

Revisiting pension asset allocation

- Developing a pension investment strategy requires an understanding of the unique risks posed by a pension liability.
- Armed with that understanding, a plan sponsor can articulate its desired strategy by identifying three key targets: return-seeking asset allocation, interest rate hedge ratio, and credit spread hedge ratio. These targets can be used as the foundation for a robust, customized portfolio construction process.
- By specifying in advance targets for each future phase of a dynamic glide path linked to the plan's funding status, sponsors can mitigate the potential for undesired emotional or tactical biases.

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Introduction

The asset allocation framework for U.S. private-sector pension plans continues to evolve. This paper summarizes Vanguard's current views on best practices for such plans. We understand, of course, that every pension plan is unique, and that each plan's asset allocation process essentially begins with a blank sheet of paper rather than with a pre-defined asset allocation. Nevertheless, our experience of managing portfolios for hundreds of pension sponsors over the past 25 years leads us to believe that some

general best practices do exist. Most of them fall somewhere within the range of what is typically considered *liability-driven investing*.

This paper assumes a basic knowledge of pension investment principles. To help readers with basic context and background, some pension-specific terms, italicized on first mention, are defined in the glossary presented in **Appendix A**. Where appropriate, we have also provided references to other Vanguard research.

Notes on risk

All investing is subject to risk, including possible loss of principal.

Past performance does not guarantee future results.

Bond funds are subject to interest rate risk, which is the chance bond prices overall will decline because of rising interest rates, and credit risk, which is the chance a bond issuer will fail to pay interest and principal in a timely manner or that negative perceptions of the issuer's ability to make such payments will cause the price of that bond to decline.

U.S. government backing of Treasury or agency securities applies only to the underlying securities and does not prevent share-price fluctuations. Unlike stocks and bonds, U.S. Treasury bills are guaranteed as to the timely payment of principal and interest.

There is no guarantee that any particular asset allocation or mix of funds will meet your investment objectives or provide you with a given level of income.

Diversification does not ensure a profit or protect against a loss.

Futures trading is speculative in nature and involves substantial risk of loss. Futures are not suitable for all investors.

Understanding key pension risks

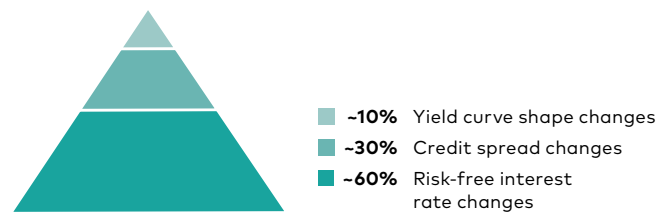
In designing and implementing a prudent investment strategy, sponsors must understand the major risk drivers associated with their plan's financial health. Plan sponsors typically view that health through the lens of *funding status* (or *funding ratio*), so it's important to understand the two main drivers of funding status risk that can be addressed through investment strategy:

- 1. Market risk.** This is the possibility that market returns on the plan's *return-seeking assets* will fall short of expectations during any given period. Market risk frequently materializes as a significant event (e.g., a market correction or crash, where we see a sudden and unexpected drop in market values over a relatively short period). Regular day-to-day fluctuations in market values, however, can also negatively affect a plan's financial health.
- 2. Interest rate risk.** This is the potential that unexpected changes in the interest rate environment will cause an adverse change in the plan's funding status. Typically, interest rate risk materializes when interest rates decline, causing the plan's *liability* value to increase.

Interest rate risk is sometimes assumed to include *credit spread risk*—the potential that changing credit spreads on fixed income securities will cause an adverse funding status change.¹ Other times, credit spread risk is considered a separate sub-category of interest rate risk. Later in this paper, we will treat the two risks separately.

Credit spread movements are the second-largest driver of pension interest rate risk, behind changes in the level of risk-free interest rates such as Treasury rates (**Figure 1**).²

FIGURE 1.
Key drivers of pension interest rate risk



Source: Vanguard, 2021.

¹ See Dutton and Plink (2018) for additional detail on credit spread risk and how it can be managed using investment-grade fixed income.

² An additional component of interest rate risk, not addressed directly in this paper, is yield curve risk (that is, the potential that changing yield curve shape will cause an adverse funding status change). While yield curve risk garners significant focus in industry marketing, our research indicates that it is far less of a concern for pension sponsors than either interest rate risk or credit spread risk. See Gannon and Dutton (2019) for additional discussion on yield curve risk.

