Determination of Effect of Introduction of Dual Treatment (Borate-Creosote) Ties on Average Tie Life and Wood Tie Life Cycle Costs

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The Railway Tie Association (RTA)

ZETA-TECH

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1. Introduction

Recent studies have shown that the treatment of conventional wood crossties with both Borate and Creosote can significantly extend tie life in high wood decay areas as compared to ties treated only with creosote. This is especially true in regions where moisture and environmental conditions are a primary factor leading to wood tie failure. Using available nationwide railroad data and the five Climate Zones as established by the "Wood Decay Deterioration Zone" map (see Figure 1), this report presents the effective increase in tie life both system-wide and for each Climate Zone based on the introduction of dual treatment (borate and). The resulting range of expected tie lives is presented for the dual treated ties and compared to the lives for conventional creosote-only ties. Finally, the economic impact of dual treatment is presented as compared to conventional creosote treatment.

2. Five-Year History of Current US Wood Tie Life

An integral part of this analysis is to determine the effect of dual treatment on the life of wood ties. Consequently, it is important to determine the current system-wide average US tie life for creosote-only ties that can serve as a baseline. To calculate this value, a five-year history of existing ties and tie installations was gathered to determine the average life of a creosote-only wood ties in the US.

Specifically, Table 1 shows the approximate number of Class 1 track miles in the US for each of the last five years. This is converted to an approximate number of ties based on a 19.5-inch tie spacing, resulting in 3249 ties per mile. This figure is then adjusted by 95% to reflect only those ties that are wood (eliminating the 5% that are made of concrete or other tie materials). Next, the number of ties installed in US Class 1 track in each of the last five years is given. Dividing the number of installed ties into the number of wood ties gives the approximate tie life. Averaging these five figures together gives a nationwide tie life for wood ties of 35.2 years (i.e. average new tie life for creosote-only wood ties in the US).

3. US Track Data Distributions for Climate, Tonnage, and Curvature

<u>Climate</u>

As shown in Figure 1, the United States has been divided into five Climate Zones as part of a study of the decay of wood products [1]. These zones represent the severity of wood decay, where Zone 1 has the lowest rate and Zone 5 has the most severe rate. Given equal tonnages and curvature, conventional creosote-only tie lives will be far lower in Zone 5 than in Zone 1 due to environmentally caused wood tie decay.

For the analysis of the effect of dual-treatment of ties, it is necessary to determine the distribution of ties in each of the five zones, to account for the increased effectiveness of the dual treatment in the high decay zones. This is achieved by taking the number of ties (or miles) in each state [2] and combining that with the percentage of each state's area that lies in each zone, as shown in Tables 2a and 2b.

Table 1: Five-Year History of Ties and Installations

Year	2006	2007	2008	2009	2010
Track Miles	162,056	161,114	160,734	160,781	160,781
Ties*	526,557,342	523,496,566	522,261,858	522,414,572	522,414,572
Wood Ties**	500,229,474	497,321,738	496,148,766	496,293,844	496,293,844
Ties Installed in 2010	14,017,000	13,464,000	14,401,000	14,463,000	14,292,000
Tie Life (years)	35.7	36.9	34.5	34.3	34.7
5-year Average of US Tie Life	**35.2**				

* based on 3249 ties per mile

** based on US ties being 95% wood and 5% concrete and other tie material

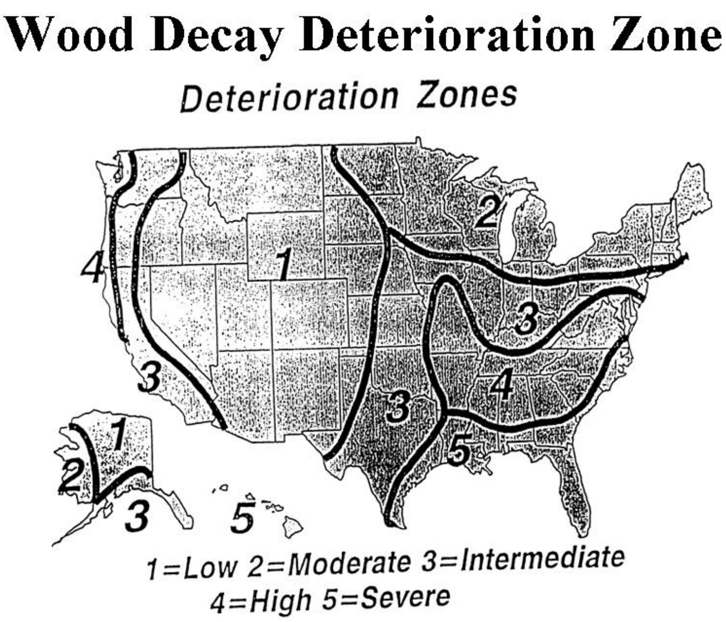

Figure 1: Five Wood Decay Zones in the United States

Table 2a: US Route Mileage by State and Zone (AL to SC)

		Distribution by Zone (%)					Route Miles in Each Zone				
State	Miles	1	2	3	4	5	1	2	3	4	5
AL	3271				60	40	0	0	0	1962.6	1308.4
AK	506	50	25	25			253	126.5	126.5	0	0
AZ	1679	100					1679	0	0	0	0
AR	2780			15	85		0	0	417	2363	0
CA	5305	25		65	10		1326.25	0	3448.25	530.5	0
CO	2684	100					2684	0	0	0	0
CT	327		40	60			0	130.8	196.2	0	0
DE	227				100		0	0	0	227	0
DC	23				100		0	0	0	23	0
FL	2875					100	0	0	0	0	2875
GA	4714				55	45	0	0	0	2592.7	2121.3
HI	0					100	0	0	0	0	0
ID	1627	100					1627	0	0	0	0
IL	7313		25	75			0	1828.25	5484.75	0	0
IN	4475		20	80			0	895	3580	0	0
IA	3925		20	40	40		0	785	1570	1570	0
KS	4890	40		60			1956	0	2934	0	0
KY	2558			80	20		0	0	2046.4	511.6	0
LA	2830					100	0	0	0	0	2830
ME	1151		100				0	1151	0	0	0
MD	759				100		0	0	0	759	0
MA	952		100				0	952	0	0	0
MI	3689		100				0	3689	0	0	0
MN	4528		100				0	4528	0	0	0
MS	2683				55	45	0	0	0	1475.65	1207.35
MO	4050				100		0	0	0	4050	0
MT	3173	100					3173	0	0	0	0
NE	3215	65		35			2089.75	0	1125.25	0	0
NV	1192	100					1192	0	0	0	0
NH	415		100				0	415	0	0	0
NJ	983			100			0	0	983	0	0
NM	1835	100					1835	0	0	0	0
NY	3494		100				0	3494	0	0	0
NC	3230				65	35	0	0	0	2099.5	1130.5
ND	3413	25	75				853.25	2559.75	0	0	0
OH	5286		35	65			0	1850.1	3435.9	0	0
OK	3275	15		85			491.25	0	2783.75	0	0
OR	2352	45		35	20		1058.4	0	823.2	470.4	0
PA	4973		30	50	20		0	1491.9	2486.5	994.6	0
RI	19		50	50			0	9.5	9.5	0	0
SC	2292				70	30	0	0	0	1604.4	687.6

Table 2b: US Route Mileage by State and Zone (SD to WY)

		Distribution by Zone (%)					Route Miles in Each Zone				
State	Miles	1	2	3	4	5	1	2	3	4	5
SD	1741	60	40				1044.6	696.4	0	0	0
TN	2635				100		0	0	0	2635	0
TX	10405	20		60		20	2081	0	6243	0	2081
UT	1358	100					1358	0	0	0	0
VT	590		100				0	590	0	0	0
VA	3212				100		0	0	0	3212	0
WA	3169	20		50	30		633.8	0	1584.5	950.7	0
WV	2231				100		0	0	0	2231	0
WI	3510		100				0	3510	0	0	0
WY	1860	100					1860	0	0	0	0

With the proportion of each state's area for each zone, the total number of route miles per zone in the US can be found. These totals are given in Table 3 along with the percentages for each zone. In addition, Table 3 also converts these total route miles into track miles and then into tie totals using a 19.5-inch tie spacing (3249 ties per mile) and adjusting for non-wood ties.

Table 3: US Mileage and Tie Count by Zone

		Distribution of Route Miles By Zone				
	All US	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
US Route Miles	139,679	27,195	28,702	39,278	30,263	14,241
Dist. (%)	100%	19.5%	20.5%	28.1%	21.7%	10.2%
US Track Miles	212,365	41,347	43,638	59,717	46,011	21,652
Percentage Wood	94.8%	90%	90%	98%	98%	98%
Wood Ties	654,131,564	120,911,350	127,610,939	190,153,628	146,510,350	68,945,298

As Table 3 shows, 10.2% of all ties (miles) are found in Zone 5 and 31.9% of all ties are found in Zones 4 and 5, the two most environmentally severe regions of the US. Overall, of the 654 billion wood ties in the US, 215 billion lie in Zones 4 and 5. Adding Zone 3, we find that 60% of all US ties lie on one of the three most severe zones, with a total of 405.5 billion wood ties.

