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Calculating the Present Value of Expected Future Medical Damages

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Associate Editor's Note

This article is a first in a series of *Litigation Economics Review* articles under the Associate Editorship category of computer software, data sources and sites on the Internet of interest to litigation economists. This article examines how litigation economists work with the life table/life expectancy data source and how to take advantage of computer software to make calculations of the present value of expected future medical damages. In the appendix to this article is a set of computer macro programs written in Visual Basic® for Applications. At the Internet site http://JohnWardEconomics.com/Medical/ is a Microsoft Excel® workbook containing those macro programs and a complete working spreadsheet model to demonstrate to the reader the power of harnessing function macros to make these sorts of calculations. In future articles that appear under this *LER* Associate Editorship category, we hope to bring to readers other similar articles that take various concepts or methods used in litigation economics and show the reader various data sources or computer software addressing their usage. We encourage anyone with suggestions of relevant computer software, data sources, or Internet sites to send an email to Krueger@JohnWardEconomics.com.

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In order to calculate the present value of a plaintiff's expected future medical damages, a litigation economist needs: (1) a life care plan specifying, at each future consumption date, the current-dollar costs of required medical care items; (2) the expected value of future price growth to inflate current-dollar medical item costs and an appropriate interest rate to calculate present value; and, (3) the expected survival conditions that the plaintiff will be alive in the future and consuming the required medical care items. In some cases, medical testimony will specify the survival condition. For example, a physician might testify that he or she expects it likely that the plaintiff will live 10 additional years. However, in most cases, litigation economists incorporate information from statistical survival models in order to figure the present value of expected future medical damages (hereafter abbreviated as *PVM*). In this article, we discuss the ways in which litigation economists use the results from survival models presented as life tables to calculate *PVM*.

Survival models recognize the continuous risk of death. Litigation economists generally utilize one of the following two risk of death measures when figuring *PVM*: (1) they use life tables that present the number of survivors within a specific population cohort by single-years-of-age beginning at age 0 proceeding to an asymptotic position near zero at an advanced age when the cohort is essentially exhausted

(the "*life table*" method)[1], or (2) they use life expectancy statistics calculated from life tables (the "*life expectancy*" approach). The *life table* method sets up a continuous mortality risk affecting *PVM* from the day after the last known survival date through an advanced age while the *life expectancy* approach results in a single, discrete age/time interval for certain survival and the occurrence of life care items/costs. If neither cost growth nor the time value of money are important in the calculation of medical damages and all life care costs are continuously required from the last known survival date through the end of life, there is only a small difference in *PVM* resulting from analyses using the *life table* method or the *life expectancy* approach. However, two situations (either together or separately) arise that will always make *PVM* from the *life table* method and *life expectancy* approach significantly diverge: (1) cost growth and/or the time value of money are important, and (2) medical items are consumed within discrete usage periods beginning after today and/or ending before the estimated terminal time of life.

In this article, we show the reasons why *PVM* are different under the *life table* method and the *life expectancy* approach. The information presented in this article does not cover the topic of determining the content of the life table that is most relevant to determine the expected length of the plaintiff's life; in this article, we require that, *a priori* to the calculation of *PVM*, an appropriate single-age life table relevant for the plaintiff has been assumed, discovered or calculated.[2] We also require in this article that the use of life tables or life expectancy calculated from life tables is the preferred choice of evaluation.[3] We demonstrate in the article that the life expectancy statistic is the sum of future mid-age survival probabilities from each exact age in the life table through the ending age in the life table. Therefore, calculating *PVM* with the *life expectancy* approach will always be inaccurate within the mathematics of the survival model. Since the inaccuracy of the *life expectancy* approach is mathematical, we encourage that litigation economists sparingly use the *life expectancy* approach to calculate *PVM* or use it side-by-side with the *life table* method to calculate *PVM* to show others the associated problems with the *life expectancy* approach and why the *life table* method of calculating *PVM* is preferred.

The *life table* method requires many calculations to determine survival and present value from today until each consumption date of each medical item in the life care plan. Within this article, we show a series of electronic spreadsheet function macros to simplify the litigation economist's work when performing *life table* method (and comparative *life expectancy* approach) *PVM* calculations. By setting growth and discount rates equal to zero, these same macros are also usable by life care planners who wish to calculate the expected current-dollar cost of their life care plans.

We start the article with an overview of the structure of the life table, survival model. We then show that *PVMs* differ when using the *life table* method and the *life expectancy* approach. Next in the article, we present the spreadsheet function macros that make the repetitive task of calculating risks of survival and *PVM* simple, quick, and accurate. In conclusion, we comment on the general uses of risk of death calculations in calculating and presenting *PVM*.

Quantifying the continuous risk of death

Everyone shares the lifetime event of death. Although theoretical probability models of mortality are based in a time frame where extremely advanced ages can be possible, most statistical estimates of mortality set the risk of survival nearly equal to zero by some advanced age (e.g., age 120).[4]

Life tables present statistical evidence of the mortality experience of a population.[5] Complete life tables are standardized with a beginning cohort size of live births, for example 100,000, and they present estimates of the number of survivors, l_x, from the original cohort of 100,000 births who will survive to the exact single-year age, x. The number of survivors at each age, l_x, is derived from a calculation of the probability of death, q_x, determined from actual mortality data recorded during the calendar year(s) studied.

After the first year of life, the conventional life table, survival model generalizes q_x by making an important assumption that l_x declines linearly from exact age x until age x+1.[6] For example, death between exact age x and x+1 will occur on average at age x+½. With the linearity of death assumption, the representation of l_x at exact single-year ages x can be expanded as follows:

(1) $\quad l_x = L_x + ½d_x,$

where, L_x is the average life table population at risk of dying between ages x and x+1 (the stationary population) and d_x is the death hazard (or, the number dying within age x to age x+1). The probability of death between ages x and x+1, q_x, is simply a ratio of the death hazard, d_x, to the number of survivors at any age, l_x. We can represent the probability of death as:

$$(2) \qquad q_x = \frac{d_x}{l_x} = \frac{d_x}{L_x + ½ d_x}.$$

To empirically estimate q_x, we can find N_x, the size of the population aged x in which every member has a chance of dying before reaching x+1, by demographically surveying to find the mid-year population, P_x (the *average* size of the observed living population from age x until age x+1) and the recorded number of deaths of persons from age x until x+1, D_x, occurring in our observation year(s). Substituting our

[1] There are several ways of delineating life tables besides age (e.g. years since the onset of disease) without significant difference in theory, estimation, or usage. In this article, for convenience of presentation, we refer to the conventional life table method that delineates an entire population by single-years of age.

[2] Note that it is not enough to have a life expectancy statistic because an infinite number of survival functions can generate the same numeric value for a life expectancy statistic.

[3] See Ciecka and Ciecka for a discussion of the properties of survival data that presents additional mortality concepts that may aid in the calculation of the present value of expected medical damages.

[4] For example, the current life tables from the National Center for Health Statistics have the survival chance at "essentially zero (somewhere between ages 110 and 120)" (see *United States Life Tables, 1998*, National Vital Statistics Reports, Volume 48, Number 18, page 37, U.S. Department of Health and Human Services' National Center for Health Statistics, 2001).

[5] The life table statistical presentation of mortality is one of the oldest methods for analyzing survival data. For a presentation of one of the original life table models, see Cutler & Ederer.

[6] During the first year of life, the mortality risk decelerates rapidly after the first few weeks of life making the linearity mortality assumption from age 0 to age 1 unrealistic.

empirical estimates into the theoretical model, we have a survival model that calculates the probability of death as:

$$(3) \qquad q_x = \frac{D_x}{N_x} = \frac{D_x}{P_x + \frac{1}{2} D_x}.$$

The methodological process of statistically estimating q_x at every possible age is detailed. Very few death records are available to estimate D_x at extremely advanced ages; hence, the estimated death hazard, D_x, asymptotically approaches 100 percent of the surviving population at advanced ages, for example at q_{120}. Putting aside further discussion of the difficulties in estimating q_x to the relevant literature, once we obtain the age vector of q_x from an empirical study for each single-year of age within the relevant population sample, we can easily construct the life table.

With a beginning size of the life table cohort, l_0, set to a number of persons born alive, for integer ages greater than 0, the survivor function, l_x, the number of survivors at exact age x, is calculated as:

$$(4) \qquad l_x = l_{x-1}(1 - q_{x-1}).$$

A standard procedure is to form the life table beginning with 100,000 persons at x_0, and then using q_x for every age thereafter, calculate l_x using equation (4) through an advanced age, $\bar{l}_x$, where l_x is essentially equal to zero (where $\bar{x}$ represents the age at which l_x is essentially zero).

Calculating *PVM* using the life table method

Using the life care plan, growth and discount rates, and the survivor function l_x, the litigation economist can calculate *PVM* for all ages within the life table (i.e., l_0 to $\bar{l}_x$).[7] The expected present value equation using the *life table* method, PV_l, for each medical item in the life care plan is:

$$(5) \qquad PV_l = \sum_{c=z}^{n} m_c \frac{l_{x|c}}{l_{x|c_0}} \frac{(1+g)^{t_c}}{(1+i)^{t_c}}.$$

where,

- m_c is the current-dollar cost of each medical item at each consumption date c;
- $l_{x|c}$ is the survivor function evaluated at the age of the plaintiff, x, at each medical item consumption date, c ($x|c$ is read as the plaintiff's numerical age at date c);
- $l_{x|c_0}$ is the survivor function evaluated at the age, x, associated with the last known date that the plaintiff is alive, c_0 (i.e., the date that *PVM* is calculated);
- g is the expected annual rate of growth in the cost of the medical item;
- i is the annual rate of interest appropriate to the calculation of present value;
- t_c is the number of years from the date c_0 to each c;
- z the first date of actual consumption, date z, can be equal to or greater than the present value date, c_0; after date z, consumption can continue to date n; and, date n can be equal to or less than $\bar{c}_l$, the date corresponding to the age $\bar{x}$ (the age at which l_x is essentially zero), hence, $c_0 \le z \le n \le \bar{c}_l$.

In Table 1, we show an example of calculating the present value of expected costs for a medical item using the *life table* method. In our example, the life care plan requires consumption of a medical item beginning today, c_0, the date of the plaintiff's 65th birthday, and continuing in one-year increments from today as long as the plaintiff is alive. In column (2) of Table 1, we show the current-dollar $10,000 cost of the medical item at each consumption date c. In column (3) of Table 1, we show actual survival data for all males ages 65 to 100 from Table 2 of the *United States Life Tables, 1998* as published by the National Center for Health Statistics, NCHS).[8] Using data within the NCHS report regarding k and s values used in the 1998 life tables, we extend the published survival data through age 120, $\bar{c}$.[9] In Column (4) of Table 1, we calculate the probability of survival as $l_{x|c} / l_{65}$ for all ages 65 to 120. Column (6) of Table 1 shows the expected value of the current-dollar future medical costs by multiplying column (2) by column (4). Column (8) of Table 1 is the present value of expected future medical costs calculated using an annual 3.5 percent inflation in the cost of the medical care item and an annual 6.0 percent discount rate. Using the assumed figures in this example, 99.94 percent of *PVM* occurs by age 100; only $180 in current-dollar expected costs and $73 in present value expected costs occur after age 100.

Opposed to our example above, when making actual *PVM* calculations, consumption dates for medical items do not usually have to fall on the dates of the plaintiff's exact ages (birthdays). Using the assumption of the linearity of mortality between exact ages, we can calculate l_x for any numerical age x within the life table after age 0. For example, suppose that instead of being exactly age 65 on the present value date, the plaintiff is age 65.35 years old. In Table 1, we see that l_{65} equals 77,547 and l_{66} equals 75,926. The number dying from age 65 to age 66, d_{65}, is equal to l_{65} minus l_{66} or 77,547 minus 75,926, or 1,621. Because we assume that d_x declines linearly between ages 65 and 66, $l_{66.35}$ simply becomes l_{65} minus 0.35 times d_{65} or 77,547 minus 0.35 times 1,621, or 76,980. Using the procedure of discovering l_x at each numerical age, we can calculate *PVM* using an exact single-year age life table beginning at any numerical age with additional consumption at any future date bounded by the date where the plaintiff's numerical age is equal to one to $\bar{l}_x$, the age that l_x is essentially equal to zero.

