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Plasm: Pension Liability and Asset Simulation Model

HOWARD E. WINKLEVOSS*

Introduction

THE MANAGEMENT OF A pension system involves making decisions regarding (1) the variety and level of benefits to be provided, (2) the manner in which such benefits will be financed, and (3) the investment of pension assets. Decisions in these three areas have not been coordinated for many pension plans. The personnel department generally establishes the benefit policy, the firm's consulting actuary usually formulates the funding policy, and the finance department tends to establish the investment policy. This type of fragmentation was not seen to be a serious problem during the early stages of most pension systems since costs, unfunded liabilities, and plan assets were relatively small. Today, however, the pension sector has become extremely important to many firms, creating the need for an analytical tool that allows decisions to be made in each of these three policy areas in a cohesive, integrated fashion.

In response to this need Winklevoss & Associates, in collaboration with Barr Rosenberg and Associates, developed PLASM—a Pension Liability and Asset Simulation Model. This model allows the user to study simultaneously the effects on plan costs and funded ratios of alternative decisions in each of the three pension policy areas. The model has been used extensively during the past three years, and during this short time some interesting results have been obtained. For example, one conclusion that might be of interest to readers of this paper is that an efficient asset mix, as measured outside the pension plan, may not be efficient for the pension plan, in as much as it may not generate the lowest variability in costs (or funded ratios) for a given expected level of costs (or funded ratios). Another example is that the higher the expected level of inflation, the more beneficial is the effect on certain financial statistics of the plan.

The purpose of this paper is to provide a brief overview of the design and capabilities of PLASM.

Overview of Plasm

PLASM is based on a Monte Carlo simulation of inflation and asset returns which, in turn, is used to produce a stochastic projection of a firm's payroll, pension costs, liabilities, and assets. The model operates in a time-sharing environment, and contains extensive prompting routines for input and output,

* Winklevoss & Associates, Inc.

providing considerable flexibility in the design of experiments and the analysis of results. In most cases the model can be parameterized based on information contained in a plan sponsor's actuarial report.

PLASM can be conceptualized as consisting of four basic sectors, in addition to the input and output routines:

- Deterministic Population Simulator
- Deterministic Liability Simulator
- Stochastic Inflation and Asset Return Simulator
- Stochastic Liability Simulator

A brief description of each sector is provided below.

Deterministic Population Simulator. PLASM simulates the membership of a pension plan on a year-by-year basis throughout a period of up to 20 years and stores each year's projected population on a computer file for later use. During this stage of operation, all calculations are made on a deterministic (or expected value) basis.

The population sector first determines the number of nonactive plan members who die each year, and then increases the ages of all survivors. In those cases where the plan provides ad hoc or automatic adjustments to benefits for inflation, the model likewise makes such adjustments.

Active employees are then exposed to various decrement rates in order to determine the number expected to die, become disabled, terminate, and retire during the year. The benefits associated with those active employees who become annuitants during the year, including beneficiaries of deceased employees, are calculated, and such individuals are placed in their respective nonactive membership categories. Employees who survive in active service are given an additional year of pension credit; their ages are increased by one year; and their salaries are increased by merit, inflation, and productivity assumptions.

Finally, PLASM's population simulator "hires" new employees each year to replace those decremented from active service. If the user specifies a growth rate (or a rate of decline) in the number of active employees, the number of employees hired is adjusted accordingly.

An illustration of the types of data produced in connection with a 20-year deterministic population simulation is given in Table I. Additional statistics can be obtained on various characteristics of active and nonactive plan members, if desired.

Deterministic Liability Simulator. The deterministic liability simulator performs an actuarial valuation on each future year's simulated plan membership in order to determine the annual contributions to the plan and related liabilities. In order to perform the actuarial valuations, PLASM makes use of the same assumptions and methods that a consulting actuary would use in performing an annual valuation of the plan. These include:

- *Actuarial Assumptions*: These include decrement assumptions, such as termination and retirement rates, and economic assumptions, such as interest and salary rates.
- *Normal Cost Method*: The method used to recognize pension costs attributable to active employees rendering service in the current year.