Tonnage

US tonnage data was broken into four categories for the analysis. Each category was given a representative value (in terms of MGT). Table 4 shows these categories together with the estimated percentage of US track for each of the four categories. These figures are used together with curvature distributions to determine expected tie lives in each of the five zones.

Table 4: US Tonnage Distribution

Tonnage Category	Representative Tonnage (MGT)	Distribution (%)
High Tonnage Main Lines (> 50 MGT)	60	34%
Moderate Tonnage Main Lines (20 to 50 MGT)	30	19%
Secondary Track	15	25%
Yards	5	22%

Curvature

Like tonnage, US curvature data was broken into three categories, each with a representative degree of curvature. Table 5 shows the three curvature categories and values together with the percentage of US track in each category.

Table 5: US Curvature Distribution

Curvature Category	Representative Curvature (degree)	Distribution (%)
Less than 2 degrees (including Tangent)	0	92%
2 degrees to less than 6	2	7%
6 degrees and above	6	1%

4. Calculated Creosote-Only Tie Lives for Each Climate Zone

Cross-tie life has been shown to vary significantly as a function of such key track, traffic and environmental factors as tie material, annual tonnage, curvature, and climate zone [3, 4]. ZETA-TECH's *TieLife* model [3, 5] was developed to calculate the average new tie life for a tie based on these key factors. This model, which draws on industry research and is continuously updated and calibrated to be in line with real world experience, has been used extensively over the last 15 years for various railroads and organizations worldwide. For this study, *TieLife* was used to calculate the average new tie life for wood ties treated only with creosote and for each of the tonnage, curvature, and climate zone categories outlined in the previous section.

Tables 6 through 10 show these tie lives for a matrix of tonnage and curvature categories with each table corresponding to one zone (Zones 1 through 5, respectively). Using the percentage distributions from the last columns of Tables 4 and 5 (tonnage and curvature, respectively), a weighted average tie life is calculated for each zone and is also shown in the tables below.

Table 6: Average New Creosote-Only Tie Life for Climate Zone 1

Tonnage Category	0 degrees	2 degrees	6 degrees
60	38.6	34.7	28.1
30	43.1	39.4	32.8
15	46.1	42.9	37.0
5	49.0	47.0	43.3
Weighted Average for Zone 1		**43.3**	

Table 7: Average New Creosote-Only Tie Life for Climate Zone 2

Tonnage Category	0 degrees	2 degrees	6 degrees
60	35.5	32.0	26.0
30	39.7	36.3	30.2
15	42.5	39.6	34.2
5	45.1	43.3	40.0
Weighted Average for Zone 2		**39.9**	

Table 8: Average New Creosote-Only Tie Life for Climate Zone 3

Tonnage Category	0 degrees	2 degrees	6 degrees
60	32.0	28.8	23.4
30	35.8	32.6	27.1
15	38.3	35.6	30.7
5	40.6	39.0	36.0
Weighted Average for Zone 3		**35.9**	

Table 9: Average New Creosote-Only Tie Life for Climate Zone 4

Tonnage Category	0 degrees	2 degrees	6 degrees
60	27.3	24.6	20.0
30	30.6	27.9	23.3
15	32.7	30.4	26.2
5	34.7	33.3	30.7
Weighted Average for Zone 4	**30.7**		

Table 10: Average New Creosote-Only Tie Life for Climate Zone 5

Tonnage Category	0 degrees	2 degrees	6 degrees
60	16.1	14.6	11.8
30	18.1	16.5	13.8
15	19.3	18.0	15.5
5	20.5	19.7	18.2
Weighted Average for Zone 5	**18.1**		

Using the percentage distributions for track miles by Climate Zone from Table 3, a system average new tie life for creosote-only ties can be calculated. This is shown below in Table 11. Note that the weighted average value is 35.2 years, matching the figure from Section 2 of this report.

Table 11: US Average New Creosote-Only Tie Life and Summary by Climate Zone

Climate Zone	Average New Creosote-Only Tie Life (years)	Distribution (%)
1	43.3	19.5%
2	39.9	20.5%
3	35.9	28.1%
4	30.7	21.7%
5	18.1	10.2%
System-wide US Average	**35.2**	100%

5. Range of Creosote-Only Tie Lives Based on the Forest Products Curve

Given an average new tie life, as was calculated for each Climate Zone in the previous section, the Forest Products Curve [1] can be used to show the distribution of failure times around that average. This is shown in Figure 2.

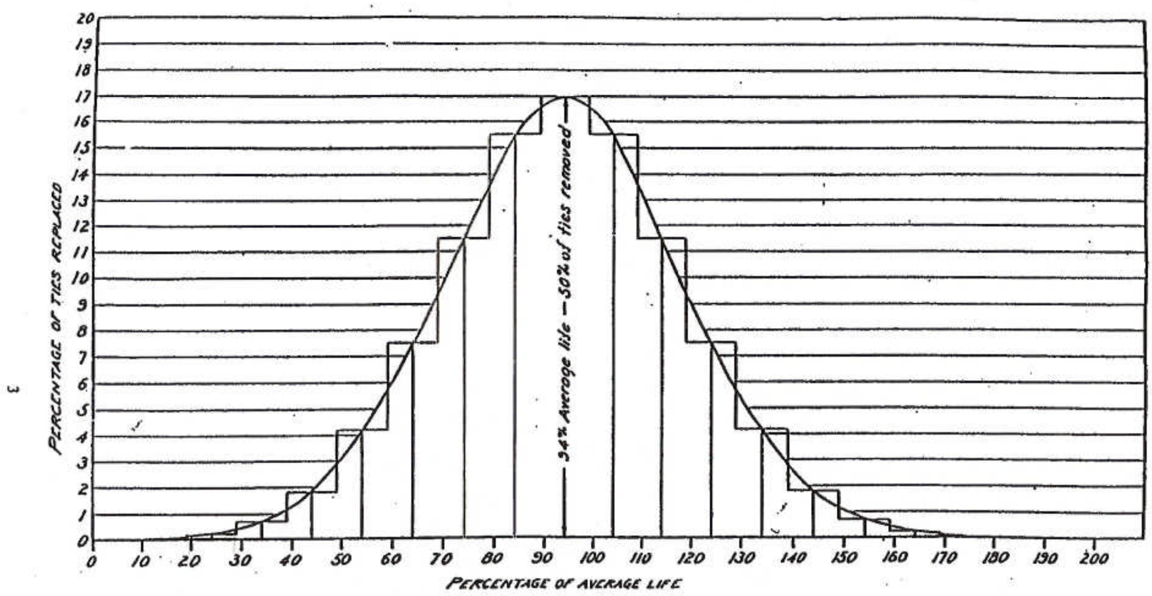

Figure 2: Forest Products Curve [1, 6]

It can be seen from this curve that, according to historical research (which was revalidated in 2008 by an RTA study [6]) the distribution of tie failures around the average life, which is a function of climate, traffic, track, and operating conditions, is in the form of a skewed "normal" distribution. As such, approximately 50% of the ties in newly constructed track will have been replaced by the time the track has reached 94% "average life" with the remaining 50% replaced at lives greater than 94% of average life. Thus, wood tie failure occurs over time with a significant number of ties failing earlier than average and likewise a significant number of ties having a life greater than average for the given track conditions. This behavior has been well established and validated.

As this distribution shows, some small number of ties will fail extremely "early" (well below the expected average life) and some will live unusually long. Most will fail in a range around the average. In order to put actual numbers to these ranges for each Climate Zone, a statistical approach is used based on Standard Deviation of the distribution, often represented by the Greek letter σ .

The standard deviation of a normal distribution of numbers gives a measure of the "spread" of the data around the average. A very small standard deviation means that nearly all of the data is very close to the average value. A large standard deviation means that the data is scattered very widely around the average. Statistically, 68% of the data in a normal distribution lies within one standard deviation (i.e. $\pm 1\sigma$) around the average. The Forest Products Curve is not truly a normal distribution but it is very nearly so. Consequently, for each Climate Zone 68% of all ties will fail within one standard deviation of the calculated new average tie life.

Going out a bit further, 95% of all data will lie within two standard deviations of the average (i.e. $\pm 2\sigma$). Extending this to plus or minus three standard deviations will cover 99.7% or very nearly all of the data in the distribution.

From the Forest Products Curve shown in Figure 2, the boundary points that encompass 68%, 95%, and 99.8% of the data around the average can be found (this is done by analyzing the area under the curve). Table 12 shows the percentage of the average tie life that corresponds to plus and minus one, two, and three standard deviations.