[7] When calculating *PVM* with consumption dates ranging within age 0 and age 1, the litigation economist will need a life table that refines survival probabilities during the first year of life greater than the linear survival probability assumption because of high infant mortality.

[8] *United States Life Tables, 1998*, National Vital Statistics Reports, Vol. 48, No. 18, U.S. Department of Health and Human Services' National Center for Health Statistics, Table 2, 2001.

[9] The current NCHS publication format truncates the published life table to age 100. However, within the life table publication, the NCHS gives readers the equations to calculate for themselves the balance of the life table that is not published within the life table report. For the procedure to extend the published life table, see page 37 of *United States Life Tables, 1998*, National Vital Statistics Reports, Volume 48, Number 18, U.S. Department of Health and Human Services' National Center for Health Statistics, 2001.

Table 1. Present value of expected future medical damages using the life table method

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Exact age	**Current-dollar cost of the medical care item**	**l_x (1998 U.S. Life Tables)**	**Probability of survival**	**Cumulative probability of survival**	**Expected current-dollar cost of medical item**	**Cumulative expected current-dollar cost of medical item**	**Discounted expected cost of medical item**	**Cumulative discounted expected cost of medical item**
65	$10,000	77,547	1.0000	1.0000	$10,000	$10,000	$10,000	$10,000
66	10,000	75,926	0.9791	1.9791	9,791	19,791	9,560	19,560
67	10,000	74,211	0.9570	2.9361	9,570	29,361	9,124	28,684
68	10,000	72,392	0.9335	3.8696	9,335	38,696	8,690	37,374
69	10,000	70,450	0.9085	4.7781	9,085	47,781	8,258	45,632
70	10,000	68,375	0.8817	5.6598	8,817	56,598	7,825	53,457
71	10,000	66,170	0.8533	6.5131	8,533	65,131	7,394	60,851
72	10,000	63,850	0.8234	7.3365	8,234	73,365	6,967	67,818
73	10,000	61,423	0.7921	8.1285	7,921	81,285	6,544	74,362
74	10,000	58,899	0.7595	8.8881	7,595	88,881	6,127	80,489
75	10,000	56,288	0.7259	9.6139	7,259	96,139	5,717	86,207
76	10,000	53,600	0.6912	10.3051	6,912	103,051	5,316	91,523
77	10,000	50,847	0.6557	10.9608	6,557	109,608	4,924	96,446
78	10,000	48,024	0.6193	11.5801	6,193	115,801	4,541	100,987
79	10,000	45,121	0.5819	12.1620	5,819	121,620	4,166	105,153
80	10,000	42,127	0.5432	12.7052	5,432	127,052	3,798	108,951
81	10,000	39,032	0.5033	13.2085	5,033	132,085	3,436	112,386
82	10,000	35,846	0.4622	13.6708	4,622	136,708	3,081	115,467
83	10,000	32,606	0.4205	14.0912	4,205	140,912	2,736	118,203
84	10,000	29,377	0.3788	14.4701	3,788	144,701	2,407	120,611
85	10,000	26,219	0.3381	14.8082	3,381	148,082	2,098	122,708
86	10,000	23,135	0.2983	15.1065	2,983	151,065	1,807	124,516
87	10,000	20,167	0.2601	15.3666	2,601	153,666	1,538	126,054
88	10,000	17,351	0.2238	15.5903	2,238	155,903	1,292	127,346
89	10,000	14,723	0.1899	15.7802	1,899	157,802	1,071	128,417
90	10,000	12,310	0.1587	15.9389	1,587	159,389	874	129,291
91	10,000	10,133	0.1307	16.0696	1,307	160,696	703	129,993
92	10,000	8,204	0.1058	16.1754	1,058	161,754	555	130,549
93	10,000	6,528	0.0842	16.2596	842	162,596	432	130,980
94	10,000	5,100	0.0658	16.3254	658	163,254	329	131,310
95	10,000	3,910	0.0504	16.3758	504	163,758	246	131,556
96	10,000	2,938	0.0379	16.4137	379	164,137	181	131,737
97	10,000	2,163	0.0279	16.4415	279	164,415	130	131,867
98	10,000	1,558	0.0201	16.4616	201	164,616	91	131,958
99	10,000	1,098	0.0142	16.4758	142	164,758	63	132,021
100	10,000	757	0.0098	16.4856	98	164,856	42	132,063
101	10,000	510	0.0066	16.4921	66	164,921	28	132,091
102	10,000	336	0.0043	16.4965	43	164,965	18	132,109
103	10,000	216	0.0028	16.4993	28	164,993	11	132,120
104	10,000	135	0.0017	16.5010	17	165,010	7	132,127
105	10,000	83	0.0011	16.5021	11	165,021	4	132,131
106	10,000	50	0.0006	16.5027	6	165,027	2	132,134
107	10,000	29	0.0004	16.5031	4	165,031	1	132,135
108	10,000	17	0.0002	16.5033	2	165,033	0.77	132,136
109	10,000	9.4	0.0001	16.5034	1	165,034	0.42	132,136
110	10,000	5.2	6.7E-05	16.5035	0.67	165,035	0.23	132,137
111	10,000	2.8	3.6E-05	16.5035	0.36	165,035	0.12	132,137
112	10,000	1.5	1.9E-05	16.5035	0.19	165,035	0.06	132,137
113	10,000	0.8	1.0E-05	16.5036	0.10	165,036	0.03	132,137
114	10,000	0.4	5.2E-06	16.5036	0.05	165,036	0.02	132,137
115	10,000	0.2	2.7E-06	16.5036	0.03	165,036	0.01	132,137
116	10,000	0.1	1.4E-06	16.5036	0.01	165,036	0.00	132,137
117	10,000	5.29E-02	6.8E-07	16.5036	0.01	165,036	0.00	132,137
118	10,000	2.66E-02	3.4E-07	16.5036	0.00	165,036	0.00	132,137
119	10,000	1.34E-02	1.7E-07	16.5036	0.00	165,036	0.00	132,137
120	10,000	6.76E-03	8.7E-08	16.5036	0.00	165,036	0.00	132,137
			16.5036		$165,036		$132,137	

The life expectancy statistic

Life expectancy is a statistic calculated from life tables. The single number life expectancy is often interpreted as the average number of years remaining to be lived by the population that survives to an exact age *x* using the age-specific rates of dying for all ages greater than *x* through the end of the life table. Using our example of a current 65-year-old, the age-specific rates of death for all persons ages 65 to the last age in the life table, age 120 in our example, quantify the life expectancy of a living 65-year-old person. Life expectancy statistics, for any age, cannot be calculated without first having a life table showing age-specific probabilities of death; or, life expectancy statistics are created from life tables.

To begin the formulation of the life expectancy statistic, we can re-write the hazard function, d_x, for the number of deaths occurring between *x* and *x*+1 as:

(6) $$d_x = l_x - l_{x+1} = l_x q_x .$$

At any exact age *x*, we can find the size of the stationary population, L_x, as:

(7) $$L_x = \tfrac{1}{2}(l_x + l_{x+1}) = l_x - \tfrac{1}{2} d_x .$$

Since L_x gives us the number of survivors at each age *x* from 0 to the end of the life table when l_x is essentially equal to zero, if we sum L_x over ages *x* to $\bar{x}$ (the age at which l_x is essentially zero), we have the total person-years yet to be lived, Y_x, as

(8) $$Y_x = \sum_{z=0}^{\bar{x}-x} L_{x+z} ,$$

where *z* is a series of integers to advance exact integer age *x* to the age at the end of the life table, $\bar{x}$. The life expectancy statistic, e_x, is computed by dividing remaining person-years yet to be lived after *x*, Y_x, by the number of survivors at l_x:

(9) $$e_x = \frac{Y_x}{l_x}$$

Since equation (9) is the division of two numbers, much like simple averages are calculated, it has become the reference point of the common interpretation of life expectancy as the average number of years remaining to be lived by the population that survives to an exact age *x*. However, using our understanding of the life table from the previous section of this article, we formulate an alternate equation of life expectancy (and an alternative interpretation of its meaning), by substituting equation (7) for Y_x in equation (9) through equation (8). Under this formulation, we see below in equation (10) that the life expectancy statistic equals the sum the series of mid-age survival probabilities through the end of the life table:

(10) $$e_x = \sum_{z=0}^{\bar{x}-x} \frac{l_{x+z} - \frac{1}{2} d_{x+z}}{l_x} .$$

Equation (10) is the survival function foundational expression for life expectancy. As seen in equation (10) the life expectancy statistic is not an expected average value of the duration of life, but simply a way of condensing a series of independent survival probabilities into one number with the summation operator.

Figure 1. Life expectancy "square" equals the total area under the probability of survival curve when probability of survival is figured at mid-year age

