# The Costs of Delaying the Funding of Public Pensions in Massachusetts

No. 109
January
2014

*A Pioneer Institute White Paper*

*by Iliya Atanasov*


PIONEER INSTITUTE
PUBLIC POLICY RESEARCH

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# The Costs of Delaying the Funding of Public Pensions in Massachusetts

Iliya Atanasov

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## 1. Introduction

The public pension systems of Massachusetts[1] did not have a deadline to fund their liabilities until the mid-1990s. Then, the General Court set 2028 as a target date to pay down all the unfunded accrued actuarial liabilities (UAAL) as part of a broad overhaul of the Commonwealth's retirement systems. The frothy securities markets of the 1990s and a roaring economy inspired many retirement boards to choose funding deadlines in the 2000s and 2010s.

But after the dotcom bubble burst around the turn of the century, more and more retirement boards pushed their funding schedules to 2028. Mounting unfunded retirement liabilities demanded ever-higher pension appropriations from many budgets, especially that of the state itself, which is supposed to cover the two thirds of statewide pension liabilities vested in the state and teachers' retirement systems.[2] During the financial crisis of 2008-2009, massive investment losses and plummeting government revenues triggered a further extension of the statutory deadline – first to 2030 and then as far out as 2040 – in order to prevent a fiscal disaster.

However, deferring pension payments comes at a cost – namely, the forgone investment returns that would have been generated had those monies been deposited in the system in a timely manner. Since the earned retirement benefits due are fixed by law, including a series of US Supreme Court rulings on the matter, it is the public fisc that ultimately makes up for the difference when investment returns fall short of assumptions. Delaying the payments further into the future is therefore a double-edged sword: it provides short-term relief but can exacerbate the problem in the long run. And the sword is doubly sharp on the backside because budgetary strains (triggering the urge to delay pension payments) tend to coincide with lows in securities markets, which is the most opportune time to invest and minimize taxpayers' costs.

The purpose of this paper is to provide tools to quantify the costs of delaying the funding of pension obligations – those incurred in the aftermath of the financial crisis as well as projected costs more generally. Policymakers should be aware of these implicit costs when making budgetary decisions, and so should taxpayers, who ultimately are liable for what essentially amounts to a long-term financing cost for current spending.

Understanding that such costs exist in theory is not enough. Decision makers should assess them in each specific case, especially in the context of large-scale liabilities such as retiree benefits, and disclose the actual costs of their financing decisions to their constituents and to the general public.

## 2. The Massachusetts Legal Framework for Public Pension Funding

Presently, Chapter 32 of the Massachusetts General Laws requires retirement boards to fund their entire liability no later than 2040 if they obtain appropriate permission from the state's pension regulator, the Public Employee Retirement Administration Commission (PERAC).[3] Funding schedules must be updated at least once every two years alongside a mandatory valuation of assets and liabilities in order to ensure that deadlines are met.

The **annual required contribution (ARC)**, as defined by the Governmental Accounting Standards Board (GASB), consists of the **normal cost**, which is the full cost of benefits accrued during the year net of employee contributions, a payment towards the existing unfunded liability called the **UAAL amortization** and certain actuarial adjustments to those two components based on actual experience. However, the funding mandates under Massachusetts law may override those requirements in either direction.

The legislature has decreed that annual appropriations (which include both the normal cost and the UAAL amortization payments) in any schedule cannot increase by more than 4.5% annually for systems with funding deadlines no later than 2030 and 4% for those funding beyond that year,[4] which is intended to prevent constituencies from deferring too much of the payments to the remote future. For this purpose, there is a further prohibition on adopting a superseding schedule that budgets a smaller payment for any given year than previously planned (until full funding is achieved) whenever full funding is scheduled after 2030. This latter provision also militates against using outsized investment returns in the short run as an excuse to reduce payments.

Within this framework, the various constituencies and their retirement boards retain considerable leeway in determining pension funding. They are mostly free to choose their own funding deadline up to the statutory mandate of 2040 as well as the steepness of the funding schedule up to the respective ceiling on the annual growth of payments. More importantly, the retirement boards have a say on the assumed rate of return (ARR) used to discount[5] future disbursements of retirement benefits (although PERAC has to approve the audit and valuation reports based on those rates). The higher that rate is, the lower the present value of the liabilities and, therefore, the smaller the statutory amount of money required to allocate for the annual amortizations of unfunded liabilities. This effect may be partially offset by a concomitant decrease in the assumed rate of salary growth, depending on the specific methods chosen by the actuary. Statewide, liabilities are still discounted at about 8% in the aggregate and no board has set a discount rate below 7%, even though boards have been lowering their ARRs gradually at PERAC's recommendation over the past few years.[6]

Even though the constituency (i.e., a municipality, town, agency or other governmental unit with an autonomous budget) is ultimately responsible for making the payments, in practice the decision to defer them comes in two parts. First, the Massachusetts legislature sets (extends) the statutory deadline for full funding. Then, the individual retirement boards determine their own schedule of payments within the limit enshrined in the statute and can ask PERAC to extend their deadline through 2040. Meanwhile, the General Court has legislated for itself more direct control over the two commonwealth systems, which account for about 2/3 of the accrued and the unfunded liabilities; those boards' deadlines were most recently moved from 2025 to 2040.

## 3. Scope of the Issue

Over the past decade or so, most public pension funds throughout the commonwealth have repeatedly taken advantage of the leeway they have in determining funding deadlines and schedules (Fig. 1).[7] Unsurprisingly, they deferred payments in the aftermath of the dotcom and mortgage bubbles. At yearend 2001, 49 boards (out of 106) still planned to be fully funded by 2020, but that number dropped quickly after the recession of the early 2000s and by 2008 had fallen to just 25. With the dismal plunge in portfolio values after the most recent financial crisis, at yearend 2012 only two boards[8] (out of 105[9]) were still projecting full funding by 2020, but they accounted for a negligible proportion of the liabilities. This trend has likely been accelerated by the gradual lowering of ARRs that has been taking place over the same period.

**Fig. 1. Number of Boards by Yearend Funding Deadline 1999-2012**

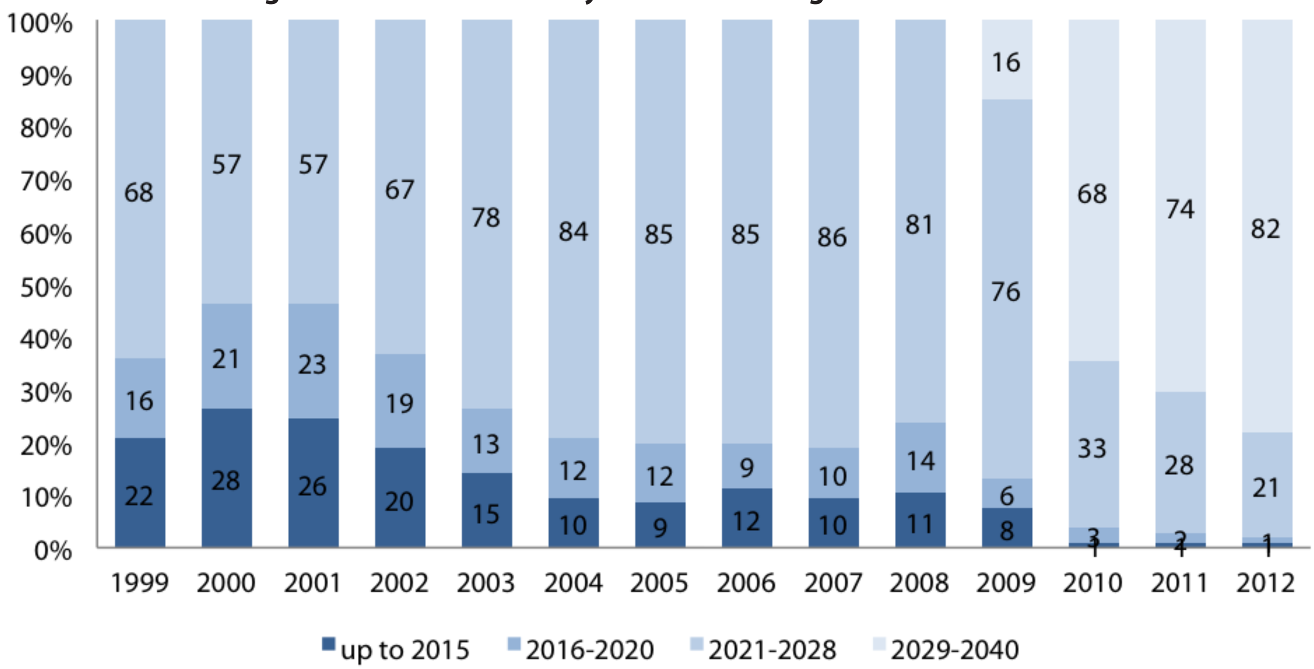
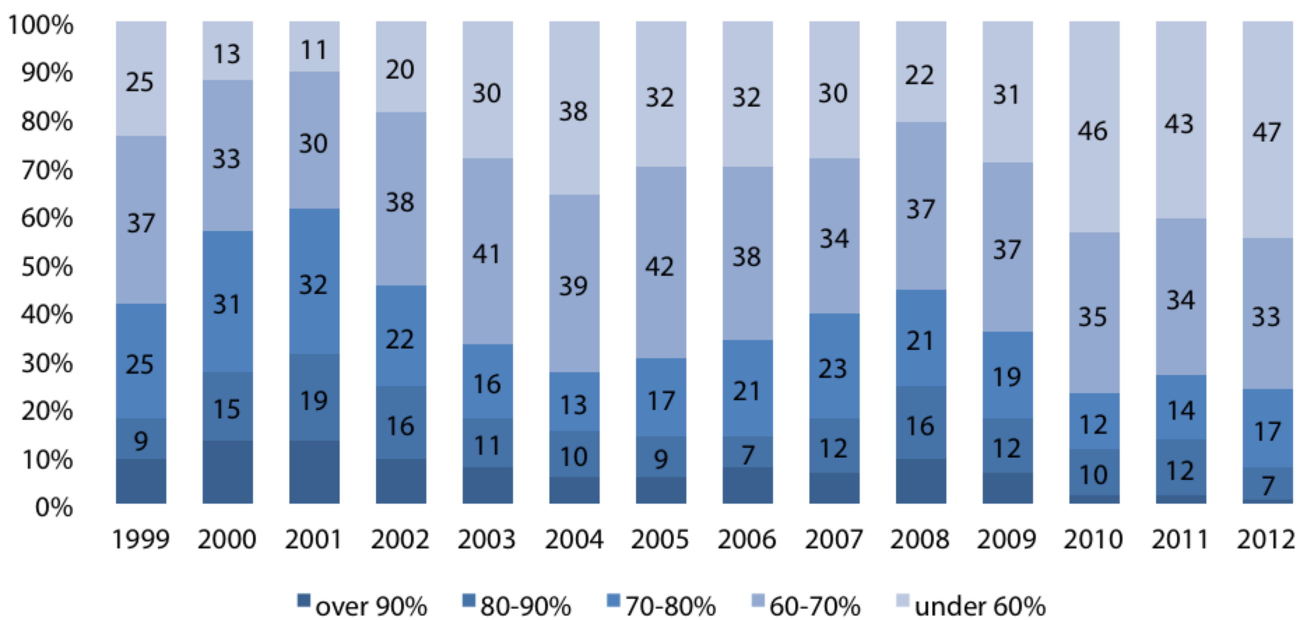



