparisons.

First, in Table 9, we can compare the basic benefit and cost metrics (note that all metrics reflect a blended average for full career and fragmented career outcomes).

Table 9
Comparison of Basic Benefit and Cost Metrics

Post-term. treatment:	*CBpartic2 Full credit*	*CBpartic2A Min credit*	*CBpartic2B Cash-out*
Repl. Ratio:			
Average	**79.9%**	**79.2%**	**81.0%**
Risk metric	**68.7%**	**70.3%**	**67.3%**
Shortfall risk (70% target)	**13.2%**	**8.3%**	**17.1%**
Cost risk metric (% pay)	**13.6%**	**14.1%**	**12.3%**
Supported pay credit rate	**9.97%**	**12.06%**	**9.99%**

Observations: What may seem like fairly minor plan changes actually produce significant changes in the benefit and cost outcomes. Moving from column one to column two, we remove some market exposure (from post-termination benefits), so the resulting benefit distribution is much tighter and slightly lower at the mean. Because the post-termination benefits have been lowered in all scenarios, our 10% of pay cost budget now also supports a significantly higher pay credit rate. The cost for the reduced level of benefit risk shows up in a higher upside cost risk metric. Moving from column one to column three, we add full market exposure to post-termination benefits (because they are assumed to be rolled into an IRA or another DC plan), so the resulting benefit distribution is wider and slightly higher at the mean. Because risk is shifted into benefits, the upside cost risk measure is improved.

Next, in Table 10, we look directly at the portability metrics that reflect the difference in benefits based on career pattern (full career vs. fragmented career).

Table 10
Portability Metrics

	CBpartic2	*CBpartic2A*	*CBpartic2B*
Post-term. treatment:	*Full credit*	*Min credit*	*Cash-out*
Average Repl. Ratio (plan only, excl. SS):			
Full career w/ single er	**40.9%**	**49.4%**	**40.9%**
Multiple ers over career	**40.9%**	**34.0%**	**42.7%**
Blended average	**40.9%**	**40.2%**	**42.0%**
Ratio fragmented / full career	**100.0%**	**68.8%**	**104.4%**

Observations: While the blended average benefit levels are similar, the distribution among full career and fragmented career changes significantly. Moving from column one to column two, we remove the opportunity for participation in positive market outcomes from post-termination benefits. As a result, there is a large difference in average benefits—the fragmented career benefit is only 68.8% of the full career benefit. For comparison, in a final pay pension plan design, the ratio is 74.5% (using the same assumptions). So even though cash balance designs are often touted as improving portability relative to a standard final pay design, we see that this is not always the case. Moving from column one to column three, the post-termination benefits now have exposure to full market outcomes (both positive and negative). On average, the post-termination benefits are improved due to the market exposure—but the flip side is significantly greater uncertainty. To see the increased uncertainty, we can look at Table 9 and see the higher shortfall risk and larger spread between the average benefit metric and the benefit risk metric. All of this increased uncertainty flows to those with a fragmented career, since the full career benefits remain essentially the same (pay credit of 9.99% vs. 9.97%).

Evaluation

In Table 11, we now evaluate the results, using the techniques discussed in Appendix F—where for each plan and asset allocation, we also create metrics for an equivalent combo DC + DB benchmark plan. We can then compare each of the risk metrics to the same metric for the equivalent combo DC + DB benchmark. The primary focus is on the adjusted-cost values, as they reflect both cost risk and shortfall risk in a single set of metrics. The path stress index is also important.

When we compare the risk metrics, if they are better than the equivalent combo DC + DB plan, we shade the result green, and if they are worse we shade the result red. Essentially neutral outcomes are shaded yellow. More specifically, we use the following rules for the adjusted-cost metric cell shading:

More than 5% lower than benchmark rate
Between 2% to 5% lower than benchmark rate
Within plus or minus 2% of benchmark rate
Between 2% to 5% higher than benchmark rate
More than 5% higher than benchmark rate

For each of these, we show results for 30%, 50% and 70% allocations to risky assets.

Table 11
Evaluation of Results

"Investment" Credit Rate:	Participating formula based on 5 year average return Minimum = 4.00% plus 50.0% of excess between 4.00% and 10.00% plus 0.0% of excess over 10.00%

CBpartic1

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.2%	74.1%	78.4%
Risk metric	64.6%	68.2%	71.6%
Shortfall risk (70% target)	63.2%	17.7%	3.9%
Cost risk metric (% pay)	11.8%	13.1%	14.7%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.2%
50% confidence-risk metric	12.2%	11.8%	12.0%
70% confidence-average	11.0%	9.5%	8.6%
70% confidence-risk metric	13.0%	12.5%	12.7%
90% confidence-average	11.9%	10.5%	9.4%
90% confidence-risk metric	14.1%	13.7%	13.8%

Combo DC+DB equiv.

	Risky Asset Alloc.		
	30%	*49%*	*69%*
DB plan weight:	*80%*	*70%*	*80%*
Repl. Ratio:			
Average	69.2%	74.0%	78.4%
Risk metric	64.8%	68.2%	71.8%
Shortfall risk (70% target)	64.3%	18.2%	3.4%
Cost risk metric (% pay)	11.9%	12.7%	14.5%
Path stress index	0.3	0.8	1.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.2%
50% confidence-risk metric	12.3%	11.5%	11.9%
70% confidence-average	11.0%	9.5%	8.6%
70% confidence-risk metric	13.0%	12.2%	12.6%
90% confidence-average	11.9%	10.6%	9.3%
90% confidence-risk metric	14.1%	13.3%	13.5%

"Investment" Credit Rate:	Participating formula based on 5 year average return Minimum = 4.00% plus 75.0% of excess between 4.00% and 10.00% plus 75.0% of excess over 10.00%

CBpartic2

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.4%	74.6%	79.9%
Risk metric	64.1%	66.8%	68.7%
Shortfall risk (70% target)	61.5%	24.7%	13.2%
Cost risk metric (% pay)	11.5%	12.5%	13.6%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.1%
50% confidence-risk metric	12.0%	11.2%	11.0%
70% confidence-average	11.0%	9.8%	8.9%
70% confidence-risk metric	12.7%	12.2%	12.1%
90% confidence-average	12.2%	11.0%	10.3%
90% confidence-risk metric	14.1%	13.7%	14.0%

Combo DC+DB equiv.

	Risky Asset Alloc.		
	30%	*49%*	*68%*
DB plan weight:	*30%*	*40%*	*45%*
Repl. Ratio:			
Average	69.5%	74.6%	79.8%
Risk metric	64.1%	66.8%	69.0%
Shortfall risk (70% target)	59.5%	23.5%	11.9%
Cost risk metric (% pay)	10.7%	11.5%	12.5%
Path stress index	0.9	1.6	2.7
Adjusted cost for a 70% RR target:			
50% confidence-average	10.3%	9.0%	8.0%
50% confidence-risk metric	11.1%	10.4%	10.0%
70% confidence-average	11.0%	9.7%	8.7%
70% confidence-risk metric	11.8%	11.2%	10.9%
90% confidence-average	12.2%	11.1%	10.2%
90% confidence-risk metric	13.1%	12.7%	12.5%

"Investment" Credit Rate:	Participating formula based on 5 year average return Minimum = 4.00% plus 75.0% of excess between 4.00% and 10.00% plus 75.0% of excess over 10.00%

Same as CBpartic2, except only the minimum rate is creditied after termination.

CBpartic2A (Kentucky Plan)

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.3%	74.3%	79.2%
Risk metric	64.5%	67.8%	70.3%
Shortfall risk (70% target)	62.8%	20.1%	8.3%
Cost risk metric (% pay)	11.8%	12.8%	14.1%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.1%
50% confidence-risk metric	12.2%	11.6%	11.4%
70% confidence-average	11.0%	9.6%	8.7%
70% confidence-risk metric	12.9%	12.3%	12.3%
90% confidence-average	12.0%	10.7%	9.8%
90% confidence-risk metric	14.1%	13.7%	13.8%

Combo DC+DB equiv.

	Risky Asset Alloc.		
	31%	*49%*	*68%*
DB plan weight:	*100%*	*55%*	*60%*
Repl. Ratio:			
Average	69.3%	74.3%	79.1%
Risk metric	64.4%	67.6%	70.4%
Shortfall risk (70% target)	64.3%	20.7%	7.0%
Cost risk metric (% pay)	12.4%	12.1%	13.3%
Path stress index	0.0	1.2	2.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	9.0%	8.0%
50% confidence-risk metric	12.9%	10.9%	10.8%
70% confidence-average	10.9%	9.6%	8.6%
70% confidence-risk metric	13.6%	11.6%	11.5%
90% confidence-average	11.8%	10.8%	9.7%
90% confidence-risk metric	14.7%	13.0%	12.8%

Table 11, continued
Evaluation of Results

"Investment" Credit Rate:	Participating formula based on 5 year average return Minimum = 0.00% plus 75.0% of excess between 0.00% and 10.00% plus 100.0% of excess over 10.00%

CBpartic3

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.4%	74.9%	80.7%
Risk metric	63.8%	65.9%	67.1%
Shortfall risk (70% target)	59.8%	28.5%	17.4%
Cost risk metric (% pay)	11.3%	12.0%	13.0%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.3%	9.0%	8.1%
50% confidence-risk metric	11.6%	10.8%	10.5%
70% confidence-average	11.1%	9.9%	9.1%
70% confidence-risk metric	12.5%	11.9%	11.8%
90% confidence-average	12.3%	11.3%	10.9%
90% confidence-risk metric	13.9%	13.6%	14.1%

Combo DC+DB equiv.