Quantifying key pension risks

Ideally, a plan sponsor will gain an understanding of the potential magnitude of market risk and interest rate risk for its plan's funding status by working with an investment management firm, actuarial consulting firm, or other professional service provider to create a risk assessment. The sample risk assessments shown in **Figure 2** use a measure called Funding Status *Value at Risk* (*VaR*) to quantify the downside risk for two hypothetical pension plans: the GHI Pension Plan, a frozen plan sponsored by GHI Corporation, and the JKL Pension Plan, a closed plan sponsored by JKL Corporation.³ The plans differ in their funding ratio, liability duration and allocation to return-seeking assets—and, therefore, in their Funding Status Value at Risk (*VaR*).

While specifics will vary depending on plan characteristics and investment strategy, plan sponsors should generally consider market risk and interest rate risk to be similar in magnitude, as in our two hypothetical examples (\$14 million versus

\$11 million for GHI; \$9 million versus \$7 million for JKL). Market risk and interest rate risk are by far the two most significant investment-related risks that must be considered in the pension asset allocation process. The imperfect correlation of these risks leads to a meaningful diversification impact—\$9 million for GHI, \$5 million for JKL—that reduces overall funding status risk. In other words, because strongly negative outcomes for both risks are not likely to occur in the same one-year period, the total risk is significantly less than the sum of the two individual risks. In a severe equity market downturn, for example, one might expect credit spreads to widen—and this widening may preclude a worst-case outcome with respect to interest rate risk.

Pension sponsors are subject to other material risks beyond market risk and interest rate risk (e.g., demographic risk, enterprise/legal risk, and operational risk; see Clinger and Gannon, 2020). However, these risks cannot be addressed or mitigated through a prudent investment strategy, and therefore are beyond the scope of this paper.

FIGURE 2.
Quantifying Funding Status Value at Risk (*VaR*)—sample risk assessments

	GHI Pension Plan	JKL Pension Plan
Plan status	Frozen (no new participants; no future benefit accruals)	Closed (no new participants; ongoing benefit accruals increase plan liability by 2% per year)
Funding ratio (asset value/Projected Benefit Obligation)	80% (\$80M/\$100M)	105% (\$105M/\$100M)
Liability duration (years)	12	15
Target return-seeking allocation	60%	30%
Funding Status Value at Risk (<i>VaR</i>) (\$ millions)	16	11
Due to market risk	14	9
Due to interest rate risk and credit spread risk	11	7
Impact of risk diversification	-9	-5

Notes: Projected Benefit Obligation (PBO) is commonly used in the pension investment process as a market-based measure of plan liability. Other U.S. Generally Accepted Accounting Principles (GAAP) liability measures, including Accumulated Benefit Obligation (ABO) and Present Value of Benefits (PVB), may also be useful for this purpose, depending on the plan sponsor's objectives. The *VaR* in the Funding Status Value at Risk (*VaR*) entry measures a 5th-percentile outcome (where 5% of outcomes are worse but 95% are better) over a one-year time horizon. Measurement date for *VaR* calculations is May 31, 2021. Numbers in the table may not sum perfectly because of rounding. See Appendix B for important details on our forecasting and risk models.

Sources: Vanguard and MSCI BarraOne.

³ See Appendix B for important details on our Value at Risk (*VaR*) estimates.

Addressing key risks through strategic asset allocation

Once a plan sponsor recognizes the nature and potential magnitude of the risks described in the previous section, it should establish a strategic asset allocation. For a private-sector pension investment portfolio, Vanguard believes that an asset allocation is best specified through the articulation of three sequential target values:

- Return-seeking asset allocation target, as a percentage of the total investment portfolio
- Interest rate hedge ratio target, as a percentage of the liability's interest rate risk
- Credit spread hedge ratio target, as a percentage of the liability's credit spread risk

The first of these targets should be a familiar concept to most investors, as it generally boils down to the balance between equity and fixed income assets. The second and third are unique to pension investing and reflect the interest rate and credit spread risk inherent in most pension liabilities. Each target is described in detail below, with illustrations that use the GHI Pension Plan from Figure 2.