Table I

Forecast of Plan Membership for XYZ Corporation

	Active Plan Members			Plan Annuitants	
Year	Number	Average Age	Average Service	Number	Pct. of Actives
1980	1,424	40.80	12.21	302	21.21
1981	1,452	40.76	11.99	335	23.05
1982	1,481	40.85	11.89	362	24.42
1983	1,511	40.96	11.81	387	25.64
1984	1,541	41.08	11.76	412	26.71
1985	1,572	41.20	11.73	434	27.61
1986	1,603	41.03	11.45	468	29.18
1987	1.635	40.97	11.23	497	30.41
1988	1.668	40.93	11.05	525	31.47
1989	1,701	40.92	10.90	550	32.36
1990	1,735	40.93	10.78	574	33.06
1991	1,770	40.62	10.39	611	34.50
1992	1,805	40.42	10.06	643	35.65
1993	1,842	40.26	9.77	674	36.60
1994	1,878	40.13	9.53	703	37.45
1995	1,916	40.04	9.32	731	38.14
1996	1,954	39.85	9.03	764	39.11
1997	1,993	39.70	8.77	797	39.97
1998	2,033	39.58	8.56	828	40.71
1999	2,074	39.49	8.38	858	41.35
2000	2,115	39.40	8.20	888	41.99

- *Supplemental Cost Method*: The method used to recognize pension costs attributable to benefit credits granted for prior service that have not yet been funded.
- *Funding Actuarial Deviations*: The method used to recognize pension costs attributable to the experience of the plan deviating from the actuary's assumptions.
- *Asset Valuation Method*: The method used to smooth the market value of plan assets for valuation purposes.

In order to perform successive years' valuations, it is necessary to know the value of plan assets. Thus, during this stage of the model, plan assets are assumed to return a deterministic rate which is specified by the user and may vary by calendar year. This return on plan assets can be different from the interest rate used in the valuation of annual costs and liabilities. Similarly, the salary increases granted to employees in the population simulator may be different than the salary assumption used for valuation purposes. Thus, PLASM is designed to deal with a dual set of assumptions—one for simulating realistic asset returns and salary increases over time and one for use in the valuation of annual pension costs and liabilities. If the investment return or salary assumptions differ from those used in the annual valuations, the deterministic forecast will incorporate the emerging actuarial gains and losses.

An illustration of the types of data produced in connection with a 20-year deterministic liability simulation is given in Tables II and III. Pension contribu-

Table II

Financial Forecast for XYZ Corporation Forecast (Dollars in Thousands)