**Fig. 2. Number of Boards by Yearend Funded Ratio 1999-2012**



Overall, the evolution of funding deadlines has followed closely the funded ratios of the retirement boards (Fig. 2), which are dependent on the corresponding ARR assumptions. As the initial funding legislation was passed in the mid-1990s, it effectively invited retirement boards to set their return assumptions at levels consistent with market performance during the bull runs of the 1980s and 1990s. Their ARRs, however, never reached 9% or more as may have happened elsewhere in the US.

Thus, a large portion of the underfunding is due to short-term bias driving unreasonable ARR assumptions relative to actual long-term (100-year or further) investment returns. Over time, the discrepancy between reality and expectations has forced the retirement boards to push out the funding deadlines in order to avert a fiscal crisis. There were 81 boards funded below their 1999 levels as of YE 2012 and 82 boards that have pushed full funding beyond 2028.

In effect, the ARR is an avenue to take on off-balance-sheet leverage for governmental units throughout the state. They can support current services with promises of future retirement benefits, then discount those liabilities at an excessive rate to prevent their balance sheets from becoming visibly unsound.

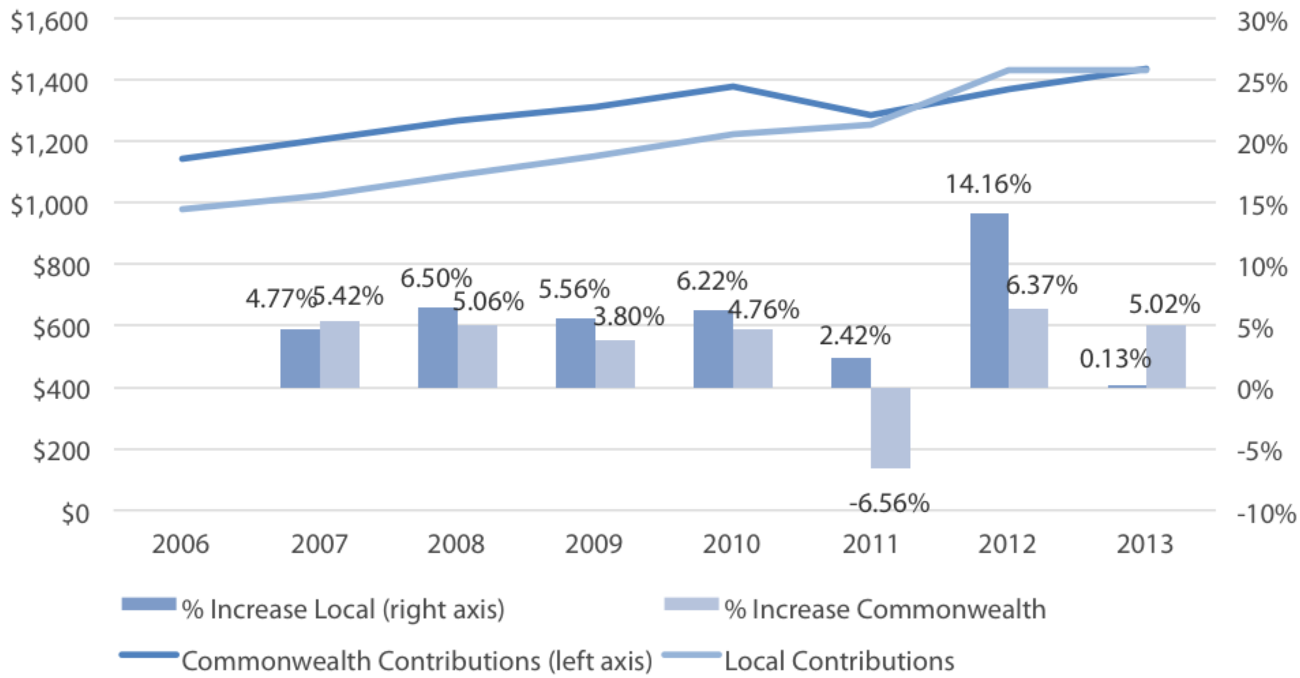
Not until the mid-1990s did GASB begin to require disclosure of those liabilities on financial reports (still without binding restrictions on discount rates). Asleep at the wheel during the financial crisis, credit-rating agencies also largely ignored the impact of these return assumptions on communities' financial health. But the lenient treatment these accounting shortcomings had received from both regulators and analysts could only last so long.

Securities markets were the first to break the veneer of serenity. The market crashes of this century exposed the ARR quasi-leverage of the retirement systems, forcing them to replace some of it with duration – and extend the funding deadlines in order to keep the pension appropriations on their budgets at manageable levels. By 2012, 81 of the 105 surviving retirement boards had lower funded ratios than they did in 1999, including the commonwealth boards.[10] Many of the remaining boards were very close to the (under)funded levels of 1999 despite more than a decade of ever-increasing pension appropriations and UAAL amortizations.

Since 2000, aggregate US equity returns have gone nowhere near previous levels and there is little reason to believe that pension funds will be able to rely on the same ARR assumptions for the coming decades – at least not credibly so.[11] Thus, the last two business cycles pushed funded ratios lower and lower, even though the latter were on a gradual path of recovery in 2003-2007. They fell to new lows during the financial crisis despite that constituencies throughout the state had been (and still are) increasing their pension appropriations (Fig. 3).[12]

An argument can be made that many budgets and especially that of the state itself could not have possibly borne the UAAL amortization burden engendered by sticking to the 2028 deadline. But there is no free lunch, certainly not for taxpayers. The reduction of pension funding involves the opportunity cost of the returns on the payments that have been deferred. Future budget appropriations must include not only the amount by which current funding is curtailed, but also an offset for the returns missed during the period of postponement.

**Fig. 3. Aggregate Pension Appropriations 2006-2013**




Maintaining predictable and stable pension appropriations is indeed a critical task and priority for fiscal managers at every level of government. Using short-term borrowing to accommodate fiscal volatility is itself a costly and precarious "solution" to pressing liquidity problems. Providing for higher UAAL amortizations would require cuts in core public services and investments and/or tax increases, neither of which are particularly desirable in a strenuous economic environment – if ever. But the public and, most importantly, budget authorities must be aware of and transparent about the implicit costs of financing current spending by deferring their payments towards accrued pension (and other) liabilities.

## 4. Understanding the Relationship between Pension Costs and Investment Returns

Contrary to what the typical debate over public pensions may lead one to believe, there is no single metric that captures all the costs and fiscal implications of pension liabilities. When making budgetary decisions regarding the funding of accrued liabilities, the effects of a delay in funding are first measured as **expected (implied) actuarial gain or loss**, which represents the investment return expected to be gained or lost based on current actuarial assumptions.

Suppose two pension systems are funding a liability due in 10 years based on some funding schedule, system A has an ARR of 5% and system B has an ARR of 8%. If each system delayed $100,000 of funding until the due date, their expected opportunity cost in the first year would be $5,000 and $8,000, respectively (the money that has not been invested in a timely manner multiplied by the ARR). In the second year, the loss would be $5,250 and $8,460 because, as with a loan or a deposit account, interest is accrued not just on the original principal, but also on the prior period's interest, which is capitalized at the end of the year.

Thus, the liability left unfunded in the second year as a result of the decision to delay would be expected to grow to $110,250 and $116,460, respectively, based on these projections. For the entire period of 10 years, system A would expect to forfeit $68,889 and system B $99,900 – these are the future values of the accrued interest on the liability for each system at the end of year 10.

The recorded actuarial gain or loss, on the other hand, reflects the *actual* investment returns gained or lost as a result of a particular funding decision. In the example above, if system A produced a net return of 10% in the first year, its actual opportunity cost on the delayed portion of payments would be $10,000. Since its overall return is higher than the ARR, system A may still end up recording an actuarial gain overall, but that does not change the fact that an additional $10,000 could have been generated if the payment was made on time. The higher the actual investment return, the higher the opportunity cost on any delayed payment.

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Because of the time value of money, borrowing from one's pension contributions has a tangible and exponentially increasing effect on the cost of the plan and the long-term financial health of the provider. But the ARR is only one way to capture that effect. To make an informed funding decision, a variety of other opportunity costs unfolding over time must be considered. Such considerations may be related to inflation, borrowing rates, the volatility of required contributions due to changes in investment returns, debt-servicing needs, socioeconomic changes, etc.

Therefore, prudent financial planning and proper fiduciary conduct require not only that projected costs be included in the decision-making process and disclosed, but also that the budget be continuously recalibrated based on experience studies reporting the realized and the expected costs at various milestones during the projected period. While PERAC regularly produces experience and valuation studies on retirement benefits, neither it, nor the Massachusetts legislature, nor most individual retirement boards conduct appropriate due diligence in estimating the fiscal impact of pushing out the funding deadlines on a case-by-case basis. Such due diligence must include:

a) disclosure of both the old and the new funding schedule;
b) the difference in annual payments;
c) the overall dollar cost of the switch in present- and future-value terms;
d) a per-dollar cost for each dollar released for other spending; and
e) a stress test including extreme economic scenarios.