	Risky Asset Alloc.		
	29%	*49%*	*68%*
DB plan weight:	*25%*	*25%*	*25%*
Repl. Ratio:			
Average	69.3%	74.9%	80.7%
Risk metric	63.8%	65.7%	66.9%
Shortfall risk (70% target)	61.4%	26.9%	17.3%
Cost risk metric (% pay)	10.6%	11.0%	11.4%
Path stress index	1.0	2.1	3.7
Adjusted cost for a 70% RR target:			
50% confidence-average	10.4%	8.9%	7.9%
50% confidence-risk metric	11.0%	9.8%	9.0%
70% confidence-average	11.1%	9.8%	8.9%
70% confidence-risk metric	11.8%	10.7%	10.2%
90% confidence-average	12.4%	11.4%	10.8%
90% confidence-risk metric	13.0%	12.4%	12.1%

"Investment" Credit Rate:	Participating formula based on 3 year average return Minimum = 0.00% plus 75.0% of excess between 0.00% and 10.00% plus 100.0% of excess over 10.00%

CBpartic4

	Risky Asset Alloc.		
	30%	*50%*	*70%*
Repl. Ratio:			
Average	69.5%	75.0%	80.8%
Risk metric	63.8%	65.7%	66.7%
Shortfall risk (70% target)	58.7%	28.2%	18.1%
Cost risk metric (% pay)	11.2%	12.0%	13.0%
Path stress index	0.0	0.0	0.0
Adjusted cost for a 70% RR target:			
50% confidence-average	10.3%	8.9%	8.0%
50% confidence-risk metric	11.5%	10.7%	10.5%
70% confidence-average	11.2%	9.9%	9.1%
70% confidence-risk metric	12.5%	11.8%	11.9%
90% confidence-average	12.4%	11.5%	11.0%
90% confidence-risk metric	13.8%	13.8%	14.3%

Combo DC+DB equiv.

	Risky Asset Alloc.		
	30%	*49%*	*68%*
DB plan weight:	*20%*	*25%*	*25%*
Repl. Ratio:			
Average	69.6%	74.9%	80.7%
Risk metric	63.8%	65.7%	66.9%
Shortfall risk (70% target)	58.6%	26.9%	17.3%
Cost risk metric (% pay)	10.5%	11.0%	11.4%
Path stress index	1.1	2.1	3.7
Adjusted cost for a 70% RR target:			
50% confidence-average	10.3%	8.9%	7.9%
50% confidence-risk metric	10.8%	9.8%	9.0%
70% confidence-average	11.0%	9.8%	8.9%
70% confidence-risk metric	11.6%	10.7%	10.2%
90% confidence-average	12.4%	11.4%	10.8%
90% confidence-risk metric	13.0%	12.4%	12.1%

Observations: From an economic point of view, these designs offer better path stress results, due to the floor crediting rate in the formula. The cost for this floor protection is reflected in noticeably worse results for the upside cost risk metric. Sponsors may therefore judge these plans based on the perceived relative value of these two outcomes, as well as the significant non-quantitative differences:

- Single plan vs. two separate plans
- Employee perception and understanding
- Ability to incorporate employee contributions
- Ability to incorporate employee choice
- Regulatory and administrative issues

Further analysis would be useful by using a revised assumption set that reflects lower return expectations than the baseline assumption set. Presumably, the cost for the floor protection will be higher, resulting in even higher upside cost risk metrics.

Appendix H: Payouts Using a Structured Withdrawal Plan Based on a Modified ARVA Design

The model used in the QE framework for analysis of payout phase designs includes a large number of parameters that can be used to specify various payout "rules" for the various components that might be included in the overall design:

- Insured immediate annuities with specified COLA and death benefit features
- Insured longevity annuities with a side longevity bridge fund (LBF) component to integrate early period payouts with the deferred payouts from the longevity annuity
- Structured withdrawal plans (SWPs) using specific payout rules:
    - Simple percentage payout rules (e.g., the standard 4% rule), with possible additional constraints and/or "guardrail" features
    - Factors based on a specified fixed period or on life expectancy values (e.g., the IRS required minimum distribution factors), with possible smoothing rules and with possible use of interest discounting procedures (e.g., annually recalculated virtual annuity, or ARVA)
    - Dynamic spending rules

In the development of the payout phase model, a wide variety of SWP designs were analyzed to compare results and identify methods that seemed to be more efficient in creating a stable income stream for periods extending to very advanced ages. The one described here is one that produced good results, based on the QE framework metrics, relative to other SWP methods. The ARVA[7] concept covers a family of methods that utilize both life expectancy factors and some kind of interest discounting process to adjust the life expectancy values. The approach used standard life expectancy[8] and interest discount factors that were updated each year according to current market conditions, and no smoothing was used. The particular modified version that performed especially well has these modifications:

- The life expectancy factors used are conservative, in that the figure used is not the age to which there is a 50% survival probability (i.e., standard life expectancy) but rather the age to which there is a 10% survival probability (i.e., the age where one has 90% confidence of "not outliving").
- Instead of adjusting the discount rate each year based on market conditions, we used a fixed rate equal to 1.5% for the assumed real interest rate plus an add-on for any equity risk taken in the investment portfolio. For the risk premium add-on, we used a conservative assumption of only a 2% total equity risk premium. The example discussed here uses a 50% allocation to risky assets in the portfolio, so we used a 1.0% add-on to get to a total discount of 2.5%.
- Smoothing rules were applied such that the payout for any year would never increase by more than 5% or decrease by more than 4% from the prior year's payout amount.

The first modification makes results more robust at advanced ages, and the other modifications provide much more year-to-year stability without sacrificing any sustainability of the income stream. Table 13 compares some of the key results with and without the modifications (the ARVA7 specs in Table 12 are the ones used for the example in this appendix).

Table 12
ARVA Specs

	Comment	*Risky Asset Alloc*	*Time Period*	*Discount Rate*	*Smoothing*
ARVA1	orig Waring/Siegel , per paper	50%	fixed 30 yrs	TIPS yld each yr	none
ARVA2	ARVA1 w/ standard life expectancy (also in Waring/Siegel paper)	50%	50th %-tile life expectancy each yr	TIPS yld each yr	none
ARVA3	conservative life expectancy	50%	90th %-tile life expectancy each yr	TIPS yld each yr	none
ARVA4	intermediate life expectancy	50%	70th %-tile life expectancy each yr	TIPS yld each yr	none
ARVA5	use fixed real interest assumption	50%	90th %-tile life expectancy each yr	1.5% real interest yield (conserv)	none
ARVA6	add equity risk premium adj to rate	50%	90th %-tile life expectancy each yr	1.5% interest + 1% ERP (= 50% x 2% conserv RA ERP)	none
ARVA7	add smoothing	50%	90th %-tile life expectancy each yr	1.5% interest + 1% ERP (= 50% x 2% conserv RA ERP)	max incr = +5%, max decr = -4%
ARVA8	alternate smoothing	50%	90th %-tile life expectancy each yr	1.5% interest + 1% ERP (= 50% x 2% conserv RA ERP)	max incr = +7%, max decr = -4%
ARVA9	increase risky asset allocation	80%	90th %-tile life expectancy each yr	1.5% interest + 1.6% ERP (= 80% x 2% conserv RA ERP)	max incr = +5%, max decr = -4%

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[7] Waring, M. Barton, and Laurence B. Siegel. 2015. The Only Spending Rule Article You Will Ever Need. *Financial Analyst Journal* vol. 71, no. 1. *https://www.cfapubs.org/doi/abs/10.2469/faj.v71.n1.2*.

[8] The article also looks at using a fixed period that starts at 30 years and adjusts downward by one year at each subsequent age.

Table 13
ARVA Results

	SWP risk asset %	--- Ben Metric*--- 1st 25 yrs	After 25	Age 85 liquidity**	--- Failure rate*** at age --- 90	95	100	--- Volatility Metric**** --- 1st 15 yrs	Next 10 yrs	After 25 yrs
ARVA1	**50%**	**68.2%**	**17.3%**	**370%**	**0.3%**	**0.3%**	**100.0%**	**17.8%**	**17.0%**	**71.1%**
ARVA2	**50%**	**80.9%**	**16.3%**	**249%**	**3.7%**	**39.9%**	**98.8%**	**24.5%**	**60.9%**	**97.4%**
ARVA3	**50%**	**61.3%**	**60.8%**	**446%**	**0.5%**	**1.4%**	**4.0%**	**20.4%**	**26.1%**	**46.4%**
ARVA4	**50%**	**72.1%**	**51.9%**	**348%**	**0.9%**	**4.4%**	**36.8%**	**20.8%**	**36.9%**	**79.3%**
ARVA5	**50%**	**61.5%**	**60.8%**	**447%**	**0.8%**	**1.3%**	**4.3%**	**15.8%**	**23.3%**	**46.1%**
ARVA6	**50%**	**68.4%**	**62.9%**	**404%**	**1.0%**	**2.4%**	**8.9%**	**22.0%**	**30.5%**	**53.9%**
ARVA7	**50%**	**67.0%**	**66.5%**	**452%**	**1.3%**	**1.7%**	**4.9%**	**13.6%**	**9.0%**	**22.4%**
ARVA8	**50%**	**68.0%**	**65.1%**	**426%**	**1.2%**	**1.9%**	**5.9%**	**14.8%**	**16.2%**	**38.3%**
ARVA9	**80%**	**70.3%**	**70.2%**	**570%**	**4.9%**	**6.0%**	**7.9%**	**20.0%**	**11.9%**	**15.2%**

** Benefit metric = risk adjusted average of [benefits / base benefits], where base benefits are from low-risk fixed-price annuity (5.85% interest)*
*** Accessible wealth at age 85 as % of final pay, adjusted for inflation*
**** Probability that benefit below 40% of baseline benefit*
***** Probablity that average benefit over rolling 3-yr period is more than 10% lower than prior 3-yr period*

Figure 33 shows the full set of metrics for this sample design (ARVA7).