Table 12: Percentage of Average New Tie Life Corresponding to $\pm 1\sigma$, $\pm 2\sigma$, and $\pm 3\sigma$

Tie Life Range in terms of Standard Deviation (σ)	Percentage of All Ties Failing in this Range	Tie Life Range in Terms of Percentage of the Average New Tie Life
$\pm 1\sigma$	68%	65.00% to 122.78%
$\pm 2\sigma$	95%	46.67% to 140.77%
$\pm 3\sigma$	99.8%	25.00% to 165.00%

As an example, for an average new tie life of 35.2 years (equal to the current US average new tie life for creosote-only wood ties), 68% of all ties will fail between 22.88 and 43.2 years. Using two standard deviations from the average, 95% of all ties will fail between 16.43 and 49.55 years. And finally, using three standard deviations, 99.8% of all ties will fail between 8.80 and 58.08 years.

Noting that the 2σ range is commonly used for practical ranges of distributions representing 95% of the ties, Table 13 shows the 2σ tie life range for each of the five climate zones using the average tie lives given in Table 11.

Table 13: Tie Life Range by Climate Zone for 95% of all Ties in Each Zone

Climate Zone	Average New Creosote-Only Tie Life (years)	Range of Tie Lives for 95% of the Ties (years)
1	43.3	20.21 to 60.95
2	39.9	18.62 to 56.17
3	35.9	16.75 to 50.54
4	30.7	14.33 to 43.22
5	18.1	8.45 to 25.48
US System-wide	**35.2**	**16.43 to 49.55**

6. Treatability of Wood Ties by Species and Life Extension with Borate

As will be shown later in this paper, the extension of life by dual treatment with borate is greater for those species of ties that are more difficult to treat with creosote. For these species where the creosote does not penetrate through the entirety of the tie as completely as desired, the addition of the borate treatment will have a more significant impact on the increase in the tie life. As such, when analyzing the overall impact of borate treatment, it is important to categorize the various wood tie species into groups so as to better represent their expected extension of life. Table 14 shows four groups of ties based on their treatability along with their prevalence in the industry.

Table 14: Treatability of Ties by Species and Distribution in US Railroads

Group Number	Treatability	Percentage of US Ties	Includes the Following Species
1	Most Difficult	40.0%	White Oak, Hickory/Pecan (20%), Sweet Gum (80%), Black Locust, Mulberry, Hardy Catalpa, Beech, Poplar (Large Heart)
2	Moderate Difficulty	17.5%	Red Oak (25%), Hickory/Pecan (80%), Sweet Gum (20%), Persimmon, Sassafras, Osage Orange, Birch, Honey Locust, Some Maples (Large Heart), Sycamore, Butternut, Kentucky Coffeetree, Boxelder
3	Relatively Easy	24.5%	Red Oak (45%), Black Gum/Tupelo Gum (20%), Ash, Basswood, Cork Elm, Some Maples, Hackberry
4	Easy	18.0%	Red Oak (30%), Black Gum/Tupelo Gum (80%), Elm

Based on dual-treatment studies that have been performed [7-12], the Railway Tie Association has been able to make determinations as to how much the borate treatment will lengthen the tie lives for each of the four treatability categories of ties (Table 14) for Climate Zones 3, 4, and 5. These life extension factors, shown below in Table 15, reflect only the environmental life extension and do not reflect the influence of mechanical degradation (primarily tonnage and curvature effects). In the analysis, life extension factors of 1.0 are used for Climate Zones 1 and 2 since it is assumed that dual-treatment will not be used for ties and these zones where mechanical degradation tends to be the dominant failure mode.

Table 15: Environmental Life Extension Factors by Treatability Group and Climate Zone[1]

		Life Extension Factors for Dual Treatment		
Treatability Group	Distribution	Climate Zone 5	Climate Zone 4	Climate Zone 3
1	40.0%	2.83	2.50	1.67
2	17.5%	2.33	1.92	1.48
3	24.5%	1.55	1.36	1.18
4	18.0%	1.18	1.14	1.05
Weighted Average for Climate Zone	100%	2.13	1.87	1.41

7. Tie Life and Tie Life Range for Dual Treated Ties

Table 13 gives the average new tie life for creosote-only ties by Climate Zone as well as the tie life range for 95% of all the ties in each zone. Using the life extension factors from Table 15, these creosote-only tie lives from Table 13 can be easily calculated. However, since the life extension factors of Table 15 reflect only the environmental effect and not the mechanical effect, the dual-treatment lives need to be adjusted. To do this, a limit is imposed whereby the expected tie life of a dual-treated tie in Zones 3, 4, and 5 cannot see a life expectancy longer than that of a creosote-only tie in Climate Zone 2. This limit allows for the environmental gain achieved by the treatment with borate, but caps that life extension based on the mechanical limit that contributes to the calculated tie life of a tie in Zone 2. With this limit in place, the average new tie lives for each Climate Zone for both creosote-only and dual-treated ties is shown in Table 16.

Table 16: Average New Tie Life for US Ties – Creosote-Only and Dual-Treated

	Tie Life (years)		
Climate Zone	Creosote-Only	Dual-Treated	Percent Increase from Dual-Treatment
1	43.3	43.3	Not dual treated
2	39.9	39.9	Not dual treated
3	35.9	39.9	11.1%
4	30.7	39.9	30.0%
5	18.1	38.6	113.3%
US System-wide	**35.2**	**40.4**	**14.8%**

[1] Tie life extension data and projections are provided by the Railway Tie Association based upon the 1987 AAR/RTA/MSU research on ties dual treated at the Atchison, Topeka and Santa Fe Railroad wood preserving plant in Somerville, TX.

Again using two standard deviations to reflect 95% of all ties, the range of tie lives can be found using the factors from Table 12 (i.e. 46.67% to 140.77%). These tie life ranges are given in Table 17.

Table 17: Tie Life Range for 95% of Ties – Creosote-Only and Dual-Treated

	Range of Tie Lives for 95% of the Ties (years)	
Climate Zone	Creosote-Only	Dual-Treated
1	20.21 to 60.95	Not dual treated
2	18.62 to 56.17	Not dual treated
3	16.75 to 50.54	18.62 to 56.17
4	14.33 to 43.22	18.62 to 56.17
5	8.45 to 25.48	18.01 to 54.34
US System-wide	**16.43 to 49.55**	**18.85 to 56.87**

As shown in Table 16, dual treatment of all Wood ties in the US would extend the system average tie life (all zones / all US) from 35.2 years to 40.4 years. This amounts to a 14.8% extension of US average wood tie life by the use of dual treatment in Zones 3, 4, and 5. The life extension is even more pronounced when looking only at Zones 4 and 5. In Zone 4, the average tie life increases from 30.7 years to 39.9 years, or a 30.0% life extension. In Zone 5, the average tie life increases from 18.1 years to 38.6 years, amounting to a 113.3% extension of life (i.e. more than doubling the life of a Zone 5 wood tie).

8. Economic Impact of Dual-Treated Ties

With the life extension of the dual treated wood ties described above, the economic impact of this change can be calculated. In this analysis, costs are compared across three different aspects: zone, interest rate, and the difference between the cost of a creosote-only tie and a dual-treated tie. In all cases, the base case for analysis is the cost to continue to use creosote-only ties year after year into the future. For these calculations, the installed cost of a creosote-only tie is taken to be $110.00. The total cost in each zone is based on the calculated life of a creosote-only tie (as first shown in Table 11) and the number of Wood ties in each zone (Table 3). Assuming a steady-state replacement rate, this produces the replacement rate and costs for creosote-only ties shown in Table 18.

As shown in Table 18 there is a fixed number of creosote-only ties that will be replaced each year until such time as all creosote-only ties have been replaced. In assessing the economic benefit of dual treatment, these creosote-only ties are replaced with dual-treated ties. As shown in the analysis of tie life extension, these dual treated ties will last considerably longer. If we assumed that all of the dual treated ties failed at the average life this would create a number of years where no ties are being replaced. To clarify this, consider Zone 5 where the creosote-only life is 18.1 years and the dual-treatment life is 38.6 years. Replacing 3,830,294 creosote-only ties each year for 18 years will finally exhaust the supply of in-track creosote-only ties. The dual-treatment ties that where put in track in year one will still have 20 more years before they reach their average life. As a result, there would be a 19-year period where no ties needed to be replaced.

Table 18: Replacement Rate and Costs for Creosote-only Ties in the US

	Zone 5	Zone 4	Zone 3
Total Wood Ties	68,945,298	146,510,350	190,153,628
Creosote-Only Tie Life (years)*	18.0	30.0	35.0
Replacement Ties Per Year	3,830,294	4,883,678	5,432,961
Cost Per Year at $110.00 Per Tie	$421,332,375	$537,204,616	$597,625,687

*Note: For the purposes of totaling annual replacements and costs, tie lives were rounded down to an integer (e.g. 18.1 rounds to 18.0, etc.)