The first four of these points are easily computable from data already prepared by PERAC, while (e) must be prepared by the commonwealth's Executive Office of Administration and Finance or the General Court's Joint Committee on Ways and Means - or the corresponding unit of an agency or local community, as applicable.

The picture is further complicated by the fact that costs can be quantified in a variety of ways. The most common actuarial practice is to use the **present value (PV)** of the cash flows in comparing different budgetary options. UAAL is reported in PV terms. However, PV's usefulness is limited by the fact that it lumps together cash flows which can be dramatically different over specific periods in the future, disregards liquidity risks and does not take into account fiscal volatility.

As implied in the earlier example, a consistent challenge – and cause of poor financial decisions – in using PV is the choice of an appropriate discount rate for future cash flows. In general, discounting approaches either rely on some **internal rate of return (IRR)** – personified, in this case, by the ARR – or external rates of return. Popular options for exogenous discount rates include inflation measures (such as the GDP deflator or the CPI), returns on so-called "risk-free" assets such as US T-bills, weighted-average cost of capital, direct financing cost (e.g., the yield on a collateralized debt obligation issued over the project) or projected returns on competing projects.

Selection of the discount rate(s) must be premised upon (1) the financial planner's goals, (2) a consistent set of accounting principles to be applied in the valuation itself and (3) a minimal amount of information entropies such as assumptions, averages, extrapolations, approximations and so on. Information entropies are dangerous and costly because they create the illusion of certainty where in fact none exists. One way to mitigate their impact is to take into account different – and often incompatible – measures of the same phenomenon. In the examples below, the inflation rate (the return on holding cash reserves) and yields on government debt of the same duration (reflective of financing costs) are considered, as the two most broadly pertinent methods of arriving at a present value in addition to the plan's own ARR.

As indicated earlier, federal and state regulations do not provide a clear set of guidelines and restrictions regarding ARRs. Since retirement boards are presumed to take in good faith the ARR they employ in actuarial valuations of pension liabilities, the same rates ought to be used in estimating the projected cost of deferring their pension appropriations.

"Information entropies are dangerous and costly because they create the illusion of certainty where in fact none exists."

An obvious empirical source of ARR "candidate values" are past investment results, but as the clichéd finance maxim goes, past performance is no guarantee for future returns. Specifically, this approach would not be able to capture long-term inflection points in market returns. Rather than just extrapolating from the most recent data, a 6% ARR fits better with very long-term data[13] and a more cautious assessment of economic growth in the coming years.

Another approach is to look at the **future value (FV)** or the total return (or cost) of the project through its entire duration. This is also problematic because results are often contingent on the assumed length of the financial plan and on the ARR, as is the case with PV. Even if alternative plans share the same PVs and FVs, they can have radically different cash-flow structures and liquidity should always be a central concern. Lack of cash on hand can force a productive enterprise to shut down – or a local community to tap expensive revolving credit lines, raise fees and taxes or cut vital services such

**Fig. 4. Liquidity Conversion Ratio**

$$\text{liquidity conversion ratio (LCR)} = \frac{\text{sum of future offsetting payments}}{\text{current cash deferred}}$$

as education and public safety. Thus, it is indispensable to project and review the entire cash flow structure of the funding plan as part of the decision-making process.

From these estimates for the different cash-flow structures that can be used to achieve a target portfolio capitalization, the financial manager can derive the rate at which each alternative budget implicitly converts present dollars of contribution to the fund into future offsets (i.e., pension appropriations). The **liquidity conversion ratio (LCR)** between the two can then be used as an additional point of comparison between two budgetary scenarios as it shows how many dollars of future tax revenue are necessary to offset each dollar of current revenue "saved" for other purposes as a result of underfunding the portfolio (Fig. 4). It invariably indicates a greater amount in future payments per every dollar deferred.[14] These costs can quickly add up, especially when the duration of the deferral, the liability and/or the steepness of the funding schedule are relatively high.

## 5. Projected Actuarial Costs and Compensating Contributions

When devising conceptual tools, one must not lose sight of the purpose – in this case, reaching a particular portfolio value by a specific date, also known as "target-date investing." To achieve the target value, any deferred contributions to the investment program need to be offset by appropriate inflows in the future. Thus, the most practical measures of the cost of deferral are based upon the changes in the cash flow structure leading to the desired amount of accumulated assets.

In the case of pension benefits and other "nondiscretionary" expenditures, offsetting cash flows typically need to be substituted in before some statutory or implicit target date. Even if a town cannot afford to repair a bridge of critical importance to its economy this year, it will ultimately have to allocate the money to replace it within some finite period not much longer than the remaining projected operational lifetime of the structure. Similarly, retirement boards have a set of statutory deadlines and restrictions on how unfunded their pension liabilities can be. Planning for these projected and largely inevitable budgetary outflows is an indispensable part of the competent manager's endeavor to minimize fiscal volatility and create a predictable and stable business environment.

The most obvious measure of underfunding costs is the ARR itself – thus the nominal annualized interest cost of postponing a payment would be 8% of the payment if the ARR for the plan is 8%. However, investments (and the corresponding budgets) often have different life spans, which can in turn be different from the owner/manager's time horizon. Thus, a bare return measure seems insufficient even without mentioning risk and liquidity. This also applies for the ARR, which is an annualized (periodic) metric, but again does not effectively account for the underlying cash-flow and expense structure, which can be of critical importance to the financial manager.

In the case of investment plans, and especially as they relate to individual retirement, an obvious candidate for an opportunity cost measure is the difference in future value of the portfolio under different investment schedules, but given a particular "expiration date" for the assets (i.e., a date at which they will be disbursed and spent such as that associated with the increasingly popular "target-date mutual funds"). The advantage in using the same target date for divestment is that the duration of all alternatives under consideration is the same, which implies that valuation is more uniformly affected by time discounting and changes in interest rates (this comes in particularly handy when considering debt instruments and other liabilities heavily affected by prevailing interest rates and inflation).

An even more significant advantage of this approach is that it takes into account investment goals and, particularly, the time horizons associated with them. Suppose an employee is considering whether to defer $1,000 from her retirement account for two years and spend it on a holiday trip instead.[15] If the expected return on her investments is 5%, that would imply a 5% capitalized cost over each of the two years – a total net opportunity cost of 10.25% or $102.5 over the two-year period.[16] In other words, she would need to invest $1,102.5 (not $1,000) to compensate for the deferred amount and get back on track with her savings. The present value of that $102.5 difference at a discount rate of 5% per annum is about $93, which is the present value of her cost of financing the trip by underfunding the pension account.

However, this is not the entire story of what the consequences might be. Suppose that she will withdraw all her funds at retirement 20 years after the purchase. Over that time, her $1,000 would have become $2,653 (Fig. 5) if invested presently and about $2,407 if delayed by two years. The difference in these future values is $246, which is much more than $102.5, the net return over two years, because it includes the return on that return over the remaining 18 years of her financial plan. When discounted at the 5% nominal rate of return of her investments, this difference in future values is again $93, exactly equal to the present value of the forfeited return over two years.

While the present values are the same, the cash flows necessary to offset the underfunding grow exponentially over time. When coupled with volatile investment returns and minimum funding mandates as in the case of Massachusetts public retirement systems, substantial underfunding therefore increases fiscal risks overall rather than helping offset them. Making up for short-term fiscal volatility by reducing the funding of pension plans comes at the cost not just of greater payments in the future, but also of higher fiscal risks in subsequent periods of economic turmoil.

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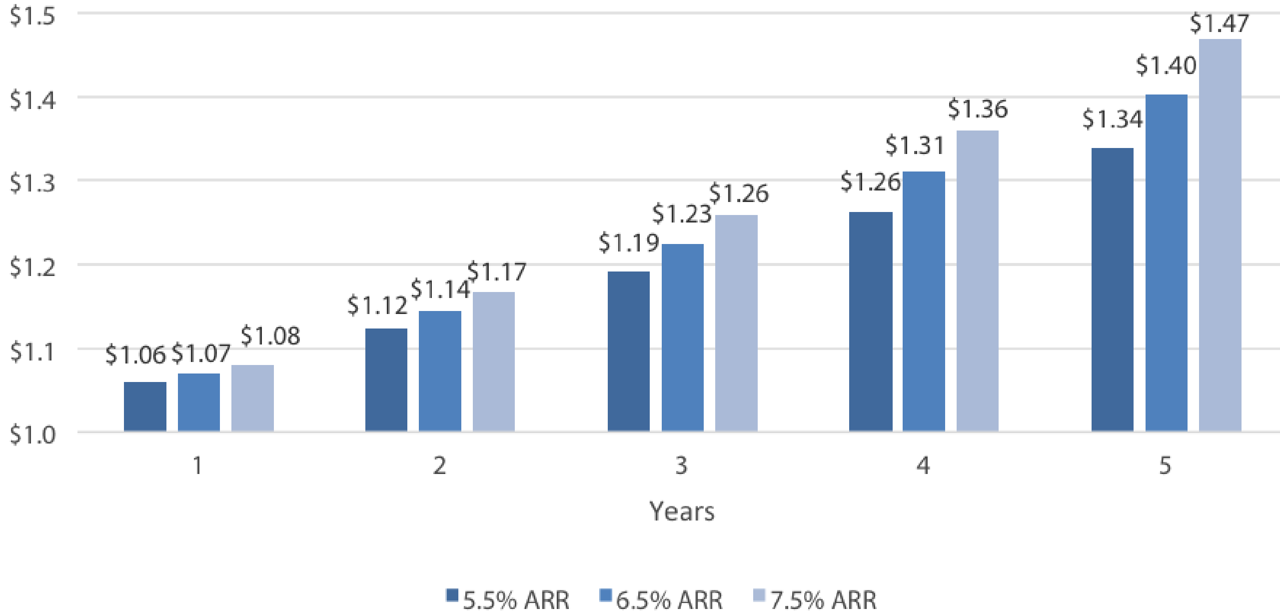
### 5.1. Nominal Lump-Sum Offsets

The simplest way to quantify the actuarial cost of underfunding a plan is to use the ARR to compute the **cumulative gross return** over the period of deferral, which produces an estimate for the lump-sum amount that would

**Fig. 5. Offsetting Lump-Sum Contributions for $1 Million Deferred Up to Five Years (dollars in millions)**




be needed to offset the deferral completely, so as to return on track to the originally planned target date for full funding and not incur any deferral costs beyond that date (Fig. 5).[17] The **cumulative net return** over the same period thus provides a future value for the cost of the deferral.

