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Worklife Expectancies Of Railroad Workers

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I. Introduction

The use of worklife expectancies separately or in conjunction with probability measures of mortality and labor force participation in LPE analyses is commonplace in forensic economics—eight variants have been surveyed in Ciecka (1994). The commonly used Bureau of Labor Statistics (BLS) tables of Bulletin 2254 (1986) and their updates (Ciecka, Donley, and Goldman, 1995 and 1996) apply to broad groups of US workers, with breakdowns by age, sex, labor force status, and a further variable, either race or education. The only occupation specific tables in common use are the railroad tables published every three years by the Association of American Railroads (AAR). The complete methodology of those tables has not been published prior to this paper, but it can safely be said that that methodology differs from the above tables generated by economists and demographers.[1] Funderburk (1988) noted the lack of documentation for the AAR tables. Although he did not provide details, Funderburk did specify the AAR's methodology in general terms, and he correctly identified the variables used, as well as the variables excluded, from the AAR's tables. In addition, he made several comments about the limitations of the tables in lawsuits. In a forthcoming paper, Ireland (1998) reconsiders, and takes issue with, some of Funderburk's arguments. The purposes of this paper are: (1) to present the railroad tables' methodology in detail and thereby to remove almost all of the remaining mystery surrounding them; (2) to provide a set of exact-age tables based on a methodology similar to the ARR but using data recently published by the US Railroad Retirement Board (RRB) in its *Twentieth Actuarial Valuation* (1997)—although an improvement on the AAR tables, these new tables still suffer from many of the defects of their predecessors; (3) to provide railroad worklife expectancies based on the data in the *Twentieth Actuarial Valuation* using BLS type methodology—these tables are a significant improvement over the AAR-type tables; and (4) to discuss the limitations of all of the foregoing tables.

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[1]Although the AAR methodology has not been published or made available to users of its tables, we have substantially reproduced the latest set of AAR work life tables from the basic data contained in the *Nineteenth Actuarial Valuation* (1994). We therefore are quite sure of the underlying methodology employed by the AAR.

II. Notation and Methodology

We employ the following notation in order to explain the methodology that has been used by the AAR to calculate worklife expectancies of railroad workers:

x	denotes exact age,
ω	denotes the youngest age for which the probability of being active in the railroad industry is zero,
s	denotes years of railroad service,
q_x	denotes the probability of dying between age x and x+1,
$d_{x,s}$	denotes the probability of a railroad disability retirement between x and x+1 given s years of service,
$r_{x,s}$	denotes the probability of a railroad age retirement between x and x+1 given s years of service,
$WLE_{x,s}$	denotes worklife expectancy for an individual at age x with s years of railroad service, and
$WLE_{x,s}^{AAR}$	denotes worklife expectancy for an individual at age x with s years of railroad service as computed by the AAR.

Consider a person who is in the railroad industry at age x and has s years of service. Then the probability of that individual remaining in the railroad industry at age x+1 is

(1) $$ {}_1p_{x,s} = 1-(q_x + d_{x,s} + r_{x,s}). $$

The probability of continuing as a railroad worker is defined recursively by

(2) $$ {}_{i+1}p_{x,s} = {}_ip_{x,s}\left[1-(q_{x+1} + d_{x+1,s} + r_{x+i,s})\right] $$

where $i = 1,\ldots,\omega - x - 1$ and ${}_{\omega-x}p_{x,s} = 0$.

The worklife expectancy at exact age x for an individual with s years of railroad service is

(3) $$ WLE_{x,s} = .5(1 + {}_1p_{x,s}) + .5({}_1p_{x,s} + {}_2p_{x,s}) + \ldots + .5({}_{\omega-x-1}p_{x,s} + {}_{\omega-x}p_{x,s}) $$

$$ = .5 + \sum_{i=1}^{\omega-x} {}_ip_{x,s} $$

where each term on the right hand side of (3) reflects the usual averaging of beginning and ending period probabilities typically used in expectancy calculations, such as average years of life calculations (Jordan, 1991, p. 173).[2]

[2]Although most of the readers of this paper may be economists, we have attempted to use standard actuarial notation in order to make our expectancy formulas as clear as possible. Accordingly, suffixed subscripts indicate the age of the life involved and years of service at that age. Prefixed subscripts indicate the time interval over which the probability of continued railroad service is taken. Although it is not customary to use a prefixed subscript when the

The worklife expectancy, as calculated by the AAR, is

$$WLE^{AAR}_{x,s} = .5\,{}_1p_{x,s} + \sum_{i=2}^{\omega-x} {}_ip_{x,s} \tag{4}$$

$$= WLE_{x,s} = .5(1 + {}_1p_{x,s}). \tag{4$'$}$$

As (4′) shows, $WLE^{AAR}_{x,s}$ is approximately one year less than $WLE_{x,s}$ when ${}_1p_{x,s}$ is close to one, which occurs for x less than 60. The AAR produces two types of tables—one based on the assumption that a railroad worker age x will have accumulated 30 years of service at age 60 and a second set of tables predicated on an individual having s years of service at age x (such a worker may, or may not, accumulate 30 years of service by age 60). For AAR tables based on the *Nineteenth Actuarial Valuation*, the mortality probability q_x is invariant to years of service; the disability retirement probability $d_{x,s}$ depends only on age for x < 60 and both age and years of service for x = 60,…,65; and the age retirement probability $r_{x,s}$ is zero prior to age 60 and it depends upon both x and s at age 60 and beyond.[3]