				Employer Contributions											
				Normal Cost		Initial Supplemental Cost		Future Supplemental Cost		Total Contributions		Investment Earnings		Benefit Payments	
Year	Active Members	Payroll	Assets at B.O.Y.	Dollars	Pct. of Pay	Dollars	Pct. of Pay	Dollars	Pct. of Pay	Dollars	Pct. of Pay	Dollars	Pct. of Pay	Dollars	Pct. of Pay
1980	1,424	29,658	38,126	1,502	5.07	2,153	7.26	0	.00	3,655	12.32	4,030	13.59	1,477	4.98
1981	1,452	33,422	44,335	1,769	5.29	2,153	6.44	299	.89	3,623	10.94	4,634	13.86	1,620	4.85
1982	1,481	37,745	50,972	2,053	5.44	2,153	5.70	144	.38	4,350	11.52	5,355	14.19	1,770	4.69
1983	1,511	42,473	58,908	2,365	5.57	1,821	4.29	318	.75	4,504	10.60	6,148	14.48	1,929	4.54
1984	1,541	47,646	67,632	2,709	5.69	1,821	3.82	377	.79	4,907	10.30	7,044	14.78	2,098	4.40
1985	1,572	53,309	77,486	3,086	5.79	1,821	3.42	535	1.00	5,442	10.21	8,051	15.10	2,413	4.53
1986	1,603	59,479	88,567	3,505	5.89	1,821	3.06	646	1.09	5,972	10.04	9,170	15.42	2,836	4.77
1987	1,635	66,246	100,874	3,970	5.99	1,821	2.75	756	1.14	6,547	9.88	10,416	15.72	3,262	4.92
1988	1,668	73,669	114,575	4,483	6.09	1,821	2.47	862	1.17	7,166	9.73	11,804	16.02	3,704	5.03
1989	1,701	81,811	129,841	5,047	6.17	1,811	2.21	963	1.18	7,821	9.56	13,350	16.32	4,161	5.09
1990	1,735	90,739	146,852	5,668	6.25	1,574	1.73	1,195	1.32	8,437	9.30	15,037	16.57	4,922	5.42
1991	1,770	100,444	165,404	6,356	6.33	1,574	1.57	1,268	1.26	9,198	9.16	16,874	16.80	5,865	5.84
1992	1,805	111,109	185,611	7,121	6.41	1,574	1.42	1,329	1.20	10,024	9.02	18,881	16.99	6,829	6.15
1993	1,842	122,818	207,687	7,964	6.48	1,574	1.28	1,368	1.11	10,906	8.88	21,077	17.16	7,825	6.37
1994	1,878	135,668	231,845	8,891	6.55	1,574	1.16	1,385	1.02	11,850	8.73	23,484	17.31	8,852	6.52
1995	1,916	149,764	258,328	9,912	6.62	1,574	1.05	1,473	.98	12,959	8.65	26,122	17.44	10,069	6.72
1996	1,954	165,119	287,340	11,019	6.67	1,574	.95	1,742	1.05	14,335	8.68	29,027	17.58	11,401	6.90
1997	1,993	181,966	319,302	12,238	6.73	1,574	.86	1,237	.68	15,049	8.27	32,157	17.67	12,780	7.02
1998	2,033	200,434	353,729	13,576	6.77	1,574	.79	968	.48	16,118	8.04	35,564	17.74	14,204	7.09
1999	2,074	220,670	391,208	15,046	6.82	1,574	.71	854	.39	17,474	7.92	39,290	17.80	15,783	7.15
2000	2,115	242,774	432,189	16,662	6.86	1,574	.65	205	.08	18,441	7.60	—	—	16,979	6.99

Table III

Funded Ratios Forecast for XYZ Corporation Forecast (Dollars in Thousands)

Year	Actuarial Value of Assets (1)	Actuarial Liability Dollars (2)	Actuarial Liability Funded Pct. (1) ÷ (2)	Plan Continuation Liability Dollars (3)	Plan Continuation Liability Funded Pct. (1) ÷ (3)	Market Value of Assets (4)	Plan Termination Liability Dollars (5)	Plan Termination Liability Funded Pct. (4) ÷ (5)	FASB-35 Liability Dollars (6)	FASB-35 Liability Funded Pct. (4) ÷ (6)
1980	35,599	60,305	59.03	36,575	97.3	38,126	32,165	118.5	34,798	109.6
1981	45,477	66,501	68.39	40,943	111.1	44,335	36,216	122.4	39,109	113.4
1982	48,639	73,492	66.18	45,944	105.9	50,972	40,830	124.8	43,994	115.9
1983	55,573	81,335	68.33	51,643	107.6	58,908	46,095	127.8	49,546	118.9
1984	64,393	90,138	71.44	58,158	110.7	67,632	52,120	129.8	55,882	121.0
1985	73,766	100,424	73.45	66,020	111.7	77,486	59,430	130.4	63,532	122.0
1986	84,306	111,291	75.75	74,277	113.5	88,567	67,253	131.7	71,612	123.7
1987	96,008	123,219	77.92	83,338	115.2	100,874	75,787	133.1	80,439	125.4
1988	109,034	136,324	79.98	93,318	116.8	114,575	85,150	134.6	90,129	127.1
1989	123,548	150,762	81.95	104,367	118.4	129,841	95,476	136.0	100,831	128.8
1990	139,721	168,070	83.13	118,027	118.4	146,852	108,290	135.6	114,088	128.7
1991	157,349	185,323	84.91	131,229	119.9	165,404	120,877	136.8	126,977	130.3
1992	176,542	203,915	86.58	145,179	121.6	185,611	134,104	138.4	140,563	132.0
1993	197,511	223,959	88.19	159,926	123.5	207,687	148,030	140.3	154,905	134.1
1994	220,459	245,657	89.74	175,593	125.6	231,845	162,772	142.4	170,132	136.3
1995	245,618	270,182	90.91	193,271	127.1	258,328	179,415	144.0	187,345	137.9
1996	273,180	295,789	92.36	211,050	129.4	287,340	196,226	146.4	204,710	140.4
1997	303,549	323,472	93.84	229,739	132.1	319,302	213,846	149.3	222,971	143.2
1998	336,241	353,513	95.11	249,472	134.8	353,729	232,402	152.2	242,270	146.0
1999	371,832	386,960	96.09	271,142	137.1	391,208	252,773	154.8	263,512	148.5
2000	410,756	419,357	97.65	290,071	141.6	432,189	270,405	159.8	282,090	153.2