However, as demonstrated by the Forest Products Curve (Figure 2), we know that ties do not all fail at exactly their average life. Instead, wood ties fail in a roughly normal distribution around that average with some small number of ties failing very prematurely and some living extremely long lives. Most, however, fail at or around the average tie life. To reflect this distribution, the yearly figure of replacement ties (e.g. 3,830,294 for Zone 5) is divided into six groups, each with a different tie life. As a whole, these six groups have a weighted average tie life equal to the dual-treatment life calculated for each given zone earlier in this report. The Forest Products Curve was used to determine what percentage of ties fail at each of these six tie lives. In this manner, the failure of the dual-treatment ties can be distributed over a range of tie lives rather than all failing at once at the average life. The six tie lives and the number of ties that fail at this time can be summarized as follows:

- 5% of all ties fail before 55% of average life with a representative life of 46.67% of average (i.e. -2 σ)
- 22% of all ties fail between 55% and 79.3% of average life with a representative life of 65% (i.e. -1 σ)
- 23% of all ties fail between 79.3% and 93.8%[2] of average life with a representative life of 87.06%
- 23% of all ties fail between 93.8% and 108.6% of average life with a representative life of 100.94%
- 22% of all ties fail between 108.6% and 133% of average life with a representative life of 122.78% (i.e. +1 σ)
- 5% of all ties fail after 133% of average life with a representative life of 140.77% of average (i.e. +2 σ)

[2] Because the Forest Products Curve (Figure 2) is a skewed normal distribution and is not symmetric around the average tie life, the point where 50% of all ties have failed actually occurs at 93.8% of the average life.

As mentioned above, three different interest rates are used, as follows: 3.0%, 6.0%, and 10.0% with the 6.0% case begin considered the most appropriate value under current economic conditions. The rates are used to adjust future expenditures and savings into “today’s dollars” (i.e. Net Present Value). In other words, any difference is expenditure in the future (e.g. year 10, 11, 12, … 50, 51, 51, etc.) is converted to its value in today’s dollars using the specified interest rate and the number of years in the future, according to the following equation:

$$\text{Net Present Value} = \text{Dollar Amount} / (1 + i)^{\wedge\, n}$$

where: i is the interest rate and n is the number of years in the future.

When comparing the costs of conventional creosote-only treatment and dual-treatment, there will be a difference in cost each year (based on the differences in cost of treatment and length of tie life). For each year going forward, this difference, whether it is positive or negative, is converted to a Net Present Value (NPV) using the equation above. By keeping a running total of these year-by-year net present value difference, the total net difference can be determined for any point in the future. In this manner, we can determine what the overall gain or loss will be, expressed in today’s dollars, for any time horizon such as 30 years out, 50 years out, or 100 years out.

With regards to the difference in price between a creosote-only tie and a dual-treated tie, we again look at three cases. As noted above, the installed cost of a creosote-only tie is taken to be $110 throughout. The three cases of dual-treated tie cost are as follows: $115.00, $112.50, and $110.00. Intuitively, it is expected that the cost of a dual-treated tie will be higher than the creosote-only cost. However, by making slight reductions to the amount of creosote used in a dual-treatment tie, the cost differential can be minimized, potentially even to being of equal cost.

Economics of Zone 5

Using the Zone 5 dual-treatment tie life as shown in Table 16 (38.6 years) and the three different cases of interest rate and tie cost differential, the economics for all Wood ties in Zone 5 can be summarized as shown in Table 19 and Figures 3 to 6. In Table 20 the same costs are shown, but in this case they are expressed in terms of net present dollars per tie (i.e. dividing total costs from Table 19 by the total number of Wood ties in Zone 5). In both cases, a positive Benefit indicates that the life cycle costs associated with the dual treated ties is lower (better) than that of the creosote only treated ties. However, since there an initial expenditure associated with the higher priced dual treated ties, the maximum “deficit” incurred (shown as a present value cost) is also shown together with the year it reaches that maximum deficit. This is the initial outlay that the user must pay prior to recouping his outlay through reduced costs for the remainder of the analysis period. Thus, though for the cases shown here, the NPV is always positive, there is a ‘deficit” incurred in the two cases where the cost of the dual treated ties is greater than that of the creosote only ties.

Table 19: Zone 5 Economic Analysis of Dual-Treated Ties (All Ties in Zone)

Zone 5 All ties	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$2,983*	$1,254	$398	$3,154	$1,371	$480	$3,325	$1,488	$562
Benefit in 65 years	$3,354	$1,322	$406	$3,541	$1,443	$488	$3,729	$1,563	$571
Maximum Deficit	-$263	-$207	-$157	-$132	-$104	-$79	$0	$0	$0
Year of Max Deficit	18	18	18	18	18	18	1 to 18	1 to 18	1 to 18

*Note: All costs expressed in millions of dollars

Table 20: Zone 5 Economic Analysis of Dual-Treated Ties (Per Tie)

Zone 5 Costs per tie	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$43.27	$18.18	$5.77	$45.74	$19.88	$6.96	$48.22	$21.58	$8.15
Benefit in 65 years	$48.64	$19.18	$5.88	$51.37	$20.93	$7.08	$54.09	$22.67	$8.28
Maximum Deficit	-$3.82	-$3.01	-$2.28	-$1.91	-$1.50	-$1.14	$0.00	$0.00	$0.00
Year of Max Deficit	18	18	18	18	18	18	1 to 18	1 to 18	1 to 18

As shown in Table 19, use of dual-treated ties is economically advantageous for all three interest rates and all three dual-treatment costs ($115, $112.50, and $110). Looking at the 65-year time horizon and the $115-cost, dual treatment will produce a gain of $400 million to $3.35 billion, depending on interest rate (a $1.3 billion gain for the 6% rate). If the cost of the dual-treated ties can be reduced to $112.50 or $110, this 65-year gain (at 6% interest) climbs from $1.3 billion to $1.44 and $1.56 billion, respectively. Again, note that all amounts are express in "today's dollars". (in actual dollars saved, the benefit over 65 years is $9.6 billion). For the 65-year time horizon and the 6% interest rate, these correspond to benefits of $19.18, $20.93, and $22.67 per tie (based on a base cost of $110 per tie) for each of the three dual treatment costs in the study.