For example, an investment of $1 million will grow to about $2.96 million in 15 years (the duration of the investment) at a 7.5% annual return, i.e., a pension system that delayed a contribution payment of $1 million would have to pay $2.96 million – almost three times more – to make up for that 15 years later. Thus, the expected FV of the loss on *not investing* $1 million for 15 years at 7.5% annually would be the cumulative net return of $1.96 million (Fig. 6), which amounts to an interest payment of 196% on the deferred contribution.[18] Since the liability-weighted aggregate ARR for Massachusetts pension systems is about 8%, communities would expect to pay over three times more 15 years down the line for every dollar diverted from pension payments to service current cash needs.

**Fig. 6. Cumulative Actuarial Cost (FV) of $1 Million at Different Durations and ARRs (dollars in millions)**

| ARR | Duration in Years | | | |
|---|---|---|---|---|
| | 10 | 15 | 20 | 30 |
| 5% | $0.63 | $1.08 | $1.65 | $3.32 |
| 6% | $0.79 | $1.40 | $2.21 | $4.74 |
| 7% | $0.97 | $1.76 | $2.87 | $6.61 |
| 8% | $1.16 | $2.17 | $3.66 | $9.06 |

### 5.2. Nominal Multiyear Offsets

Lump-sum payments rarely are a recommended strategy for pension funding since the deferred payments tend to be fairly large as compared to the overall budget they come from. Another consideration is the market situation at the time of the funding (e.g., the market can crash soon after the investment is made or the economy can make the investment difficult by reducing tax receipts). Unfortunately, this approach is typically employed in designing a much more common financing tool – municipal bonds. Governmental units still often use traditional bonds with lump-sum payments of the face value at maturity instead of annuities or other instruments that spread the repayment of the principal throughout their lifetime.

Especially after an extended deferral, financial managers would rather add a compensating cash flow over several years of the remaining lifetime of the investment plan. One such option is to overlay the compensatory contributions through the entire remaining schedule of the investment program without changing the target date. The **level-dollar method** of applying such an offset involves paying in the same dollar amount every year through the target date. Massachusetts retirement systems, however, mostly use a schedule of increasing appropriations, with the annual increase capped by statute.

With either type of underlying schedule, one way to quantify the cost of delayed funding is simply to look at the total increase in future payments due to the extension of the funding period. Figure 7 presents two alternate funding schedules for an unfunded liability of $1 million discounted at an ARR of 8% with payments applied at the end of each year and increasing by 4% annually. Moving the funding deadline from the end of Year 20 to the end of Year 30 decreases the required contributions for the first 20 years by about 22%, but increases the overall nominal cost by 47%.[19]

In this scenario, the plan provider gains additional liquidity of $490,184 over the first 20 years, but has to pay in $1,553,760 during the 10-year extension to offset the underpayments, producing a liquidity conversion ratio of nearly 317% for the switch from Schedule A to Schedule B. For every $1 released for budget use during the original period, some extra 3.17 tax dollars must be committed during the extension.

Pushing a funding deadline from 20 to 30 years into the future, increases the cost of amortizing $1 million unfunded liability by more than $1 million – or over 47%.

These metrics provide a nominal tax-dollar value for the tradeoff - the nominal liquidity conversion ratio - between the two schedules. A governmental unit moving from the 20- to the 30-year schedule is accepting an additional interest cost of over $1 million, but how does this actuarial loss translate into current dollars?

### 5.3. Present Value of Deferral Costs

The natural temptation is to utilize the ARR to discount the difference in future payments, in which case the present value of the shift comes down to exactly zero because that is how the amortizations are projected in the first place. However, the appropriate point of comparison may be the present value of the return on investing the same dollar in another project for the period of delay. For example, if a town is considering paying less towards its UAAL this year in order to repair a bridge, the financial manager would have to compare the opportunity cost of one-year delay in pension funding with the present value of the expected increase in the repair cost of the bridge if the renovation were postponed for the same amount of time or had to be funded through borrowing. Thus, especially in the context of longer-term financial planning, it may be useful to estimate opportunity costs taking into account other financing

**Fig. 7. Sample Amortization Schedules for an Unfunded Liability of $1 Million at 8% ARR and 30-Year Duration**

| End of Year | 20-Year Schedule A | 30-Year Schedule B | Liquidity Added (Subtracted) | Present Value of Liquidity Change at 5% | Present Value of Liquidity Change at 3% |
|---|---|---|---|---|---|
| 1 | $75,486 | $59,025 | $16,461 | $15,677 | $15,982 |
| 2 | $78,506 | $61,386 | $17,120 | $15,528 | $16,137 |
| 3 | $81,646 | $63,841 | $17,804 | $15,380 | $16,294 |
| 4 | $84,912 | $66,395 | $18,517 | $15,234 | $16,452 |
| 5 | $88,308 | $69,051 | $19,257 | $15,089 | $16,612 |
| 6 | $91,849 | $71,813 | $20,028 | $14,945 | $16,773 |
| 7 | $95,514 | $74,685 | $20,829 | $14,803 | $16,936 |
| 8 | $99,335 | $77,673 | $21,662 | $14,662 | $17,100 |
| 9 | $103,308 | $80,780 | $22,528 | $14,522 | $17,266 |
| 10 | $107,440 | $84,011 | $23,429 | $14,384 | $17,434 |
| 11 | $111,738 | $87,371 | $24,367 | $14,247 | $17,603 |
| 12 | $116,207 | $90,866 | $25,341 | $14,111 | $17,774 |
| 13 | $120,856 | $94,501 | $26,355 | $13,977 | $17,946 |
| 14 | $125,690 | $98,281 | $27,409 | $13,843 | $18,121 |
| 15 | $130,718 | $102,212 | $28,506 | $13,712 | $18,297 |
| 16 | $135,946 | $106,301 | $29,646 | $13,581 | $18,474 |
| 17 | $141,384 | $110,553 | $30,832 | $13,452 | $18,654 |
| 18 | $147,040 | $114,975 | $32,065 | $13,324 | $18,835 |
| 19 | $152,921 | $119,574 | $33,347 | $13,197 | $19,018 |
| 20 | $159,038 | $124,357 | $34,681 | $13,071 | $19,202 |
| 21 | $0 | $129,331 | $-129,331 | $-46,422 | $-69,522 |
| 22 | $0 | $134,504 | $-134,504 | $-45,980 | $-70,197 |
| 23 | $0 | $139,884 | $-139,884 | $-45,542 | $-70,878 |
| 24 | $0 | $145,480 | $-145,480 | $-45,109 | $-71,566 |
| 25 | $0 | $151,299 | $-151,299 | $-44,679 | $-72,261 |
| 26 | $0 | $157,351 | $-157,351 | $-44,253 | $-72,963 |
| 27 | $0 | $163,645 | $-163,645 | $-43,832 | $-73,671 |
| 28 | $0 | $170,191 | $-170,191 | $-43,415 | $-74,386 |
| 29 | $0 | $176,998 | $-176,998 | $-43,001 | $-75,109 |
| 30 | $0 | $184,078 | $-184,078 | $-42,592 | $-75,838 |
| Total | $2,247,833 | $3,310,409 | $-1,062,576 | $-158,089 | $-375,484 |

alternatives or economic conditions – i.e., by discounting future values through some external measure such as the rate of inflation or municipal-bond yields.

To implement such a model, it is sufficient to discount the difference in cash flows between two schedules at the inflation and/or the financing rate. Whenever the external discount rate (e.g., inflation) is lower than the ARR, the present value of the cost of deferral becomes positive. The governmental unit incurs a loss of about $158,000 if it funds a project by underfunding the pension plan instead of borrowing at 5% (Fig. 7). The losses escalate as the appropriate exogenous discount rate diverges from the expected internal rate of return for the retirement plan (the ARR). If cash flows from the shift in the example were discounted at an expected rate of inflation of 3%, the present value of the cost increases to $375,000.

Conversely, when the discount rate is greater than the ARR, the externally discounted cost becomes lower than zero, which makes it attractive to consider deflecting the pension funding to other needs. This makes it easy to see why a governmental unit facing high borrowing costs may underfund its plan by pushing out the deadline to full funding. Unfortunately, the constituencies facing such high borrowing costs tend to be ones of poor credit or already high debt – issues only exacerbated by any additional underfunding of the pension plans.

Present-value metrics are as dangerous as they are convenient if they are the only ones relied upon to make financial decisions, especially over longer periods. The present value of the deferral cost can be a difficult point of comparison between competing projects and budgetary priorities. How does one compute the return on building a new school or providing unemployment benefits? And even when present values are estimable, they omit a critical part of financial planning – the time structure and volatility of the cash flows underlying those present values. Private enterprises with positive present values – valuable products and cutting-edge innovation – fail every day because they run out of cash before they marketize those advantages. Thus, nominal flows must always be taken into account and used as the primary yardstick when making such decisions.

## 6. Estimated Deferral Costs 2011-2014 and Beyond

While projected costs and compensating cash flows must be an indispensable part of the budgetary process, it is important to monitor and calibrate performance in order to improve predictive quality. This may be complex and time-consuming as it requires constructing at least one alternate scenario from a set of observed data.

To illustrate this process and provide a practical example of the bottom-line impact of deferring pension funding, it is sufficient to look at the recent experience in the two largest public retirement systems in Massachusetts. As part of pension reforms enacted in 2010, the commonwealth extended the funding deadlines for the state and teachers' retirement boards from 2025 to 2040. As a result, the overall pension appropriations for FY 2011 fell 6.56% instead of increasing, which freed up resources for other spending.