It's important to note that selecting these three targets is a unique process for every pension sponsor, one that depends on plan circumstances, objectives, and risk tolerance. While we set forth some general best practice guidelines based on years of managing portfolios for pension sponsors, we also advocate using custom asset-liability models to identify suitable strategic asset allocation targets tailored to individual plan needs.

Return-seeking asset allocation target

The return-seeking asset allocation target—i.e., the proportion of the portfolio to be allocated to return-seeking assets—represents one of the most impactful decisions related to a plan's long-term risk/return profile that a sponsor can make. While exposing a plan to market risk may help improve long-term returns and funding status outcomes over the long term, it also carries the obvious possibility of unexpected, outsized losses during market downturns.

A custom asset-liability study can help a plan sponsor identify a return-seeking asset allocation target that optimizes the balance between return potential and downside risk. Depending on a plan's circumstances, an appropriate allocation to return-seeking assets could range from 0% (for a frozen plan where the only objective is to stabilize the funding level in advance of a plan termination) to 70% or higher (for an open pension plan with a long time horizon and sufficient risk tolerance). Within this range, a sponsor's ideal return-seeking asset allocation target depends broadly on the following factors:

- **Funding status.** An underfunded plan may derive greater benefit from higher returns than a fully funded plan, and therefore may have a higher return-seeking allocation target.
- **Plan status.** An open plan (ongoing accruals, including those for new entrants) has a need to fund ongoing accruals, and therefore may have a higher return-seeking allocation target than a closed or frozen plan.
- **Plan demographics.** A plan with a younger demographic profile has a longer time horizon than a plan with an older profile, and therefore may have a higher return-seeking allocation target.
- **Business cyclicality.** A noncyclical business is typically able to take on more asset-liability risk than a cyclical business, and therefore may have a higher return-seeking allocation target.

For our hypothetical GHI Pension Plan, the risk/return trade-off for reducing exposure to return-seeking assets is shown in **Figure 3**.

Reducing the allocation to return-seeking assets naturally reduces expected market risk—and it also decreases interest rate risk, as the

reallocated funds are invested in *liability-hedging assets*. The sponsor of the GHI Pension Plan and its advisors can use information like this to jointly determine whether the reduced expected long-term return is worth the additional risk protection.

FIGURE 3.
Impact of reducing return-seeking asset exposure—GHI Pension Plan

	Scenario 1: With current return-seeking allocation target	Scenario 2: With reduced return-seeking allocation target
Funding ratio (asset value/Projected Benefit Obligation)	80%	80%
Hurdle rate	3%	3%
Target return-seeking allocation	60%	40%
Expected portfolio return (10-year, annualized)	4.40%	3.80%
Funding Status Value at Risk (VaR), total (\$ millions)	16	11
Due to market risk	14	10
Due to interest rate risk and credit spread risk	11	7
Impact of risk diversification	-9	-7

Notes: Projected Benefit Obligation (PBO) is commonly used in the pension investment process as a market-based measure of plan liability. Other U.S. Generally Accepted Accounting Principles (GAAP) liability measures, including Accumulated Benefit Obligation (ABO) and Present Value of Benefits (PVB), may also be useful for this purpose, depending on the plan sponsor's objectives. The hurdle rate is a simple estimate of the expected growth of the pension liability that accounts for both service cost and interest cost, assuming a stable interest rate environment and ignoring the impact of benefit payments. The rate is therefore also a basic estimate of the long-term investment return needed for a plan to maintain a stable funding ratio. In this case, the service cost is 0% (because the plan is frozen), while the interest cost is 3%; thus, the hurdle rate is 3%. The VaR in the Funding Status Value at Risk (VaR) entry measures a 5th-percentile outcome (where 5% of outcomes are worse but 95% are better) over a one-year time horizon. Measurement date for VaR calculations is May 31, 2021. Numbers in the table may not sum perfectly because of rounding. Expected portfolio return figures are calculated using the Vanguard Capital Markets Model (VCMM); simulations are as of March 31, 2021. See Appendix B for important details on our forecasting and risk models.

IMPORTANT: The projections and other information generated by the Vanguard Capital Markets Model® (VCMM) regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. Distribution of return outcomes from VCMM derived from 10,000 simulations for each modeled asset class. Simulations are as of March 31, 2021. Results from the model may vary with each use and over time. For more information on VCMM, see Appendix B.

Sources: Vanguard and MSCI BarraOne.