Figure 33
Full Set of Metrics for Sample Using ARVA7

12/8/2018 13:26

Description of payout method being analyzed:

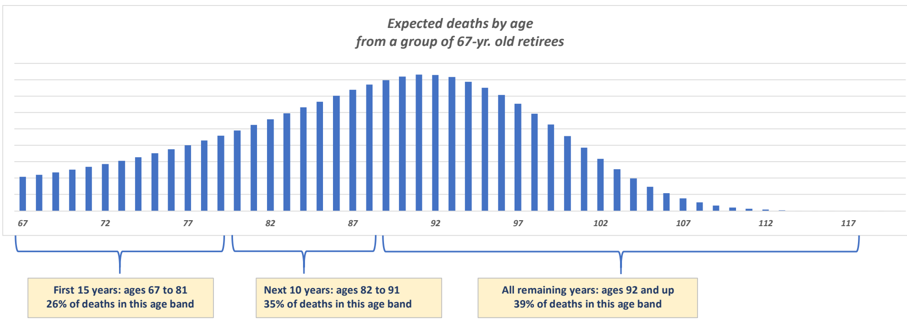
Allocation of distribution (by percent of initial balance)

Immediate annuity -- insurance company	0%
Immediate annuity -- fixed rate in-plan	0%
Longevity insurance	0%
Longevity bridge fund (LBF)	
Balance to "Structured Withdrawal Plan" (SWP)	100%

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*

SWP alloc. to risk assets		*SWP alloc. to TIPS*		*SWP methodology (see parameters for details):*
50%	*at 67*	0%	*at 67*	*Base spend rate uses factors = 1 / PV for selected rate and nper*
50%	*at 70*	0%	*at 70*	*This method is used for all years*
50%	*at 75*	0%	*at 75*	
50%	*at 80*	0%	*at 80*	
50%	*at 85+*	0%	*at 85+*	

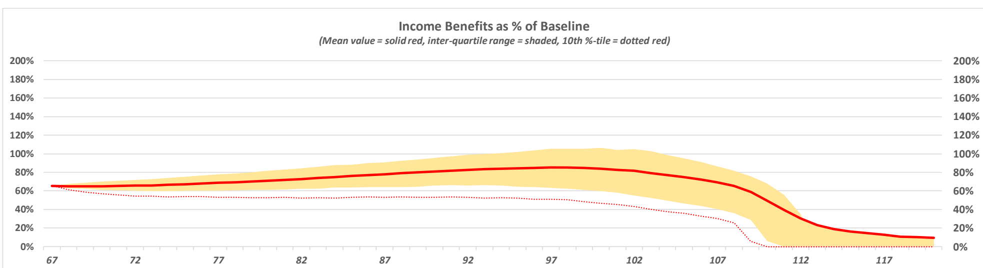
Age groupings used in analysis:



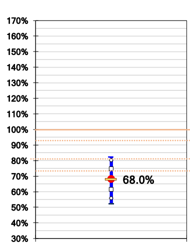
Range of income benefits as percent of baseline*:

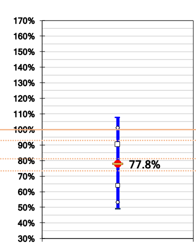
"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.85%, no load, full CPI COLA, no death benefits.

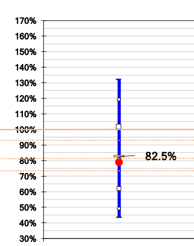
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.



First 15 years: ages 67 to 81		Next 10 years: ages 82 to 91		All remaining years: ages 92 and up	







%tile	Ages 67 to 81	%tile	Ages 82 to 91	%tile	Ages 92 and up
95%	82.4%	95%	107.7%	95%	132.2%
90%	80.2%	90%	101.0%	90%	119.3%
75%	74.8%	75%	90.3%	75%	101.5%
50%	68.1%	50%	77.9%	50%	78.9%
25%	61.5%	25%	64.1%	25%	61.9%
10%	55.9%	10%	53.4%	10%	49.3%
5%	52.4%	5%	49.0%	5%	43.7%
Mean	68.0%	Mean	77.8%	Mean	82.5%

Alternate benchmarks

- 100% = Full baseline, no death benefit
- 93% = Baseline, but with death benefit
- 81% = Group annuity pricing, with death benefit & fixed 2.5% COLA
- 74% = Retail annuity pricing, with death benefit & fixed 2.5% COLA

Sensitivity to initial age 67 conditions:

Initial interest rate at age 67:	Mean	Mean	Mean
High (avg. highest quintile)	70.5%	82.0%	88.7%
Medium (avg. 20th to 80th percentile)	68.0%	77.8%	82.3%
Low (avg. lowest quintile)	65.5%	73.7%	77.0%

Expected inflation at age 67:	Mean	Mean	Mean
High (avg. highest quintile)	69.4%	79.6%	84.7%
Medium (avg. 20th to 80th percentile)	68.0%	77.8%	82.4%
Low (avg. lowest quintile)	66.6%	76.0%	80.5%

Figure 33, continued
Full Set of Metrics for Sample Using ARVA7

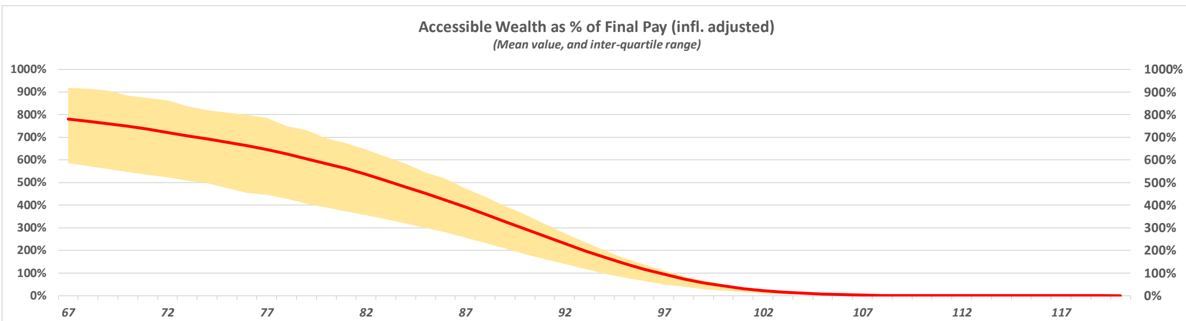
Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

	Shortfall risk (using 3-yr. avg.): First 15 yrs. (Ages 67 to 81)	Next 10 yrs. (Ages 82 to 91)	Failure rate at: Age 90	Age 95	Age 100	Age 105	Age 110
			Survival probability				
60% of baseline	**27.4%**	**22.0%**	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	**5.1%**	**8.4%**					
40% of baseline	**0.4%**	**1.1%**	**1.3%**	**1.7%**	**4.9%**	**16.3%**	**54.0%**
30% of baseline	**0.0%**	**0.1%**	**0.3%**	**0.6%**	**1.1%**	**4.7%**	**41.3%**

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	Next 10 yrs. (92 to 101)
Decline by 10+ percent	**13.6%**	**9.0%**	**22.4%**
Decline by 15+ percent	**4.4%**	**2.9%**	**10.0%**
Decline by 20+ percent	**0.8%**	**0.4%**	**2.6%**
Decline by 25+ percent	**0.1%**	**0.0%**	**0.4%**

Level of accessible wealth as percent of final pay (inflation adjusted)
(Note that the age 67 value is before the purchase of any annuities.)



Death benefits paid as percent of total payments

	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	All remaining yrs. (92 and up)
%tile			
95%	**35.5%**	**60.3%**	**76.0%**
75%	**31.3%**	**52.2%**	**63.7%**
50%	**29.5%**	**48.5%**	**59.8%**
25%	**28.3%**	**46.5%**	**58.1%**
5%	**27.2%**	**45.2%**	**56.6%**
Mean	**30.1%**	**50.0%**	**62.0%**

Cost risk to sponsor for any fixed price annuities (cost spread as % of pay over career)

	Change in cost as % of pay: For "Baseline"	For selected payout parameters
%tile		
95%	**1.7%**	**0.0%**
75%	**0.4%**	**0.0%**
50%	**-0.4%**	**0.0%**
25%	**-1.1%**	**0.0%**
5%	**-2.2%**	**0.0%**
Mean	**-0.3%**	**0.0%**

Figure 33, continued
Full Set of Metrics for Sample Using ARVA7

12/8/2018 13:26

Description of payout method being analyzed:

Allocation of distribution (by percent of initial balance)

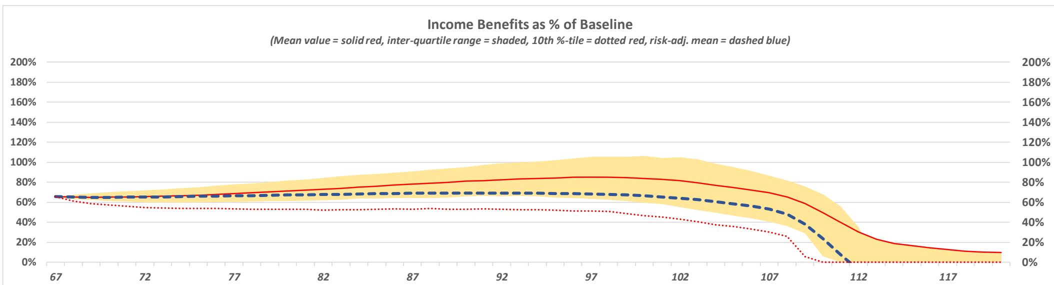
Immediate annuity -- insurance company	**0%**
Immediate annuity -- fixed rate in-plan	**0%**
Longevity insurance	**0%**
Longevity bridge fund (LBF)	
Balance to "Structured Withdrawal Plan" (SWP)	**100%**

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*

SWP alloc. to risk assets		*SWP alloc. to TIPS*		*SWP methodology (see parameters for details):*
50%	*at 67*	0%	*at 67*	*Base spend rate uses factors = 1 / PV for selected rate and nper*
50%	*at 70*	0%	*at 70*	*This method is used for all years*
50%	*at 75*	0%	*at 75*	
50%	*at 80*	0%	*at 80*	
50%	*at 85+*	0%	*at 85+*	

Range of income benefits as percent of baseline*:

"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.85%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.