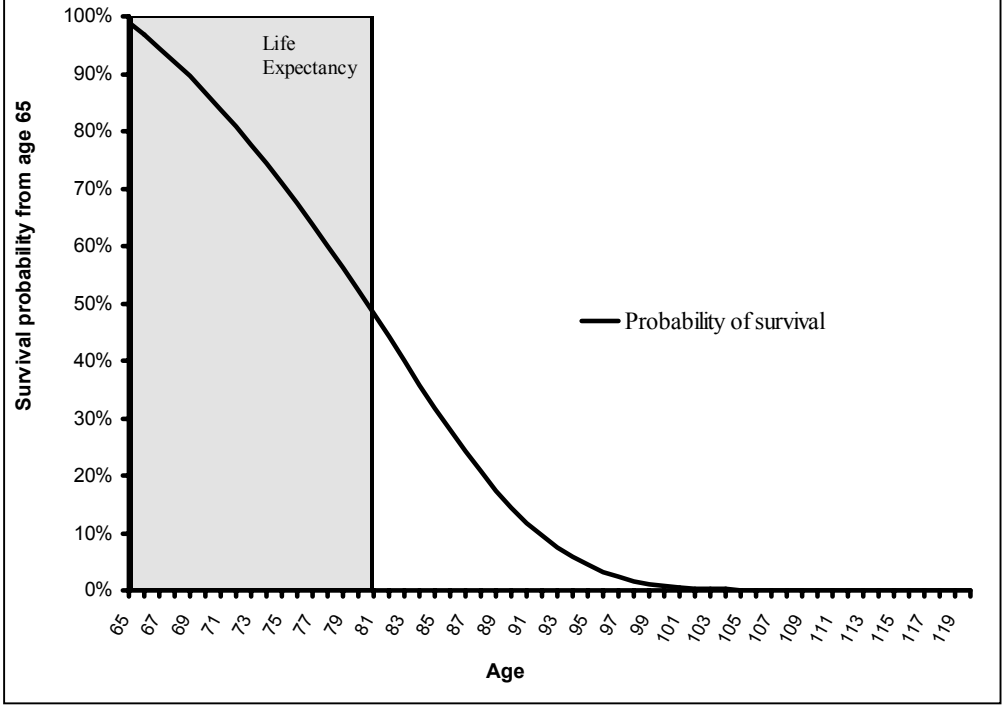

Table 2. Two different ways of calculating life expectancy

(1) Exact age	(2) l_x *(1998 U.S. Life Tables)*	(3) d_x - number dying between ages	(4) L_x - stationary population = $l_x - d_x/2$	(5) Y_x - stationary population in all remaining ages	(6) e_x - life expectancy = Y_x / l_x	(7) Probability of survival = L_x/l_{65}	(8) Cumulative probability of survival
65	77,547	1,621	76,736	1,241,028	**16.0036**	0.9895	0.9895
66	75,926	1,714	75,069	1,164,292	15.3346	0.9680	1.9576
67	74,211	1,819	73,302	1,089,223	14.6773	0.9453	2.9028
68	72,392	1,942	71,421	1,015,921	14.0336	0.9210	3.8238
69	70,450	2,076	69,412	944,500	13.4067	0.8951	4.7189
70	68,375	2,205	67,272	875,088	12.7984	0.8675	5.5865
71	66,170	2,320	65,010	807,816	12.2082	0.8383	6.4248
72	63,850	2,427	62,636	742,806	11.6337	0.8077	7.2325
73	61,423	2,524	60,161	680,170	11.0735	0.7758	8.0083
74	58,899	2,612	57,594	620,008	10.5265	0.7427	8.7510
75	56,288	2,687	54,944	562,415	9.9918	0.7085	9.4595
76	53,600	2,754	52,223	507,471	9.4677	0.6734	10.1330
77	50,847	2,823	49,435	455,247	8.9534	0.6375	10.7705
78	48,024	2,903	46,573	405,812	8.4502	0.6006	11.3710
79	45,121	2,994	43,624	359,239	7.9617	0.5625	11.9336
80	42,127	3,095	40,579	315,615	7.4920	0.5233	12.4569
81	39,032	3,186	37,439	275,036	7.0465	0.4828	12.9397
82	35,846	3,240	34,226	237,597	6.6283	0.4414	13.3810
83	32,606	3,229	30,992	203,371	6.2372	0.3997	13.7807
84	29,377	3,159	27,798	172,380	5.8678	0.3585	14.1391
85	26,219	3,084	24,677	144,582	5.5145	0.3182	14.4573
86	23,135	2,968	21,651	119,905	5.1829	0.2792	14.7365
87	20,167	2,815	18,759	98,254	4.8721	0.2419	14.9784
88	17,351	2,628	16,037	79,495	4.5815	0.2068	15.1853
89	14,723	2,413	13,517	63,458	4.3100	0.1743	15.3596
90	12,310	2,177	11,222	49,941	4.0569	0.1447	15.5043
91	10,133	1,929	9,169	38,719	3.8211	0.1182	15.6225
92	8,204	1,676	7,366	29,551	3.6019	0.0950	15.7175
93	6,528	1,428	5,814	22,185	3.3984	0.0750	15.7925
94	5,100	1,191	4,505	16,371	3.2097	0.0581	15.8506
95	3,910	972	3,424	11,865	3.0349	0.0442	15.8947
96	2,938	775	2,550	8,442	2.8733	0.0329	15.9276
97	2,163	604	1,860	5,891	2.7242	0.0240	15.9516
98	1,558	460	1,328	4,031	2.5867	0.0171	15.9687
99	1,098	341	928	2,703	2.4602	0.0120	15.9807
100	757	247	634	1,775	2.3441	0.0082	15.9889
101	510	174	423	1,141	2.2377	0.0055	15.9943
102	336	120	276	718	2.1404	0.0036	15.9979
103	216	80	176	443	2.0517	0.0023	16.0001
104	135	52	109	267	1.9712	0.0014	16.0015
105	83	33	66	158	1.8984	0.0009	16.0024
106	50	21	40	91	1.8328	0.0005	16.0029
107	29	12	23	52	1.7742	0.0003	16.0032
108	17	7	13	29	1.7220	0.0002	16.0034
109	9	4	7	16	1.6761	0.0001	16.0035
110	5	2	4	8	1.6359	5.14E-05	16.0035
111	3	1	2	4	1.6011	2.76E-05	16.0035
112	1	7.09E-01	1	2	1.5709	1.46E-05	16.0036
113	7.80E-01	3.76E-01	5.91E-01	1	1.5443	7.63E-06	16.0036
114	4.03E-01	1.97E-01	3.05E-01	6.12E-01	1.5189	3.93E-06	16.0036
115	2.06E-01	1.02E-01	1.56E-01	3.08E-01	1.4907	2.01E-06	16.0036
116	1.05E-01	5.19E-02	7.88E-02	1.52E-01	1.4514	1.02E-06	16.0036
117	5.29E-02	2.63E-02	3.98E-02	7.32E-02	1.3845	5.13E-07	16.0036
118	2.66E-02	1.32E-02	2.00E-02	3.35E-02	1.2571	2.58E-07	16.0036
119	1.34E-02	6.64E-03	1.01E-02	1.35E-02	1.0044	1.30E-07	16.0036
120	6.76E-03	0	3.38E-03	3.38E-03	0.5000	4.36E-08	16.0036
						16.0036	

In Table 2, we continue with our example using the *U.S. Life Tables, 1998* data for a male age 65. We show l_x, d_x, L_x, Y_x, and e_x in columns (2) through (6) of Table 2. In column (7) of Table 2, we show the probability of survival for the 65-year old male at each mid-year age using l_{65} and L_x at each age 65 to age 120. Summing all of the mid-year probabilities of survival from age 65 to age 120, our equation (10), equals the computation of Y_{65}/l_{65}, our equation (9). Visually, we show this result in Figure 1. At age 65, males have a life expectancy of 16 years. In figure 1, the rectangular life expectancy box represents 16 full years of expected life (dimension of 100 percent survival for 16 years of age). The total area underneath the partial-year probability of survival line from age 65 to age 120 also equals 16 full-years of expected life. The identical results from equations (9) and (10) can be repeated at any whole age from age 0 to age 120.

According to the *U.S. Life Tables, 1998* data for a male age 65, life expectancy is 16 years. From Table 2, we see that the cumulative sum in the probabilities of survival from age 65 to age 80 (16 years) is 12.4569 or 77.8 percent of the eventual life expectancy of 16.0036 years. In this light, 22.2 percent of life expectancy years are contributed at ages beginning at age 81 (16 years following age 65) continuing through the end of the life table. By age 94, 99.0 percent of the survival probability contributions to life expectancy have occurred (15.8506/16.0036) and by age 100, the percent of survival probability contributions to life expectancy rises to 99.9 percent. These figures point out the need for precision life care planning. Using our example of an exactly 65-year old male, age 65 plus 16 years ends medical consumption on the exact age 81. By age 81, only 77.8 percent of life expectancy years are recognized. If the life care planner states that "if the plaintiff is alive at age 81, the life care item is no longer needed," then 22.2 percent of the 16 years of life expectancy are irrelevant to the calculation of *PVM*.

Calculating *PVM* using the *life expectancy* approach

Using the life care plan, growth and discount rates, and the life expectancy statistic, e_x, the litigation economist using the *life expectancy* approach calculates the expected present value, PV_e, for each medical item in the life care plan as:

$$(11) \qquad PV_e = \sum_{c=z}^{n} m_c \frac{(1+g)^{t_c}}{(1+i)^{t_c}}.$$

where the *life expectancy* approach allows,[10]

m_c is the current-dollar cost of the medical item at each consumption date c;
g is the expected annual rate of growth in the cost of the medical item;
i is the annual rate of interest appropriate to the calculation of present value;
t_c is the number of years from the date c_0 to each c;
z the first date of actual consumption, date z, equal to or greater than the present value date, c_0; after date z, consumption continues to date n that is less than or equal to $\bar{c}_e$, the date corresponding to the age $x + e_x$.

In Table 3, we show an example of calculating *PVM* beginning on a plaintiff's 65th birthday and continuing as long as the plaintiff is alive using the *life expectancy* approach. In Table 3, the plaintiff's 65th birthday corresponds with the beginning present value date, c_0. In column (2) of Table 3, we show the current $10,000 cost of the medical item annually for 16 whole-years[11] corresponding to the life expectancy, e_{65}, that we calculated in Table 2. Column (4) of Table 3 is the present value of expected future medical costs calculated using an annual 3.5 percent inflation in the cost of the medical care item and an annual 6.0 percent discount rate. Using the assumed figures in this example, *PVM* is $134,587 using the life expectancy approach in contrast to the $132,137 in damages calculated in Table 1 using the *life table* method.

Table 3. Present value of expected future medical damages using the simple life expectancy approach

(1)	(2)	(3)	(4)	(5)
Exact age	Current-dollar cost of the medical care item	Cumulative expected current-dollar cost of medical item	Discounted expected cost of medical item	Cumulative discounted expected cost of medical item
65	$10,000	$10,000	$10,000	$10,000
66	10,000	20,000	9,764	19,764
67	10,000	30,000	9,534	29,298
68	10,000	40,000	9,309	38,607
69	10,000	50,000	9,089	47,696
70	10,000	60,000	8,875	56,572
71	10,000	70,000	8,666	65,237
72	10,000	80,000	8,461	73,699
73	10,000	90,000	8,262	81,961
74	10,000	100,000	8,067	90,028
75	10,000	110,000	7,877	97,904
76	10,000	120,000	7,691	105,595
77	10,000	130,000	7,510	113,105
78	10,000	140,000	7,332	120,437
79	10,000	150,000	7,160	127,597
80	10,000	160,000	6,991	134,587
	$160,000		**$134,587**	

[10] To this point in the article, we have associated the use of survival probabilities from life tables as the *life table* method to calculate *PVM* and the use of the life expectancy statistic as the *life expectancy* approach to calculate *PVM*. We have deliberately used the word "method" with life tables and the word "approach" with life expectancy. Equations (1) to (4) describe a "method" to calculate the survival probabilities in the PV_l equation (5) allowing timed, scheduled consumption of medical items at any date from today to the date associated with age $\bar{x}$. In contrast, the life expectancy statistic is a summary time-interval. Since life expectancy does not proceed with the timed, scheduled consumption of medical items within the life care plan, the usage of life expectancy to calculate *PVM* becomes an "approach" in contrast to the mathematical methodology of survival analysis that is used in the *life table* method of calculating *PVM*. So, the proceeding phrase "the *life expectancy* approach allows" indicates that the *life expectancy* approach is a substitute for the exact survival method and that it has internal inconsistencies regarding the timing of medical item consumption and survival probability that are described throughout this article.

[11] The published values of life expectancy in the *U.S. Life Tables* are rounded to the nearest one-hundredth decimal place, so if using the published table in our example life expectancy would be 16 whole-years.

PVM calculated using the *life expectancy* approach are 1.85 percent higher than damages in the *life table* method; however, damages without present value calculations are 3.15 percent higher using the *life table* method than the simple *life expectancy* approach.

In comparison to the *life table* method, serious problems with using the *life expectancy* approach appear to the reader. Below we discuss two problems glaring from the results of our simple examples:[12]

1. In Table 2, our e_x was not the integer 16, but the numeric value 16.0036. Following the "life certain" application of e_x where the date at age $x+e_x$ is interpreted as the terminal date of life, the plaintiff would purchase 17 units of the medical item because he would be "expected to die" the day after his 81st birthday. Purchasing 17 units of the medical item would be inappropriate because, according to the life table, the plaintiff's survival probabilities would result in an expected 16.5036 consumed units of the medical item. Figuring 17 units of the medical item, *PVM* under the *life expectancy* approach would be 7.02 percent higher than our Table 1 *life table* method *PVM*.

   While some medical items are subject to some level of division of consumption within time intervals, many are not and require whole units of consumption. Assume that the medical item in the example is a durable item that requires replacement each year and is not subject to division. Use of the *life expectancy* approach where the date at age $x+e_x$ sets the terminal age of life forces the litigation economist to calculate 17 units of the medical item. Since the life expectancy statistic has a 0.0036 partial-year, the consumption period of the 17th unit of the medical item is around 36 hours. These problems abound with the decimal portion of life expectancy years.[13]

   If e_x is not considered as providing the addition to current age for the terminal date of life but alternatively as expected number of units that will be consumed in the future, a litigation economist might multiply the cost of the 17th unit by a 0.36 percent chance that the 17th unit would be consumed. However, problems with the *life expectancy* approach continue to persist under this procedure of handling the decimal portion of e_x. Recognizing partial unit consumption acknowledges that it is not that plaintiffs will be partially consuming medical care items, but that the chance that the plaintiffs are alive to be able to consume medical care items in the future creates the decimal portion of e_x. Therefore, working with continuous survival risk on one hand with the survival chance of the decimal portion of e_x and calculating *PVM* inside a discrete time interval of length e_x on the other is inconsistent.
2. When the first consumption of the medical item occurs at c_0, there is an understatement of expected medical damages using the *life expectancy* approach when counting total units consumed as equal to the life expectancy. The life expectancy statistic for each exact age x is calculated using the sum of mid-age survival probabilities. As we see in equation (10), the survival contribution to life expectancy made during age x is less than one. However, when calculating expected medical damages, the first consumption occurs at exact age x where the survival probability is equal to one. We show the actual consumption ages and survival probabilities of the medical item in Table 1. Since consumption occurs at exact ages, the sum of the probabilities of survival are greater in the *life table* method than in the *life expectancy* approach which figures survival probability at the mid-year age (see Table 2). The expected units consumed using the *life table* method of survival to the exact date where consumption occurs are 16.5036, while the *life expectancy* approach, because it does not follow the timing of actual consumption but follows mid-age survival, has 16.0036 expected units consumed.