Interest rate hedge ratio target

Pension liability values are calculated as present values using market rates on high-quality corporate bonds, and therefore are inherently sensitive to changes in interest rates (with sensitivity typically measured using the concepts of *duration*, *dollar duration*, or *DV01*). Understanding, measuring, and mitigating interest rate risk is a critical component in constructing a pension investment strategy. The desired level of interest rate hedging, articulated through an interest rate hedge ratio target, will guide portfolio construction for the plan's liability-hedging assets.

A plan's interest rate hedge ratio is defined as the portion of liability risk due to fluctuating interest rates that is expected to be offset by the investment portfolio's liability-hedging assets. Thus, for example, if a plan with a 90% interest rate hedge ratio experiences a liability increase of \$10 million because of falling interest rates, its sponsor would expect the plan's liability-hedging portfolio to increase by \$9 million.⁴

In Vanguard's view, a plan's interest rate hedge ratio target should be at least as high as its funding ratio—or 100%, if the funding ratio exceeds 100% (Dion and Dutton, 2020). Any plan meeting this threshold can be said to be “fully hedged” against interest rate risk (because it is at least preserving the ratio of assets to liabilities when interest rates change). Pension plan sponsors not meeting this threshold are implicitly making a bet on the future direction, magnitude, and speed of change in U.S. Treasury rates relative to future movements already priced in the market.

Using this guideline, an ideal interest rate hedge ratio target for the GHI Pension Plan will be 80% or higher, since the plan is 80% funded. However, the plan likely cannot meet an 80% interest rate hedge ratio without derivatives, because 60% of the investment portfolio is allocated to return-seeking assets for reasons described in the prior section.

⁴ The actual increase may deviate from \$9 million, particularly if the shape of the yield curve dramatically changes. However, as noted earlier in this paper, the risk from changing yield curve shape is significantly lower than the risk from changes to overall interest rate levels.

Figure 4 illustrates this concept, again using GHI Pension Plan as our hypothetical example. Scenario 1 shows the level of hedging that may be feasible without derivatives, while Scenario 2 shows the impact of adding a custom U.S. Treasury futures overlay to achieve an 80% interest rate hedge ratio.

For many plans, achieving the hedging threshold articulated in this section will only be possible through the use of derivatives such as Treasury futures. Some plan sponsors may not have access to derivative-based strategies, and others may not

be comfortable with the increase in operational complexity. The sponsors of the GHI Pension Plan would need to recognize that while an 80% interest rate hedge ratio may be ideal, it also would require derivative investments to achieve. If derivative investments are not a possibility, then the achievable interest rate hedge ratio is constrained, and that constraint should be taken into account when establishing the plan's interest rate hedge ratio target.

FIGURE 4.

Impact of using a futures overlay to reduce interest-rate risk exposure—GHI Pension Plan

	Scenario 1: Without futures overlay	Scenario 2: With futures overlay
Funding ratio (asset value/Projected Benefit Obligation)	80%	80%
Target return-seeking allocation	60%	60%
Target interest rate hedge ratio	50%	80%
Funding Status Value at Risk (VaR), total (\$ millions)	16	14
Due to market risk	14	14
Due to interest rate risk and credit spread risk	11	7
Impact of risk diversification	-9	-7

Notes: Projected Benefit Obligation (PBO) is commonly used in the pension investment process as a market-based measure of plan liability. Other U.S. Generally Accepted Accounting Principles (GAAP) liability measures, including Accumulated Benefit Obligation (ABO) and Present Value of Benefits (PVB), may also be useful for this purpose, depending on the plan sponsor's objectives. The VaR in the Funding Status Value at Risk (VaR) entry measures a 5th-percentile outcome (where 5% of outcomes are worse but 95% are better) over a one-year time horizon. Measurement date for VaR calculations is May 31, 2021. Numbers in the table may not sum perfectly because of rounding. See Appendix B for important details on our forecasting and risk models.

Source: Vanguard and MSCI BarraOne.