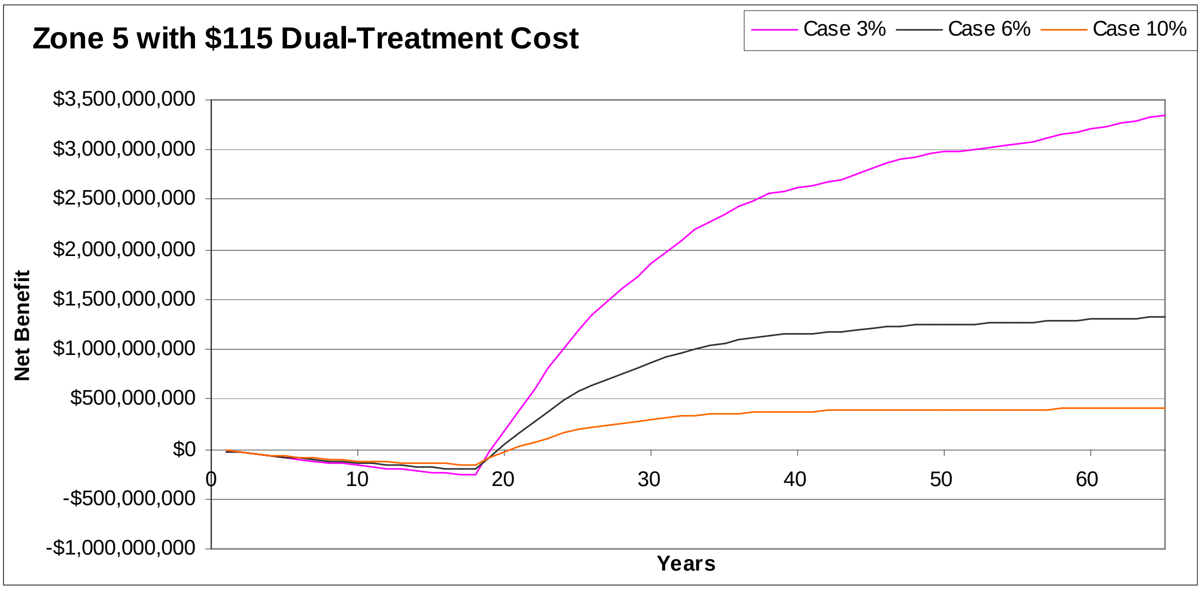

Figure 3: Zone 5 Net Benefit for Dual-Treatment Installed Cost of $115 per Tie

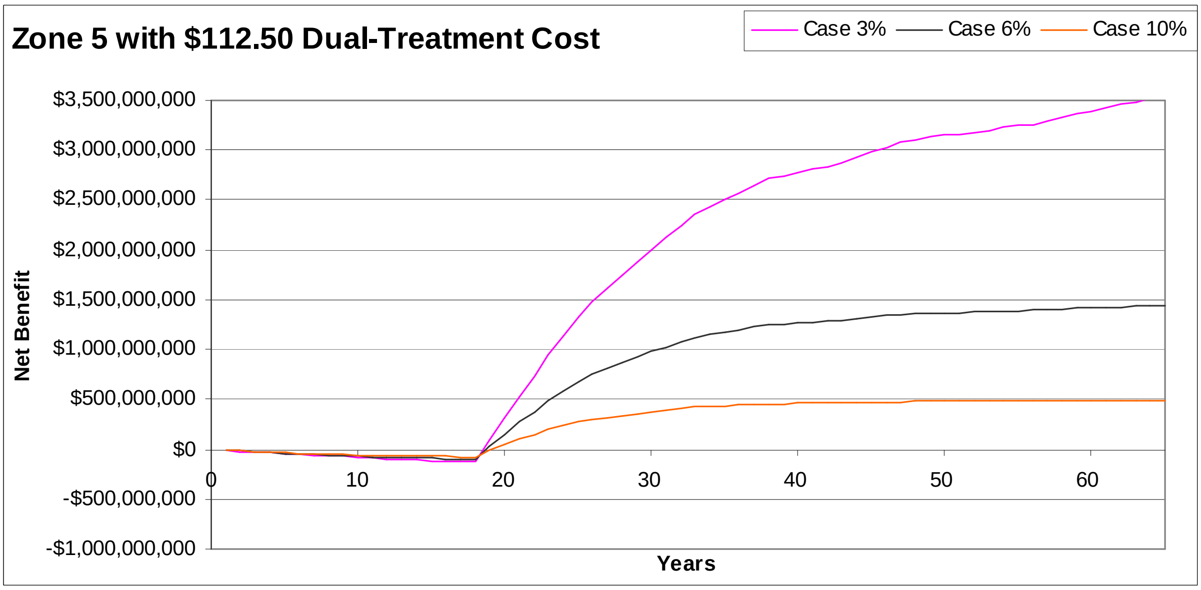

Figure 4: Zone 5 Net Benefit for Dual-Treatment Installed Cost of $112.50 per Tie

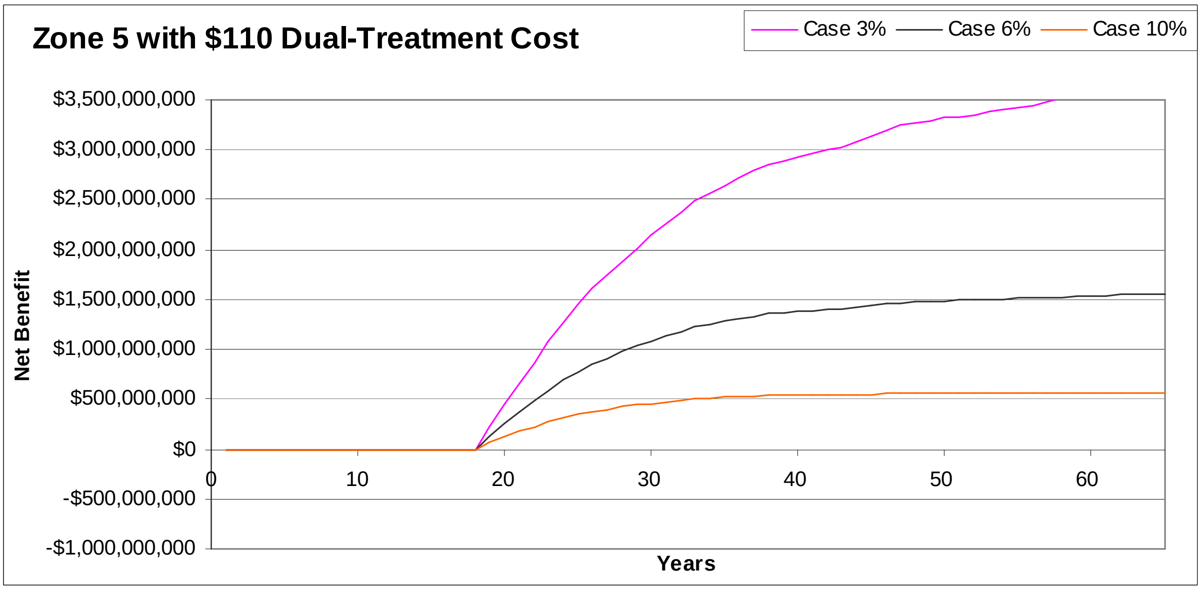

Figure 5: Zone 5 Net Benefit for Dual-Treatment Installed Cost of $110 per Tie

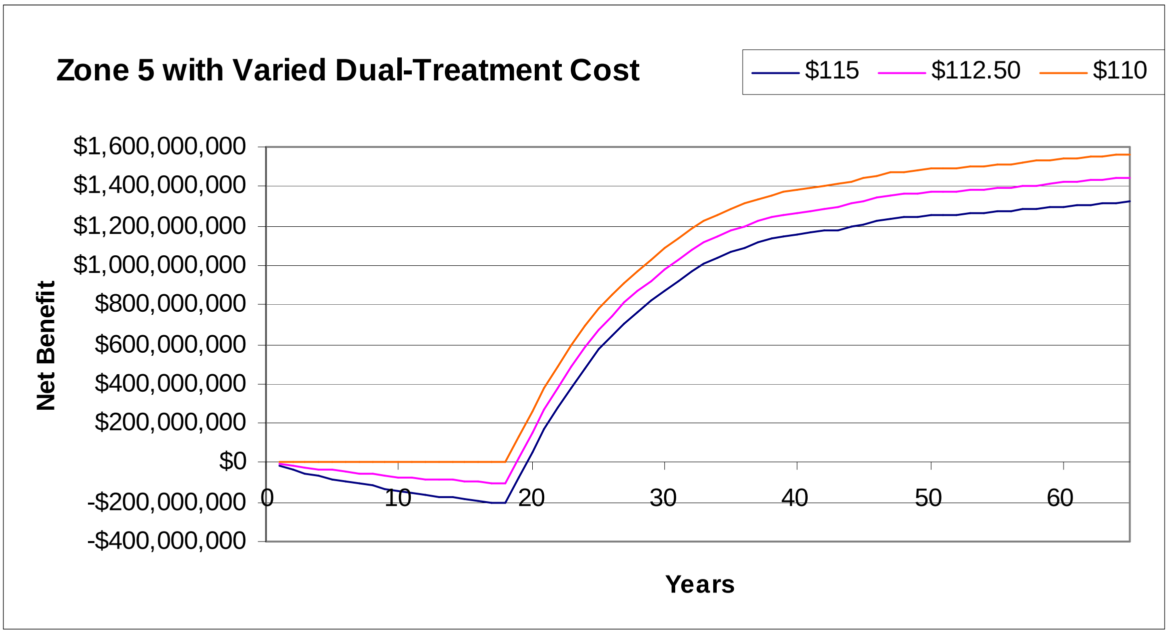

Figure 6: Zone 5 Net Benefit for 6% Interest and Varying Dual-Treatment Installed Cost

Economics of Zone 4

Following the example for Zone 5 above, Tables 21 and 22 and Figures 7 to 10 show the economic results for Zone 4. For this Zone, an economic benefit (positive NPV) is obtained for dual treatment for all cases of 3% and 6% interest and for all cases where the dual treated cost is $112.50 or $110.00. Only in the case of 10% interest and a $115 cost per dual-treated tie is the economic benefit negative. Thus for the 65-year time horizon and the 6% interest rate, these correspond to benefits of $0.99, $2.27, and $3.54 per tie (based on a base cost of $110 per tie) for each of the three dual treatment costs in the study.

Table 21: Zone 4 Economic Analysis of Dual-Treated Ties (All Ties in Zone)

Zone 4	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
All ties	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$896	$148	-$101	$1,177	$328	$17	$1,458	$509	$135
Benefit in 65 years	$883	$145	-$102	$1,196	$332	$17	$1,509	$519	$134
Maximum Deficit	-$479	-$336	-$230	-$239	-$168	-$115	$0	$0	$0
Year of Max Deficit	30	30	30	30	30	30	1 to 30	1 to 30	1 to 30

*Note: All costs expressed in millions of dollars

Table 22: Zone 4 Economic Analysis of Dual-Treated Ties (Per Tie)

Zone 4	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
Costs per tie	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$6.11	$1.01	-$0.69	$8.03	$2.24	$0.11	$9.95	$3.48	$0.92
Benefit in 65 years	$6.03	$0.99	-$0.69	$8.16	$2.27	$0.12	$10.30	$3.54	$0.93
Maximum Deficit	-$3.27	-$2.29	-$1.57	-$1.63	-$1.15	-$0.79	$0.00	$0.00	$0.00
Year of Max Deficit	30	30	30	30	30	30	1 to 30	1 to 30	1 to 30