III. Worklife Tables Based on the *Twentieth Actuarial Valuation*

Table 1 and Table 2 show worklife expectancies utilizing formula (3) and data from the *Twentieth Actuarial Valuation*.[4] Table 1 contains worklife expectancies, denoted by $WLE_{x,30|60}$, for railroad workers who will accumulate at least 30 years of service by age 60. Table 2 shows worklife expectancies, $WLE_{x,s}$, by age and years of service. In the RRB's actuarial database, workers, who are exposed to a force causing exit from active status (because of death, age disability retirement, or age retirement), have their age recorded in an exposure year as the age attained on their birthday in that year. Assuming a uniform distribution of birthdays throughout the year, the "average birthday" is about June 30. Therefore, the average individual attaining age x during the year will have been age x-.5 at the start of the year. Thus, to obtain probabilities at exact age x analogous to life tables, we average the (x - .5) entry with the next (x + .5) entry in the RRB tables. The result is a worklife table at exact age x which permits interpolation when the injured party is between exact ages. The AAR tables, in contrast, are tabulated by "age on last birthday," requiring, for example, a 49.01 and a 49.99-year-old person to have the same worklife. Needless to say, in lawsuits, where specific information is available, it should be used if it can be used.

time interval is one period, we have chosen to use the notation ${}_1p_{x,s}$ in formula (1) for clarity. Furthermore, the first term on the right hand side of (3) could be written as $.5({}_0p_{x,s} + {}_1p_{x,s})$ instead of $.5(1+{}_1p_{x,s})$ since a person active in the railroad industry at age x is, by definition, active zero years in the future See Jordan (1991, pp. 29, 30) for a discussion of standard actuarial notation.

[3] The mortality table in the *Nineteenth Actuarial Valuation* is Table S-3, disability retirements are from Table S-10, and age retirements are found in Table S-9. The AAR work life tables can be reproduced exactly, or to within one-tenth or two-tenths of a year between ages 17-59 by using formula (4) and the data from Tables S-3, S-9, and S-10.

[4] Data were taken from Tables S-4, S-11, and S-10 for mortality, disability retirements, and age retirements, respectively.

Table 1
Worklife Expectancies at Exact Age and 30 Years of Service at Age 60
Based on the *Twentieth Actuarial Valuation* and AAR-Type Methodology

Exact Age	$WLE_{x,30\|60}$	Exact Age	$WLE_{x,30\|60}$
18	38.1	45	13.7
19	37.1	46	13.0
20	36.1	47	12.3
21	35.1	48	11.5
22	34.1	49	10.8
23	33.2	50	10.0
24	32.2	51	9.3
25	31.2	52	8.5
26	30.2	53	7.7
27	29.2	54	7.0
28	28.3	55	6.2
29	27.3	56	5.4
30	26.4	57	4.6
31	25.4	58	3.7
32	24.5	59	2.9
33	23.5	60	2.2
34	22.6	61	1.7
35	21.6	62	1.7
36	20.7	63	2.2
37	19.7	64	2.4
38	19.0	65	2.5
39	18.2	66	2.6
40	17.5	67	2.6
41	16.7	68	2.5
42	16.0	69	2.5
43	15.2	70	2.4
44	14.5		

Source: Computed with formula (3) applied to data from *Twentieth Actuarial Valuation*, Tables S-4, S-10, and S-11 adjusted to reflect exact ages.

Table 2
Worklife Expectancies $WLE_{x,s}$ $WLE_{x,30|60}$ at Exact Age and Years of Service Based on the *Twentieth Actuarial Valuation* and AAR-Type Methodology and WLE_x^{ID} and WLE_x^{POP}

Years of Service	Exact Age					
	18	19	20	21	22	23
0	38.3	37.5	36.7	36.0	35.2	34.4
1	38.1	37.3	36.5	35.8	35.0	34.2
2	N/A	37.1	36.3	35.5	34.8	34.0
3	N/A	N/A	36.1	35.3	34.6	33.8
4	N/A	N/A	N/A	35.1	34.3	33.6
5	N/A	N/A	N/A	N/A	34.1	33.4
6	N/A	N/A	N/A	N/A	N/A	33.2
$WLE_{x,30\|60}$	38.1	37.1	36.1	35.1	34.1	33.2
WLE_x^{ID}	37.8	37.3	36.6	35.9	35.2	34.4
WLE_x^{POP}	37.6	37.1	36.5	35.8	35.1	34.4

Table 2 (continued)

Years of Service	Exact Age					
	24	25	26	27	28	29
0	33.6	32.8	32.0	31.2	30.4	29.6
1	33.4	32.6	31.8	31.0	30.2	29.4
2	33.2	32.4	31.6	30.8	30.1	29.3
3	33.0	32.2	31.4	30.7	29.9	29.1
4	32.8	32.0	31.2	30.5	29.7	28.9
5	32.6	31.8	31.0	30.3	29.5	28.7
6	32.4	31.6	30.8	30.1	29.3	28.5
7	32.2	31.4	30.6	29.9	29.1	28.3
8	N/A	31.2	30.4	29.6	28.9	28.1
9	N/A	N/A	30.2	29.4	28.7	27.9
10	N/A	N/A	N/A	29.2	28.4	27.5
11	N/A	N/A	N/A	N/A	28.3	27.7
12	N/A	N/A	N/A	N/A	N/A	27.3
$WLE_{x,30\mid 60}$	32.2	31.2	30.2	29.2	28.4	27.3
WLE_x^{ID}	33.6	32.8	31.9	31.1	30.2	29.3
WLE_x^{POP}	33.6	32.9	32.0	31.2	30.4	29.5