Credit spread hedge ratio target

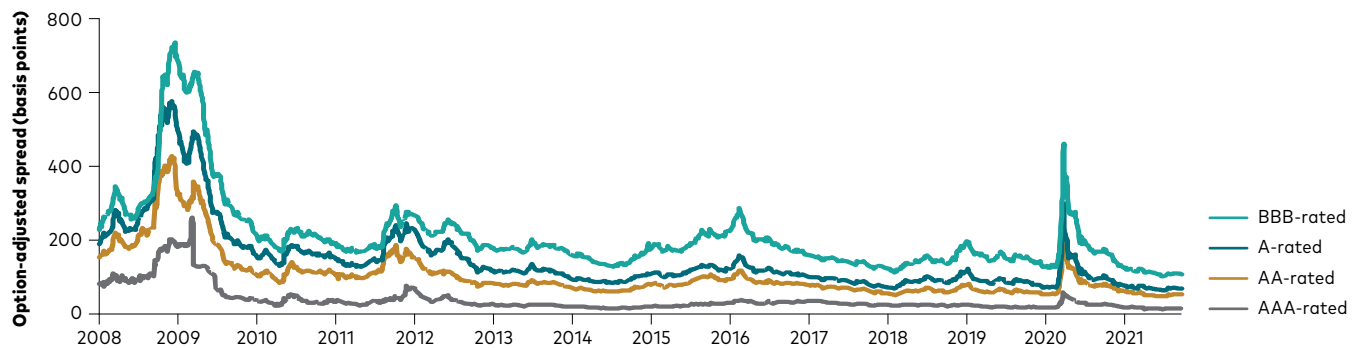
The definition of credit spread hedge ratio is generally similar to that of interest rate hedge ratio. It is defined as the portion of liability risk borne from changing credit spreads that is expected to be offset by the liability-hedging portion of the investment portfolio. As previously mentioned, pension liability values are calculated using market rates on high-quality corporate bonds. Pension liabilities are thus inherently sensitive not only to changes in risk-free interest rates, but also to changes in yield spread between high-quality investment-grade corporate (credit) bonds and U.S. Treasury bonds. We refer to this risk as credit spread risk and use the concept of credit spread hedge ratio to assess the extent to which an investment portfolio is expected to mitigate such risk.

For example, if a plan with a 50% credit spread hedge ratio experiences a liability increase of \$10 million because of tightening credit spreads, its

sponsor would expect the plan's liability-hedging portfolio to increase by \$5 million, assuming the underlying assumptions hold.

Investment-grade credit bonds with different credit ratings—AAA, AA, A, BBB—will respond differently to various market changes over time. A change in AA spreads (which directly impact pension liabilities) may lead to a larger spread movement in lower-quality credit and a smaller spread movement in higher-quality credit. These relationships can vary over time, as illustrated in **Figure 5**, and this variability also limits the precision of forward-looking credit spread hedge ratio estimates. (The "underlying assumptions" used in the credit spread hedge ratio represent a nuance that is absent in the interest rate hedge ratio, which is calculated in a more straightforward, "scientific" way and does not require assumptions about how credit ratings relate to each other.)

FIGURE 5.
Corporate bond spreads



Note: Chart shows option-adjusted spread over Treasuries for the period from January 1, 2008, through July 31, 2021.

Source: Bloomberg.

Given all of this, credit spread hedge ratios should be interpreted as a best estimate of long-term relationships rather than a precise prediction of the future relationship between a plan's assets and liabilities. Material deviations between expected and actual credit spread hedge ratios will sometimes occur, particularly in volatile market conditions.

A plan's "ideal" credit spread hedge ratio target depends on both the plan's interest rate hedge ratio target and its target allocation to return-seeking assets. An appropriate starting point for selecting a credit spread hedge ratio target is indicated by the formula:

$$\begin{aligned} & \text{Credit spread hedge ratio target} \\ & = \\ & (\text{Interest rate hedge ratio target}) * \\ & (\text{Allocation to liability-hedging assets})^5 \end{aligned}$$

This formula expresses and reflects two ideas:

- All else equal, it makes intuitive sense to set a plan's credit spread hedge ratio target equal to its interest rate hedge ratio target. Since a pension liability is sensitive to both interest rates (e.g., U.S. Treasury rates) and AA credit spreads, a plan sponsor who wants, for example, to hedge 75% of liability risk might naturally aim for a 75% interest rate hedge ratio target and a 75% credit spread hedge ratio target.
- This approach, while intuitively appealing, is too simple. Given the persistent positive correlation of equity performance to investment-grade credit spreads over the long term, an adjustment is needed to avoid unintentionally "overhedging" the credit risk of a plan's liability.