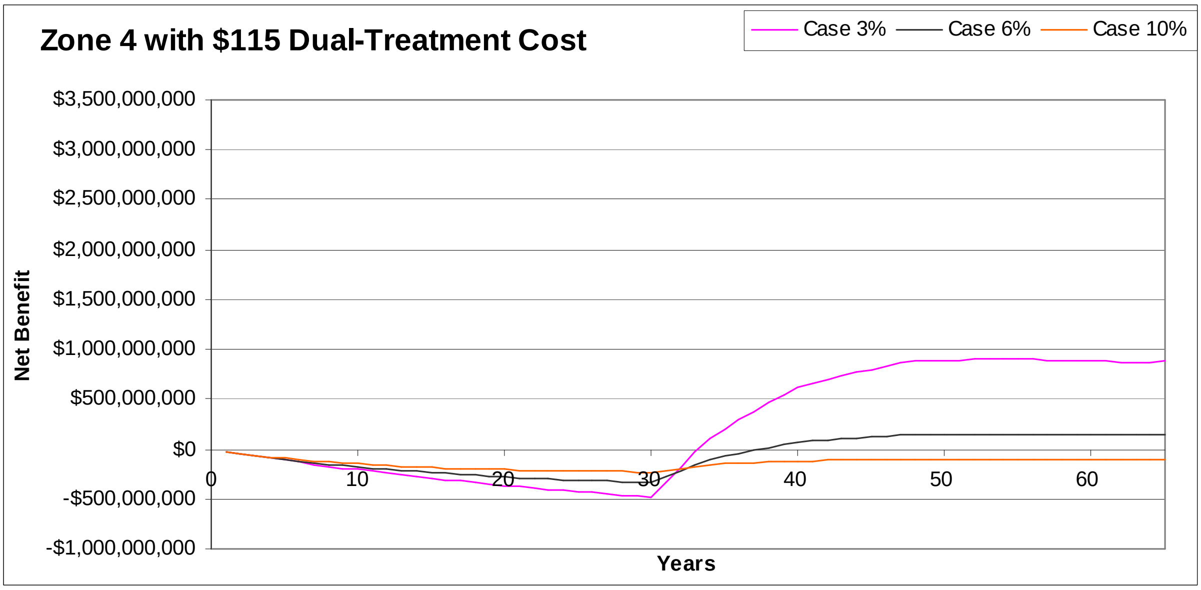

Figure 7: Zone 4 Net Benefit for Dual-Treatment Installed Cost of $115 per Tie

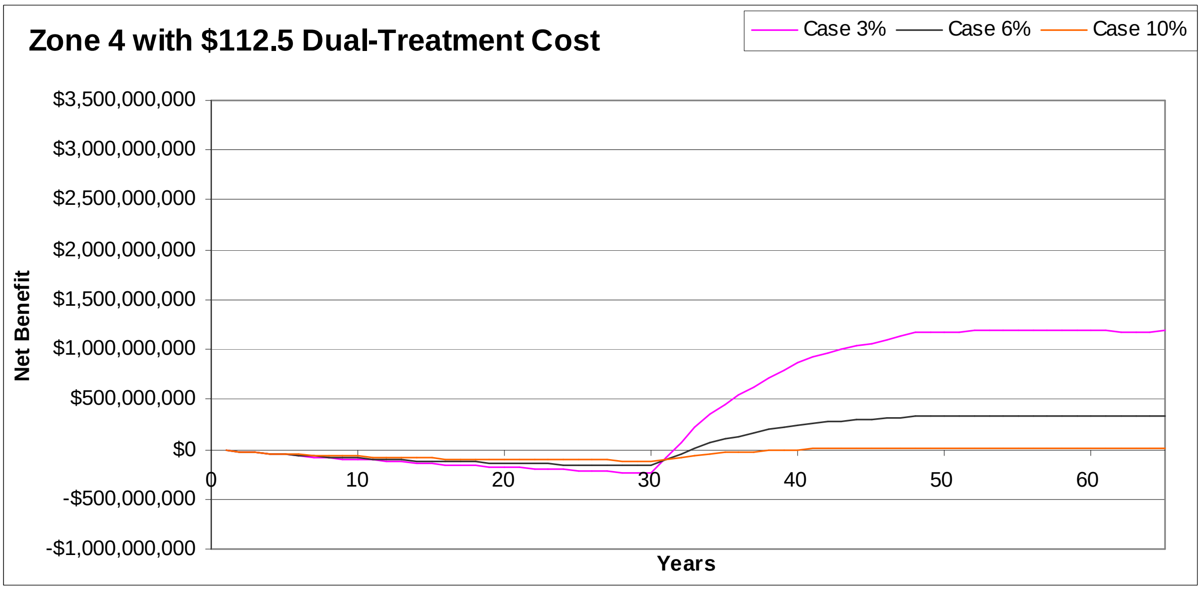

Figure 8: Zone 4 Net Benefit for Dual-Treatment Installed Cost of $112.50 per Tie

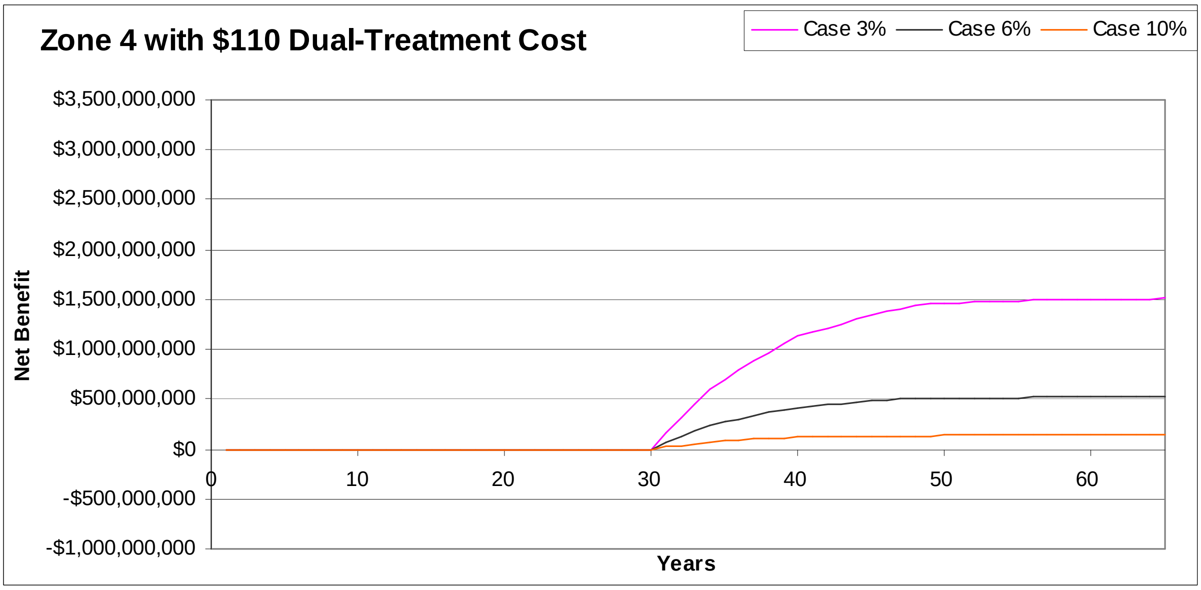

Figure 9: Zone 4 Net Benefit for Dual-Treatment Installed Cost of $110 per Tie

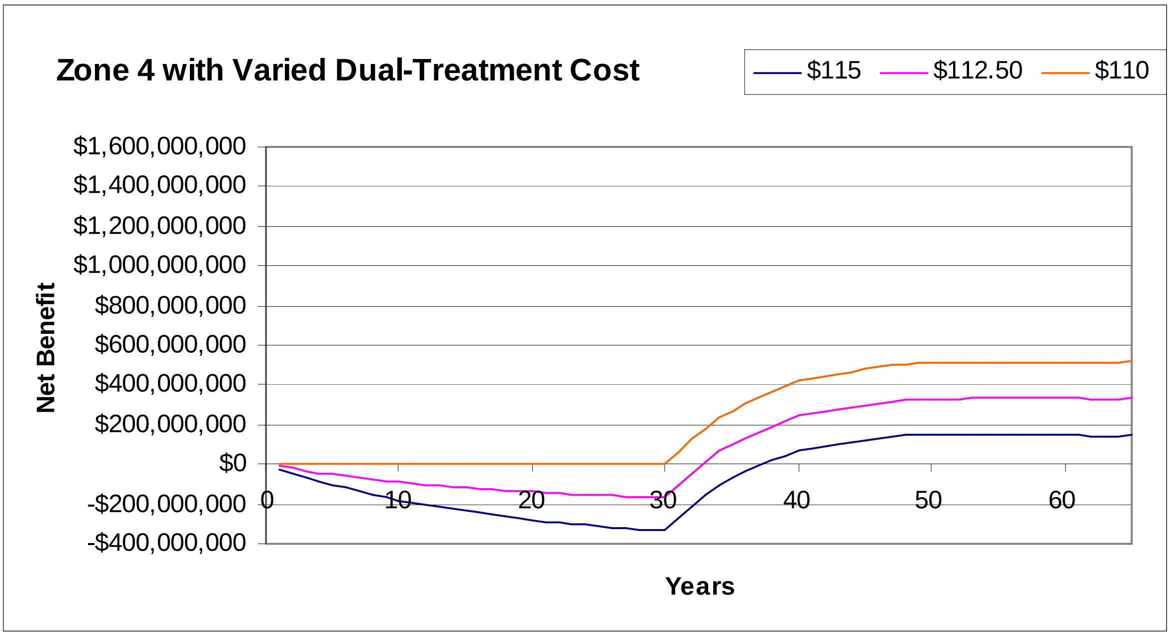

Figure 10: Zone 4 Net Benefit for 6% Interest and Varying Dual-Treatment Installed Cost

Economics of Zone 3

Applying the same methodology to Zone 3 gives the results shown in Tables 23 and 24 and Figure 11 to 14. For Zone 3, the economic benefit of dual treatment is a little more mixed.