Consumption timing in life care plans and *PVM*

Since the equations for *PVM* using the *life table* method or the *life expectancy* approach are different, the levels of *PVM* that each calculate are different.[14] If we examine consumption timing in life care plans and the formulation of *PVM*, we can identify which way of calculating *PVM*, the *life table* method or the *life expectancy* approach, is mathematically appropriate.

Life is a 1/0 event (you are alive then you are dead). The range of age for calculating survival probability or life expectancy is the same, x to $\bar{x}$. The *life expectancy* approach follows the timing of life: we calculate *PVM* from today to $x+e_x$ with 100 percent survival and then with 0 percent survival after $x+e_x$ to $\bar{x}$. The *life table* method follows the frequency distribution of survival in the population after the exact age x: we calculate *PVM* from the day after today to age $\bar{x}$ with less than 100 percent survival at any age $x|c$ associated with the survival frequency table of a relevant population.

We can state that the *life table* method is the appropriate way of calculating *PVM* for the following reasons:

[12] The problems with the *life expectancy* approach are not limited to these two areas.

[13] The problem of partial units is not present with the *life table* method. From equation (5), we see that when using the *life table* method, we first set up the series of consumption dates of whole-units of each life care item, m, and then we multiply the present value of m by the chance of survival from today to m_c. Equation (5) does not force medical item consumption dates to be continuous within the boundaries of c_0 and $\bar{c}_l$ ($c_0 \le z \le n \le \bar{c}_l$) regarding medical item consumption dates. In contrast, the nature of the life expectancy statistic as shown in either equation (9) or in equation (10) forces medical item consumption dates to be continuous within the boundaries of c_0 and $\bar{c}_l$ ($c_0 = z < n = \bar{c}_e$). However, numerous items in life care plans are not consumed continuously from c_0 to $\bar{c}_e$, hence the *life expectancy* approach is always inappropriate for those medical items.

[14] Ben-Zion and Reddall wrote about these differences in 1985.

1. With or without an injury, the hazard of death for all persons is a continuous risk and greater than zero beginning with the first moment of the future. Since the life care plan specifies the date of the occurrence of consumption of the medical care item, to calculate *PVM*, the litigation economist must use a statistical method of calculating the probability of survival upon which the consumption of each medical item is conditioned. The *life table* method specifically utilizes the continuous death hazard in calculating *PVM* for any medical item consumable on any future date. Since the *life table* method calculates the probability of survival to each medical item consumption date, it mathematically calculates the correct *PVM*.
2. As shown in equation (10), life expectancy is the sum of independent survival probabilities beginning with the first mid-year age to each future mid-year age through $\bar{x}$. Therefore, the life expectancy statistic has no association to the probability of survival to each medical item consumption date in the life care plan upon which condition of being alive to make the consumption is required; hence, the *life expectancy* approach cannot mathematically calculate the correct *PVM*. Referring back to Figure 1, the life expectancy "square" (dimensioned 100% survival for 16 whole-years) equals the sum of the total area from the axes to the "probability of survival line." Although the survival probabilities that comprise e_{65} are for age 65.5, 66.5, 67.5, … , 120.5, the *life expectancy* approach front-loads 55 years of life expectancy survival probabilities into the 16 whole years from age 65-80. Herein lies a major inconsistency in the *life expectancy* approach: it takes $\bar{x}$ - x + 1 year-long age intervals to construct life expectancy, but the life expectancy approach condenses survival and present value compounding to the first e_x years after x.
3. The life expectancy statistic sums survival probabilities continuously from each age x until age $\bar{x}$. Life care plans have many medical items with consumption ending before $\bar{x}$ and in those situations, it is impossible to change the *life expectancy* approach to only account for the death hazard between the first consumption date and the last consumption date before $\bar{x}$. In the situations where medical care items end at ages $b < x+e_x$, the mortality of the population at ages greater than age b is irrelevant to the calculation of *PVM*. The only relevant survival probabilities for *PVM* are from the first consumption date, by date, through age b. Therefore, using the *life expectancy* approach is inappropriate with these medical items and it will always overstate *PVM*. In these instances, the numerators of life expectancy equations (9) or (10) will not match the time-intervals for medical item consumption, so the *life expectancy* approach will give mathematically incorrect *PVM*.
4. Life care plans have many items that begin after the last known date that the plaintiff is alive. Since the plaintiff will have to be alive in order to begin consuming those medical items, there will be a new life expectancy for the plaintiff on the first consumption date of those medical items. If medical items begin their consumption after c_0 and are continuously consumed until $\bar{x}$, we can compute *PVM* with a new life expectancy and then adjust *PVM* by the probability of survival from today to the first consumption date. However, this 'actuarial' type calculation does not fix the other problems with the *life expectancy* approach still present because the calculation of *PVM* still utilizes the life expectancy statistic, not the probability of the occurrence of medical item consumption. An example of this problem is as follows: a medical care item begins on a date after the attainment of age x, say x+4. The plaintiff must be alive at age x+4 in order to begin to consume the medical care item. If the plaintiff is alive at age x+4, he or she has a new life expectancy age other than $x+e_x$ because the mortality rates of those aged x, x+1, x+2, and x+3 are irrelevant to the separate group of persons alive at age x+4. The only relevant survival probabilities for *PVM* in this case are from x+4 to $\bar{x}$. Generally, but depending upon the specific life table, adding an extra year of life results in a net addition of life expectancy before the present value calculation. In these situations, the denominators of the life expectancy equations (9) or (10) will not match the time for medical item consumption, so the *life expectancy* approach will give mathematically incorrect *PVM*.
5. Life care plans have many medical items that are the compound of discussion items (3) and (4) above: the medical item consumption date is after the last known date that the plaintiff is alive and ends at an age less than $\bar{x}$. With those medical items, the life expectancy statistic takes on even less relevance because those dying before the first consumption date and those dying after the last consumption date are irrelevant to the survival conditions during specific ages at dates $c>c_0$ through the date of age $b < x+e_x$; hence, the *life expectancy* approach is inappropriate to the calculation of *PVM*. Alternatively, in these situations the numerators and denominators of the life expectancy equations (9) or (10) will not match the time for medical item consumption, so the *life expectancy* approach will give mathematically incorrect survival conditions.

In tables 4 through 6, we show the percent differences in *PVM* between the *life table* method and the *life expectancy* approach by sex, net discount rate, and current exact age of the plaintiff. We calculate the percent difference in each of these tables as $PV_l/PV_e - 1$: the percent differences describe how much lower or higher PV_l is as compared to PV_e. We use the *U.S. Life Tables 1998* data for all males and all females. The percentage differences between the *life table* method and the *life expectancy* approach in the following tables are unique to the use of these 1998 life tables with their estimated survival conditions from specific population estimates in a specific year. Results will vary when using different life tables, populations, and survival estimates.

Table 4. Percent differences in *PVM* (*life table* method divided by *'current' life expectancy* approach minus one) with consumption of a medical item beginning today and continuing monthly for the plaintiff's lifetime, by sex, net discount rate, and current exact age

MALES	Net discount rate										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	2.4%	1.1%	0.0%	-0.7%	-1.2%	-1.6%	-1.8%	-1.8%	-1.9%	-1.8%	-1.7%
5	2.3	1.0	0.0	-0.8	-1.3	-1.7	-1.9	-2.0	-2.0	-2.0	-1.9
10	2.3	1.0	-0.1	-0.9	-1.5	-1.9	-2.1	-2.3	-2.4	-2.4	-2.3
15	2.6	1.2	0.1	-0.8	-1.5	-2.0	-2.3	-2.5	-2.7	-2.7	-2.7
20	2.5	1.1	0.0	-0.9	-1.6	-2.1	-2.5	-2.8	-2.9	-3.0	-3.0
25	2.6	1.2	0.1	-0.8	-1.6	-2.1	-2.5	-2.8	-3.0	-3.2	-3.2
30	2.6	1.2	0.1	-0.9	-1.6	-2.2	-2.7	-3.0	-3.3	-3.4	-3.5
35	2.4	1.1	-0.1	-1.0	-1.8	-2.5	-3.0	-3.4	-3.7	-3.9	-4.0
40	2.5	1.1	-0.1	-1.1	-1.9	-2.6	-3.2	-3.7	-4.0	-4.3	-4.5
45	2.6	1.2	0.0	-1.1	-2.0	-2.7	-3.4	-3.9	-4.4	-4.7	-5.0
50	2.6	1.2	0.0	-1.1	-2.0	-2.9	-3.6	-4.2	-4.7	-5.1	-5.5
55	2.6	1.2	0.0	-1.1	-2.1	-3.0	-3.7	-4.4	-5.0	-5.5	-5.9
60	2.7	1.3	0.1	-1.1	-2.1	-3.0	-3.8	-4.5	-5.2	-5.7	-6.2
65	2.2	0.9	-0.3	-1.3	-2.3	-3.2	-4.0	-4.8	-5.4	-6.0	-6.6

FEMALES	Net discount rate										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	1.9%	0.8%	0.0%	-0.5%	-0.9%	-1.1%	-1.3%	-1.3%	-1.3%	-1.2%	-1.2%
5	1.8	0.7	0.0	-0.6	-1.0	-1.2	-1.4	-1.4	-1.4	-1.3	-1.3
10	1.9	0.9	0.0	-0.6	-1.0	-1.3	-1.5	-1.6	-1.6	-1.5	-1.5
15	1.9	0.9	0.0	-0.6	-1.1	-1.4	-1.7	-1.8	-1.8	-1.8	-1.8
20	1.9	0.8	-0.1	-0.7	-1.2	-1.6	-1.8	-2.0	-2.0	-2.0	-2.0
25	2.1	0.9	0.0	-0.7	-1.2	-1.7	-1.9	-2.1	-2.2	-2.3	-2.3
30	2.1	0.9	0.0	-0.8	-1.4	-1.8	-2.2	-2.4	-2.5	-2.6	-2.7
35	2.2	1.0	0.0	-0.8	-1.4	-1.9	-2.3	-2.6	-2.8	-3.0	-3.1
40	2.3	1.1	0.0	-0.8	-1.5	-2.1	-2.5	-2.9	-3.2	-3.4	-3.5
45	2.3	1.1	0.0	-0.9	-1.6	-2.3	-2.8	-3.2	-3.5	-3.8	-4.0
50	2.4	1.1	0.0	-0.9	-1.7	-2.4	-3.0	-3.5	-3.9	-4.2	-4.5
55	2.4	1.1	0.0	-1.0	-1.8	-2.6	-3.2	-3.8	-4.3	-4.7	-5.0
60	2.5	1.3	0.1	-0.9	-1.8	-2.6	-3.3	-3.9	-4.5	-5.0	-5.4
65	2.3	1.1	0.0	-1.0	-1.9	-2.7	-3.5	-4.1	-4.7	-5.3	-5.7

In Table 4, we show the percent differences calculated in *PVM* for any constant consumption of a medical item beginning today and continuing monthly for the plaintiff's lifetime.[15] Since the first consumption date coincides with today, PV_e is calculated using the conventional 'current' life expectancy equal to current exact age plus remaining life expectancy years. Working through an example, suppose that the life care plan is for a male currently age 50 and a medical item in the plan is consumed monthly beginning today and continuing to the expected end of life and the item currently costs $100. Then, the percent difference between PV_l and PV_e for this medical item is -3.6 percent (meaning PV_l is lower than PV_e) when the net discount rate is 2.0 percent. When medical item cost growth and the time value of money are not important (i.e., the net discount rate is equal to zero), there is minimal difference between PV_l is as compared to PV_e. As net discount rates grow further from zero, the percent differences between PV_l and PV_e also grow. As the current exact age of the plaintiff increases, so does the percent difference between PV_l and PV_e.