Table 2 (continued)

Years of Service	Exact Age					
	30	31	32	33	34	35
0	29.0	28.4	28.0	27.6	27.0	26.2
1	28.6	28.0	27.4	27.0	26.6	26.0
2	28.5	27.7	27.0	26.5	26.0	25.7
3	28.3	27.5	26.7	26.0	25.5	25.1
4	28.1	27.3	26.5	25.7	25.1	24.5
5	27.9	27.1	26.3	25.5	24.7	24.1
6	27.7	26.9	26.1	25.3	24.5	23.7
7	27.5	26.7	25.9	25.1	24.4	23.6
8	27.3	26.5	25.7	25.0	24.2	23.4
9	27.1	26.3	25.6	24.8	24.0	23.2
10	26.9	26.1	25.4	24.6	23.8	23.0
11	26.7	26.0	25.2	24.4	23.6	22.8
12	26.5	25.8	25.0	24.2	23.5	22.7
13	26.4	25.6	24.8	24.1	23.3	22.5
14	N/A	25.4	24.6	23.9	23.1	22.3
N/A	N/A	N/A	24.5	23.7	22.9	22.1
N/A	N/A	N/A	N/A	23.5	22.7	22.0
N/A	N/A	N/A	N/A	N/A	22.6	21.8
N/A	N/A	N/A	N/A	N/A	N/A	21.6
$WLE_{x,30\mid 60}$	26.4	25.4	24.5	23.5	22.6	21.8
WLE_x^{ID}	28.4	27.5	26.6	25.7	24.8	23.9
WLE_x^{POP}	28.7	27.8	26.9	26.1	25.2	24.3

Table 2 (continued)

Years of Service	Exact Age 36	37	38	39	40	41
0	25.4	24.5	23.7	22.9	22.1	21.2
1	25.3	24.4	23.6	22.8	21.9	21.1
2	25.1	24.3	23.4	22.6	21.8	21.0
3	24.7	24.1	23.3	22.5	21.6	20.8
4	24.1	23.7	23.1	22.3	21.5	20.7
5	23.5	23.1	22.7	22.1	21.4	20.5
6	23.1	22.5	22.1	21.8	21.2	20.4
7	22.8	22.1	21.6	21.2	20.8	20.2
8	22.6	21.8	21.1	20.6	20.2	19.8
9	22.4	21.6	20.8	20.2	19.6	19.2
10	22.2	21.4	20.6	19.8	19.2	18.6
11	22.1	21.3	20.5	19.7	18.9	18.3
12	21.9	21.1	20.3	19.6	18.8	18.0
13	21.7	21.0	20.2	19.4	18.6	17.9
14	21.6	20.8	20.0	19.2	18.5	17.7
15	21.4	20.6	19.8	19.1	18.3	17.6
16	21.2	20.4	19.7	18.9	18.2	17.4
17	21.0	20.3	19.5	18.7	18.0	17.2
18	20.8	20.1	19.3	18.6	17.8	17.1
19	20.7	19.9	19.1	18.4	17.6	16.9
20	N/A	19.7	19.0	18.2	17.5	16.7
21	N/A	N/A	19.0	18.2	17.5	16.7
22	N/A	N/A	N/A	18.2	17.5	16.7
23	N/A	N/A	N/A	N/A	17.5	16.7
24	N/A	N/A	N/A	N/A	N/A	16.7
$WLE_{x,30\|60}$	20.7	19.7	19.0	18.2	17.5	16.7
$WLE_{x}ID$	23.0	22.1	21.1	20.2	19.3	18.5
$WLE_{x}POP$	23.5	22.6	21.7	20.9	20.0	19.1

Table 2 (continued)

Years of Service	Exact Age 42	43	44	45	46	47
0	20.4	19.5	18.7	17.8	17.0	16.1
1	20.3	19.4	18.6	17.7	16.9	16.0
2	20.1	19.3	18.4	17.6	16.7	15.9
3	20.0	19.2	18.3	17.5	16.6	15.8
4	19.9	19.0	18.2	17.3	16.5	15.7
5	19.7	18.9	18.1	17.2	16.4	15.5
6	19.5	18.7	17.9	17.1	16.3	15.4
7	19.4	18.6	17.8	16.9	16.1	15.3
8	19.2	18.5	17.6	16.8	16.0	15.2
9	18.9	18.3	17.5	16.6	15.8	15.0
10	18.3	17.9	17.3	16.5	15.7	14.8
11	17.7	17.3	17.0	16.4	15.6	14.8
12	17.4	16.8	16.4	16.1	15.5	14.8
13	17.1	16.5	15.9	15.6	15.2	14.6
14	16.9	16.2	15.5	15.0	14.7	14.3
15	16.8	16.0	15.3	14.6	14.1	13.8
16	16.6	15.9	15.1	14.3	13.7	13.2
17	16.5	15.7	15.0	14.2	14.8	12.8
18	16.3	15.6	14.8	14.1	13.3	12.6
19	16.1	15.4	14.6	13.9	13.2	12.4
20	16.0	15.2	14.5	13.7	13.0	12.3
21	16.0	15.2	14.5	13.7	13.0	12.3
22	16.0	15.2	14.5	13.7	13.0	12.3
23	16.0	15.2	14.5	13.7	13.0	12.3
24	16.0	15.2	14.5	13.7	13.0	12.3
25	16.0	15.2	14.5	13.7	13.0	12.3
26	N/A	15.2	14.5	13.7	13.0	12.3
27	N/A	N/A	14.5	13.7	13.0	12.3
28	N/A	N/A	N/A	13.7	13.0	12.3
29	N/A	N/A	N/A	N/A	13.0	12.3
30	N/A	N/A	N/A	N/A	N/A	12.3
$WLE_{x,30\|60}$	16.0	15.2	14.5	13.7	13.0	12.3
$WLE_{x}ID$	17.6	16.7	15.8	14.9	14.1	13.2
$WLE_{x}POP$	18.3	17.4	16.6	15.7	14.9	14.1