There is a clear benefit (positive NPV) for all tie costs for the 3% case and for all interest rates when the dual-treatment tie cost is $110. For a cost of $112.50, however, the benefit comes only for the 3% and 6% cases, and for the $115 cost it is only for the 3% interest rate. Here too, for the 65-year time horizon and the 6% interest rate, these correspond to benefits of $0.30 ($112.50 cost case) and $1.43 per tie ($110 cost case), based on a base cost of $110 per tie, for each of the noted dual treatment costs in the study[3].

Table 23: Zone 3 Economic Analysis of Dual-Treated Ties (All Ties in Zone)

Zone 3	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
All ties	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$187	-$152	-$207	$517	$56	-$73	$847	$265	$60
Benefit in 65 years	$152	-$158	-$207	$518	$57	-$73	$884	$273	$61
Maximum Deficit	-$584	-$394	-$262	-$292	-$197	-$131	$0	$0	$0
Year of Max Deficit	35	35	35	35	35	35	1 to 35	1 to 35	1 to 35

*Note: All costs expressed in millions of dollars

Table 24: Zone 3 Economic Analysis of Dual-Treated Ties (Per Tie)

Zone 3	Creo $110, Dual $115			Creo $110, Dual $112.5			Creo $110, Dual $110		
Costs per tie	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%	3.0%	6.0%	10.0%
Benefit in 50 years	$0.98	-$0.80	-$1.09	$2.72	$0.30	-$0.39	$4.46	$1.39	$0.31
Benefit in 65 years	$0.80	-$0.83	-$1.09	$2.72	$0.30	-$0.38	$4.65	$1.43	$0.32
Maximum Deficit	-$3.07	-$2.07	-$1.38	-$1.53	-$1.04	-$0.69	$0.00	$0.00	$0.00
Year of Max Deficit	35	35	35	35	35	35	1 to 35	1 to 35	1 to 35

[3] As noted, there was no benefit associated with the $115 dual treated tie cost.

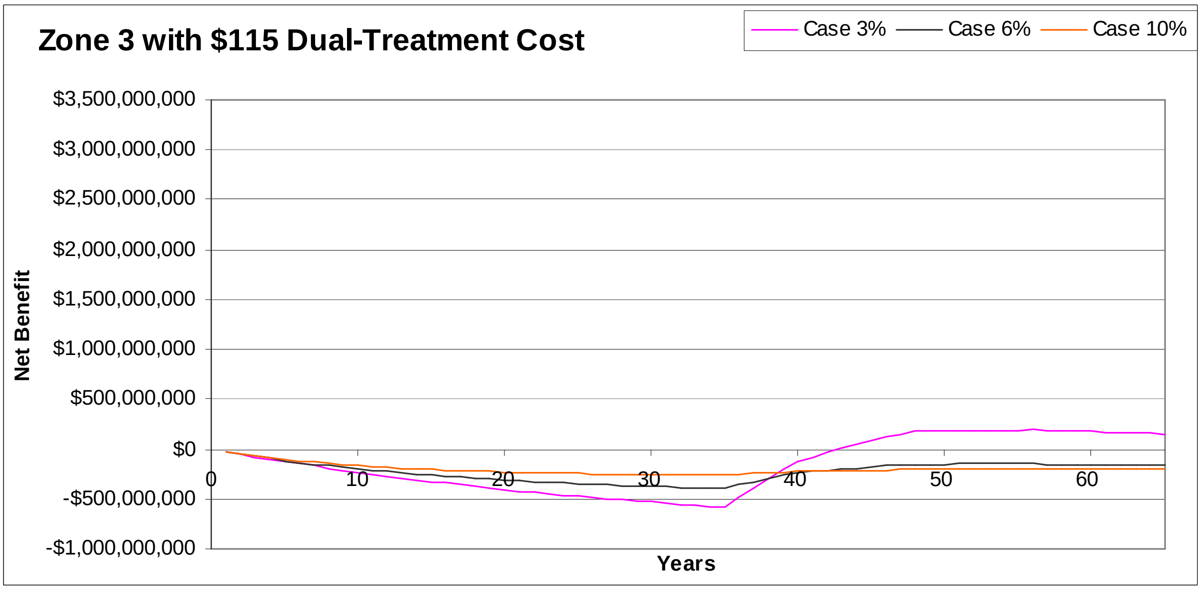

Figure 11: Zone 3 Net Benefit for Dual-Treatment Installed Cost of $115 per Tie

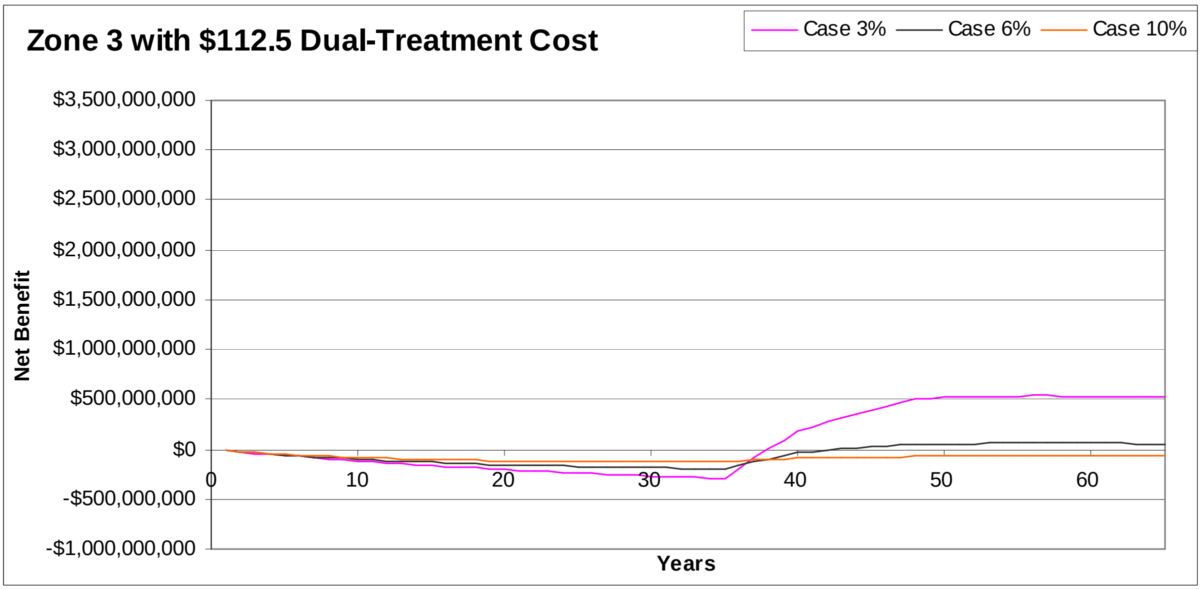

Figure 12: Zone 3 Net Benefit for Dual-Treatment Installed Cost of $112.50 per Tie