To estimate the costs and budgetary impacts of delaying the pension funding in this period, it was necessary to construct two scenarios: an extended one, where UAAL amortizations are estimated on the basis of a close approximation to actual policy, and a baseline scenario, where funding schedules were targeting the prior 2025 deadline.[20] Notably, the state has granted itself an exemption from the 4% appropriation ceiling. As a result, the commonwealth's appropriations increase by 5% in FY 2013 and 2014, 6% in FY 2015-2018 and 4% thereafter. These discrepancies were disregarded in the analysis, which may understate the cost estimates.

Extension costs consist of three components – the costs realized during the past periods (the returns that would have been earned on delayed contributions), the expected return (or interest) on those costs for the remainder of the funding schedule as of its last update and the interest costs on the future difference between payments. To reduce complexity and the number of assumptions necessary for the estimation, the scenario comparison disregards certain cost components, thus it may understate or overstate some of the deferral costs over time.[21]

The overall difference in UAAL amortization appropriations for the state and teachers' systems between the two scenarios is just under $2.32 billion for the period 2011-2014 (Fig. 8). The extension freed up an estimated $534 million for the 2011 budget and $627 million for the 2014 budget. The spread in annual amortizations between the two scenarios continues to increase through 2025, when it surpasses $1.1 billion. However, the increased liquidity comes at a steep price. Pushing the funding deadline from 2025 to 2040 could add $26.4 billion in forgone-interest cost – nearly doubling the amount of cash needed to fully fund the 2010 UAAL of $17.5 billion.

For a fuller account of the accrued fiscal impact of the deadline extensions, it is necessary to add the expected future interest on the $2.32 billion estimated funding difference between the two scenarios for FY 2011-2014. This interest would vary depending on the assumed duration of the liabilities and rate of return on the assets. At the state and teachers' systems' current ARR of 8%,[25] the already incurred $2.32 billion underfunding implies an additional interest cost of some estimated $2.69 billion[26] over the next ten years alone.

The $2.32 billion underfunding relative to the old schedule implies an additional forgone-interest cost of some estimated $2.69 billion over the next ten years alone.

The switch defers an estimated $11.9 billion overall in 2011-2025, but requires more than $38.4 billion in offsetting payments in the 2026-2040 period, which translates into a

**Fig. 8. Fiscal Impacts for Baseline and Extended Scenarios (dollars in millions)[22]**

| Funding Deadline | Baseline 2025 | Extended 2040 | Difference |
|---|---|---|---|
| Total Payments[23] | $33,209 | $59,652 | -$26,442 |
| FY 2011-2014 Payments[23] | $6,836 | $4,517 | $2,319 |
| FY 2011 Amortization[23] | $1,598 | $1,064 | $534 |
| FY 2014 Amortization[23] | $1,823 | $1,196 | $627 |
| Amortization as % of FY 2014 Budget[24] | 5.36% | 3.52% | 1.84% |
| Amortization as % of FY 2025 Budget[24] | 6.29% | 3.91% | 2.37% |

liquidity conversion ratio of 3.06. For every dollar subtracted from the length of the old schedule, up to $3.06 on average will need to be paid in during the 15-year extension.

## 7. The Element of Surprise

Why do political leaders accept such adverse tradeoffs? A common justification is that the opportunity costs will be dispersed over a long period, which would significantly reduce their "real" value. On the other hand, the underlying accounting procedures are quite complex and difficult to grasp by policymakers, who face an overwhelming multitude of budgetary decisions every year. While they may realize that there certainly are costs involved in deferring the payments, there is a rather distinct difference between grasping this issue conceptually and taking into account the actual amounts of those costs when considering budgetary alternatives.

There may be a grain of truth in both of these propositions. But a closer look at the structure of UAAL amortizations supplies a much more compelling rationale for the costly funding deferrals – the fiscal volatility engendered by the volatility of portfolio returns during this period. Of the metrics discussed heretofore, only the complete projected funding schedule provides a glimpse of the way pension payments evolve over time, but it still does not take into account the impact not just of the cumulative investment return, but of the volatility of returns, salary increases, demographics and other variables whose future values are unknown.

The cost of the plan is reflected not just in the overall number of dollars needed to maintain it, but by the fiscal stress it can potentially create on an annual basis. Even a plan that is well funded and managed in the long run can experience bouts of severe fiscal stress in the short run, which can impair local budgets. This makes it very important to take into account the **fiscal volatility** implied by a particular funding method in addition to the overall stock of necessary payments.

Fiscal volatility can be a concern that adds both flexibility and rigidity when designing funding schedules. On one hand, huge market shocks like the one experienced in 2008-2009 could justify extending the payments beyond existing funding deadlines. On the other, minimum required payments regardless of funding status may be instituted in preparation for such shocks in the future. Communities may be well advised to pay in the full normal cost accrued during the year even if their pension system is substantially overfunded to mitigate the increase in payments that could be necessitated by the next crisis in the securities markets.

Effective cash-flow management requires ensuring appropriate liquidity to meet operational and capital investment needs and a contingency cushion as protection against unforeseen revenue shocks. This is particularly important in the context of government budgets because (1) costs tend to be rigid and hard to adjust in the short run; (2) both costs and revenues are strongly correlated with the business cycle; and (3) there is a political and economic "predictability premium" associated with engaging in frequent policy modifications to meet current fiscal needs. Thus, the various types of opportunity costs by themselves are not sufficient and a liquidity risk component must be utilized in rigorous financial planning.

The changes in Massachusetts public pensions' funding schedules so far this century bring home a very fundamental financial principle – the higher the leverage of a financial instrument, the higher the associated volatility in valuation and cash flows. In the case of defined-benefit pensions, the obvious measure of leverage is their funded level. But because of the way liabilities are valued actuarially, leverage is ultimately vested in the ARR of the retirement board. The higher the discount rate at which liabilities are valued and funded, the higher the volatility in budgetary appropriations necessary to achieve full funding by a fixed deadline.

Unreasonably high ARR assumptions not only undermine the financial health of pension providers, but also impair their ability to predict and allocate suitable budgetary appropriations in due course, which pushes the actual funding costs even higher. When funding adjustments are necessary, public actuaries must conduct a thorough cost-benefit analysis following the procedures established heretofore and provide it to the appropriate decision makers. This information should also be made available to the public in an unrestricted and accessible manner.

Lax accounting rules and flawed actuarial practices leading to opaqueness and poor decision making are among the main causes of the unraveling of defined-benefit plans in the private sector. The Financial Accounting Standards Board (FASB) and other regulators were asleep at the wheel, taking decades to standardize the discount rates for pension liabilities and push them down to reasonable levels, while tightening the funding rules for defined-benefit plans. This allowed corporations to obfuscate their true labor costs and report higher earnings by effectively underfunding their pension plans – solidifying a vicious circle of unsustainably high productivity, earnings and income growth expectations, leading to higher debt and equity valuations and, consequently, even lower levels of funding.

But the markets could allow unsavory leverage levels to survive only so long. The underperformance triggered a backlash of overrelgulation and unjustifiably low discount rates, which brought the onus of compliance and funding costs to unbearable levels. As accounting rules gradually tightened and portfolio returns came in, ever more companies discontinued their DB plans and replaced them with defined-contribution plans such as 401(k) accounts. Hundreds of private DB plans with hundreds of thousands of beneficiaries still fail every year and their liabilities have to be taken over by the Pension Bankruptcy Guarantee Corporation – that is, by taxpayers. Pension liabilities have been a major driver of corporate bankruptcies – the names of GM and Chrysler are among those that quickly come to mind. A similar scenario but with much graver consequences will unravel in the public sector if stricter rules and better enforcement are not forthcoming in short order.

The rising number and scale of municipal bankruptcies in the last few years – most recently that of Detroit – underscore the latter point. Since retirement liabilities (including healthcare benefits) are now disclosed in financial statements and underfunding relative to the annual required contribution is transferred directly onto the balance sheet, their impact on the borrowing costs of state and local governments is more direct than ever. Thus, the plan leverage due to underfunding not only makes the governmental unit's budget more vulnerable to economic crises, but also increases the cost and reduces the availability of the credit financing that could be used to weather adverse events outside of bankruptcy.

## 8. Conclusion

Massachusetts should use improving economic conditions to ensure its public retirement systems' long-term sustainability and lead the way for the rest of the country. The commonwealth should adopt strict accounting rules for the valuation of pension liabilities, including a ceiling on the ARR and Draconian penalties for localities that substantially underfund their pensions – measures that could include some form of state receivership out of bankruptcy.

Retirement boards and PERAC should be required to provide much greater transparency about pension liabilities. The complete old and new payment projections as well as full cost disclosures should accompany any changes in funding schedules – in nominal dollars, in present value adjusted for inflation and the cost of borrowing, year-by-year differences in required contributions and liquidity conversion ratios based on those metrics. The funding schedules should be stress-tested for asset-price drops of 10 to 30%. Plan administrators and board members should be held personally responsible for noncompliance with these disclosure rules.

Such measures will be costly and unwelcome, but the alternatives are grim, including local bankruptcies and the continued dismantling of defined-benefit plans. Transparency and better accounting standards for retirement boards will ultimately help policymakers devise better budgets and reduce fiscal volatility, allowing them to focus on core priorities such as education and infrastructure. Public employees will be more confident that they will be secure in their retirement, while all taxpayers will benefit from a lower charge on their tax bill and a more effective government.

## About the Author

**Iliya Atanasov** is Pioneer's Senior Fellow on Finance, leading the research tracks on pension portfolio management, infrastructure and municipal performance. Iliya is a PhD candidate in Political Science and Government and MA candidate in Statistics as well as a former Presidential Fellow at Rice University. He also holds BAs in Business Administration, Economics and Political Science/International Relations from the American University in Bulgaria.