Table 2 (continued)

Years of Service	Exact Age					
	48	49	50	51	52	53
0	15.3	14.5	13.6	12.8	12.4	12.3
1	15.2	14.3	13.5	12.7	11.8	11.4
2	15.1	14.2	13.4	12.5	11.7	10.9
3	14.9	14.1	13.3	12.4	11.6	10.7
4	14.8	14.0	13.1	12.3	11.5	10.6
5	14.7	13.8	13.0	12.2	11.3	10.5
6	14.6	13.7	12.9	12.0	11.2	10.4
7	14.4	13.6	12.8	11.9	11.1	10.3
8	14.3	13.5	12.6	11.8	11.0	10.1
9	14.2	13.4	12.5	11.7	10.8	10.0
10	14.0	13.2	12.4	11.6	10.7	9.9
11	14.0	13.2	12.4	11.6	10.7	9.9
12	13.9	13.1	12.3	11.5	10.7	9.9
13	13.9	13.1	12.2	11.5	10.7	9.9
14	13.8	13.0	12.2	11.4	10.6	9.8
15	13.4	12.9	12.2	11.3	10.5	9.8
16	12.9	12.6	12.0	11.3	10.5	9.7
17	12.3	12.0	11.7	11.2	10.5	9.6
18	12.0	11.5	11.1	10.8	10.3	9.6
19	11.7	11.1	10.6	10.3	10.0	9.5
20	11.5	10.8	10.2	9.7	9.4	9.1
21	11.5	10.8	10.0	9.4	9.0	8.7
22	11.5	10.8	10.0	9.3	8.7	8.2
23	11.5	10.8	10.0	9.3	8.5	7.9
24	11.5	10.8	10.0	9.3	8.5	7.7
25	11.5	10.8	10.0	9.3	8.5	7.7
26	11.5	10.8	10.0	9.3	8.5	7.7
27	11.5	10.8	10.0	9.3	9.0	7.7
28	11.5	10.8	10.0	9.3	8.5	7.7
29	11.5	10.8	10.0	9.3	8.5	7.7
30	11.5	10.8	10.0	9.3	8.5	7.7
31	11.5	10.8	10.0	9.3	8.5	7.7
32	N/A	10.8	10.0	9.3	8.5	7.7
33	N/A	N/A	10.0	9.3	8.5	7.7
34	N/A	N/A	N/A	9.3	8.5	7.7
35	N/A	N/A	N/A	N/A	8.5	7.7
36	N/A	N/A	N/A	N/A	N/A	7.7
$WLE_{x,30/60}$	11.5	10.8	10.0	9.3	8.5	7.7
$WLE_x ID$	12.3	11.5	10.7	9.8	9.0	8.2
$WLE_x POP$	13.3	12.5	11.7	10.9	10.1	9.4

Table 2 (continued)

Years of Service	Exact Age 54	55	56	57	58	59
0	11.9	11.8	12.2	12.4	12.4	12.2
1	11.3	10.9	10.9	11.3	11.5	11.4
2	10.5	10.4	10.0	9.9	10.3	10.5
3	9.9	9.5	9.4	9.0	9.0	9.4
4	9.8	9.0	8.6	8.4	8.1	8.0
5	9.7	8.8	8.0	7.6	7.5	7.1
6	9.5	8.7	7.9	7.0	6.6	6.5
7	9.4	8.6	7.7	6.9	6.1	5.7
8	9.3	8.5	7.6	6.8	5.9	5.1
9	9.2	8.3	7.5	6.7	5.8	5.0
10	9.0	8.2	7.4	6.5	5.7	4.8
11	9.0	8.2	7.4	6.5	5.7	4.8
12	9.0	8.2	7.4	6.5	5.7	4.8
13	9.0	8.2	7.4	6.5	5.7	4.8
14	9.0	8.2	7.4	6.5	5.7	4.8
15	9.0	8.2	7.4	6.5	5.7	4.8
16	8.9	8.2	7.4	6.5	5.7	4.8
17	8.9	8.1	7.3	6.5	5.7	4.8
18	8.8	8.0	7.3	6.5	5.7	4.8
19	8.8	8.0	7.2	6.4	5.6	4.8
20	8.6	7.9	7.1	6.3	5.6	4.8
21	8.4	7.9	7.2	6.4	5.6	4.8
22	7.9	7.7	7.2	6.4	5.6	4.8
23	7.5	7.2	6.9	6.4	5.7	4.8
24	7.2	6.7	6.4	6.2	5.6	4.9
25	7.0	6.4	5.9	5.6	5.4	4.8
26	7.0	6.2	5.6	5.1	4.8	4.6
27	7.0	6.2	5.4	4.8	4.3	4.0
28	7.0	6.2	5.4	4.6	3.9	3.4
29	7.0	6.2	5.4	4.6	3.7	3.1
30	7.0	6.2	5.4	4.6	3.7	2.9
31	7.0	6.2	5.4	4.6	3.7	2.9
32	7.0	6.2	5.4	4.6	3.7	2.9
33	7.0	6.2	5.4	4.6	3.7	2.9
34	7.0	6.2	5.4	4.6	3.7	2.9
35	7.0	6.2	5.4	4.6	3.7	2.9
36	7.0	6.2	5.4	4.6	3.7	2.9
37	7.0	6.2	5.4	4.6	3.7	2.9
38	N/A	6.2	5.4	4.6	3.7	2.9
39	N/A	N/A	5.4	4.6	3.7	2.9
40	N/A	N/A	N/A	4.6	3.7	2.9
41	N/A	N/A	N/A	N/A	3.7	2.9
42	N/A	N/A	N/A	N/A	N/A	2.9
$WLE_{x,30\|60}$	7.0	6.2	5.4	4.6	3.7	2.9
$WLE_x ID$	7.5	6.8	6.0	5.3	4.6	4.0
$WLE_x POP$	8.7	8.0	7.4	6.8	6.2	5.7