In Table 5, we show the percent differences calculated in *PVM* for any constant consumption of a medical item beginning fifteen years from today and continuing monthly for the plaintiff's lifetime. Since the first consumption date coincides with today, PV_e is calculated using the 'actuarial' life expectancy equal to future exact age plus remaining life expectancy years at that future age multiplied by the chance of survival from today to that future age. Working through an example, suppose that the life care plan is for a male currently age 25 and a medical item in the plan is consumed monthly beginning at age 40 and continuing to the expected end of life and the item currently costs $100. Then, the percent difference between PV_l and PV_e for this medical item is –3.7 percent (meaning PV_l is lower than PV_e) when the net discount rate is 2.5 percent. When medical item cost growth and the time value of money are not important (i.e., the net discount rate is equal to zero), there is minimal difference between PV_l is as compared to PV_e at young ages because of low death hazards at young ages. However, as age increases (and life expectancy shortens) the difference between PV_l and PV_e grows. As net

[15] Constant consumption in our examples means that the medical care item will be consumed in each consecutive month from the starting consumption date through the ending consumption date. Since we are taking the ratio of *PVM's* the current-dollar costs of the life care items cancel so the current-dollar cost of the medical care item is irrelevant to the percentage difference calculation.

Table 5. Percent differences in *PVM* (*life table* method divided by the *'actuarial' life expectancy* approach minus one) with consumption of one medical item beginning fifteen years from today and continuing monthly for the plaintiff's lifetime, by sex. net discount rate, and current exact age

MALES	**Net discount rate**										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	2.5%	1.1%	0.0%	-0.9%	-1.5%	-2.0%	-2.4%	-2.6%	-2.7%	-2.8%	-2.8%
5	2.5	1.1	0.0	-0.9	-1.6	-2.1	-2.5	-2.8	-2.9	-3.0	-3.0
10	2.6	1.2	0.1	-0.8	-1.6	-2.1	-2.5	-2.8	-3.0	-3.2	-3.2
15	2.6	1.2	0.1	-0.9	-1.6	-2.2	-2.7	-3.0	-3.3	-3.4	-3.5
20	2.4	1.1	-0.1	-1.0	-1.8	-2.5	-3.0	-3.4	-3.7	-3.9	-4.0
25	2.5	1.1	-0.1	-1.1	-1.9	-2.6	-3.2	-3.7	-4.0	-4.3	-4.5
30	2.6	1.2	0.0	-1.1	-2.0	-2.7	-3.4	-3.9	-4.4	-4.7	-5.0
35	2.6	1.2	0.0	-1.1	-2.0	-2.9	-3.6	-4.2	-4.7	-5.1	-5.5
40	2.6	1.2	0.0	-1.1	-2.1	-3.0	-3.7	-4.4	-5.0	-5.5	-5.9
45	2.7	1.3	0.1	-1.1	-2.1	-3.0	-3.8	-4.5	-5.2	-5.7	-6.2
50	2.2	0.9	-0.3	-1.3	-2.3	-3.2	-4.0	-4.8	-5.4	-6.0	-6.6
55	2.3	1.1	0.0	-1.0	-2.0	-2.8	-3.7	-4.4	-5.1	-5.8	-6.4
60	2.4	1.3	0.3	-0.6	-1.5	-2.4	-3.2	-3.9	-4.6	-5.2	-5.8
65	2.3	1.3	0.4	-0.5	-1.3	-2.1	-2.8	-3.5	-4.2	-4.8	-5.4

FEMALES	**Net discount rate**										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	2.0%	0.9%	0.0%	-0.6%	-1.1%	-1.4%	-1.7%	-1.8%	-1.8%	-1.8%	-1.8%
5	1.9	0.8	-0.1	-0.7	-1.2	-1.6	-1.8	-2.0	-2.0	-2.0	-2.0
10	2.1	0.9	0.0	-0.7	-1.2	-1.7	-1.9	-2.1	-2.2	-2.3	-2.3
15	2.1	0.9	0.0	-0.8	-1.4	-1.8	-2.2	-2.4	-2.5	-2.6	-2.7
20	2.2	1.0	0.0	-0.8	-1.4	-1.9	-2.3	-2.6	-2.8	-3.0	-3.1
25	2.3	1.1	0.0	-0.8	-1.5	-2.1	-2.5	-2.9	-3.2	-3.4	-3.5
30	2.3	1.1	0.0	-0.9	-1.6	-2.3	-2.8	-3.2	-3.5	-3.8	-4.0
35	2.4	1.1	0.0	-0.9	-1.7	-2.4	-3.0	-3.5	-3.9	-4.2	-4.5
40	2.4	1.1	0.0	-1.0	-1.8	-2.6	-3.2	-3.8	-4.3	-4.7	-5.0
45	2.5	1.3	0.1	-0.9	-1.8	-2.6	-3.3	-3.9	-4.5	-5.0	-5.4
50	2.3	1.1	0.0	-1.0	-1.9	-2.7	-3.5	-4.1	-4.7	-5.3	-5.7
55	2.1	0.9	-0.1	-1.1	-2.0	-2.8	-3.6	-4.3	-4.9	-5.4	-6.0
60	1.9	0.8	-0.2	-1.1	-1.9	-2.7	-3.5	-4.2	-4.8	-5.4	-5.9
65	1.6	0.6	-0.3	-1.2	-2.0	-2.7	-3.5	-4.2	-4.8	-5.4	-6.0

discount rates grow further from zero, the percent differences between PV_l and PV_e also grow. As the current exact age of the plaintiff increases, the percent difference between PV_l and PV_e levels and then falls.

In Table 6, we show the percent differences calculated in *PVM* for any constant consumption of a medical item beginning today and continuing monthly for fifteen years. Working through an example, suppose that the life care plan is for a male currently age 55 and a medical item in the plan is consumed monthly beginning at age 55 and continuing to age 70 and the item currently costs $100. Then, the percent difference between PV_l and PV_e for this medical item is -9.2 percent (meaning PV_l is lower than PV_e) when the net discount rate is 1.0 percent. Again, there is minimal difference between PV_l is as compared to PV_e at very young ages because of low death hazards at young ages. However, as age increases (and life expectancy shortens), the difference between PV_l and PV_e also grows exponentially. As net discount rates grow further positive from zero, the percent differences between PV_l and PV_e shrink because the time value of money lowers PV_e increasingly.

In Table 7, we show the percent differences calculated in *PVM* for the consumption of a medical item once, exactly fifteen years from today. Working through an example, suppose that the life care plan is for a male currently age 40 and a medical item in the plan is consumed once at age 55 and the item currently costs $100. The percent difference between PV_l and PV_e for this medical item is –6.8 percent (meaning PV_l is lower than PV_e). Since the medical item is consumed only once, the growth and discount portions of the PV equations cancel leaving the difference between PV_l and PV_e equal to the survival probability from the exact age, x, to x+15. Again, as age increases (and life expectancy shortens), the difference between PV_l and PV_e also grows exponentially.

In tables 5 through 7, we presented a series of similar examples associated with medical item consumption not following a schedule of continuous consumption from c_0 to either $\bar{c}_e$ or $\bar{c}_l$. These examples focused on consumption in a combination of beginning or stopping fifteen years after the current exact age. In actual life care plans, there are many different combinations consumption durations beginning at various ages. Because of the wide-ranging possible reasons for differences in *PVM* calculated using the life table method or life expectancy approach, it is impossible to generalize how much lower (or higher) PV_l will be than PV_e.

Table 6. Percent differences in *PVM* (*life table* method divided by the *'current' life expectancy* approach minus one) with consumption of one medical item beginning today and continuing monthly for fifteen years, by sex. net discount rate, and current exact age

MALES	Net discount rate										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
5	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
10	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
15	-0.9	-0.9	-0.9	-0.9	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
20	-1.1	-1.1	-1.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
25	-1.2	-1.2	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.1	-1.0	-1.0
30	-1.5	-1.4	-1.4	-1.4	-1.4	-1.4	-1.3	-1.3	-1.3	-1.3	-1.3
35	-2.0	-2.0	-2.0	-1.9	-1.9	-1.9	-1.8	-1.8	-1.8	-1.8	-1.7
40	-2.9	-2.9	-2.8	-2.8	-2.7	-2.7	-2.7	-2.6	-2.6	-2.5	-2.5
45	-4.3	-4.2	-4.1	-4.1	-4.0	-4.0	-3.9	-3.8	-3.8	-3.7	-3.7
50	-6.4	-6.3	-6.2	-6.1	-6.0	-5.9	-5.8	-5.7	-5.6	-5.6	-5.5
55	-9.7	-9.6	-9.5	-9.3	-9.2	-9.0	-8.9	-8.8	-8.6	-8.5	-8.4
60	-14.6	-14.4	-14.2	-14.0	-13.8	-13.6	-13.4	-13.2	-13.0	-12.8	-12.6
65	-21.1	-20.8	-20.5	-20.2	-19.9	-19.6	-19.3	-19.0	-18.8	-18.5	-18.2

FEMALES	Net discount rate										
Exact age	-1.0%	-0.5%	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%
1	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
5	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
10	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
15	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
20	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3
25	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
30	-0.8	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
35	-1.1	-1.1	-1.1	-1.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
40	-1.6	-1.6	-1.6	-1.6	-1.5	-1.5	-1.5	-1.5	-1.4	-1.4	-1.4
45	-2.5	-2.4	-2.4	-2.4	-2.3	-2.3	-2.3	-2.2	-2.2	-2.1	-2.1
50	-3.9	-3.8	-3.8	-3.7	-3.7	-3.6	-3.5	-3.5	-3.4	-3.4	-3.3
55	-6.1	-6.0	-5.9	-5.8	-5.7	-5.6	-5.5	-5.5	-5.4	-5.3	-5.2
60	-9.3	-9.2	-9.1	-8.9	-8.8	-8.6	-8.5	-8.4	-8.3	-8.1	-8.0
65	-14.0	-13.8	-13.6	-13.4	-13.2	-13.0	-12.8	-12.6	-12.4	-12.2	-12.0

PVM Computation Algorithm

Before calculating a *PVM*, we must have an algorithm or procedure to work through each of the *PVM* computation steps. Following algorithms we can design computer software to make *PVM* calculations. The main steps required to make a *life table* method *PVM* calculation are:

1. Obtain data. Obtain the beginning and ending of the time interval bounding consumption of the medical care item. Obtain the frequency of consumption (e.g. monthly, annually, every 5 years, etc.) that the medical care item will be consumed within the interval. Obtain the current-dollar cost of the medical care item, the expected future annual growth in the cost of the medical care item, and an appropriate interest rate to calculate present value. Obtain the plaintiff's date of birth, the relevant life table, and the last known survival date of the plaintiff (also the present value date).
   Beginning on the first consumption date, do: calculate the number of persons alive on the last known survival date, $l_{x|c_0}$. Calculate the number of persons alive on the consumption date, l_c. Calculate the probability of

Table 7. Percent differences in *PVM* (*life table* method divided by *life expectancy* approach minus one) with consumption of one medical item 15 years from today, by sex and current exact age

	Any net discount rate	
Exact age	Males	Females
1	-0.5%	-0.3%
5	-0.7	-0.4
10	-1.3	-0.5
15	-1.9	-0.7
20	-2.2	-0.9
25	-2.5	-1.2
30	-3.4	-1.8
35	-4.7	-2.6
40	-6.8	-3.9
45	-10.2	-6.1
50	-15.4	-9.5
55	-22.9	-14.6
60	-33.1	-22.0
65	-45.7	-32.1

survival to be alive to be able to consume the medical item as $l_{x|c} / l_{x|c_0}$. Multiply the cost of the medical item times the probability of survival times the net discount factor and store the expected present value of the medical item on that date.

2. Increment time to the next consumption date by the frequency of medical item consumption. If the next consumption date using the frequency of medical item consumption is less than the ending consumption date repeat the previous step and add the expected present value on the new consumption date to the stored value(s) from the previous consumption date(s). If the next consumption date is greater than the ending consumption date, stop and return the accumulated expected present value of the medical item.