The dashed line in the chart shows values for the "risk-adjusted" metric, which is used for evaluation and comparision of various payout options.
The key summary values for this metric are shown below, and plotted in the following graph:

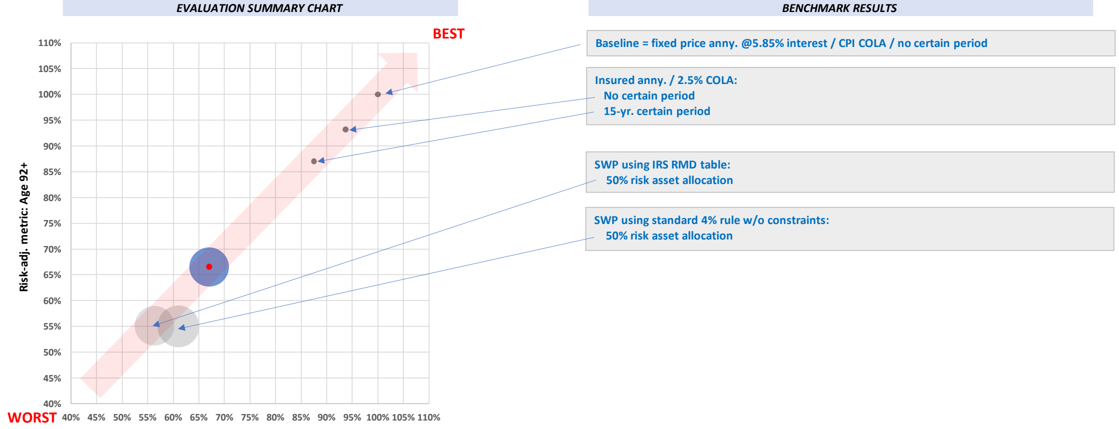
Mean value -- first 25 years	**67.0%**
Weighted mean value -- remaining years (age 92+)	**66.5%**

Evaluation chart

In the graph below, the position of the evaluation point is based on the risk-adjusted metric values shown above, and the size of the surrounding circle represents the average amount of accessible assets at age 85 (a proxy for both liquidity and the potential for a bequest at death). A single point indicates no liquidity at age 85. The primary evaluation factor is the location, indicating the risk-adjusted metric outcome -- with best results in the upper right corner. Liquidity (size of circle) is a secondary evaluation factor -- with larger circles preferred.

Accessible assets at age 85 (% of final pay, inflation adjusted) = 452%

EVALUATION SUMMARY CHART | *BENCHMARK RESULTS*



Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

	------------- Shortfall risk (using 3-yr. avg.) ----------------		------------- Failure rate at: ----------------				
	First 15 yrs. (Ages 67 to 81)	**Next 10 yrs. (Ages 82 to 91)**	**Age 90**	**Age 95**	**Age 100**	**Age 105**	**Age 110**
					---------- Survival probability ----------		
60% of baseline	**27.4%**	**22.0%**	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	**5.1%**	**8.4%**					
40% of baseline	**0.4%**	**1.1%**	**1.3%**	**1.7%**	**4.9%**	**16.3%**	**54.0%**
30% of baseline	**0.0%**	**0.1%**	**0.3%**	**0.6%**	**1.1%**	**4.7%**	**41.3%**

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	**Next 10 yrs. (82 to 91)**	**Next 10 yrs. (92 to 101)**
Decline by 10+ percent	**13.6%**	**9.0%**	**22.4%**
Decline by 15+ percent	**4.4%**	**2.9%**	**10.0%**

Appendix I: Payout Arrangement Combining Longevity Annuity with SWP and Longevity Bridge

The sample design shown in this appendix illustrates the potential value of adding some collective mortality risk pooling in the form of an insured longevity annuity (e.g., an annuity purchased at retirement but with payments deferred until age 85).

There are three separate components that work together in this design:

- **Insured longevity annuity.** This example assumes that an insured longevity annuity is purchased at age 67 using up to 15% of the accumulated balance (if the 15% portion of the balance buys a projected age 85 benefit of more than 25% income replacement on an inflation-adjusted basis, then only the portion required to achieve a 25% income replacement benefit is used to purchase the annuity). The annuity price at age 67 is developed on a stochastic basis for each scenario, using a formula that reflects the projected values at age 67 for the 10-year Treasury yield, the yield curve slope and the risk premium for high quality corporate bonds. The price includes an assumed 5% load for expenses, profits and contingencies. A fixed COLA of 2.5% applies to benefits after age 85, and there are no death benefits either before or after age 85.
- **Longevity bridge fund (LBF).** This is a side fund managed specifically to provide income benefits for the period up to age 85, providing a "bridge" to the deferred payments from the longevity annuity. For this example, we assume that the fund is invested 50% in risky assets and 50% in TIPS. The amount allocated to the LBF is the present value of 18 years of inflation adjusted benefits that will match at age 85 the initial longevity annuity benefit. The present value is based on a conservative estimate of the expected real investment return for the LBF assets. The LBF is drawn down with benefit payouts over the 18-year period, and there are rules to gradually decrease the payout amounts if investment performance is significantly worse than expected or increase the payout amounts if investment performance is significantly better than expected.
- **Structured withdrawal plan (SWP).** The remaining amount, if any, from the accumulation balance is invested in a SWP. In this example, we use the modified ARVA design described in Appendix H, except that we increase the allocation to risky assets from 50% to 80% to recognize the lower risk of the insured longevity annuity component, and we change the smoothing rule so that benefit increases are capped at 7% (instead of 5%). At age 85, the SWP will also absorb any remaining balance in the LBF side fund, and prior to age 85 additional payouts may be triggered in the event that the LBF side fund has no more assets.

The use of a longevity annuity presents complications in managing the remaining assets with respect to investment and payout patterns, but the improvement in results under the QE framework metrics are significant, as can be seen in Table 14.

Table 14
Results for all Scenarios

RESULTS FOR ALL SCENARIOS:			--- Ben Metric*---			--- Failure rate*** at age ---			--- Volatility Metric**** ---		
	Risk asset %	*Smoothing param.*	*1st 25 yrs*	*After 25*	*Age 85 liquidity*****	*90*	*95*	*100*	*1st 15 yrs*	*Next 10 yrs*	*After 25 yrs*
Standard 4% rule	**50%**	**NA**	**61.0%**	**55.0%**	**508%**	**0.7%**	**3.0%**	**9.3%**	**0.0%**	**0.3%**	**5.0%**
ARVA-type SWP only	**50%**	**+5% , -4%**	**67.0%**	**66.5%**	**452%**	**1.3%**	**1.7%**	**4.9%**	**13.6%**	**9.0%**	**22.4%**
SWP/LBF + 15.0% longevity(max)	**80%**	**+7% , -4%**	**81.3%**	**86.0%**	**258%**	**0.0%**	**0.1%**	**0.1%**	**8.4%**	**6.5%**	**4.8%**
Insured annuity w/ 2.5% COLA & 15-yr.CP	**NA**	**NA**	**87.5%**	**87.0%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**2.4%**	**2.5%**	**2.9%**

** Benefit metric = risk adjusted average of [benefits / base benefits], where base benefits are from low-risk fixed-price annuity (5.85% interest).*
*** Accessible wealth at age 85 as % of final pay, adjusted for inflation.*
**** Probablity that benefit falls below 40% of baseline benefit.*
***** Probablity that average benefit over rolling 3-yr period is more than 10% lower than prior 3-yr period.*
For collective program, the volatility is based on total benefit (base+bonus). Volatility for base only would be nil.

The results are much better than just using a SWP with modified ARVA rules and are reasonably close to the fully insured annuity results, but with significant retention of liquidity—which often seems to be highly valued by retirees. The rules used to develop this sample payout arrangement could be programmed within a packaged product for possible use as a default payout option for any DC plan.

In Figure 34, we show the complete set of QE framework metrics for this sample payout design.