Table 2 (continued)

Years of Service	Exact Age 60	61	62	63	64	65
0	12.0	11.8	11.5	11.1	10.6	10.2
1	11.3	11.1	10.9	10.6	10.2	9.7
2	10.5	10.4	10.2	10.0	9.7	9.3
3	9.6	9.6	9.4	9.3	9.0	8.8
4	8.5	8.7	8.6	8.5	8.3	8.1
5	7.1	7.5	7.7	7.7	7.6	7.4
6	6.2	6.1	6.6	6.8	6.8	6.6
7	5.6	5.2	5.2	5.6	5.9	5.8
8	4.7	4.6	4.2	4.2	4.7	4.9
9	4.1	3.7	3.6	3.3	3.2	3.7
10	4.0	3.2	2.8	2.7	2.3	2.3
11	4.0	3.2	2.8	2.7	2.3	2.3
12	4.0	3.2	2.8	2.7	2.3	2.3
13	4.0	3.2	2.8	2.7	2.3	2.3
14	4.0	3.2	2.8	2.7	2.3	2.3
15	4.0	3.2	2.8	2.7	2.3	2.3
16	4.0	3.2	2.8	2.7	2.3	2.3
17	4.0	3.2	2.8	2.7	2.3	2.3
18	4.0	3.2	2.8	2.7	2.3	2.3
19	4.0	3.2	2.8	2.7	2.3	2.3
20	4.0	3.2	2.8	2.7	2.3	2.3
21	4.0	3.2	2.8	2.7	2.3	2.3
22	4.0	3.2	2.8	2.7	2.3	2.2
23	4.0	3.1	2.7	2.6	2.3	2.2
24	4.0	3.1	2.7	2.6	2.3	2.2
25	4.1	3.2	2.7	2.6	2.2	2.2
26	4.0	3.2	2.8	2.6	2.2	2.2
27	3.8	3.2	2.9	2.6	2.2	2.1
28	3.2	2.9	2.8	2.8	2.3	2.1
29	2.6	2.3	2.4	2.7	2.4	2.2
30	2.2	1.7	1.7	2.2	2.4	2.5
31	2.2	1.7	1.7	2.2	2.4	2.5
32	2.2	1.7	1.7	2.2	2.4	2.5
33	2.2	1.7	1.7	2.2	2.4	2.5
34	2.2	1.7	1.7	2.2	2.4	2.5
35	2.2	1.7	1.7	2.2	2.4	2.5
36	2.2	1.7	1.7	2.2	2.4	2.5
37	2.2	1.7	1.7	2.2	2.4	2.5
38	2.2	1.7	1.7	2.2	2.4	2.5
39	2.2	1.7	1.7	2.2	2.4	2.5
40	2.2	1.7	1.7	2.2	2.4	2.5
41	2.2	1.7	1.7	2.2	2.4	2.5
42	2.2	1.7	1.7	2.2	2.4	2.5
43	2.2	1.7	1.7	2.2	2.4	2.5
44	N/A	1.7	1.7	2.2	2.4	2.5
45	N/A	N/A	1.7	2.2	2.4	2.5
46	N/A	N/A	N/A	2.2	2.4	2.5
47	N/A	N/A	N/A	N/A	2.4	2.5
48	N/A	N/A	N/A	N/A	N/A	2.5
$WLE_{x,30\mid 60}$	2.2	1.7	1.7	2.2	2.4	2.5
WLE_xID	3.3	2.7	2.5	2.8	2.8	2.9
WLE_xPOP	5.2	4.8	4.5	4.2	4.0	3.8

Table 2 (continued)