The main steps required to make a *life expectancy* approach *PVM* calculation are:

1. Obtain data. Obtain the beginning and ending of the time interval bounding consumption of the medical care item. Obtain the frequency of consumption (e.g. monthly, annually, every 5 years, etc.) that the medical care item will be consumed within the interval. Obtain the current-dollar cost of the medical care item, the expected future annual growth in the cost of the medical care item, and an appropriate interest rate to calculate present value. Obtain the plaintiff's date of birth, the relevant life expectancy statistic to set the boundary of time from the last known survival date of the plaintiff (also the present value date) to the terminal time of life ($x+e_x$).
2. Beginning on the first consumption date, do: multiply the cost of the medical item times the net discount factor and store the present value of the medical item on that date.
3. Increment time to the next consumption date by the frequency of medical item consumption. If the next consumption date using the frequency of medical item consumption is less than the ending consumption date repeat the previous step and add the expected present value on the new consumption date to the stored value(s) from the previous consumption date(s). If the next consumption date is greater than the ending consumption date, stop and return the accumulated expected present value of the medical item.

Visual Basic and Excel

Microsoft Excel has the most extensive and flexible macro language of any spreadsheet program widely available. With Excel, we can design a table in a workbook to show the contents of the life care plan and also embed a Visual Basic for Applications (VBA) program into the workbook to make our *PVM* calculations to insert into the life care plan table.

Visual Basic is a programming language that has many built-in functions that operate the same way as Excel's built-in functions. Any user of Excel (or other spreadsheets) is probably familiar with functions such as PV(rate,nper,pmt), a function that returns the present value of an investment. To use the PV function in Excel, the user types into a cell, for example, the formula =PV(6%,10,$100). This Excel function would return the present value of $100 payments for 10 years with a 6 percent discount rate. Within Excel's built-in function library is a small program that calculates present value when the PV function is called for and supplied with the required parameters rate, nper, and pmt. Using VBA, we can write our own functions for use within Excel to perform practically any series of calculations using parameters we pass to the VBA program and then the VBA program makes its programmed series of calculations and returns to us a result.

Using VBA to write your own function macros is simple. In the following steps, we show how to create a simple macro for adding two numbers together and then return the sum to the spreadsheet. The example below uses Microsoft Excel 2000. Other versions of Excel have similar steps for creating VBA function macros but the names of the Windows will be slightly different.

1. Open a blank Excel workbook and save it with the name "SUM".
2. Using your mouse, under the "Tools" menu, slide down to "Macro" and then slide over to select "Visual Basic Editor" (the shortcut for this step is to hit Alt+F11 on your keyboard). A new window titled "Microsoft Visual Basic – SUM.xls" will now appear on your computer.
3. Within the "Microsoft Visual Basic – SUM.xls" window, using your mouse go to the "Insert" menu and then slide down and select "Module". A new window titled "Microsoft Visual Basic – SUM.xls – [Module 1 (Code)]" will now appear on your computer. In this window, type the following text:

```
Function macro_sum(number_1, number_2)
macro_sum = number_1 + number_2
End Function
```

4. Using your mouse, go to the "File" menu and then slide down to the choice "Close and Return to Microsoft Excel" (the shortcut for this step is to hit Alt+Q on your keyboard). You will now close the VBA windows and return to the Excel workbook.
5. In any cell in any worksheet within the "SUM" workbook, type the following formula:
   `=macro_sum(5,12)`
6. When you hit the "enter" key, Excel will look for a function titled "macro_sum" within the macro modules stored in the workbook, pass the two parameters 5 and 12 to the function macro, run the macro, and return the value 17.

You have just created a macro in Excel! The sophistication of any Excel VBA macro is limited only to your imagination in writing a set of instructions for Excel and/or VBA to make a series of calculations returning its result to a worksheet. There are many good books available to learn more about Excel VBA and the help system within Excel provides definitions and examples of all of VBA's internal functions and syntax.

A VBA Excel macro for calculating *PVM*

In this article's Appendix, we show the complete text of a series of VBA function macros that calculate *PVM*. These macros are a part of an Excel workbook that provides a

Figure 2. The life care table with PVM calculations called from VBA function macros

Table 1. Present value of expected future medical damages
Plaintiff's name: Joe Plaintiff

Today's date: 9/25/2000

Medical care item	Beginning consumption date	Ending consumption date	Cost per unit of each medical care item	Units required	Consumption frequency	Consumption frequency time units	Medical item annual cost growth	Appropriate medical item discount rate	Current-dollar expected costs to life expectancy	Current-dollar expected costs over remaining lifetime	Present value expected costs to life expectancy	Present value expected costs over remaining lifetime
Medical care item #1	Today	Lifetime	$120,000	1.0	1	Year	3.5%	6.0%	$6,360,000	$6,417,928	$3,651,933	$3,576,487
Medical care item #2	Today	Lifetime	$10,000	1.0	1	Month	3.5%	6.0%	$6,360,000	$6,363,078	$3,612,394	$3,521,329
Medical care item #3	Age 25	8/25/2015	$10,000	1.0	1	Month	3.5%	6.0%	$1,800,000	$1,785,217	$1,514,582	$1,502,970
Medical care item #4	Age 40	8/25/2035	$10,000	1.0	1	Month	3.5%	6.0%	$2,400,000	$2,274,224	$1,335,468	$1,269,958
Medical care item #5	Age 60	Lifetime	$10,000	1.0	1	Month	3.5%	6.0%	$2,160,000	$2,303,637	$762,343	$748,401
								Sum	**$6,360,000**	**$6,363,078**	**$3,612,394**	**$3,521,329**
Medical care item #6	Today	Lifetime	$10,000	5.0	5	Years	4.0%	7.0%	$550,000	$554,847	$298,288	$291,908
Medical care item #7	Age 60	Age 60	$100	5.0	1	Month	3.5%	6.0%	$500	$446	$217	$193
Medical care item #8	1/1/2015	12/1/2019	$10,000	1.0	3	Months	4.0%	7.0%	$200,000	$195,510	$124,701	$121,917
Column A	**Column B**	**Column C**	**Column D**	**Column E**	**Column F**	**Column G**	**Column H**	**Column I**	**Column J**	**Column K**	**Column L**	**Column M**

Table column title	Function macro call with parameters
Current-dollar expected costs to life expectancy	macro_lifecare("Current","Current",date_dob,integer_race_sex,date_t0,$B7,$C7,$D7,$E7,$F7,$G7,$H7,$I7)
Current-dollar expected costs over remaining lifetime	macro_lifecare("Survive","Current",date_dob,integer_race_sex,date_t0,$B7,$C7,$D7,$E7,$F7,$G7,$H7,$I7)
Present value expected costs to life expectancy	macro_lifecare("Current","PV",date_dob,integer_race_sex,date_t0,$B7,$C7,$D7,$E7,$F7,$G7,$H7,$I7)
Present value expected costs over remaining lifetime	macro_lifecare("Survive","PV",date_dob,integer_race_sex,date_t0,$B7,$C7,$D7,$E7,$F7,$G7,$H7,$I7)

complete software solution for calculating *PVM*. The workbook is downloadable from the Internet site http://JohnWardEconomics.com/Medical/. Documentation on how to use the workbook in making *PVM* calculations is contained within the workbook. Documentation for the macro is contained within the macro itself. Readers are encouraged to download the workbook and try different scenarios of *PVM* calculations.

Within the Appendix's "ForensicMacros Module", there are four different function macros: macro_lifecare, macro_prob_alive, macro_date_life_expectancy, and macro_double_yearfrac. The macro_lifecare function calculates the present value of expected future medical damages using the *life table* method or two different *life expectancy* approaches. The function macro_prob_alive calculates the probability of survival from the date of last known survival to any future date. The function macro_date_life_expectancy looks up remaining life expectancy in a lookup table and calculates the date associated with the life expectancy age. The function macro_double_yearfrac calculates the numeric difference between two dates.

In Figure 2, we show an example table within an Excel workbook to show *PVM* for a life care plan. The boxed area represents an example table that depicts the medical care items in a life care plan and each item's *PVM*. Below the table, we show the columns within a worksheet in the workbook and the associated function macro formulas contained within columns *J* through *M* of the worksheet. Medical care items within a life care plan are describable by the information in columns *A* through *G* of Figure 2. The litigation economist supplies the expected cost growth and appropriate discount rate by item in columns *H* and *I*. Using the variables "date_dob", "integer_race_sex", and "date_t0" contained elsewhere in the workbook, the litigation economist can choose the type of *PVM* calculation for the first parameter of the function macro "macro_lifecare", the type of dollars calculated with the second parameter, and the last eight parameters are simply references to the data contained in columns *B* through *I* of the table showing the medical items in the life care plan. The macro macro_lifecare allows a variety of ways of inputting beginning and ending consumption dates; it allows for various units and frequencies of consumption; and, each medical item can have its own expected growth and appropriate discount rate.

Within Figure 2, we show a variety of *PVM* for medical items for a 25-year old plaintiff using the *U.S. Life Table, 1998* data for all persons. Assume that medical care items #1 and #2 both present the cost of supportive care. In item #1, we show the annual cost of supportive care while in item #2, the monthly cost of supportive care (annual cost divided by twelve) is listed. Using the *life expectancy* approach, the total current-dollar costs are the same no matter if costs are calculated annually or monthly, however, future-dollar costs and *PVM* are remarkably different in all other calculations. Medical care items #3, #4, and #5 all sum to the continuous consumption timeframe as shown in item #2, but the differences in between *PVM* under the life table method and life expectancy approach are again illustrated as we saw in tables 5, 6, and 7. Medical care items #6, #7, and #8 show various ways to depict information in a life care plan.

Conclusion

The life care plan presents the required consumption of medical items on specific future dates. Litigation economists use the present value formula, the current-dollar amounts of medical items on each specific consumption date, and a mortality risk to calculate the present value of expected future medical damages. As described in this article, litigation economists rely on life tables for calculating the probability that the plaintiff would be alive at each specific future date in order to consume the required medical item. An alternative approach to accounting for mortality risk has been the use of the life expectancy statistic that is calculated from life tables. However, we have shown in this article that use of the life expectancy statistic embeds certain inaccuracies to the calculation of the present value of expected future medical damages. In nearly every litigation economics assignment, the economist makes a projection of anticipated economic losses absent risk, adjusts those losses for the risks that they would occur, and then discounts the risk-adjusted losses to present value. From this viewpoint, the calculation method of the present value of expected future medical damages points squarely to the usage of the *life table* method of calculating economic damages as described in this article.

In this article, we show that *PVM* under the *life table* method is comparable with *PVM* from the *life expectancy* approach only when the following two conditions exist within the analysis: (1) all medical items begin today and continue as long as the plaintiff is alive, and (2) the net discount rate is

zero. Seldom are the above two conditions present throughout each item in a life care plan, therefore the *life expectancy* approach introduces certain inaccuracies to the calculation of *PVM*. In the introduction to this article, we are clear to point out that the procedures presented within this article require that the use of life tables or life expectancy calculated from life tables is the preferred choice of evaluation. The life expectancy statistic does not exist without the life table and its associated survival probabilities. An expert may believe that the life table calculations are too burdensome to explain to a jury. However, this comment flies in the face of the fact that the life table survival probabilities have primacy to the life expectancy statistic. Hence, experts using $x + e_x$ as the terminal age of life care consumption should be careful to distinguish that they are not actually following the timing of the occurrence of e_x, but are using an approach outside the survival model that generates e_x in stating that they are expecting a "life certain" to age $x + e_x$.

A traditional approach by litigation economists to calculate the present value of expected future medical damages is to construct a custom table within an electronic spreadsheet showing age or years down the first column and medical item costs and discount factors in adjacent columns. While this approach presents a columnar view of how the present value of expected medical damages appears over time, it certainly is not concisely descriptive of how the individual medical care items are consumed/discounted. Such a columnar method results in pages upon pages of numbers, especially when each row in a table represents a month where consumption occurs. As an alternative to the undescriptive columnar method, we present a series of electronic spreadsheet macros that allow a clear descriptive tabular method of calculating the present value of expected medical damages. The tabular calculation method with macros allows medical damages to be calculated consistently, accurately, and quickly as opposed to the tedious columnar approach that can easily result in errors because the litigation economist is forced to work with literally tens-of-thousands of numbers in a lengthy life care plan.