Figure 34
Complete Set of QE Framework Metrics

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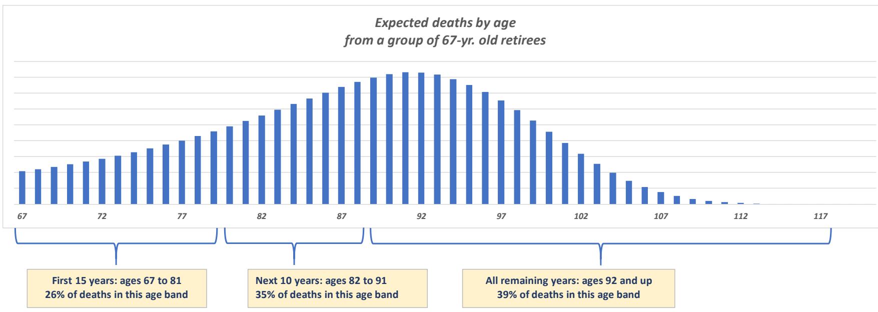
Description of payout method being analyzed:

Allocation of distribution (by percent of initial balance)

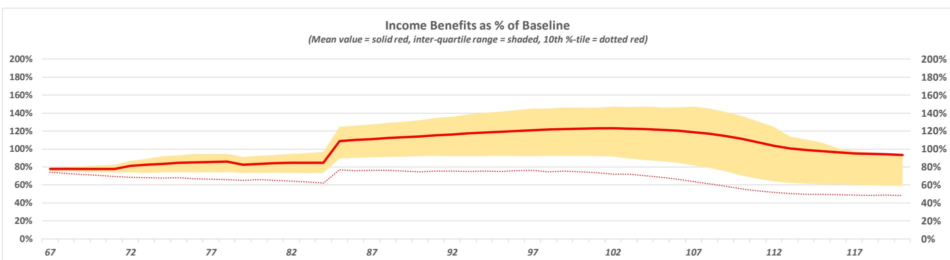
			*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*
Immediate annuity -- insurance company	**0%**					
Immediate annuity -- fixed rate in-plan	**0%**					
Longevity insurance	**15%**		NA	2.5%	5%	Stochastic market rates
Longevity bridge fund (LBF)	**47% on avg**		***LBF alloc. to risk assets = 50%***	***LBF alloc. to TIPS = 50%***		
Balance to "Structured Withdrawal Plan" (SWP)	**40% on avg**		***SWP alloc. to risk assets***	***SWP alloc. to TIPS***		***SWP methodology (see parameters for details):***
			80% *at 67*	0% *at 67*		***Base spend rate uses factors = 1 / PV for selected rate and nper***
			80% *at 70*	0% *at 70*		***This method is used for all years***
			80% *at 75*	0% *at 75*		
			80% *at 80*	0% *at 80*		
			80% *at 85+*	0% *at 85+*		

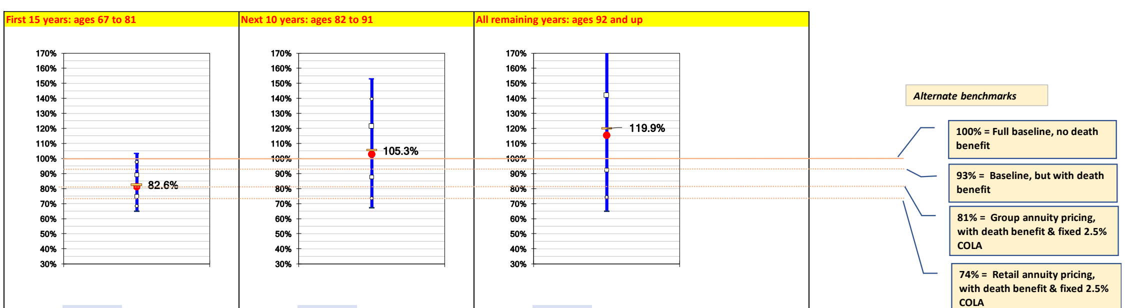
Age groupings used in analysis:



Range of income benefits as percent of baseline*:

*"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.85%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.*





%tile	First 15 years: ages 67 to 81	%tile	Next 10 years: ages 82 to 91	%tile	All remaining years: ages 92 and up
95%	103.3%	95%	152.8%	95%	190.2%
90%	97.8%	90%	139.5%	90%	172.0%
75%	89.4%	75%	121.5%	75%	141.9%
50%	81.4%	50%	102.9%	50%	115.5%
25%	74.9%	25%	87.7%	25%	92.3%
10%	68.5%	10%	73.7%	10%	74.4%
5%	65.0%	5%	67.7%	5%	65.4%
Mean	82.6%	Mean	105.3%	Mean	119.9%

Sensitivity to initial age 67 conditions:

Initial interest rate at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	**88.1%**	**123.4%**	**143.3%**
Medium (avg. 20th to 80th percentile)	**82.6%**	**103.4%**	**117.7%**
Low (avg. lowest quintile)	**77.1%**	**93.0%**	**103.1%**
Expected inflation at age 67:	**Mean**	**Mean**	**Mean**
High (avg. highest quintile)	**85.2%**	**115.7%**	**132.9%**
Medium (avg. 20th to 80th percentile)	**82.5%**	**103.6%**	**117.6%**
Low (avg. lowest quintile)	**80.4%**	**100.1%**	**113.7%**

Figure 34, continued
Complete Set of QE Framework Metrics

Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

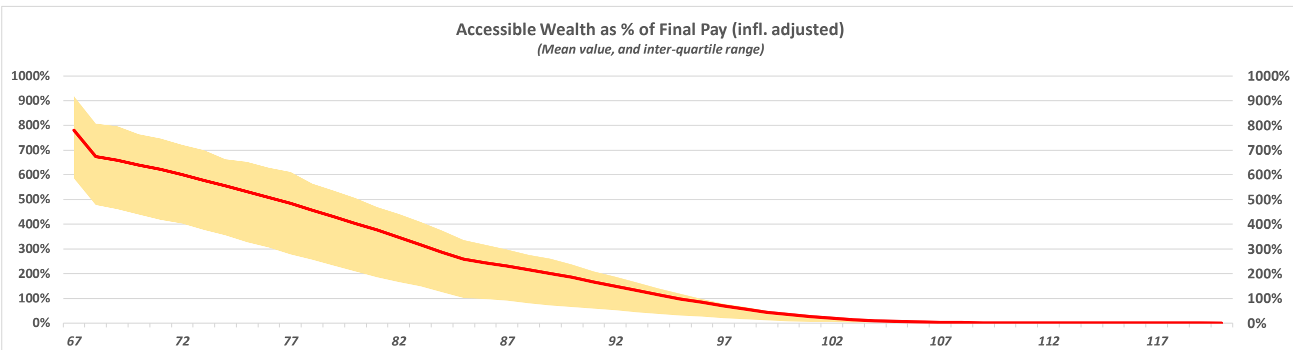
	Shortfall risk (using 3-yr. avg.)		Failure rate at:				
	First 15 yrs. (Ages 67 to 81)	Next 10 yrs. (Ages 82 to 91)	Age 90	Age 95	Age 100	Age 105	Age 110
			Survival probability				
60% of baseline	2.6%	4.9%	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	0.3%	1.5%					
40% of baseline	0.1%	0.7%	0.0%	0.1%	0.1%	0.2%	1.3%
30% of baseline	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	Next 10 yrs. (92 to 101)
Decline by 10+ percent	8.4%	6.5%	4.8%
Decline by 15+ percent	2.2%	2.6%	1.1%
Decline by 20+ percent	0.6%	1.6%	0.1%
Decline by 25+ percent	0.2%	1.1%	0.0%

Level of accessible wealth as percent of final pay (inflation adjusted)

(Note that the age 67 value is before the purchase of any annuities.)



Death benefits paid as percent of total payments

%tile	First 15 yrs. (67 to 81)	Next 10 yrs. (82 to 91)	All remaining yrs. (92 and up)
95%	26.4%	46.8%	69.6%
75%	23.0%	35.0%	49.1%
50%	20.9%	28.2%	38.0%
25%	18.3%	20.7%	26.6%
5%	14.9%	5.0%	0.0%
Mean	20.7%	27.5%	37.5%

Cost risk to sponsor for any fixed price annuities (cost spread as % of pay over career)

	Change in cost as % of pay	
%tile	For "Baseline"	For selected payout parameters
95%	1.7%	0.0%
75%	0.4%	0.0%
50%	-0.4%	0.0%
25%	-1.1%	0.0%
5%	-2.2%	0.0%
Mean	-0.3%	0.0%

Figure 34, continued
Complete Set of QE Framework Metrics

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Description of payout method being analyzed:

Allocation of distribution (by percent of initial balance)

Immediate annuity -- insurance company	**0%**
Immediate annuity -- fixed rate in-plan	**0%**
Longevity insurance	**15%**
Longevity bridge fund (LBF)	**47% on avg**
Balance to "Structured Withdrawal Plan" (SWP)	**40% on avg**

*Death benefit?**	*COLA*	*Load*	*Pricing interest rate*
NA	*2.5%*	*5%*	*Stochastic market rates*

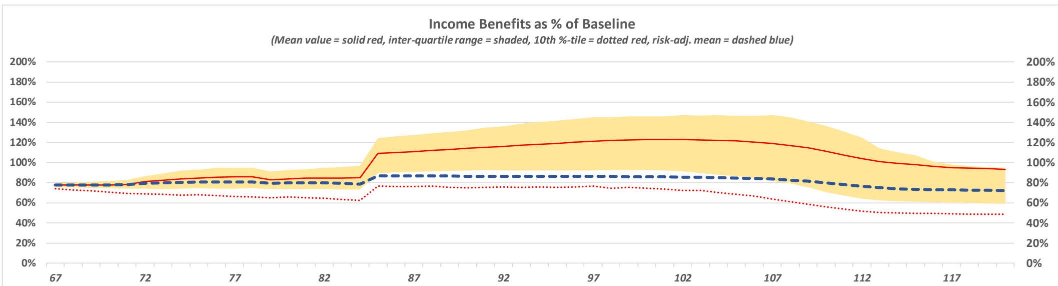
LBF alloc. to risk assets = 50% *LBF alloc. to TIPS = 50%*

SWP alloc. to risk assets		*SWP alloc. to TIPS*	
80%	*at 67*	0%	*at 67*
80%	*at 70*	0%	*at 70*
80%	*at 75*	0%	*at 75*
80%	*at 80*	0%	*at 80*
80%	*at 85+*	0%	*at 85+*

SWP methodology (see parameters for details):
Base spend rate uses factors = 1 / PV for selected rate and nper
This method is used for all years

Range of income benefits as percent of baseline*:

"Baseline" benefits are based on conversion of age 67 balance to lifetime income using a fixed-price lifetime annuity, interest rate = 5.85%, no load, full CPI COLA, no death benefits.
Age sub-group values are weighted averages, using deaths at each age as the weighting factor.