Years of Service	Exact Age				
	66	67	68	69	70
0	9.7	8.8	7.9	7.0	6.1
1	9.3	8.8	7.9	7.0	6.1
2	8.8	8.4	7.9	7.0	6.1
3	8.4	7.9	7.5	7.0	6.1
4	7.8	7.5	7.0	6.6	6.1
5	7.2	6.9	6.5	6.1	5.6
6	6.5	6.3	6.0	5.6	5.1
7	5.7	5.5	5.3	5.1	4.7
8	4.9	4.8	4.6	4.4	4.1
9	3.9	3.9	3.8	3.7	3.4
10	2.7	3.0	3.0	2.9	2.7
11	2.7	3.0	3.0	2.9	2.7
12	2.7	3.0	3.0	2.9	2.7
13	2.7	3.0	3.0	2.9	2.7
14	2.7	3.0	3.0	2.9	2.7
15	2.7	3.0	3.0	2.9	2.7
16	2.7	3.0	3.0	2.9	2.7
17	2.7	3.0	3.0	2.9	2.7
18	2.7	3.0	3.0	2.9	2.7
19	2.7	3.0	3.0	2.9	2.7
20	2.7	3.0	3.0	2.9	2.7
21	2.7	3.0	3.0	2.9	2.7
22	2.7	3.0	3.0	2.9	2.7
23	2.7	3.0	3.0	2.9	2.7
24	2.7	3.0	3.0	2.9	2.7
25	2.7	2.9	2.9	2.8	2.7
26	2.6	2.9	2.9	2.8	2.7
27	2.6	2.8	2.9	2.8	2.7
28	2.5	2.8	2.8	2.7	2.6
29	2.5	2.7	2.7	2.6	2.5
30	2.6	2.6	2.5	2.5	2.4
31	2.6	2.6	2.5	2.5	2.4
32	2.6	2.6	2.5	2.5	2.4
33	2.6	2.6	2.5	2.5	2.4
34	2.6	2.6	2.5	2.5	2.4
35	2.6	2.6	2.5	2.5	2.4
36	2.6	2.6	2.5	2.5	2.4
37	2.6	2.6	2.5	2.5	2.4
38	2.6	2.6	2.5	2.5	2.4
39	2.6	2.6	2.5	2.5	2.4
40	2.6	2.6	2.5	2.5	2.4
41	2.6	2.6	2.5	2.5	2.4
42	2.6	2.6	2.5	2.5	2.4
43	2.6	2.6	2.5	2.5	2.4
44	2.6	2.6	2.5	2.5	2.4
45	2.6	2.6	2.5	2.5	2.4
46	2.6	2.6	2.5	2.5	2.4
47	2.6	2.6	2.5	2.5	2.4
48	2.6	2.6	2.5	2.5	2.4
49	2.6	2.6	2.5	2.5	2.4
$WLE_{x,30\mid 60}$	2.6	2.6	2.5	2.5	2.4
WLE_xID	2.9	2.8	2.7	2.5	2.4
WLE_xPOP	3.6	3.4	3.3	3.1	2.9

Source: Computed with formula (3) applied to data from *Twentieth Actuarial Valuation*, Tables S-4, S-10, and S-11 adjusted to reflect exact ages.

Table 3
Calendar Year Rates of Immediate Age Retirement Years of Service

Age	Years of Service 10-29	Years of Service 30 and Over
60	0%	17%
61	0	17
62	27	67
63	20	45
64	16	33
65	49	41
66	40	30
67	30	30
68 to 74	25	30
75 and older	50	50

Source: *Twentieth Actuarial Valuation*(1997), Table S-10.

Readers of previous AAR studies will note that the tables based on years of service contain as a subset the worklife expectancies appearing in an accompanying summary table carrying the words "applicable to employees who have or would have 30 or more years of service at age 60" (AAR, 1995). Tables 1 and 2 exhibit the same property. For example, for 42-year-old employees in Table 2, the additional years of worklife calculation shows 20.4 years with 0 years experience, falls to 16.0 at 20 years experience, and remains (to within 1 decimal) at 16.0 years, which is the figure reported in the "30 years of service at age 60 table" in Table 1. Thus the summary table has an interpretation as the minimal worklife expectancy for those of a given age, which may mitigate against the obvious criticism—"how does the economist know that 30 years would have been achieved?" The logic is that, in our example and generally, this worker began at age 42 - 20 = 22; and thus has 30 years of experience by age 60, becoming eligible for an immediate age and service annuity. As shown in Table 3, this annuity is taken by 17% of those eligible. Of those so eligible who elect to work to age 62 and receive an unreduced age and service annuity, fully 67% retire at that age.[5] We see that the reason that additional worklife is higher for those with less experience is the inability to retire without 30 years of experience.

For worklife tables based on the *20th Actuarial Valuation*, the underlying charts in the *Twentieth Actuarial Valuation* show disability retirement for the first time broken down by service—grouped as 10-19 years and 20+ years. The calculations in Tables 1 and 2 now must keep track of experience in computing disability probability, and the logic of the single exit model requires that service years are consecutive, so that Tables 1 and 2 are constructed exactly as the AAR tables in this respect. Our Table 1 for "30 years service at age 60" remains a minimal worklife expectancy at any age.

Table 4 is similar to Table 1 in that both deal with workers with 30 years of service by age 60. However, Table 4 utilizes a Markov process model, which the BLS has called an increment-decrement model of labor

[5]Of those workers with 30 years of service at age 60, approximately 78% elect to receive an age retirement annuity by age 62, 88% receive an age annuity by age 63, and 95% by age 65

force activity.[6] This formulation allows both separations and accessions through transition probabilities. These transition probabilities, which lie at the heart of the increment-decrement model, are taken from Ciecka, Donley, and Goldman (1995); but the railroad specific transition probabilities for active-to-inactive transitions (i.e., retirements) are used for ages 60 and above (see Table 3). Mortality data also are railroad specific from age 18 to 75 (Table S-4 from the *Twentieth Actuarial Valuation*). Transition probabilities and mortality are assumed to be zero after age 75 because the probability of activity in the railroad sector beyond that age (for those with 30 years of service) is very small (approximately .0008). Except for young ages (18 and 19) and older ages (69 and 70), the work lives in Table 4, WLE_x^{ID}, are larger than in Table 1; but they are smaller than those in the population, denoted by WLE_x^{POP}.