References

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Appendix: VBA Excel Macro Module

```
' ForensicMacros Module
Function macro_lifecare(string_life_type As String, _
                        string_dollar_type As String, _
                        date_dob As Date, _
                        integer_race_sex As Integer, _
                        date_t0 As Date, _
                        date_item_begins As Variant, _
                        date_item_ends As Variant, _
                        double_cost_per_unit As Double, _
                        double_units_required_in_time_interval As Double, _
                        integer_time_interval As Double, _
                        string_year_or_month As String, _
                        double_cost_growth As Double, _
                        double_cost_discount As Double _
                        ) As Double
' Purpose:
' This function macro is used for calculating total life care costs in current, future, or present value
' dollars.

' The life table method calculates the probability of survival from the last known date that the plaintiff
' is alive to any future date.
'
' This macro also includes two other life expectancy approaches that are often used by forensic economists
' (1) the current life expectancy approach where the termination of life occurs with the life expectancy
' figured at the Plaintiff's current age, and (2) the actuarial life expectancy approach where any need that
' begins at a date after today, life expectancy is figured at that day and then the result is adjusted by
' the chance of survival to that future beginning date.

' Conventions:
' The input variable descriptions follow the format variable-type_description.

' Description of macro parameters:
' Parameter #1 - string_life_type
'   This parameter specifies the type of life care calculation desired:
'     Valid entries:
'       "Current_Life_Expectancy"   - life expectancy at today's date
'       "Actuarial_Life_Expectancy" - life expectancy at future beginning date actuarially adjusted for
'                                     survival
'                                     to today's date
'       "Survival_Life_Table"       - probability of survival period to period.
'     The following abbreviations are allowed "Current", "Actuarial", and "Surviv" (to allow "Survive"
'     or "Survival").
'
' Parameter #2 - string_dollar_type
'   This parameter specifies the type of dollar calculation desired:
'     Valid entries:
'       "Current_Dollars"       - no growth or discounting
'       "Future_Dollars"        - growth but no discounting
'       "Present_Value_Dollars" - growth and discounting.
'     The following abbreviations are allowed: "Current", "Future", and any string starting with the word
'     "P" (e.g. "PV" or "Present").
'
' Parameter #3 - date_dob
'   This parameter specifies the date of birth of the plaintiff.
'     Valid entries:
'       Any valid Excel date is required.
'       In this macro workbook, the date of birth is asked for in the opening worksheet and is stored under
'       the name date_dob.
'
' Parameter #4 - integer_race_sex
'   This parameter signifies the column number of the life expectancy
'   and whole life table representing the race and sex combination of the
'   plaintiff.
'     Valid entries:
'       In this macro, the life data used has 9 race/sex combinations so valid entries are 1 to 9.  This
'       data is stored in the this workbook's variable name integer_race_sex that is set by selecting
'       a list in a pop-down menu on the DataInput-Plaintiff worksheet.
'
```

```
' Parameter #5 - date_t0
'   This time=0 date is used to identify the certain date of: (1) the date used to calculate the present
'   value of lifecare costs, and (2) the date where the chance of being alive is certain.  This date
'   is most often set to the data the analysis was prepared or the trial or settlement date.
'     Valid entries:
'       Any valid Excel date is required.
'       In this macro workbook, this date is asked for in the opening worksheet and is stored under the
'       name date_t0.
'
' Parameter #6 - date_item_begins
'   This is the date that the lifecare cost item begins.
'     Valid entries:
'        "Today" - the date associated with date_t0
'        "Age #" - a future birthday associated with age (e.g. "Age 40","Age 50.5")
'        Any valid Excel date is also accepted (e.g. 9/1/2000).
'
' Parameter #7 - date_item_ends
'   This is the date that the lifecare cost item ends.
'     Valid entries:
'        "Today"    - the date associated with date_t0
'        "Age #"    - a future birthday associated with an age (e.g. "Age 40","Age 50.5")
'        "Lifetime" - when using the life expectancy approaches, the date of remaining life expectancy is
'                     calculated within the macro; when using the life table approach, the last birthday
'                     within the life table is calculated (the life table within this macro ends at age
'                     120).
'        Any valid Excel date is also accepted (e.g. 9/1/2000).
'
' Parameter #8 - double_cost_per_unit
'   This is the per unit cost of life care item.
'     Valid entries: Any numeric data with the format #.#.
'
' Parameter #9 - double_units_required_in_time_interval
'   This is the number of units required per year or per month.
'     Valid entries: Any numeric data with the format #.#.
'
' Parameter #10 - integer_time_interval
'   This is the time interval between the years or months in which the lifecare item are used (e.g. 10 units
'   needed every "3" months). The macro is set up to accept this parameter as a double variable type in
'   order to check for input error in the advent that an integer was not inputted.
'     Valid entries: Any integer with the format #.
'
' Parameter #11 - string_year_or_month
'   This parameter specifies the time interval or periodic use of the lifecare item in year or month
'   intervals.
'     Valid entries:
'       String values only of:
'          "Month", "Months", "Monthly", "M" or "Year", "Years", "Yearly", "Y".

' Parameter #12 - double_cost_growth
'   This is the annual percent change in cost of the lifecare item.
'     Valid entries:
'       Any numeric data with the format #.#.
'
' Parameter #13 - double_cost_discount
'   This is the annual interest rate for discounting lifecare costs to present value.
'     Valid entries:
'       Any numeric data with the format #.#.

'I. TRANSFORM AND CHECK THE INPUT DATA
' A. The parameters date_item_begins and date_item_ends are variant variable types allowing either string
'    (VarType=8) or date (VarType=7) input.  In this section, the macro transforms the string input to the
'    dates to which the strings correspond.
  If VarType(date_item_begins) = 8 Then
    If UCase(date_item_begins) = "TODAY" Then
      date_item_begins = date_t0
    ElseIf UCase(Left(date_item_begins, 4)) = "AGE " Then
      date_item_begins = DateSerial(Year(date_dob) + _
        Int(CDbl(Right(date_item_begins, Len(date_item_begins) - 4))), _
                                  Month(date_dob), _
                                    Day(date_dob) _
                                   ) _
                       + _
        (CDbl(Right(date_item_begins, Len(date_item_begins) - 4)) - _
     Int(CDbl(Right(date_item_begins, Len(date_item_begins) - 4)))) * 365
```

Appendix: VBA Excel Macro Module, continued

```
    Else
    ' Return #VALUE! because of bad parameter data
      macro_lifecare = CVErr(2015)
    ' Go to the end of the macro to exit with an error value set.
      GoTo GetOut
    End If
  ElseIf VarType(date_item_begins) <> 7 Then
   ' Return #VALUE! because of bad parameter data
     macro_lifecare = CVErr(2015)
   ' Go to the end of the macro to exit with an error value set.
     GoTo GetOut
  End If

  If VarType(date_item_ends) = 8 Then
    If UCase(date_item_ends) = "TODAY" Then
      date_item_ends = date_t0
    ElseIf UCase(Left(date_item_ends, 4)) = "AGE " Then
      date_item_ends = DateSerial(Year(date_dob) + _
        Int(CDbl(Right(date_item_ends, Len(date_item_ends) - 4))), _
                                Month(date_dob), _
                                  Day(date_dob) _
                                 ) _
                      + _
        (CDbl(Right(date_item_ends, Len(date_item_ends) - 4)) - _
     Int(CDbl(Right(date_item_ends, Len(date_item_ends) - 4)))) * 365
    ElseIf UCase(Left(date_item_ends, 4)) = "LIFE" Then
      If UCase(Left(string_life_type, 6)) = "SURVIV" Then
        date_item_ends = DateSerial(Year(date_dob) + 120, _
                                  Month(date_dob), _
                                    Day(date_dob) _
                                   )
      ElseIf UCase(Left(string_life_type, 9)) = "ACTUARIAL" Then
        date_item_ends = macro_date_life_expectancy( _
                                                  date_dob, _
                                                  integer_race_sex, _
                                                  (date_item_begins) _
                                                  )
      ElseIf UCase(Left(string_life_type, 7)) = "CURRENT" Then
        date_item_ends = macro_date_life_expectancy( _
                                                  date_dob, _
                                                  integer_race_sex, _
                                                  (date_t0) _
                                                  )
      End If
    Else
    ' Return #VALUE! because of bad parameter data
      macro_lifecare = CVErr(2015)
    ' Go to the end of the macro to exit with an error value set.
      GoTo GetOut
    End If
  ElseIf VarType(date_item_ends) <> 7 Then
   ' Return #VALUE! because of bad parameter data
     macro_lifecare = CVErr(2015)
   ' Go to the end of the macro to exit with an error value set.
     GoTo GetOut
  End If

' B. Perform a check on the order of parameter dates for consistency.
    If date_dob > date_t0 _
       Or date_dob > date_item_begins _
       Or date_dob > date_item_ends _
       Or date_t0 > date_item_begins _
       Or date_t0 > date_item_ends _
       Or date_item_begins > date_item_ends _
    Then
     ' Return #VALUE! to the worksheet because one of the parameter dates are out of order.
       macro_lifecare = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If
```

```
' C. Make sure that integer_time_interval is an integer and then reset the variable to an integer because
'    function DateAdd only wants integer values.
     If (integer_time_interval - Int(integer_time_interval)) <> 0 Then
       macro_lifecare = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If
    integer_time_interval = Int(integer_time_interval)

' D. Only accept yearly and monthly intervals for the timing of life care costs.
     Dim string_y_or_m As String
     string_y_or_m = UCase(Left(string_year_or_month, 1))
   ' Set the interval for the dateadd function
     If string_y_or_m = "Y" Then
        string_y_or_m = "YYYY"
     ElseIf string_y_or_m = "M" Then
            string_y_or_m = "M"
     Else
      ' Return #VALUE! because first character of time interval of the periods was not "Y" or "M"
        macro_lifecare = CVErr(2015)
      ' Go to the end of the macro to exit with an error value set
        GoTo GetOut
     End If

  ' Check race and sex value to be in the range of 1 to 9
    If Not (1 <= integer_race_sex And integer_race_sex <= 9) Then
     ' return #VALUE! to the worksheet because the race and sex range is out of order
       macro_life_care = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set
       GoTo GetOut
    End If

  ' Reset leap year dates for same cost estimation and programming of leap and non-leap years
    If date_dob = DateSerial(Year(date_dob), 2, 29) Then _
       date_dob = DateSerial(Year(date_dob), 3, 1)
    If date_t0 = DateSerial(Year(date_t0), 2, 29) Then _
       date_t0 = DateSerial(Year(date_t0), 3, 1)
    If date_item_begins = DateSerial(Year(date_item_begins), 2, 29) Then _
       date_item_begins = DateSerial(Year(date_item_begins), 3, 1)
    If date_item_ends = DateSerial(Year(date_item_ends), 2, 29) Then _
       date_item_ends = DateSerial(Year(date_item_ends), 3, 1)

'II. SET-UP VARIABLES AND ARRAYS USED WITHIN MACRO
   ' Establish and set the beginning value of the sum of lifecare item cost over equal to zero before
   ' looping
     Dim double_sum_cost As Double
     double_sum_cost = 0
   ' Establish the date for iterating to ending date
     Dim date_valuation As Date
   ' Establish the life expectancy table array
     Dim array_life_expectancy As Range
   ' The workbook must contain a named range called "range_life_expectancy" with life expectancy data from
   '  age 0 to age 120.
     Set array_life_expectancy = Range("range_life_expectancy")

'III. SET-UP GROWTH AND DISCOUNT DATA
    ' Change the values of double_cost_growth and double_cost_discount to fit the type of calculation
    ' desired: (1) current dollars, (2) future dollars, (3) present value dollars.
      If UCase(Left(string_dollar_type, 7)) = "CURRENT" Then
       double_cost_growth = 0
       double_cost_discount = 0
      ElseIf UCase(Left(string_dollar_type, 6)) = "FUTURE" Then
       double_cost_discount = 0
      ElseIf UCase(Left(string_dollar_type, 1)) <> "P" Then
     ' return #VALUE! to the worksheet because of bad string_dollar_type input
       macro_lifecare = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set
       GoTo GetOut
      End If
```