The last item of the formula provides this proportional reduction in the credit spread hedge ratio target based on the amount allocated to return-seeking assets. Although the correlation between equity markets and credit spreads varies over time, our formula implies an approximately 1-to-1 relationship on average, which is supported by analysis conducted by Vanguard.

Using this formula, an ideal credit spread hedge ratio target for the GHI Pension Plan could be 32% (80% interest rate hedge ratio target, multiplied by 40% liability-hedging allocation).

Putting it all together

Vanguard believes plan sponsors should not only specify a target allocation between return-seeking and liability-hedging assets, but should also set an interest rate hedge ratio target and credit spread hedge ratio target to guide portfolio construction. Ideally, these three targets should be explicitly included in a pension sponsor's investment policy statement.

Once these three targets are established, portfolio construction (i.e., the selection of specific investment managers, strategies, and vehicles) can ensure that the total portfolio is built to achieve the targets as closely as possible.

5 While the formula expresses Vanguard's baseline best thinking for establishing a plan's credit spread hedge ratio target, it is not intended to be highly precise. For any individual pension plan, there is a range of credit spread hedge ratio targets that may be appropriate. This is mainly because the credit spread hedge relationship is less stable than the interest rate hedge relationship, as described elsewhere in this paper. Actual experience is likely to deviate materially from the expected credit spread hedge ratio, especially in times of elevated volatility. Similarly, the relationship between credit spreads and equity returns will vary over time. Our guidance here relies on a number of assumptions for relationships that will vary over time, and therefore should not be interpreted as a highly precise optimization of credit spread risk. Finally, credit spread risk for pension sponsors is secondary in magnitude to interest rate risk, so a deviation in credit spread hedge ratio is not expected to have a material impact on long-term funding status volatility.

Determine when asset allocation should change in the future

Pension investment strategies frequently incorporate a dynamic component, commonly referred to as a glide path, which adjusts strategic asset allocation targets based, generally, on the achievement of predefined triggers.⁶ Many private sector pension plans in the U.S., particularly frozen plans, have implemented a glide-path strategy in recognition that a plan's funding status risk is asymmetrical: The risk/return trade-off diminishes as a plan gets better funded, and it is difficult to realize the full value of surplus pension assets that remain after all benefits are paid. The marginal utility gained from additional return lessens as funding status improves beyond a certain point. The role of a glide path, therefore, is to reduce asset-liability risk as a plan's funding level increases.⁷

There has been significant research on glide-path optimization and implementation, which can be summarized as follows:

- Glide paths are typically constructed with portfolio transitions from return-seeking assets into liability-hedging assets as the plan's funding status improves. The process generally uses triggers based on funding ratio, whereby asset allocation targets adjust in a pre-determined manner as successive funding ratios are met.

- Some plan sponsors have explored or implemented other types of glide-path triggers (e.g., interest rates, equity market index values, calendar dates, etc.), though there is no evidence that this increased complexity translates to superior outcomes. Market-based triggers are highly correlated with increasing funding ratios, so they may not ultimately change investment outcomes much at all.
- Glide paths reduce or eliminate emotional or tactical biases regarding portfolio allocation. To reduce any behavioral temptation to second-guess the glide-path strategy at a later date, plan sponsors should include details of the agreed-upon glide path in the pension plan's investment policy statement.
- To maximize glide-path effectiveness, a plan's funding status needs to be continually monitored to ensure that allocations are adjusted when conditions dictate.

When developing a custom glide path, a plan sponsor would ideally establish not only the funding level that will serve as the trigger to implement each phase, but also the three asset allocation targets—the return-seeking allocation target, the interest rate hedge ratio target, and the credit spread hedge ratio target—that will apply at each phase. In Vanguard's experience, a custom asset-liability study is an important step in ensuring that a glide path is sufficiently aligned with the plan sponsor's investment objectives and risk tolerance.

⁶ See Wolfram and Dutton (2018) for additional detail on developing and managing a glide-path strategy.