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## Appendix I. Funding Deadlines

This appendix lists the funding deadlines of all retirement boards as reflected in PERAC's annual reports. Darker shades indicate remoter deadlines to full funding. If a board was fully or nearly fully funded in a given year, its deadline is listed as the current year.

| Retirement System | Year of Report | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** |
| Adams | 2010 | 2021 | 2021 | 2015 | 2015 | 2013 | 2013 | 2013 | 2013 | 2015 | 2015 | 2030 | 2030 | 2030 |
| Amesbury | 2017 | 2017 | 2017 | 2020 | 2020 | 2025 | 2025 | 2026 | 2026 | 2025 | 2025 | 2034 | 2034 | 2036 |
| Andover | 2018 | 2018 | 2018 | 2018 | 2018 | 2024 | 2024 | 2024 | 2026 | 2026 | 2026 | 2040 | 2040 | 2040 |
| Arlington | 2012 | 2012 | 2011 | 2017 | 2022 | 2022 | 2021 | 2020 | 2019 | 2019 | 2019 | 2032 | 2033 | 2032 |
| Athol | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2027 | 2027 | 2030 | 2040 | 2040 | 2040 |
| Attleboro | 2021 | 2021 | 2028 | 2028 | 2028 | 2026 | 2026 | 2026 | 2022 | 2022 | 2029 | 2029 | 2029 | 2030 |
| Barnstable County | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2038 | 2038 | 2038 |
| Belmont | 2018 | 2014 | 2017 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2027 | 2027 | 2027 |
| Berkshire County | 2028 | 2019 | 2019 | 2019 | 2022 | 2022 | 2018 | 2018 | 2016 | 2016 | 2024 | 2024 | 2022 | 2022 |
| Beverly | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2024 | 2024 | 2023 | 2023 | 2030 | 2030 | 2030 |
| Blue Hills Regional School | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2025 | 2025 | 2022 | 2022 | 2035 | 2035 | 2032 |
| Boston | 2020 | 2020 | 2020 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2025 | 2025 | 2025 |
| Braintree | 2028 | 2023 | 2023 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2026 | 2026 | 2030 | 2030 | 2033 |
| Bristol County | 2028 | 2028 | 2018 | 2018 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2027 | 2027 | 2030 |
| Brockton | 2028 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2018 | 2018 | 2030 | 2030 | 2030 |
| Brookline | 2028 | 2017 | 2017 | 2023 | 2023 | 2023 | 2023 | 2026 | 2026 | 2025 | 2025 | 2028 | 2028 | 2030 |
| Cambridge | 2024 | 2009 | 2009 | 2009 | 2009 | 2013 | 2013 | 2015 | 2015 | 2013 | 2013 | 2029 | 2029 | 2029 |
| Chelsea | 2022 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2025 | 2025 | 2029 | 2029 | 2028 | 2028 |
| Chicopee | 2028 | 2019 | 2019 | 2019 | 2019 | 2019 | 2019 | 2022 | 2021 | 2021 | 2021 | 2027 | 2026 | 2026 |
| Clinton | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2030 | 2040 | 2029 | 2029 |
| Concord | 2014 | 2004 | 2004 | 2013 | 2013 | 2016 | 2016 | 2012 | 2012 | 2011 | 2011 | 2021 | 2021 | 2030 |
| Danvers | 2012 | 2012 | 2012 | 2014 | 2024 | 2024 | 2024 | 2024 | 2024 | 2024 | 2028 | 2030 | 2030 | 2036 |
| Dedham | 2018 | 2018 | 2011 | 2011 | 2011 | 2020 | 2020 | 2020 | 2020 | 2012 | 2012 | 2025 | 2025 | 2034 |
| Dukes County | 2021 | 2021 | 2021 | 2021 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2028 | 2028 | 2026 | 2026 |
| Easthampton | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2021 | 2021 | 2035 | 2035 | 2033 |
| Essex County | 2028 | 2025 | 2025 | 2026 | 2026 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2035 | 2035 |
| Everett | 2028 | 2028 | 2028 | 2028 | 2028 | 2027 | 2027 | 2028 | 2028 | 2026 | 2026 | 2030 | 2030 | 2030 |
| Fairhaven | 2028 | 2017 | 2017 | 2019 | 2019 | 2019 | 2019 | 2019 | 2019 | 2017 | 2017 | 2030 | 2033 | 2032 |
| Fall River | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2028 | 2028 | 2028 | 2028 | 2030 | 2040 | 2040 | 2040 |
| Falmouth | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2037 | 2037 | 2037 |
| Fitchburg | 2028 | 2025 | 2025 | 2026 | 2026 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2030 | 2030 | 2035 |
| Framingham | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2030 | 2030 | 2030 |
| Franklin County | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2030 | 2030 | 2035 |

| Retirement System | Year of Report 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gardner | 2028 | 2018 | 2018 | 2026 | 2028 | 2028 | 2024 | 2024 | 2024 | 2021 | 2021 | 2021 | 2030 | 2030 |
| Gloucester | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2037 | 2037 | 2037 |
| Greater Lawrence Sanitary District | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2018 | 2018 | 2030 | 2030 | 2030 | 2026 |
| Greenfield | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2026 | 2026 | 2030 | 2030 | 2038 | 2038 |
| Hampden County | 2028 | 2027 | 2027 | 2027 | 2027 | 2024 | 2025 | 2026 | 2026 | 2024 | 2024 | 2024 | 2036 | 2036 |
| Hampshire County | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2025 | 2025 | 2025 | 2033 | 2033 | 2034 |
| Haverhill | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2032 | 2032 | 2032 |
| Hingham | 2008 | 2008 | 2008 | 2024 | 2024 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2040 | 2040 | 2032 |
| Holyoke | 2021 | 2019 | 2019 | 2019 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2030 | 2030 | 2032 |
| Hull | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2025 | 2025 | 2030 | 2030 | 2033 |
| Lawrence | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2040 | 2040 | 2038 |
| Leominster | 2028 | 2028 | 2028 | 2028 | 2028 | 2017 | 2017 | 2015 | 2015 | 2012 | 2012 | 2018 | 2016 | 2016 |
| Lexington | 2025 | 2003 | 2003 | 2010 | 2010 | 2015 | 2015 | 2015 | 2015 | 2008 | 2009 | 2020 | 2020 | 2030 |
| Lowell | 2017 | 2017 | 2012 | 2012 | 2012 | 2022 | 2022 | 2028 | 2028 | 2028 | 2028 | 2034 | 2032 | 2032 |
| Lynn | 2028 | 2024 | 2024 | 2028 | 2028 | 2028 | 2028 | 2028 | 2027 | 2027 | 2030 | 2030 | 2031 | 2031 |
| Malden | 2028 | 2021 | 2021 | 2021 | 2019 | 2024 | 2024 | 2028 | 2028 | 2028 | 2028 | 2030 | 2030 | 2030 |
| Marblehead | 2016 | 2015 | 2015 | 2025 | 2028 | 2028 | 2028 | 2023 | 2023 | 2019 | 2019 | 2030 | 2030 | 2037 |
| Marlborough | 2020 | 2020 | 2020 | 2020 | 2023 | 2023 | 2023 | 2023 | 2022 | 2022 | 2025 | 2025 | 2025 | 2025 |
| Mass Housing Finance Agency | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2013 | 2013 | 2013 | 2013 | 2028 | 2028 | 2022 | 2022 |
| Mass Port Authority | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2040 | 2040 | 2040 | 2030 |
| Mass State | 2017 | 2018 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2025 | 2025 | 2040 | 2040 | 2040 |
| Mass Teachers | 2017 | 2018 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2025 | 2025 | 2040 | 2040 | 2040 |
| Mass Turnpike Authority | 1999 | 2000 | 2001 | 2002 | 2003 | 2023 | 2023 | 2028 | 2028 | 2028 | 2028 | NA | NA | NA |
| Mass Water Resources Authority | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2024 | 2024 | 2024 | 2024 | 2024 | 2024 |
| Maynard | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2023 | 2023 | 2030 | 2030 | 2029 | 2029 |
| Medford | 2022 | 2022 | 2021 | 2021 | 2025 | 2025 | 2028 | 2026 | 2026 | 2028 | 2028 | 2040 | 2040 | 2040 |
| Melrose | 2020 | 2019 | 2019 | 2019 | 2019 | 2019 | 2019 | 2019 | 2021 | 2024 | 2024 | 2035 | 2035 | 2030 |
| Methuen | 2028 | 2028 | 2024 | 2024 | 2024 | 2025 | 2025 | 2025 | 2028 | 2028 | 2028 | 2040 | 2040 | 2032 |
| Middlesex County | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2035 | 2035 | 2035 |
| Milford | 2019 | 2016 | 2016 | 2016 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2030 | 2030 | 2037 | 2037 |
| Milton | 2015 | 2015 | 2015 | 2015 | 2020 | 2020 | 2020 | 2020 | 2016 | 2016 | 2021 | 2021 | 2022 | 2022 |
| Minuteman Regional School | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Montague | 2028 | 2020 | 2020 | 2020 | 2020 | 2020 | 2016 | 2015 | 2015 | 2015 | 2015 | 2019 | 2021 | 2025 |
| Natick | 2024 | 2020 | 2020 | 2024 | 2024 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2030 | 2030 |
| Needham | 2028 | 2010 | 2010 | 2010 | 2023 | 2022 | 2022 | 2022 | 2021 | 2021 | 2028 | 2027 | 2027 | 2030 |
| New Bedford | 2028 | 2028 | 2028 | 2024 | 2024 | 2024 | 2024 | 2025 | 2026 | 2026 | 2030 | 2036 | 2036 | 2036 |