Appendix: VBA Excel Macro Module, continued

```
'IV. LOOP FOR TOTAL LIFECARE COSTS
   ' Set the initial loop value and then perform calculations for total lifecare costs.
     date_valuation = date_item_begins
     Do Until date_valuation > date_item_ends
      ' Multiply cost per unit and units needed within time interval for period costs and then compute
      ' present value by life type.
        If UCase(Left(string_life_type, 7)) = "CURRENT" Or _
           UCase(Left(string_life_type, 9)) = "ACTUARIAL" Then
         ' Working with the life expectancy calculation method.
           double_period_cost = double_cost_per_unit * _
             double_units_required_in_time_interval * _
             ((1 + double_cost_growth) / (1 + double_cost_discount)) ^ _
             macro_double_yearfrac(date_t0, date_valuation)
        ElseIf UCase(Left(string_life_type, 6)) = "SURVIV" Then
         ' Working with the life table survival calculation method.
           double_period_cost = double_cost_per_unit * _
             double_units_required_in_time_interval * _
             macro_prob_alive(date_dob, _
                              integer_race_sex, _
                              date_t0, _
                              date_valuation _
                              ) * _
             ((1 + double_cost_growth) / (1 + double_cost_discount)) ^ _
             macro_double_yearfrac(date_t0, date_valuation)
        Else
         ' return #VALUE! to the worksheet because of bad string_life_type parameter input.
           macro_lifecare = CVErr(2015)
         ' Go to the end of the macro to exit with an error value set.
           GoTo GetOut
        End If
      ' Add this loop's present value of costs to the accumulating present value of costs.
        double_sum_cost = double_period_cost + double_sum_cost
      ' Increment date_valuation to the next time interval.
        date_valuation = DateAdd(string_y_or_m, _
                                 integer_time_interval, _
                                 date_valuation _
                                 )
     Loop

'V. RETURN SUM OF COSTS AT THE END OF THE LOOP

    If UCase(Left(string_life_type, 9)) = "ACTUARIAL" Then
       macro_lifecare = macro_prob_alive(date_dob, _
                                         integer_race_sex, _
                                         date_t0, _
                                         (date_item_begins) _
                                         ) * _
                        double_sum_cost
    Else
       macro_lifecare = double_sum_cost
    End If

GetOut:
End Function
```

```
Function macro_prob_alive(date_dob As Date, _
                          integer_race_sex As Integer, _
                          date_q0 As Date, _
                          date_value As Date _
                          ) As Double
' Purpose:
' Function macro in Visual Basic for Excel for calculating the chance of survival (1- probability of death)
' between two dates: "date_q0" which is the date that assumes Prob(Alive) = 1 and "date_value" which is the
' date after "date_q0" that you want to calculate Prob(Alive) < 1.
'
' The data requirements for this macro are a life table of number of survivors from any whole life table.
' The survivor table is placed within the workbook and given the name "range_life_table_survivors".  This
' table should consist solely of the survivors by age running down the worksheet.  The dimension should be:
' rows = # of ages which survivor data is available; and,
' columns = # of race, sex combinations for which survivorship data are available.
' This macro is designed for a survivor table ranging from age 0 to age 120.  The macro can easily be
' changed to accommodate a whole life table of differing dimensions.

' Description of macro parameters:

' Parameter #1 - date_dob
'   This parameter specifies the date of birth of the plaintiff.
'     Valid entries:
'       Any valid Excel date is required.
'
' Parameter #2 - integer_race_sex
'   This parameter signifies the column number of the life expectancy and life table representing the race
'   and sex combination of the plaintiff.
'     Valid entries:
'       In this macro, the life table used has 9 race/sex combinations so valid entries are 1 to 9.
'
' Parameter #3 - date_q0
'   This time=0 date is used to identify the certain date of the last date where the chance of being alive
'   is certain.
'     Valid entries:
'       Any valid Excel date is required.
'
' Parameter #4 - date_value
'   This is a date >= date_q0 that you want to calculate the chance of survival from date_q0 to date_value.
'     Valid entries:
'       Any valid Excel date is also accepted (e.g. 9/1/2000).
'
'I. CHECK FOR GOOD INPUT DATA
  ' Check the order of input dates.
    If date_dob > date_q0 _
     Or date_dob > date_value _
     Or date_q0 > date_value _
    Then
     ' Return a #VALUE! to the worksheet because the input dates
     ' were out of order.
       macro_prob_alive = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If

  ' Reset leap year dates for same cost estimation and programming of leap/non-leap years.
    If date_dob = DateSerial(Year(date_dob), 2, 29) Then _
       date_dob = DateSerial(Year(date_dob), 3, 1)
    If date_q0 = DateSerial(Year(date_q0), 2, 29) Then _
       date_q0 = DateSerial(Year(date_q0), 3, 1)
    If date_value = DateSerial(Year(date_value), 2, 29) Then _
       date_value = DateSerial(Year(date_value), 3, 1)

  ' Check race and sex value to be in the range of 1 to 9
    If Not (1 <= integer_race_sex And integer_race_sex <= 9) Then
     ' return #VALUE! to the worksheet because the race and sex range is out of order
       macro_prob_alive = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set
       GoTo GetOut
    End If
```

Appendix: VBA Excel Macro Module, continued

```
'II. LOCATE SURVIVOR DATA
   ' Establish the array survivors.
     Dim array_survivors As Range
   ' The workbook must contain a named range called
   ' "range_life_table_survivors".  In this workbook, this range contains data from ages 0 to 120.
     Set array_survivors = Range("range_life_table_survivors")
'III. COMPUTE AGES AND SURVIVORS
  ' Compute the number of survivors at date_q0 and date_value.
    Dim double_survive_now As Double
    double_survive_now = _
     array_survivors(Int(macro_double_yearfrac(date_dob, date_q0)) + 1, integer_race_sex) + _
    (array_survivors(Int(macro_double_yearfrac(date_dob, date_q0)) + 2, integer_race_sex) - _
     array_survivors(Int(macro_double_yearfrac(date_dob, date_q0)) + 1, integer_race_sex)) * _
    (macro_double_yearfrac(date_dob, date_q0) - Int(macro_double_yearfrac(date_dob, date_q0)))

    Dim double_survive_value As Double
    double_survive_value = _
    array_survivors(Int(macro_double_yearfrac(date_dob, date_value)) + 1, integer_race_sex) + _
   (array_survivors(Int(macro_double_yearfrac(date_dob, date_value)) + 2, integer_race_sex) - _
    array_survivors(Int(macro_double_yearfrac(date_dob, date_value)) + 1, integer_race_sex)) * _
(macro_double_yearfrac(date_dob, date_value) - Int(macro_double_yearfrac(date_dob, date_value)))

'IV. CALCULATE PROBABILITY ALIVE
     macro_prob_alive = double_survive_value / double_survive_now

GetOut:
End Function
```

```
Function macro_date_life_expectancy(date_dob As Date, _
                                    integer_race_sex As Integer, _
                                    date_q0 As Date _
                                    ) As Date
' Purpose:
' Function macro for calculating the date of life expectancy at "date_q0" which is the date of evaluation
' that assumes Prob(Alive) = 1.
'
' The data requirements for this macro are a life expectancy table calculated from any whole life table.
' The life expectancy table is placed within the workbook and given the name "range_life_expectancy".
' This table should consist solely of the remaining life expectancies by age running down the worksheet.
' The dimension should be: rows = # of ages which the life expectancy data is available; and, columns =
' # of race, sex combinations for which survivorship data are available.  This macro is designed for a
' life expectancy table ranging from age 0 to age 120.

' Description of macro parameters:
' Parameter #1 - date_dob
'   This parameter specifies the date of birth of the plaintiff.
'     Valid entries: Any valid Excel date is required.
' Parameter #2 - integer_race_sex
'   This parameter signifies the column number of the life expectancy and life table representing the race
'   and sex combination of the plaintiff.
'     Valid entries:
'       In this macro, the life table used has 9 race/sex combinations so valid entries are 1 to 9.
' Parameter #3 - date_q0
'   This time=0 date is used to identify the certain date of the last date where the chance of being alive
'   is certain.
'     Valid entries: Any valid Excel date is required.

'I. CHECK FOR GOOD INPUT DATA
  ' Check the order of input dates.
    If date_dob > date_q0 _
    Then
     ' Return a #VALUE! to the worksheet because the input dates were out of order.
       macro_date_life_expectancy = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If
  ' Check to see if the race and sex value to be in the range of 1 to 9
    If Not (1 <= integer_race_sex And integer_race_sex <= 9) Then
     ' Return a #VALUE! to the worksheet because the race and sex range is out of order.
       macro_date_life_expectancy = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If

'II. LOCATE LIFE EXPECTANCY DATA
   ' Establish the array of life expectancy values
     Dim array_life_expectancy As Range
     Set array_life_expectancy = Range("range_life_expectancy")

' Calculate the date of life expectancy assuming survival to the date_q0.
  macro_date_life_expectancy = _
    DateSerial(Year(date_dob) + _
      Int(Int(macro_double_yearfrac(date_dob, date_q0)) + _
      array_life_expectancy(Int(macro_double_yearfrac(date_dob, _
                                                      date_q0)) + 1, _
                                                      integer_race_sex _
                                                      )) _
                , _
                Month(date_dob) _
                , _
                Day(date_dob)) _
     + _
      (array_life_expectancy(Int(macro_double_yearfrac(date_dob, _
                                                       date_q0)) + 1, _
                                                       integer_race_sex _
                                                       ) - _
   Int(array_life_expectancy(Int(macro_double_yearfrac(date_dob, _
                                                       date_q0)) + 1, _
                                                       integer_race_sex _
                                                       ))) * 365
GetOut:
End Function
```

Appendix: VBA Excel Macro Module, continued

```
Function macro_double_yearfrac(date_start As Date, _
                               date_end As Date _
                               ) As Double
' Purpose:
' A function macro for calculating numeric difference in dates.
' Parameters:
' Description of macro parameters:
'
' Parameter #1 - date_start
'   This parameter specifies the beginning date.
'     Valid entries:
'       Any valid Excel date is required.
'
' Parameter #2 - date_end
'   This parameter specifies the ending date.
'     Valid entries:
'       Any valid Excel date is required.

'I. CHECK FOR GOOD KEY INPUT DATA
  ' Check the order of the input dates.
    If date_start > date_end _
    Then
     ' Return a #VALUE! to the worksheet because the input dates were out of order
       macro_double_yearfrac = CVErr(2015)
     ' Go to the end of the macro to exit with an error value set.
       GoTo GetOut
    End If

'II. CHANGE FEBRUARY 29th DATES
   ' Change February 29th dates so we can consistently use 365 days in a year.
    If Month(date_start) = 2 And Day(date_start) = 29 Then
      date_start = DateSerial(Year(date_start), 2, 28)
    End If
    If Month(date_end) = 2 And Day(date_end) = 29 Then
      date_end = DateSerial(Year(date_end), 2, 28)
    End If

'III. CALCULATE NUMERIC DIFFERENCE IN DATES
   ' Calculate the difference in dates based upon if in the current year the beginning month and day
   ' has been reached
      If DateSerial(Year(date_end), _
                    Month(date_start), _
                    Day(date_start _
                    )) > _
                    date_end Then
     ' Have not yet arrived to beginning month and day this year. Compute numeric date difference using
     ' 1998 to avoid leap year problems for fraction of age.
       macro_double_yearfrac = (Year(date_end) - Year(date_start) - 1) + _
         (DateSerial(1998, Month(date_end), Day(date_end)) - _
          DateSerial(1998 - 1, Month(date_start), Day(date_start))) / 365
      Else
    ' Or, have already had birthday this year.
    ' Do the same as above except fraction of age occurs entirely in the current year.
        macro_double_yearfrac = (Year(date_end) - Year(date_start)) + _
          (DateSerial(1998, Month(date_end), Day(date_end)) - _
           DateSerial(1998, Month(date_start), Day(date_start))) / 365
       End If
    ' Check for a bad age at date_end because the rest of the macros in this workbook terminate at age 120.
      If Not (0 <= macro_double_yearfrac And macro_double_yearfrac <= 120) _
        Then
        macro_double_yearfrac = CVErr(2015)
        GoTo GetOut
      End If

GetOut:
End Function
```