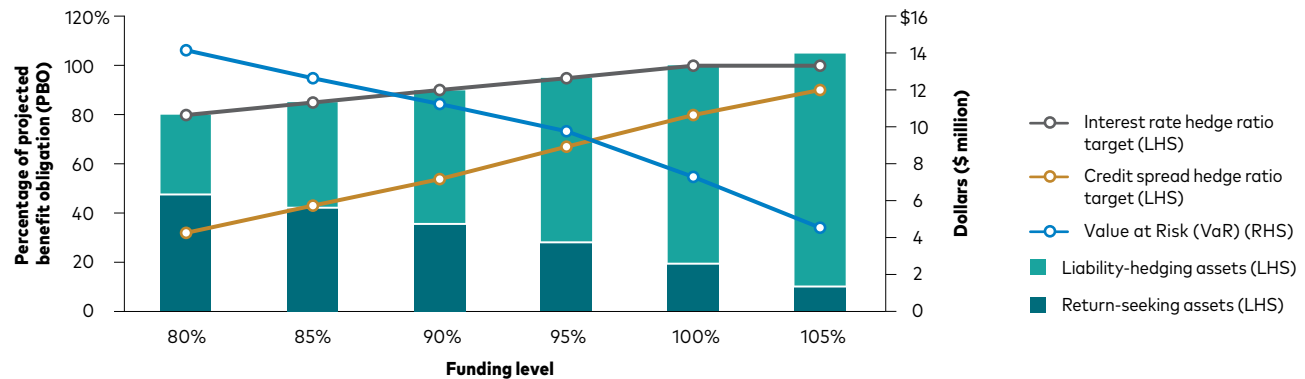
⁷ See Gannon and Klein (2020) for additional detail on investment considerations unique to frozen pension plans.

A sample glide path for our hypothetical GHI Pension Plan is shown in **Figure 6**.

A key decision point in establishing the glide path is the plan's funding-level objective—the funding level at which the plan's return-seeking allocation target will reach its minimum and its interest rate hedge ratio target will reach its maximum. For the GHI Pension Plan, we show a funding-level

objective of 105% of the *Projected Benefit Obligation (PBO)*, which is typical for many frozen plans. For plans that are not yet frozen, the optimal strategy may be to have a higher funding-level objective—or even have no glide path at all—since further accumulation of surplus can help cover future benefit costs not yet reflected in the PBO liability measurement.

FIGURE 6.
Sample glide path for GHI Pension Plan



Funding level	80%	85%	90%	95%	100%	105%
Target return-seeking allocation	60%	50%	40%	30%	20%	10%
Target interest rate hedge ratio	80%	85%	90%	95%	100%	100%
Target credit spread hedge ratio	32%	43%	54%	67%	80%	90%
Funding Status Value at Risk (VaR), total (\$ millions)	14	13	11	10	7	5
Due to market risk	14	13	11	9	6	3
Due to interest rate risk and credit spread risk	7	6	5	4	4	3
Impact of risk diversification	-7	-6	-4	-3	-2	-2

Notes: Projected Benefit Obligation (PBO) is commonly used in the pension investment process as a market-based measure of plan liability. Other U.S. Generally Accepted Accounting Principles (GAAP) liability measures, including Accumulated Benefit Obligation (ABO) and Present Value of Benefits (PVB), may also be useful for this purpose, depending on the plan sponsor's objectives. The VaR in the Funding Status Value at Risk (VaR) entry measures a 5th-percentile outcome (where 5% of outcomes are worse but 95% are better) over a one-year time horizon. Measurement date for VaR calculations is May 31, 2021. Because of rounding, VaR figures may not add up exactly. See Appendix B for important details on our forecasting and risk models.

Sources: Vanguard and MSCI BarraOne.

Conclusion

With a clear understanding of the unique risks posed by a pension liability, a plan sponsor can begin to articulate its desired strategy by identifying three key targets for its plan: return-seeking asset allocation, interest rate hedge ratio, and credit spread hedge ratio. These key targets can be used as the foundation for a robust, customized portfolio construction process. Setting these targets for each future phase of a dynamic glide path based on the plan's funding status can also help preclude undesired effects from any emotional or tactical biases.

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Appendix A. Glossary of key terms

Credit spread. The difference in yield between a risk-free (e.g., U.S. Treasury) bond and another debt security of the same maturity but different credit quality, typically measured in basis points (1 basis point = 0.01%).

Dollar duration. The sensitivity of an investment portfolio (or pension liability) to changing interest rates or credit spreads, expressed as the estimated dollar impact of a 1% change in rates.

Duration. The sensitivity of an investment portfolio (or pension liability) to changing interest rates or credit spreads, expressed as the estimated percentage impact of a 1% change in rates.