| Retirement System | Year of Report | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
| Newburyport | 2022 | 2022 | 2022 | 2025 | 2025 | 2025 | 2025 | 2027 | 2027 | 2027 | 2027 | 2035 | 2035 | 2038 |
| Newton | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2027 | 2028 | 2028 | 2028 | 2026 | 2038 | 2038 | 2038 |
| Norfolk County | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2022 | 2022 | 2031 | 2031 | 2031 |
| North Adams | 2028 | 2026 | 2019 | 2019 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 |
| North Attleboro | 2009 | 2009 | 2028 | 2027 | 2027 | 2028 | 2028 | 2025 | 2025 | 2025 | 2025 | 2033 | 2033 | 2033 |
| Northampton | 2028 | 2027 | 2027 | 2027 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2036 |
| Northbridge | 2028 | 2022 | 2022 | 2028 | 2028 | 2028 | 2028 | 2022 | 2022 | 2016 | 2016 | 2030 | 2030 | 2035 |
| Norwood | 1999 | 2000 | 2001 | 2027 | 2027 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2030 | 2030 |
| Peabody | 2017 | 2014 | 2017 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2030 | 2030 | 2036 |
| Pittsfield | 2026 | 2026 | 2026 | 2028 | 2028 | 2028 | 2028 | 2028 | 2025 | 2025 | 2030 | 2036 | 2036 | 2036 |
| Plymouth | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2022 | 2022 | 2022 | 2027 | 2027 | 2027 |
| Plymouth County | 2027 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2026 | 2025 | 2025 | 2025 | 2029 | 2030 | 2030 |
| Quincy | 2023 | 2023 | 2019 | 2019 | 2028 | 2028 | 2028 | 2028 | 2023 | 2023 | 2023 | 2040 | 2040 | 2040 |
| Reading | 2026 | 2026 | 2021 | 2021 | 2026 | 2026 | 2026 | 2026 | 2024 | 2024 | 2028 | 2028 | 2030 | 2030 |
| Revere | 2019 | 2019 | 2019 | 2019 | 2019 | 2023 | 2023 | 2025 | 2025 | 2023 | 2023 | 2023 | 2027 | 2027 |
| Salem | 2027 | 2027 | 2024 | 2024 | 2024 | 2024 | 2024 | 2025 | 2025 | 2025 | 2025 | 2030 | 2030 | 2032 |
| Saugus | 2020 | 2020 | 2020 | 2020 | 2028 | 2028 | 2028 | 2028 | 2022 | 2022 | 2027 | 2027 | 2024 | 2024 |
| Shrewsbury | 2007 | 2002 | 2002 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 |
| Somerville | 2023 | 2023 | 2023 | 2023 | 2023 | 2025 | 2025 | 2025 | 2022 | 2022 | 2026 | 2026 | 2035 | 2035 |
| Southbridge | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2040 | 2040 | 2038 |
| Springfield | 2023 | 2024 | 2024 | 2024 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2039 | 2039 | 2037 |
| Stoneham | 2015 | 2015 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2023 | 2023 | 2023 | 2023 |
| Swampscott | 2024 | 2021 | 2021 | 2026 | 2026 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2034 | 2030 | 2030 |
| Taunton | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2022 | 2022 | 2020 | 2022 | 2023 | 2023 | 2030 |
| Wakefield | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2023 | 2023 | 2038 | 2038 | 2038 |
| Waltham | 2012 | 2012 | 2012 | 2017 | 2017 | 2026 | 2026 | 2026 | 2027 | 2019 | 2019 | 2032 | 2031 | 2031 |
| Watertown | 2013 | 2013 | 2013 | 2015 | 2015 | 2019 | 2019 | 2019 | 2017 | 2017 | 2022 | 2022 | 2022 | 2022 |
| Webster | 2028 | 2028 | 2028 | 2026 | 2026 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2027 | 2027 | 2029 |
| Wellesley | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2030 | 2030 | 2030 | 2030 |
| West Springfield | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2026 | 2026 | 2026 | 2030 | 2030 | 2035 |
| Westfield | 2028 | 2028 | 2028 | 2028 | 2028 | 2028 | 2024 | 2024 | 2024 | 2024 | 2024 | 2024 | 2032 | 2032 |
| Weymouth | 2028 | 2028 | 2021 | 2021 | 2028 | 2028 | 2023 | 2023 | 2021 | 2021 | 2021 | 2030 | 2030 | 2035 |
| Winchester | 2013 | 2013 | 2015 | 2015 | 2028 | 2028 | 2028 | 2028 | 2021 | 2021 | 2030 | 2030 | 2021 | 2021 |
| Winthrop | 2013 | 2013 | 2014 | 2014 | 2019 | 2019 | 2021 | 2021 | 2019 | 2019 | 2028 | 2028 | 2023 | 2023 |
| Woburn | 2017 | 2011 | 2011 | 2011 | 2011 | 2011 | 2026 | 2026 | 2022 | 2022 | 2022 | 2035 | 2035 | 2035 |
| Worcester | 2008 | 2000 | 2001 | 2028 | 2028 | 2025 | 2023 | 2023 | 2023 | 2019 | 2030 | 2040 | 2035 | 2035 |
| Worcester County | 2028 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2026 | 2028 | 2028 | 2028 | 2040 | 2040 | 2040 |

# Appendix II. Analytical Derivations for Opportunity-Cost Metrics

This appendix presents the algebraic derivations of various methods for offsetting deferred payments and for estimating the associated actuarial costs.

Let there be a financial plan with some initial deferred contribution $A_0$, whereas:

- time is divided into equally long periods denoted by $t$;
- each plan has $T \in \mathrm{N}$ periods;
- $r$ is the **periodic net rate of return** on the plan portfolio;
- $R$ is the **periodic gross rate of return** on the plan portfolio;
- $a_t$ is the **cash contribution** to the investment plan at end of period $t$;
- $F_t$ is the **future value** of a portfolio at the end of period $t$;
- $\eta$ is the **nominal interest cost** of deferral;
- $\lambda$ is the **liquidity conversion ratio**.

### A. Lump-Sum Offset and Nominal Interest Cost

If $n$ is the lifetime of the asset in periods, the future actuarial value $F_n$ on an initial investment $A_0$ is given by:

$$F_n(A_0; \tilde{r}) = A_0 \tilde{R}^n = A_0(1+\tilde{r})^n$$

The ratio of the future value and the initial investment amount is the *expected cumulative gross return factor* on a dollar of funding over its lifetime $n$:

$$C(\tilde{r}, n) \equiv \frac{F_n}{A_0} = \tilde{R}^n = (1+\tilde{r})^n$$

For a retirement plan, multiplying this factor by an amount $A_0$ deferred over $n$ periods produces an actuarial estimate of the necessary **lump-sum offsetting contribution** at the end of the deferral period.

The **cumulative net return** on any amount invested $A_0$ equals:

$$F_n - A_0 = A_0\tilde{R}^n - A_0 = A_0\left(\tilde{R}^n - 1\right) = A_0((1+\tilde{r})^n - 1) = A_0(C(\tilde{r}, n) - 1)$$

Dividing by the initial investment produces the **cumulative net return factor** for each dollar of investment:

$$c(\tilde{r}, n) \equiv \frac{F_n - A_0}{A_0} = \tilde{R}^n - 1 = (1+\tilde{r})^n - 1 = C(\tilde{r}, n) - 1$$

The **nominal interest cost** of the deferral is then $\eta(A_0; \tilde{r}, n) \equiv F_n - A_0 = A_0 c(\tilde{r}, n)$.
The liquidity conversion ratio equals the needed future value divided by the money presently deferred:

$$\lambda_0(\tilde{r}, n) \equiv \frac{F_n}{A_0} = C(\tilde{r}, n) = (1+\tilde{r})^n$$

This equation can be formalized as:

**Proposition 1.** When a deferred payment is offset by a lump sum contributed at the end of the deferral, the liquidity conversion ratio equals the cumulative gross return factor over the period of deferral.

### B. Level-Dollar Offset Schedule and Nominal Interest Cost

After a deferral of $n$ periods out of an $m$-period funding schedule,[27] the subsequent level-dollar amortizations $a$ of the deferred liability must produce some target future value over the remaining $m - n$ periods, which should equal the lump-sum offset appreciated at the same ARR:

$$a\tilde{R}^{n-m-1} + a\tilde{R}^{n-m-2} + \cdots a\tilde{R} + a = a\sum_{t=1}^{n-m} \tilde{R}^{t-1} = a\sum_{t=1}^{n-m} C(\tilde{r}, t-1)$$

$$A_0 C(\tilde{r}, n) C(\tilde{r}, m-n) = A_0 C(\tilde{r}, m) = \sum_{t=1}^{m-n} a(1+\tilde{r})^{t-1} = a\sum_{t=1}^{m-n} C(\tilde{r}, t-1)$$

Hence, the **level-dollar amortization** is given by:

$$a(A_0; \tilde{r}, m, n) = \frac{A_0 C(\tilde{r}, m)}{\sum_{t=1}^{m-n} C(\tilde{r}, t-1)} = \frac{A_0 (1+\tilde{r})^m}{\sum_{t=1}^{m-n} (1+\tilde{r})^{t-1}}$$

The **liquidity conversion ratio** on the level-dollar amortization schedule is given by:

$$\lambda_l(\tilde{r}, m, n) \equiv \frac{(m-n) a(A_0; \tilde{r}, m, n)}{A_0} = \frac{(m-n)(1+\tilde{r})^m}{\sum_{t=1}^{m-n} (1+\tilde{r})^{t-1}}$$

Note that the lump-sum offset is just a special case of the level-dollar one because when $a$ is a singleton:

$$\lambda_l(\tilde{r}, m, n) = \lambda_l(\tilde{r}, m, m-1) = \frac{(m-m+1) a(A_0; \tilde{r}, m, m-1)}{A_0} = (1+\tilde{r})^m = \lambda_0(\tilde{r}, m)$$

The level-dollar **nominal interest cost** is:

$$\eta(A_0; \tilde{r}, m, n) = (m-n) a(\tilde{r}, m, n) - A_0 = A_0 \lambda_l(\tilde{r}, m, n) - A_0 = A_0(\lambda_l(\tilde{r}, m, n) - 1)$$

This result can be generalized further in the following:

**Proposition 2.** For any deferred payment $A_0 \neq 0$, the nominal interest cost equals the deferred payment multiplied by one less than the liquidity cost ratio: $\eta = A_0(\lambda - 1)$.