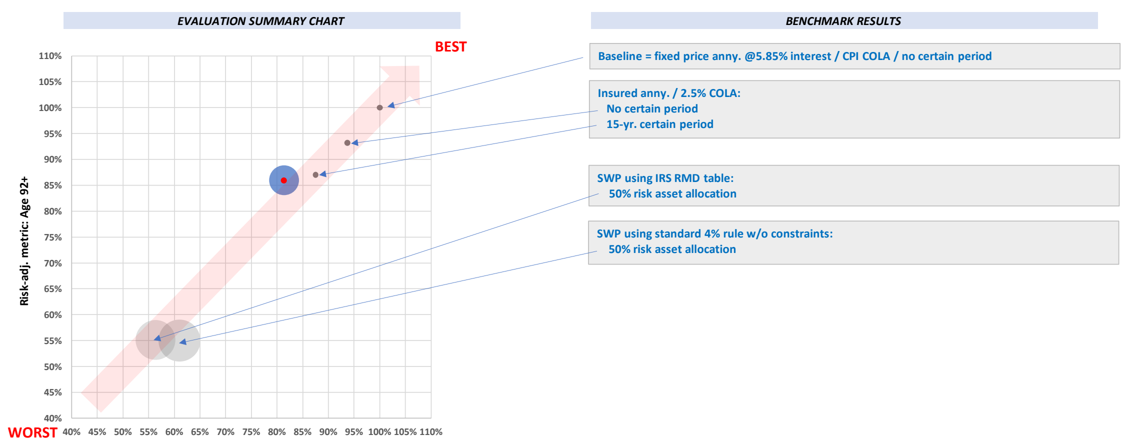
The dashed line in the chart shows values for the "risk-adjusted" metric, which is used for evaluation and comparision of various payout options.
The key summary values for this metric are shown below, and plotted in the following graph:

Mean value -- first 25 years	**81.3%**
Weighted mean value -- remaining years (age 92+)	**86.0%**

Evaluation chart

In the graph below, the position of the evaluation point is based on the risk-adjusted metric values shown above, and the size of the surrounding circle represents the average amount of accessible assets at age 85 (a proxy for both liquidity and the potential for a bequest at death). A single point indicates no liquidity at age 85. The primary evaluation factor is the location, indicating the risk-adjusted metric outcome -- with best results in the upper right corner. Liquidity (size of circle) is a secondary evaluation factor -- with larger circles preferred.

Accessible assets at age 85 (% of final pay, inflation adjusted) = 258%



Shortfall risk / "failure rate" = probability of ratio to baseline value falling below:

	------------- Shortfall risk (using 3-yr. avg.) ----------------		------------- Failure rate at: ----------------				
	First 15 yrs. (Ages 67 to 81)	**Next 10 yrs. (Ages 82 to 91)**	**Age 90**	**Age 95**	**Age 100**	**Age 105**	**Age 110**
			---------- *Survival probability* ----------				
60% of baseline	**2.6%**	**4.9%**	*47.0%*	*26.5%*	*10.4%*	*2.3%*	*0.3%*
50% of baseline	**0.3%**	**1.5%**					
40% of baseline	**0.1%**	**0.7%**	**0.0%**	**0.1%**	**0.1%**	**0.2%**	**1.3%**
30% of baseline	**0.0%**	**0.3%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Volatility risk = probability that ratio to baseline value (3-yr. average) drops by more than:

	First 15 yrs. (67 to 81)	**Next 10 yrs. (82 to 91)**	**Next 10 yrs. (92 to 101)**
Decline by 10+ percent	**8.4%**	**6.5%**	**4.8%**
Decline by 15+ percent	**2.2%**	**2.6%**	**1.1%**

Appendix J: A Collective Payout Arrangement

The following material is excerpted from a paper by Rowland Davis available on the SOA website.[9]

Collective Payout Program: Summary of Plan Provisions

Here I describe the key features of a proto-type design that I have tested using the QE framework for payout programs. Obviously, this is just one illustration of a fund that fits into the collective risk-sharing family. Alternative choices for the plan design parameters are plausible (subject to testing for sustainability).

- There is a single investment pool, invested 35% in risk assets (U.S. and non-U.S. equities) and 65% in a core-type fixed income fund. For the most part, I would assume index funds are used to minimize expense charges. (I assume an expense charge of 0.25% each year, including administrative and investment expenses.)
- At retirement the lump sum is transferred into the collective payout fund, where it is used to purchase a base annuity income. Pricing would be based on a conservative estimate of the long-term expected return on the portfolio. The pricing structure would remain fixed from year-to-year, but the board would have authority to change it if there are significant changes in future return expectations or for periodic updates of mortality assumption. Any change could be phased in over a period of years. For the plan discussed in this paper, I use a 5.5% interest rate for the annuity prices, which is approximately the 25th percentile net return expected over a 30-year period in the QE framework simulation model. If the 10-year Treasury yield is ever higher than 6%, then the annuities would be priced using the 10-year Treasury yield plus 50 basis points to approximate market pricing in the high-yield environment.
- The annuity will include a 15-year certain period, which provides something very close to a "return of principal" guarantee for retirees.
- The base annuity benefit would be increased by a fixed 2.5% COLA factor each year after retirement, subject to the adjustment features described below.
- The fund would most often be in a surplus position relative to the liability for the base benefit, using a 5.5% discount rate. (More details on funded ratios will be shown in a later section.) If the funded ratio exceeds 110%, then one-time bonus payments would become payable for the following year, based on a published schedule. The schedule I used is based on this formula, where FR is the funded ratio at the beginning of the year: Bonus % = FR – 100% + max(0, FR – 130%). As an example, if the funded ratio was 141%, then the bonus percent would be 52% (applied to the base benefit amount). The bonus percent is capped at 100%.
- These bonus payments are for a single year only—they do not become part of the future base benefit income. However, the board always has full discretion to make special ad hoc decisions. If the funded position of the plan is very strong, the board could decide to issue some of the bonus in the form of an increase in the base benefit, increasing the liabilities of the plan.
- If the funded ratio falls below a specified trigger level for two out of the preceding three years, then the 2.5% COLA is suspended for the following year. Once the funded ratio has exceeded a specified second trigger for two out of the preceding three years, the COLA is reinstated. For this paper, I set the first trigger at 85% initially, increasing to 90% after 20-years of fund operation, and then to 95% at year 30. The second trigger, to restore the COLA, is set at the first trigger plus 10 percentage points.
- The board would always reserve the right to reduce annuity benefits in emergency situations, to maintain sustainability. (In my testing, this type of adjustment was never required.)

[9] Davis, Rowland. 2018. A Middle Ground for Public Plans. In *Retirement 20/20 Papers*. Society of Actuaries. *https://www.soa.org/globalassets/assets/library/essays/2018/retirement-20-20/retirement-20-20-davis.pdf*.

- Finally, collective risk-sharing programs generally have something like an evolutionary process, as the fund rules operate over time to build toward the target level, or range, of surplus assets. To support this process, I have assumed that for the first five years of operation the fund would pay no bonuses, nor would there be any COLA suspensions.

Payout Phase Analytics: Funded Status

With the previously described plan and using the QE framework simulation model, I ran a multicohort forecast of results to ensure the sustainability of the fund. Table 15 shows the range of funded ratios at various times after the fund starts operation. The "liability" is measured as the present value of expected base benefits, including future COLA's (even though these are not guaranteed), using a 5.5% discount rate (the same rate used to price the annuity conversion factors).

Table 15
Range of Funded Ratios After Fund Start-up

	------------- Yrs. After Fund Start-up -------------					
	5	10	20	30	40	50
Percentile range:						
95%	111%	115%	127%	136%	142%	150%
75%	103%	105%	114%	124%	129%	133%
50%	98%	99%	106%	114%	120%	125%
25%	94%	93%	98%	106%	111%	116%
5%	87%	83%	87%	91%	99%	103%
Shortfall probabilities:						
<100%	61.8%	53.8%	31.1%	14.5%	6.4%	2.4%
<90%	10.8%	16.9%	8.4%	4.2%	0.8%	0.4%

While the evolution is slow, the fund ultimately stabilizes with a median funded ratio of about 125%, and only rare occurrence of less than a 100% funded ratio (and almost never below 90% funded.) Even during the process of building surplus levels, however, the fund operates very effectively, as I will show in the next section.

Payout Phase Analytics: Benefits

Table 16 shows some statistics for the bonus payments that would be payable across the lifetime for various retiree cohorts. These results also illustrate the evolutionary process of a collective fund like this.

Table 16
Bonus Payments Payable Across the Lifetime

	------------ Cohort # -------------			
	1	11	21	31
Average % of years with bonus	20%	44%	68%	80%
Average bonus when paid	16%	23%	27%	31%

Even the very first retiree cohort under the program could expect to receive significant bonus payments, on average, over their lifetime. The bonus impact grows substantially as the plan reaches a more mature level of expected funded status. Although the initial cohort cannot expect to benefit as much from bonus payments, the value they receive from the favorable annuity pricing is still very substantial (as will be illustrated later).