DV01. The sensitivity of an investment portfolio (or pension liability) to changing interest rates or credit spreads, expressed as the estimated dollar impact of a 1 basis point (0.01%) change in rates. Short for "dollar value of one basis point."

Funding ratio. See *funding status*.

Funding status. A comparison between the value of the plan's assets and a present value of future benefit obligations (generally referred to as a *liability*). Can be measured in percentage terms measured in percentage terms (i.e., a funding ratio, equal to assets divided by liability) or dollar terms (i.e., a surplus or deficit, equal to assets minus liability).

Glide path. A series of pre-planned adjustments to an underfunded pension plan's investment strategy set up to reduce downside risk as a plan becomes better funded.

Liability. A calculation of present value of a pension plan's future obligations according to a defined set of regulations or accounting standards; *Projected Benefit Obligation* (PBO) is a market-based liability measure frequently used for investment management purposes.

Liability-driven investing. A pension asset allocation strategy selected based on liability-centric factors (such as projected *funding status*, expected volatility of funding status, expected impact on contributions, or projected pension expense).

Liability-hedging assets. Investments whose primary objective is to increase the correlation of returns on plan assets and liabilities; asset classes may include (but are not limited to) domestic investment-grade fixed income (credit and Treasury), and interest rate derivatives such as U.S. Treasury futures.

Projected Benefit Obligation (PBO). The liability measure used in U.S. GAAP corporate balance sheet and income statement accounting; generally reflects accrued benefits plus the projected impact of future salary increases (but not future years of service); commonly used as a liability metric for investment decisions, particularly when the plan sponsor's primary objective is to manage the volatility of accounting results.

Return-seeking assets. Investments whose primary objective is to generate a return that exceeds interest on the plan liability (i.e., exceeds the rate of return on high-quality corporate bonds) over the long term, thereby improving the plan's funding ratio; asset classes may include (but are not limited to) equities, real estate, and alternatives.

Value at Risk (VaR). A measure of the potential loss in a pension plan's funding status at a 95% probability (or 1-in-20 year negative outcome); represents a two-standard-deviation movement in funding position.

Appendix B. Forecasting and risk measurement methodology

Vanguard Capital Markets Model

The projections and other information generated by the Vanguard Capital Markets Model® (VCMM) regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. VCMM results will vary with each use and over time.

The VCMM projections are based on a statistical analysis of historical data. Future returns may behave differently from the historical patterns captured in the VCMM. More importantly, the VCMM may be underestimating extreme negative scenarios unobserved in the historical period on which the model estimation is based.

The VCMM is a proprietary financial simulation tool developed and maintained by Vanguard's primary investment research and advice teams. The model forecasts distributions of future returns for a wide array of broad asset classes. Those asset classes include U.S. and international equity markets, several maturities of the U.S. Treasury and corporate fixed income markets, international fixed income markets, U.S. money markets, commodities, and certain alternative investment strategies. The theoretical and empirical foundation for the VCMM is that the returns of various asset classes reflect the compensation investors require for bearing different types of systematic risk (beta). At the core of the model are estimates of the dynamic statistical relationship between risk factors and asset returns, obtained from statistical analysis based on available monthly financial and economic data from as early as 1960.

Using a system of estimated equations, the model then applies a Monte Carlo simulation method to project the estimated interrelationships among risk factors and asset classes as well as uncertainty and randomness over time. The model generates a large set of simulated outcomes for each asset class over several time horizons. Forecasts are obtained by computing measures of central tendency in these simulations. Results produced by the tool will vary with each use and over time.

Value at Risk (VaR) and MSCI BarraOne information

Value at Risk (VaR) estimates in this paper were made using MSCI Barra's multi-factor asset-liability risk model. The MSCI Barra models are intended to help investors understand sources of risk and return within securities and portfolios of securities. The models pertain to risks present in the equity, fixed income, currency, commodity, and other alternative markets. As a predictive model, this model may not achieve this intended purpose, especially over shorter-term periods. The model may not account for all risks actually present, and may incorrectly infer the magnitude of the risks and the degree that they will influence security returns in the future. The model is continually updated based on MSCI Barra's ongoing research. The model itself is not to be construed as advice of which securities to own or the degree of return that will be earned by any security in the future. The model may be applied in the course of providing advice by Vanguard Investment Advisers, Inc. In this report, it is intended to ease communication related to the sources of risk and return within a portfolio of securities from a variety of asset classes.

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