*Proof:* $\eta \equiv \sum_k a_k - A_0 \Rightarrow \frac{\eta}{A_0} = \frac{\sum_k a_k}{A_0} - 1 = \lambda - 1$. Hence $\eta = A_0(\lambda - 1)$.■

### C. Rising Offset Schedule and Nominal Interest Cost

If $s$ is the steepness of the amortization schedule (i.e., the annual percentage increase of the amortization relative to the prior year) and the first amortization payment is denoted by $a_1$, the $k$th payment is computed as $a_k = a_1 (1+s)^{k-1}$, where $k \in [1, m-n] \in \mathbb{N}$. Equating the sum of cumulative gross returns on those payments to the target future value $A_0 C(\tilde{r}, m)$ as in the prior paragraph renders:

$$F_m = \sum_{t=1}^{m-n} a_1 (1+s)^{t-1} (1+\tilde{r})^{m-n-t} = a_1 \sum_{t=1}^{m-n} C(s, t-1) C(\tilde{r}, m-n-t) = A_0 C(\tilde{r}, m)$$

The first payment can then be produced using the last equality from above:

$$a_1(A_0;\tilde{r},m,n,s)=\frac{A_0C(\tilde{r},m)}{\sum_{t=1}^{m-n}C(s,t-1)C(\tilde{r},m-n-t)}=\frac{A_0(1+\tilde{r})^m}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}$$

Then for the *k*th payment more generally:

$$a_k(A_0;\tilde{r},m,n,s)=\frac{A_0C(\tilde{r},m)C(s,k-1)}{\sum_{t=1}^{m-n}C(s,t-1)C(\tilde{r},m-n-t)}=\frac{A_0(1+\tilde{r})^m(1+s)^{k-1}}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}$$

Note that $a_1(\tilde{r},\ m,\ n,0)=a(\tilde{r},\ m,\ n)$ for any admissible $\tilde{r},\ m,\ n$ – exactly as would be expected from a practical perspective; the level-dollar method is just a special case of the rising-schedule method.

The corresponding liquidity conversion ratio is given by:

$$\lambda_s(\tilde{r},m,n,s)=\frac{\sum_{k=1}^{m-n}a_k}{A_0}=\frac{1}{A_0}\sum_{k=1}^{m-n}\frac{A_0(1+\tilde{r})^m(1+s)^{k-1}}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}=$$
$$=\frac{(1+\tilde{r})^m}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}\sum_{k=1}^{m-n}(1+s)^{k-1}$$

**Proposition 3.** For any admissible $n,s\geq 0$, $m>n$ and $\tilde{r}>0$, $\lambda_s>1$.

*Proof:*

$$\lambda_s(\tilde{r},m,n,s)=\frac{(1+\tilde{r})^m}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}\sum_{k=1}^{m-n}(1+s)^{k-1}=\frac{\sum_{k=1}^{m-n}(1+s)^{k-1}(1+\tilde{r})^m}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}=$$
$$=\frac{\sum_{q=1}^{m-n}(1+s)^{q-1}(1+\tilde{r})^m}{\sum_{q=1}^{m-n}\ (1+s)^{q-1}(1+\tilde{r})^{m-n-q}}$$

Compare the $m-n$ summands in the numerator of the type $(1+s)^{q-1}\,(1+\tilde{r})^m$ and in the denominator of the type $(1+s)^{q-1}\,(1+\tilde{r})^{m-n-q}$

a) Since $s\geq 0$ by construction, $\forall q\in \mathrm{R}:(1+s)^{q-1}>0$.

b) Since $n\geq 0$ and $q\geq 1$ by construction, $m>m-n-q$, but $\tilde{r}>0\Longrightarrow(1+\tilde{r})^m>(1+\tilde{r})^{m-n-q}$.

From (a) and (b), each summand in the numerator must be larger than the corresponding summand in the denominator, therefore the numerator is strictly larger than the denominator and thus $\lambda>1$. ■

Again, $\lambda_s(\tilde{r},\ m,\ n,\ 0)=\lambda_l(\tilde{r},\ m,\ n)$ for any admissible $\tilde{r},\ m,\ n$.

Using Proposition 2, the interest cost must then be:

$$\eta(A_0;\tilde{r},m,n,s)=A_0(\lambda_s(\tilde{r},m,n,s)-1)=\frac{A_0(1+\tilde{r})^m}{\sum_{t=1}^{m-n}\ (1+s)^{t-1}(1+\tilde{r})^{m-n-t}}\sum_{k=1}^{m-n}(1+s)^{k-1}-A_0$$

**Proposition 4.** For any admissible $n$, $s > 0$, $m > n$ and $A_0$, $\tilde{r} \gg 0$, $\eta(A_0;\tilde{r}; m, n, s) > 0$.

*Proof:* By Proposition 2, $\eta = A_0\,(\lambda - 1)$, but $\lambda > 1$ by Proposition 3 and therefore $\eta > 0$ as long as $A_0 > 0$. ■

## Appendix III. Estimation Methods for Annual UAAL Amortizations

Since the specific UAAL amortization component of the appropriations for every board-year was not publicly available, it was necessary to impute it based on other available data. If $\tilde{r}_0$ is the ARR in the year of the estimate, $U_0$ is the unfunded liability and $n$ is the total number of years remaining until the funding deadline, the future value $F_n$ that needs to be covered can be represented as:

$$F_n = U_0(1 + \tilde{r}_0)^n$$

Obviously, some of the liabilities would come due before the funding deadline, but for lack of more detailed data, it is necessary to equate the duration of the liability and the funding schedule. This assumption is fairly reasonable since most systems are expected to continue growing so that newly earned benefits would gradually extend the overall duration of the fund.

The target future value must equal the sum of all annual amortizations appreciated at the corresponding ARR and rising at the rate of increase of the board's funding schedule. If $\pi$ is the base (first) payment for the schedule, and $s$ is the annual increase of the amortization payments, then:

$$F_n = \sum_{t=1}^{n} \pi(1+s)^{t-1}(1+\tilde{r})^{n-t}$$

Thus, it is possible to estimate the initial payment $\pi$:

$$\pi = \frac{U_0(1+\tilde{r})^n}{\sum_{t=1}^{n}(1+s)^{t-1}(1+\tilde{r})^{n-t}} = \frac{U_0}{\sum_{t=1}^{n}(1+s)^{t-1}(1+\tilde{r})^{-t}}$$

This method assumes that (1) all payments are made at yearend and invested immediately; (2) the annual amortization value rises at the annual rate of increase of the total appropriation; and (3) the duration of the liabilities is equal to the duration of the funding schedule. A comparison to actuarial data from PERAC shows that the estimates are very close to actuarially determined figures after the impact of outsized investment returns is considered.

In practice, adjustments to the funding schedule require time to observe, estimate and budget. A retirement fund would need time after yearend to obtain the net value of its ending portfolio, project whether an adjustment is necessary and finally budget any extra amounts needed to paid towards the UAAL. For example, the 2009 closing value of the portfolio would be observable in 2010 and appropriate budget adjustments would not take place until the beginning of the next fiscal year. Thus, in constructing the two alternate funding schedules for the state and teacher's systems, it was assumed they would begin in 2011 and last for 15 and 30 periods, respectively, for the baseline and for the extended schedule.

To simplify the calculation and make it more transparent, no intermediate adjustments were made for investment returns and changes of book value and of total liabilities in the four fiscal years since 2010.

## Endnotes

1. This paper does not deal with the pension funding of the MBTA, whose retirement plans are not subject to 32 MGL, which governs public pensions in the commonwealth, and were underfunded by over $725mn as of yearend 2011.
2. Hereafter, these two will be referred to as the "commonwealth" boards.
3. 2010 St. 188, which extended the funding deadlines, also amended 32 MGL § 102 to increase the COLA base from $12,000 to $13,000 for the commonwealth boards and for those boards that want to fund through 2040.
4. The statute allows some exceptions - ramping up their funding at up to 8% for the first 3-5 years - for boards in particularly troubled financial condition, but those account for a minute fraction of total assets and liabilities in Massachusetts systems.
5. The terms ARR and discount rate are used interchangeably for the purposes of this study, unless otherwise noted, even though they may not always be equivalent in actuarial practice.
6. Atanasov, Iliya. *The Fiscal Implications of Massachusetts Retirement Boards' Investment Returns*. Pioneer Institute White Paper No. 90. Boston, MA: 2012.
7. All data are sourced from PERAC unless otherwise noted. The fully funded boards each year are counted as fully funded by 2015. Visit MassPensions.com to track each board's funding deadlines over time.
8. The Minuteman Regional School District's, which was fully funded, and Leominster.
9. The Massachusetts Turnpike Authority Retirement System was merged into the State Employees' Retirement System with the abolition of the authority in 2009.
10. Visit MassPensions.com for a breakdown of funded levels by the boards' own actuarial estimates.
11. The monetary expansion that has driven asset prices up since the last financial crisis cannot last indefinitely.
12. Observe that the agency boards have been close to fully funded or even overfunded throughout the past decade, thus their payments were quite reasonably likely to decrease often during the period under examination.
13. Atanasov 2012.
14. See Appendix II for a formal proof of this proposition.
15. Tax implications are ignored for the purposes of this example; generally, they do not affect government contributions to public-employee retirement plans such as those in Massachusetts.
16. See Appendix II for analytical derivations of these results.
17. For a complete mathematical derivation of the measures utilized in this section, please refer to Appendix II.
18. The impact of inflation is ignored under the assumption that benefits should be more or less protected from rising price levels and maintain the same real value.

19. See Appendix II for a more detailed discussion of cost metrics.
20. As part of the changes, the state also switched from a 4.5% to 4% amortization increase for both systems, which is also taken into account in the estimates. The exact estimation algorithm is available in Appendix III.
21. See Appendix III for further details on the estimation methods.
22. Numbers may not add exactly due to rounding.
23. Estimated; does not include normal cost.
24. Estimated on $34 billion budget for FY 2014 with 3% projected annual growth.
25. As of yearend 2012, the ARR was lowered to 8%. While the schedules are projected on the then-current 8.25% ARR of 2009, future opportunity costs are computed with the most recent 8% ARR.
26. Estimate based on a 10-year compound interest of 8%; rounded.
27. All contributions are assumed to be made at the beginning of the period.

185 Devonshire Street, Suite 1101, Boston, MA 02110 Telephone: 617.723.2277 www.pioneerinstitute.org