tions in Table II are partitioned into normal costs and supplemental costs, with the latter further divided into the supplemental costs associated with the initial unfunded liability of the plan, and the supplemental costs associated with actuarial gains and losses that develop during the simulation. As shown in Table III, PLASM develops several liability measures to monitor the plan's asset accumulation.

Stochastic Inflation and Asset Return Simulator. The asset simulator developed by Barr Rosenberg and Associates is based on a Monte Carlo simulation of inflation and the following seven asset categories:

- Equities
- Treasury Bills
- Government Bonds
- Corporate Bonds
- Mortgages
- Real Estate Equities
- Foreign Securities

The asset simulator generates returns for these asset categories *jointly* with future expected and unexpected inflation. Investment returns and inflation exposure of investment strategies follow from this.

The first sector of the simulator develops returns on treasury bills and bonds. The model is based on the past relationship of the term structure of forward rates to inflation over the period from 1952 to 1978. Consistent with this historical experience, future values for promised yields and realized returns on short, intermediate, and long bonds are simulated. Expected and unexpected (surprise) inflation is also simulated. Short and long rates on treasury securities, the latter being more important, determine expected inflation. Random or unexpected inflation, in turn, is an important determinant of the changing interest rates and consequent returns on government bonds. The updated forward rate structure is the basis for the expected future inflation.

The second sector of the simulator develops the return on corporate assets: bonds and equities. Research has shown that it is more appropriate to model these as two elements of a single construct—the long term liabilities of the corporate sector or corporate aggregate (CA) portfolio. Changes in the leverage of the corporate sector, such as the explosive growth in bonded debt over the past decade, alter the rewards and risks from bonds and equities. This is clearly seen in the historical record, and is supported by an understanding of the fundamentals of capital structure: when leverage increases, both bond and equity risk increase.

The model forecasts risk and reward for the corporate aggregate portfolio as a function of unexpected inflation, government bond returns, and other factors. Unexpected inflation is an important determinant, for it has explained almost one half of the variance of CA returns since 1952.

The return on corporate bonds is then derived. It is influenced by government bond returns (interest rate risk) and return to the CA portfolio (default risk). The residual, after subtraction of bonded debt value, is the value of equity and determines the return on equity. The leverage in the corporate sector is also modeled through a behavioral equation which predicts new issue of debt and equity as a function of the past performance of these two categories.

The simulator also develops returns on foreign equity, represented by the Capital International Europe, Far East and Australia Index. Investor returns in dollars from international assets have co-varied strongly with domestic events: foreign asset returns are positively related to domestic equity returns and negatively related with the return on long treasury bonds.

Finally, the simulator deals with real estate. As with corporate assets, the aggregate return is first modeled and then decomposed into mortgage return and the residual accruing to equity holders.

In summary, the model provides a complete framework for the returns on seven asset categories, together with expected and actual inflation. Parameters of the model allow the user to set expected reward, variance, correlation, and inflation exposure for all asset categories. The model also uses parameters characterizing the sector exposure of each portfolio asset (such parameters include alpha, beta, and bond portfolio duration). The user may modify these parameters selectively to reflect his judgement. The model (as modified) first computes the approximate mean, variance, and inflation exposure of return on any investment strategy, and then develops the exact distribution of these in the simulation process. The user can review the approximate characteristics, before entering the simulation, to consider respecifying the investment strategy.