Table 17 summarizes some results for COLA suspensions over the first 25 years of retirement.

Table 17
COLA Suspensions Over First 25 Years of Retirement

	------------ Cohort #	-------------		
	1	*11*	*21*	*31*
No COLA suspensions	**72%**	**70%**	**78%**	**88%**
Between 1 and 5 suspensions	**25%**	**26%**	**19%**	**10%**
More than 5 suspensions	**3%**	**4%**	**3%**	**1%**

For all cohorts, there is at least a 70% expectation that they will not experience any COLA suspension during the first 25 years of retirement. Ultimately, that expectation is close to 90% for later cohorts. Experiencing more than five COLA suspensions is rare.

Payout Phase Analytics: Comparative

The QE framework has a relatively straight-forward approach for comparative analysis of different payout program designs. First, a set of **baseline** benefits are determined from the simulation model:

- Initial accumulated fund balances are set at age 67 for each scenario equal to the standard DC plan accumulation using a typical target date fund and a 37-year accumulation period.
- These lump sums are then converted to lifetime benefits using fixed-price annuities that include a CPI COLA, and which are priced with a 5.85% discount rate (the expected return from a fund with a 30% risky asset allocation, as in a conservative DB plan). There is no load in the pricing, and no death benefits are assumed.

The intention is that these baseline benefits represent something like the best-case scenario from the participant's point of view.

Next the benefit stream generated from any payout program design can be calculated for each scenario using the simulation model. The ratio of these benefits to the baseline benefit for each year of each scenario are calculated, and these ratios are used as the basis for analysis. Various metrics are available, but the primary ones for comparative analysis are developed as follows:

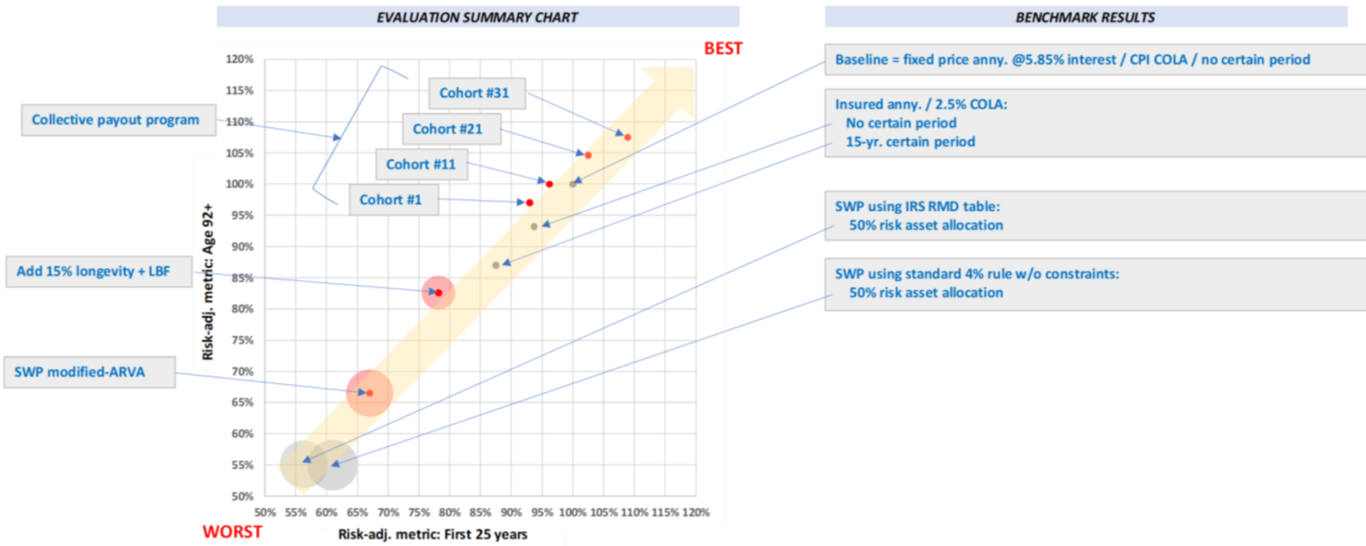
- Develop a risk-adjusted version for each ratio, reflecting the basic goal of maintaining a mostly level income stream, adjusted for inflation. Since the baseline benefits are fully CPI-indexed, the goal is for the benefit ratio measure to remain relatively uniform throughout the retiree's lifetime. If later years show significantly inflated values relative to the inflation-adjusted starting value, these results will receive a reduced weight. Conversely, if values in later years show significantly decreased values relative to the inflation-adjusted starting value, these receive a higher weight.
- Split the retiree lifetime into the first 25 years after retirement (approximately the life expectancy), and all years after that.
- For each of these periods, determine the average value of the risk-adjusted metric described above.

The results can then be plotted in a graph, as shown in Figure 35. This graph also contains the results for some important benchmark designs, including insured annuities as well as several structured withdrawal plans (SWP).

- The standard 4% rule (initial payment is 4% of lump-sum accumulation, with later payments increased by CPI).
- Withdrawals based on the IRS required minimum distribution life expectancy factors.
- Withdrawals based on an enhanced SWP using the annually recalculated virtual annuity (ARVA) methodology (with specific modifications). This is not a standard benchmark, but it is shown here to help illustrate the value of the collective program relative to a good SWP that includes no annuitization, or mortality risk pooling.
- The enhanced ARVA/SWP above, but with 15% of the accumulated balance used to purchase a longevity annuity starting at age 85, with a longevity bridge fund (LBF) to fund benefits up to age 85. This is also not a standard benchmark, but helps to show the value of mortality risk pooling.

Where a shaded circle appears around a plotted result, that indicates liquidity at age 85 (accessible wealth as a multiple of pay). Results for the collective payout program are plotted for various retiree cohorts.

Figure 35
Evaluation Summary Chart



The graph shows how well the collective program performs, relative to all of the other plotted results. This is true even for the first retiree cohort. The values improve noticeably as the program reaches a more mature state.

Appendix K: Demographic Assumptions

The following is a summary of all demographic assumptions used for developing the metrics used in the QE framework.

Accumulation period/retirement age. The benchmark employee used for the accumulation calculations is assumed to have 37 years of benefit/savings accumulation, starting at age 30 and with retirement at age 67.

Mortality. Pre-retirement mortality is included as part of the total turnover assumption described below. Post-retirement mortality is based on the RP-2014 mortality table, using unisex rates with a 50% male/50% female blend. For the accumulation phase, the rates are projected forward (by the number years equal to [Age – 67] + 37) using an estimate of the MP-2014 projection rates based on a 5% interest assumption. For the payout phase, we use the same unisex RP-2014 mortality table, with full projection using the MP-2014 projection rates.

Pre-retirement turnover. For the accumulation metrics, two separate calculations are done: one calculation assumes a full 37-year career with no turnover, and the second calculation is for what we call a "fragmented career" where breaks in employment are assumed. These two calculations are then blended together to obtain the final value for any metric. There are three levels of turnover that can be used: high, moderate and low. Baseline metric results are based on the moderate turnover assumption, while the high and low assumptions can be used for sensitivity testing. The turnover rates from the SOA 2003 Pension Plan Turnover Study[10] served as the underlying rates used to develop all three variations.

- **Moderate** (baseline) turnover is designed to reflect a participant population with an aggregate annual turnover of 10% per year. From this assumption, we developed a standard fragmented career that would have job changes at ages 39 and 47, so three separate career segments of nine years, eight years and 20 years. The final metrics are based on a blend of 40% full career and 60% fragmented career results.
- **Low** turnover is designed to reflect a participant population with an aggregate annual turnover of 5% per year. From this assumption, we developed a standard fragmented career that would have job changes at ages 36 and 46, so three separate career segments of six years, 10 years and 21 years. The final metrics are based on a blend of 65% full career and 35% fragmented career results.
- **High** turnover is designed to reflect a participant population with an aggregate annual turnover of 15% per year. From this assumption, we developed a standard fragmented career that would have job changes at ages 35, 41 and 48, so four separate career segments of five years, six years, seven years and 19 years. The final metrics are based on a blend of 25% full career and 75% fragmented career results.

It is important to note that the turnover assumption only has an impact on plan structures that do not accrue benefits uniformly. So for a benchmark DC plan there is no assumed impact, as we assume full vesting and indexing for each career segment. Most of the impact of the turnover assumption will be seen in DB plan designs, where some degree of backloading is possible.

[10] Frees, Edward. 2003 Pension Plan Turnover Study. Society of Actuaries. https://www.soa.org/resources/experience-studies/2000-2004/research-2003-soa-pension-plan-turnover-study/

Career pay progression. Pay increases each year are set at the rate of wage inflation (a stochastic variable; see Appendix L for details) plus an assumed age-based merit/promotional increase. The merit/promotional rates are based on typical pay progressions for median income workers, and are shown below:

2% per year from age 30 to age 39

0.6% per year from age 40 to age 49

0.4% per year from age 50 to age 59

0% after age 59

The cumulative merit/promotional effect is a 35% increase in pay from age 30 to the retirement age of 67, e.g., taking the age 35 pay level from $39,000 to a final pay level of $52,650 (in current dollars relative to the age 30 starting point).

Factors to convert lump sums to lifetime income. For the accumulation phase, a pricing formula is used that estimates market-priced insured annuity prices for each scenario in the simulation model consistent with the stochastic economic results (priced at interest rates linked to the prevailing Treasury yields at retirement), and with a 5% load for expenses, contingencies and profits. The annuity is a lifetime annuity with a 2% fixed COLA. For the payout phase, a similar approach is used but with more control on the specifics of the annuity (i.e., options for different COLA features and for death benefits).