Table 4
Worklife Expectancies at Exact Age and 30 Years of Service At Age 60 Based on the *Twentieth Actuarial Valuation* and a Markov Processes Model of Labor Force Activity

Exact Age	WLE_x^{ID}	Exact Age	WLE_x^{ID}
18	37.8	45	14.9
19	37.3	46	14.1
20	36.6	47	13.2
21	35.9	48	12.3
22	35.2	49	11.5
23	34.4	50	10.7
24	33.6	51	9.8
25	32.8	52	9.0
26	31.9	53	8.2
27	31.1	54	7.5
28	30.2	55	6.8
29	29.3	56	6.0
30	28.4	57	5.3
31	27.5	58	4.6
32	26.6	59	4.0
33	25.7	60	3.3
34	24.8	61	2.7
35	23.9	62	2.5
36	23.0	63	2.8
37	22.1	64	2.8
38	21.1	65	2.9
39	20.2	66	2.9
40	19.3	67	2.8
41	18.5	68	2.7
42	17.6	69	2.5
43	16.7	70	2.4
44	15.8		

Source: Mortality probabilities are from Table S-4 and active-to-inactive and active-to-active transition probabilities from Table S-10 from the *Twentieth Actuarial Valuation* for ages 60 and above. All other transition probabilities are from Ciecka, Donley, and Goldman (1995), rescaled to reflect railroad mortality.

[6]See Bulletin 2135 *Tables of Working Life: The Increment-Decrement Model* (1982) for an explanation of the nature of this formulation of labor market activity. A shorter explanation can be found in Ciecka, Donley, and Goldman (1995).

IV. Comments and Limitations

The classic Bulletin 2135, *Tables of Working Life: The Increment-Decrement Model* (BLS, 1982) discusses the assumptions in the older, conventional working life table and the increment-decrement model. In the older model, the exits from the labor force were, like death, absorbing states—one enters the labor force at most once. The newer model incorporates transition probabilities at each age between the active and inactive states, permitting several exits and accessions to the labor force. In both cases, a well-defined population of workers is identified (total, active, or inactive workers at a given age), and the worklife expectancy is identified as the future active years of this cohort divided by the number in the cohort.[7] Equivalently, the sum of the probabilities of being active is computed, conditionally or unconditionally on the initial state. The AAR methodology, used in Tables 1 and 2, is similar to the conventional working life table in that only separations occur (because of death, disability, or age retirement); there are no accessions. Table 4, however, is an increment-decrement table that allows for separations and accessions.

There are two important senses in which an ideal litigation worklife table would differ from any of the population worklife tables produced above: (1) deaths should be deaths net of work-related deaths compensable by (future) lawsuits; and (2) participation should be net of withdrawals from work-related injuries compensable in lawsuits. Workers working in risky occupations or risky industries face a stream of earnings which in any future year is the maximum of what they would earn if uninjured and what they would earn from that part of a lawsuit replacing those earnings. Thus, in theory they do not bear the loss from injury on the job reflected in industry specific or job specific disabilities or mortalities. In using the BLS worklife measures or their progeny, we and the profession are implicitly assuming these probabilities are small enough to ignore. However, for railroad workers, these probabilities are exceedingly high—between 3% and 4% are injured in their late 50's and early 60's. Not only are these probabilities included, but they are a major force in pulling the AAR railroad worklife expectancies below that of the overall population. Funderburk (1988, p. 67) has pointed out that a legal principle of equity (that "one should not benefit as a consequence of one's own misdeeds") would be violated if railroads were allowed to use tables which showed reduced worklife expectancies because railroads were "maintaining an unsafe work environment." This appears to be a normative argument as far as economics is concerned—unjust enrichment in the law—with which we have no quarrel. Ireland also identifies Funderburk's argument as normative and goes on to criticize him for not considering compensating wage differentials and the safety of railroad work relative to other physical outside labor. In our view, economists testifying on damages may not be able to rely on their interpretation of the legal principle of unjust enrichment and may have difficulty introducing normative and welfare economics concepts in a setting where courts expect them to be testifying on issues based on positive economics. Our point is that positive economics does provide a rationale for netting out the probabilities of future

[7]The older tables use subterfuge (see BLS Bulletin 2135, area abc in Figure B-6, p. 51) by inflating both years of activity and the size of the active population during early ages when computing work life expectancies for active individuals.

compensable accidents from worklife table construction, regardless of whether these accidents are the result of unsafe work environments or other risks less under the control of railroads.

The mortality of railroad workers, on the other hand, compares favorably with that of the US population. At ages 20, 30, 40, 50, and 60, the mortality rates (in the *Nineteenth Actuarial Valuation*) for railroad workers are approximately 28%, 32%, 45%, 49%, and 47% of the mortality probabilities for all males in the US respectively.[8] Lower mortality, of course, leads to longer worklife expectancies. Furthermore, reduced labor force participation due to morbidity is not included in the AAR methodology; this is a major shortcoming that also leads to longer worklife expectancies. In addition, for workers with less than 10 years of railroad experience, their probability of remaining in railroad work the next year equals their probability of survival, according to the AAR model: they cannot retire (because they do not have 10 years of service) and they cannot become disabled (because they do not have 10 years of service to receive a disability pension). Inspection of Table S-11 (*Twentieth Actuarial Valuation*) shows that the disability probability is zero after age 65, presumably because most older workers would then qualify for a pension, based on age or disability.