Stochastic Liability Simulator. The fourth major sector of PLASM integrates the results of the previous sectors to produce a stochastic forecast of a firm's payroll, pension costs, assets, and liabilities. First, the inflation and asset simulator sector is directed to generate up to 300 trials of inflation rates and asset returns over a period of up to 20 years. These trials are then successively applied to the deterministic forecast, transforming it into a stochastic process.

Transforming the deterministic returns on plan assets which were used in the deterministic liability simulator into stochastic returns, and determining the corresponding actuarial gains and losses, is a relatively straightforward process. Developing stochastic pension liabilities as a function of stochastic inflation, on the other hand, is somewhat complex and requires extensive computations. The salary and benefit payments of active and nonactive plan members must be recalculated for each trial of the simulation in order to capture the resulting actuarial gains and losses. Combining these gains and losses with those developed through stochastic asset returns produces the final stochastic forecast. Thus, PLASM forecasts reflect the results attributable to the interdependencies of asset *and* pension plan liability movements.

Illustrations of the types of output that can be developed by PLASM are shown in the accompanying figures. Figure 1 shows the results of adopting one investment policy, consisting of 80% equities and 20% corporate bonds, on the distribution of pension contributions during a 15 year period. Figure 2 shows the corresponding funding percentages for the plan, based on the actuarial liability under the funding method in use. In each case, the 10th, 30th, 50th, 70th and 90th percentiles are plotted. The use of the model, however, often involves the comparison of simulations under different policy decisions and/or capital market parameters. The following section provides an overview of the types of parameters that can be studied when running PLASM.