Social Security. The replacement rates used in the QE framework include a Social Security benefit equal to 39% of final pay. This value is an estimate of the age 67 benefit level for a median income earner retiring 30+ years in the future.

Appendix L: Overview of Simulation Methodology

The various quantitative risk and reward metrics used in the QE framework are derived from calculations using a pre-determined set of economic scenarios, created by a stochastic simulation model. This appendix describes the model and assumptions used.

Model Structure

The scenarios that represent our economic simulation results are created by a model using a cascade structure with the following primary components:

- Price inflation is the initial variable that is modeled.
- Two separate variables are then built from the price inflation results: wage inflation, and bond yields (which is actually a collection of yield variables, for various types and maturities of bonds).
- After bond yields are available, the returns on various types of bonds, and bond portfolios, are developed.
- After bond returns are available, the returns on risky asset portfolios are developed, with specifications for the mean return, volatility and correlation factor with bonds.

The following sections describe these steps in more detail. The model produces 1,000 scenarios, each stretching over a 100-year period. A Latin hypercube sampling technique is used so that the distributions are smooth (i.e., the various random number distributions used to drive the model have a smoothness roughly equal to that of a 10,000 sample using a standard random number generating process).

Price inflation. The model develops price inflation results (using CPI) for each scenario by setting inflation in any year equal to the prior year's inflation, plus the sum of three factors:[11]

- A mean reversion factor, which tends to pull inflation levels back toward a long-term expected equilibrium level, but which also includes an upward-trend persistence factor that temporarily mitigates some of the mean reversion in the face of a period of rising inflation
- An inflation shock factor that can trigger a one-time spike in inflation of between 2% and 8% with a specified probability (no more than once in any five-year period)
- A standard noise factor with a normal distribution, but with the mean value set proportional to the level of inflation over recent years (i.e., higher inflation creates more volatility)

Wage inflation. Wage inflation for any year is set equal to a weighted geometric average of recent price inflation, plus a defined spread for real wage growth.

Bond yields. The yield on the 10-year Treasury bond is developed as follows:

$$\text{Nominal Yield} = (1 + \text{real yield})*(1 + \text{inflation risk premium})*(1 + \text{expected inflation}) - 1,$$

where the real yield is a random variable with mean reversion, the inflation risk premium is influenced by recent levels and patterns of inflation, and expected inflation reflects both an expected equilibrium inflation level, as well as recent levels and patterns of inflation.

Treasury yields for other maturities (one, five, 20 and 30 year) are developed using a Nelson-Siegel methodology.[12]

Bond returns. With Treasury yield results, the returns on Treasury bonds are determined, and the return on an "all Treasury" portfolio is determined as a weighted average of the different maturity bonds. Finally, the return on a "core

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[11] The model incorporates ideas developed by Robert Clarkson in Clarkson, Robert S. 1991. A Non-Linear Stochastic Model for Inflation. 2nd AFIR Colloquium, 3:233–53. *http://www.actuaires.org/AFIR/colloquia/Brighton/Clarkson.pdf*.

[12] Nelson, Charles R., and Andrew F. Siegel. 1987. Parsimonious Modeling of Yield Curves. *Journal of Business* 60, no. 4. *http://www.jstor.org/stable/2352957*.

fixed income" portfolio (e.g., Barclay's Aggregate) is developed by adding a stochastic premium (primarily for credit risk, but also including duration effects) in order to achieve the targeted mean return and standard deviation. These are the fixed income returns used in the simulation results.

Risky asset returns. Finally, the returns for the risky asset portfolio (e.g., global equities) are developed. The baseline model incorporates both long-term mean reversion and fat-tailed distributions.[13] An alternative model using a simple lognormal approach is also available, through a parameter switch. The results under both models are calibrated to produce the same long-term mean outcomes (40-year results for geometric average returns, standard deviation and correlation with fixed income returns).

Economic Assumptions

The model described above is calibrated to produce distributions of results that meet target values for the baseline assumption set (mean or median values, volatility and correlations). The assumption targets used are intended to be representative of a reasonable long-term economic equilibrium status. This means that the year one values may not be representative of actual market conditions at any single point in time. Although this approach would be completely unacceptable for any model designed for use in pricing, valuation or financing strategy decisions, the QE framework does not try to accomplish any of these things. Instead, the purpose of the QE framework is to provide a stable basis for making comparative evaluations of various retirement plan designs, or systems. Any attempt to incorporate a constantly shifting set of current initial conditions would remove the desired stability of this framework for use across a period of years. Evaluations would quickly become out of date, leading to one of two very undesirable situations: (1) prior evaluation and analysis work would need to be constantly updated, or (2) the ability to compare evaluations done at different points of time would be lost.

However, the model does allow for sensitivity testing of results under varying assumptions. Any of the distributions for key economic variables may be "shifted" up or down away from the baseline set, through the use of parameters. This results in adjusted mean values for the selected variables.

In selecting our target values for the baseline set, we looked for some evidence of current expert practitioner expectations (in 2016 and updated in 2018). Most banks and investment-related businesses use assumption sets that are continually adjusted to reflect current market conditions, and often only extend over a five- or 10-year horizon. Deriving long-term equilibrium expectations is impossible for most of these. However, two major actuarial/investment consulting organizations (Mercer and AonHewitt) publish assumption sets that include both 10-year and 30-year expectations, which allows a direct determination of long-term equilibrium expectations (i.e., using years 11 through 30). In addition, for the 2018 update we utilized a survey from Horizon Actuarial that includes both 10-year and 20-year return expectations from 12 investment firms. These values, and a few others, served as guidelines for our choices as shown in Table 18.

[13] Davis, Simulation of Long-Term Stock Returns.

Table 18
Key Assumptions for Equilibrium Economy

	US price infl	Real return on US bonds*	Equity risk premium** US	Equity risk premium** Non-US developed	Equity risk premium** Emerging market	Equity risk premium** Global
Current QE baseline	2.50%	2.00%				3.50%
Outside reference points						
Mar-16						
Mercer	2.20%	2.60%	2.40%	2.70%	3.80%	3.00%
Aon Hewitt	2.10%	1.20%	3.00%	3.75%	3.85%	4.00%
SSA interm	2.60%					
Survey of Professional Forecasters	2.20%					
Mar-18						
Mercer	2.20%	2.20%	2.60%	2.70%	3.80%	2.80%
Aon Hewitt	2.30%	1.10%	2.90%	4.65%	4.15%	3.75%
Horizon survey	2.56%	2.77%	3.66%	3.02%	4.09%	3.42%
SSA interm	2.60%					
Survey of Professional Forecasters	2.25%					

** Core US bond portfolio*
*** Premium vs US bonds*

Tables 19 and 20 show percentile and mean values for baseline distributions of key economic variables. Table 19 shows long-term compound (geometric average) results over 40 years. Table 20 shows typical single-year results.

Table 19
Long-Term Results

	Price inflation	Wage inflation	Bond returns	--- Risky asset returns --- Baseline	Lognormal
Percentile values:					
95th	3.44%	3.83%	5.46%	13.24%	15.47%
75th	2.73%	3.23%	4.76%	9.45%	9.87%
50th	2.50%	3.00%	4.49%	7.94%	7.90%
25th	2.27%	2.79%	4.27%	6.58%	5.87%
5th	1.88%	2.41%	3.77%	3.08%	1.53%
Mean value	2.52%	3.03%	4.51%	8.00%	8.00%

Table 20
Single-Year Results

	Price inflation	Wage inflation	10-yr. Treas. yld.	Bond returns	--- Risky asset returns --- Baseline	Lognormal
Percentile values:						
95th	8.98%	7.63%	7.21%	17.23%	66.48%	62.04%
75th	3.13%	3.56%	4.91%	7.93%	20.19%	21.67%
50th	2.25%	2.75%	4.23%	4.49%	8.70%	7.92%
25th	1.51%	2.10%	3.66%	1.17%	-2.10%	-4.15%
5th	-0.30%	1.11%	2.40%	-6.81%	-35.41%	-28.16%
Mean value	2.55%	3.05%	4.34%	4.62%	9.68%	9.67%

The single-year standard deviation assumptions are shown in Table 21.

Table 21
Single-Year Standard Deviation Assumptions

	Price inflation	Wage inflation	10-yr. Treas. yld.	Bond returns	Risky asset returns
Standard deviation	1.6%	1.3%	0.9%	5.0%	19.4%

The correlation between single-year fixed income and risky asset returns is assumed to be 4.5%.

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The SOA has a history of working with public policy makers and regulators in developing historical experience studies and projection techniques as well as individual reports on health care, retirement and other topics. The SOA's research is intended to aid the work of policymakers and regulators and follow certain core principles:

Objectivity: The SOA's research informs and provides analysis that can be relied upon by other individuals or organizations involved in public policy discussions. The SOA does not take advocacy positions or lobby specific policy proposals.

Quality: The SOA aspires to the highest ethical and quality standards in all of its research and analysis. Our research process is overseen by experienced actuaries and non-actuaries from a range of industry sectors and organizations. A rigorous peer-review process ensures the quality and integrity of our work.

Relevance: The SOA provides timely research on public policy issues. Our research advances actuarial knowledge while providing critical insights on key policy issues, and thereby provides value to stakeholders and decision makers.

Quantification: The SOA leverages the diverse skill sets of actuaries to provide research and findings that are driven by the best available data and methods. Actuaries use detailed modeling to analyze financial risk and provide distinct insight and quantification. Further, actuarial standards require transparency and the disclosure of the assumptions and analytic approach underlying the work.

Society of Actuaries
475 N. Martingale Road, Suite 600
Schaumburg, Illinois 60173
www.SOA.org