AAR-type worklife expectancies (Tables 1 and 2) are expectancies for those workers who remain in the railroad industry. The tables do not reflect withdrawals form railroad service for causes other than death, disability retirement, and age retirement; whereas our Table 4 is an attempt to include separations and accessions.

V. Conclusions

The railroad worklife tables based on ARR methodology, new and old, appear superficially to resemble the more established economic and demographic counterparts. They converge to somewhat lower worklife expectancies, which we suspect has met with many economists' priors about riskiness of railroad work, decline in the railroad workforce, and the retirement plan offering age-reduced pension benefits at age 60 and full benefits at 62. However, upon reviewing the methodology used in the railroad tables, it can be said that they reflect a serendipitous mixture of upward and downward biases.

All of the worklife expectancies computed in this paper are exhibited in Table 2, plus worklife expectancies for the entire male population (denoted by WLE_x^{POP}) from Ciecka, Donley and Goldman (1995). Figures 1 and 2 illustrate some of the most salient differences among these worklife expectancies. The difference between WLE_x^{POP} and WLE_x^{ID} increases until age 61 and then declines, but there is only one year or less than one year separating these expectancies between age 18 and 50 and between ages 65 and 70. The difference between WLE_x^{POP} and $WLE_{x30|60}$ is bimodal and is larger than between WLE_x^{POP} and WLE_x^{ID}. Peak differences of a little less than three years occur at ages 35-40 and 59-62. The difference between $WLE_{x,0}$ and $WLE_{x,30|60}$ is very small at age 18 but grows to approximately ten years between ages 60 and 62, reflecting the importance of years of service in order to retire.

In our opinion, WLE_x^{ID} is preferable to $WLE_{x,30|60}$. However, the reader will notice that we have not offered worklife expectancies for workers not ex-

[8]Mortality probabilities for all males in the US were calculated from *Vital Statistics of the United States, 1991* (1995, p. 11).

pected to attain 30 years of service by age 60. In our opinion, for such workers it is best to obtain worklife expectancies from other general tables like WLE_x^{POP}, that contain worklife expectancies which usually are between $WLE_{x,0}$ and $WLE_{x,30|60}$.

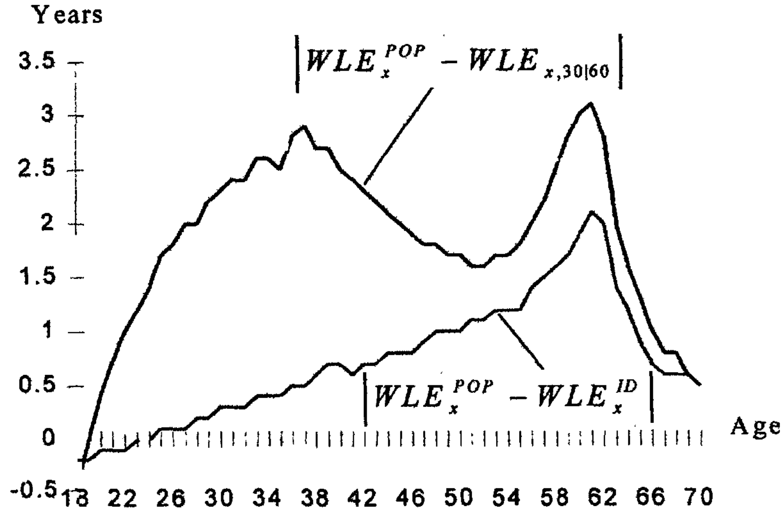

Figure 1. Differences in Worklife Expectancies between Entire Male Population and Railroad Workers

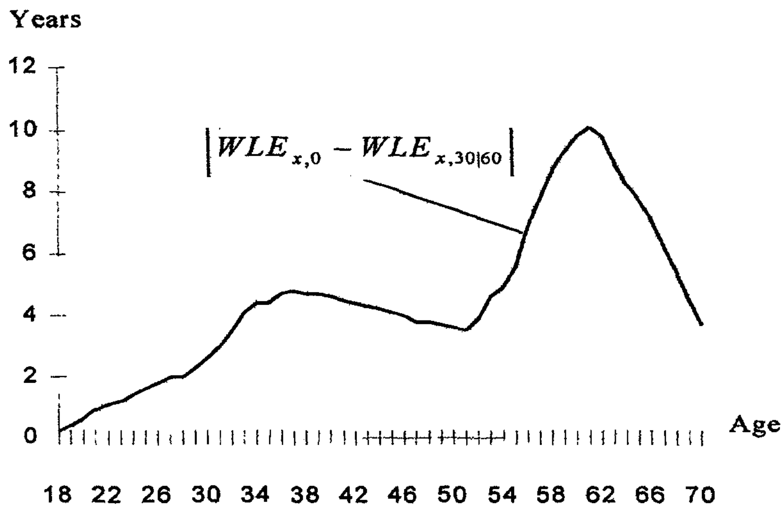

Figure 2. Difference in Worklife Expectancies between Railroad Workers with No Service and 30 Years of Service by Age 60

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