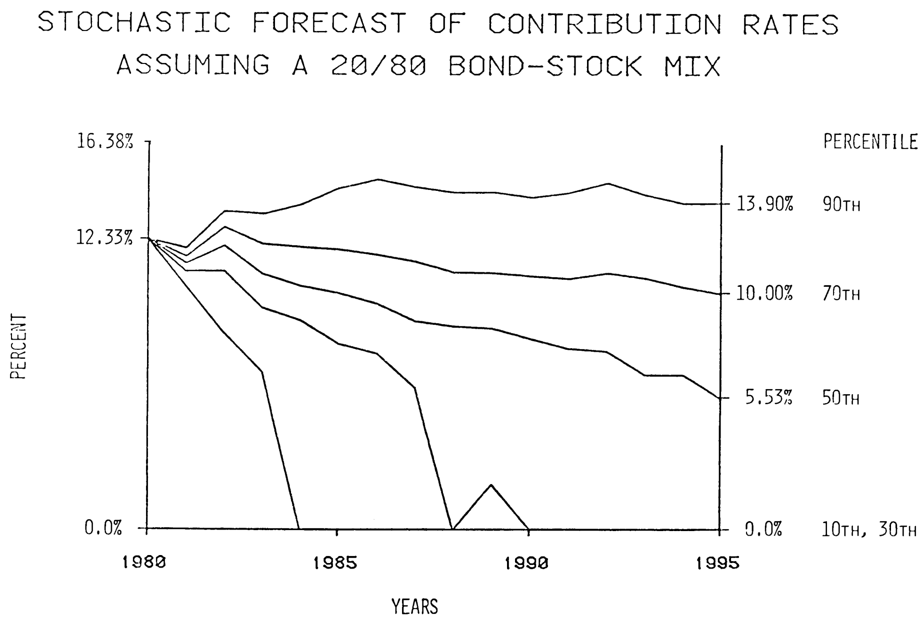

Figure 1

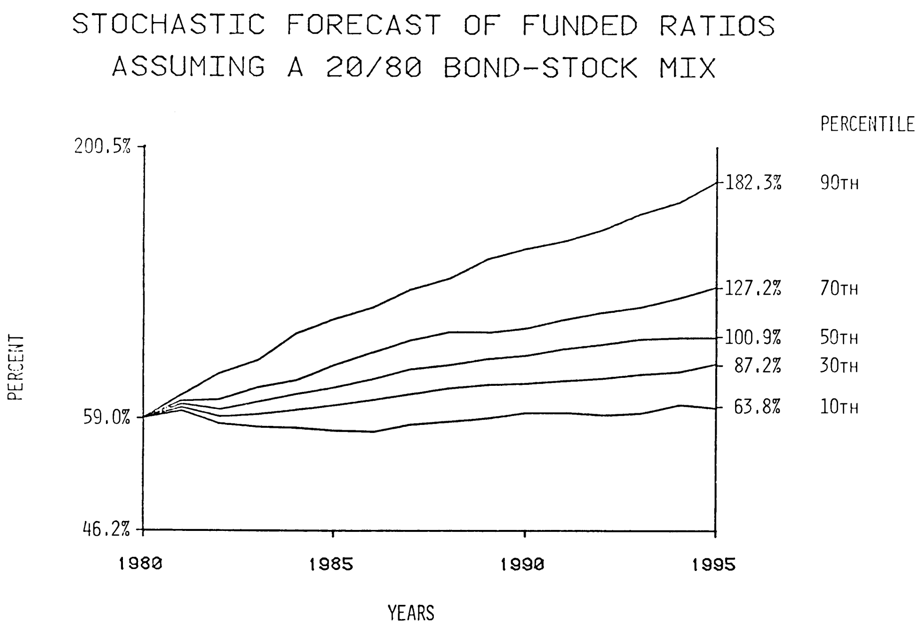

Figure 2

Plasm Capabilities

As noted below, PLASM can illustrate the effects of simultaneous policy changes in areas of investment, funding, and benefit design.

Investment Policy Decision Parameters

- *Asset Allocation*: An unlimited number of asset mixes can be specified for up to seven classes of assets.
- *Level of Active Management*: The alpha and residual risk of each asset class in the portfolio can be specified.
- *Portfolio Characteristics*: The portfolio characteristics can be described by adjusting the beta and/or duration of each asset category.
- *Capital Market Assumptions*: The volatility, expected real return, and inflation hedge properties of the asset classes can be modified in order to examine the sensitivity of simulated policy outcomes to these attributes.

Funding policy Decision Parameters

- *Funding Benchmark*: Any one of a number of liability measures can be used to monitor the accumulation of plan assets.
- *Actuarial Assumptions*: All of the actuarial assumptions used to determine annual costs and liabilities in the actuarial valuation process can be changed from those that are currently used with the plan. These include:
  - Valuation interest rate
  - Non-merit salary increase components (i.e., inflation and productivity)
  - Salary increase due to merit
  - Parameters for estimating future Social Security benefits and/or taxable wage bases
  - Size of each future year's active population
  - Rate of increase in retirement benefits after retirement
  - Mortality rates
  - Termination rates
  - Retirement rates
  - Disability rates
- *Asset Valuation Method*: Any of the traditional types of asset valuation procedures used to smooth the market value of assets can be simulated.
- *Funding of Actuarial Deviations*: Any of the generally used methods can be specified. The correct treatment of actuarial gains and losses is critical in stochastic simulations because the effects of random fluctuations in salaries and plan assets impact on costs through the funding of such deviations.
- *Normal Cost Method*: The method currently used to determine the plan's normal cost can be changed to any of the methods found in practice.
- *Supplemental Cost Method*: The method currently used to amortize the plan's unfunded liability can be changed to any of the methods found in practice and different amortization methods can be established for different portions of the unfunded liability.

Benefit Policy Decision Parameters

- *Benefit Formula*: The retirement benefit formula can be changed and may include formulas that are integrated with Social Security benefits on a step rate and offset basis.

- *Eligibility Requirements*: The eligibility requirements for retirement, disability, termination, and survivor benefits can be altered.
- *Retirement Incentives*: The level of benefits payable at early and late retirement can be changed.
- *COLA Provisions*: Ad hoc benefit increases, or the introduction of an automatic COLA, can be specified.

Summary

As with any model, there is no substitute for common sense in the design of experiments and in the interpretation of results. As for pension management, the interaction of plan benefit policies, funding policies, investment policies, and capital markets is so complex that one is virtually forced to use a computer simulation model to organize the likely impact of various policy alternatives in conjunction with the variability of future capital markets in order to formulate a rational, integrated set of pension decisions. PLASM has been found to be an extremely powerful educational tool for management and often demonstrates an optimal set of decisions that differ substantially from management's current practices.

The model is available to plan sponsors and the consulting community through a subscription with Winklevoss & Associates, Inc.