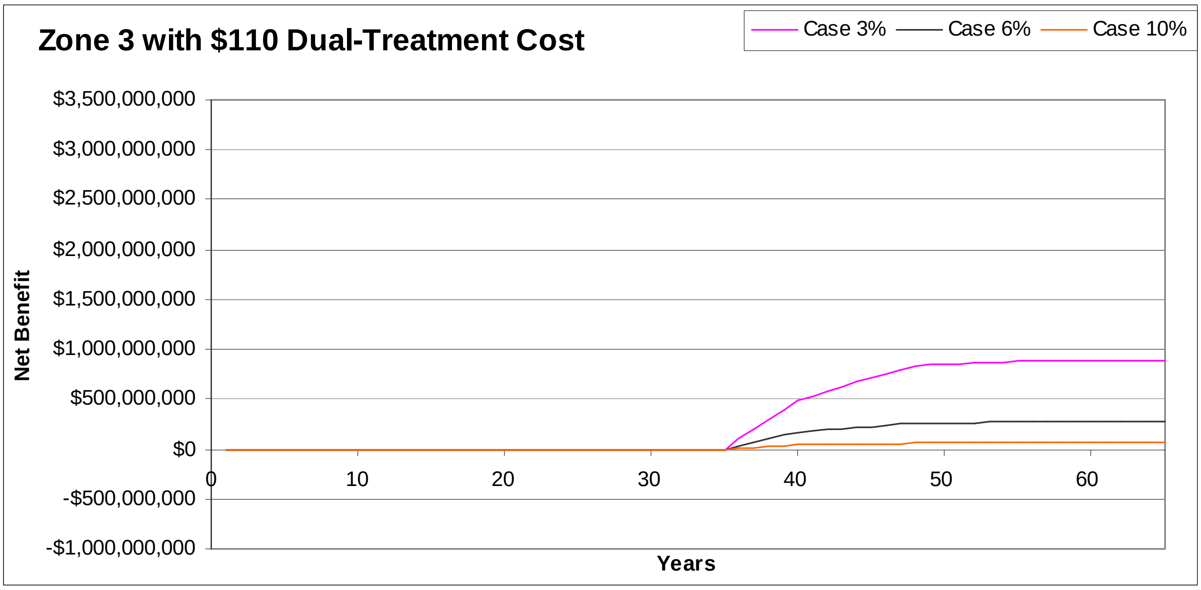

Figure 13: Zone 3 Net Benefit for Dual-Treatment Installed Cost of $110 per Tie

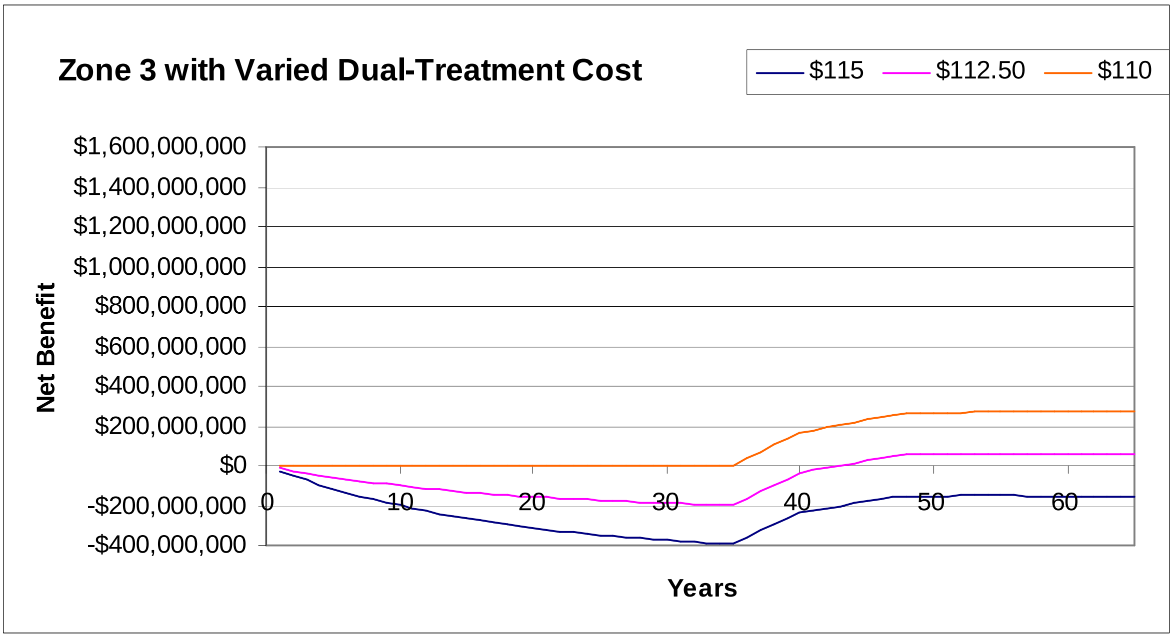

Figure 14: Zone 4 Net Benefit for 6% Interest and Varying Dual-Treatment Installed Cost

Economics Summary

In reviewing the results from the tables above, it is clear that there is a substantial economic benefit to dual treated ties in Zone 5. There is also a substantial benefit in Zone 4 provided that the interest rate is below 10% or the cost differential between creosote-only and dual-treatment is less then $5 per tie. The benefit in Zone 3 is more tenuous and would require either a long term low interest rate (near 3%) or a minimal difference in tie treatment costs.

Using the 6% interest rate as a standard, Figures 15 to 17 show the year by year economic benefit for the three cases of dual-treatment installed tie cost ($115, $112.50, and $110). In the cases where the dual-treatment ties cost more than the creosote-only ties ($115 and $112.50), the net benefit is increasingly negative at first (the previously noted deficit). However, once the point is reached where all of the creosote-only ties have expired and been removed, the benefit quickly and sharply changes to the positive direction. For Zones 4 and 5, it quickly reaches a positive net benefit. For Zone 3, however, a positive outcome is not reached in the $115 case and is only a small positive number for the $112.50 case.

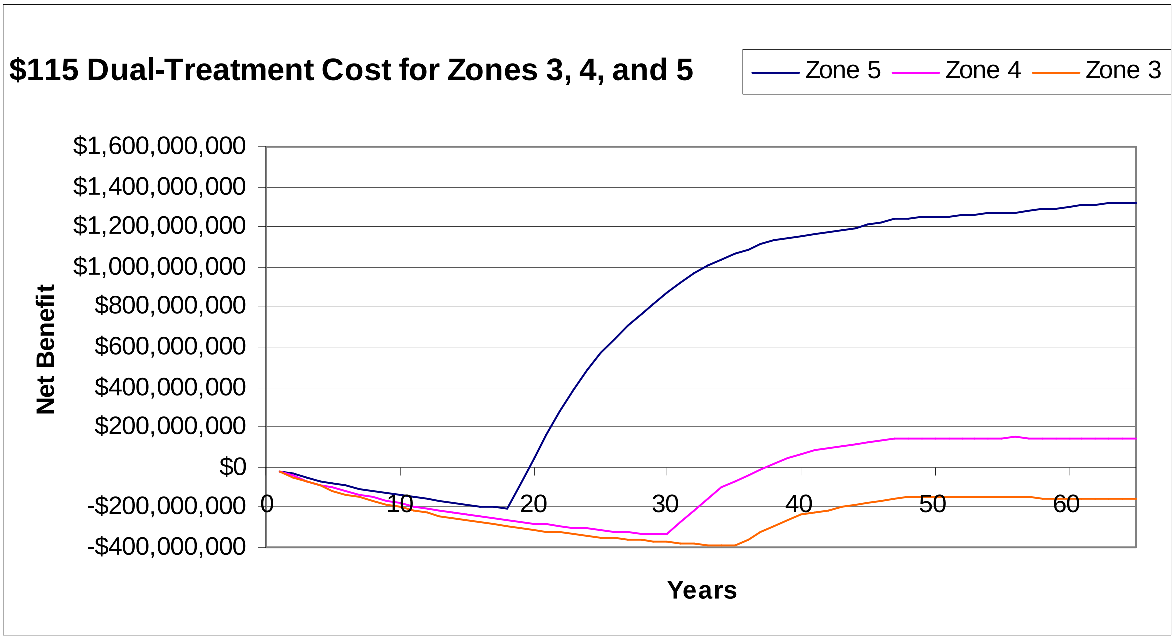

Figure 15: Net Benefit of $115 Dual-Treatment Installed Cost and 6% Interest Rate

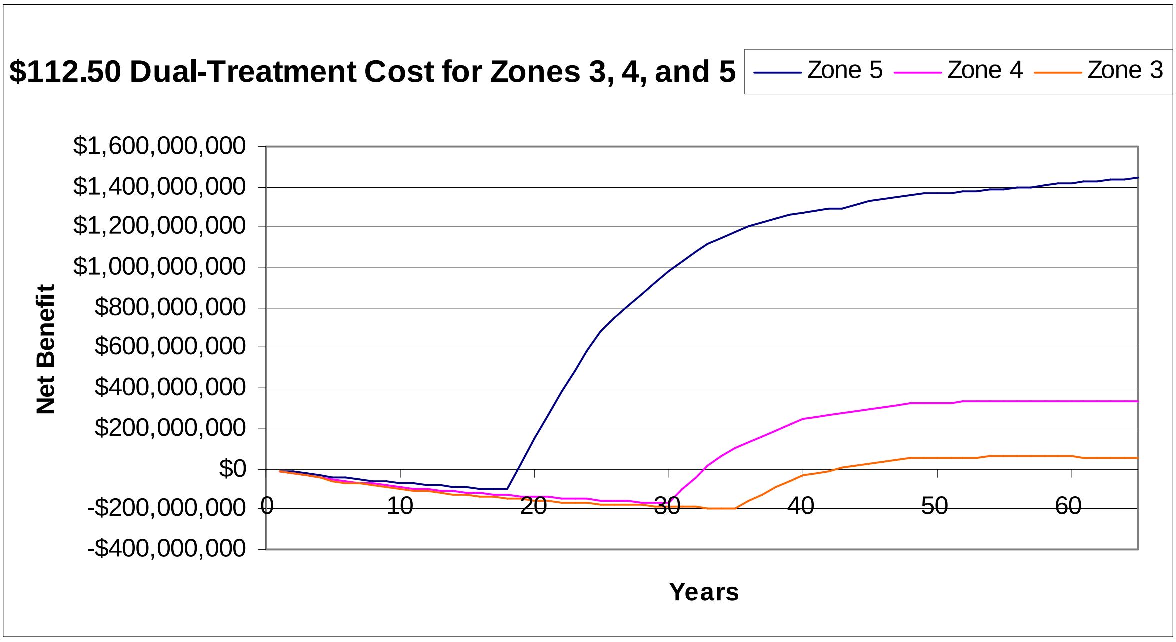

Figure 16: Net Benefit of $112.50 Dual-Treatment Installed Cost and 6% Interest Rate

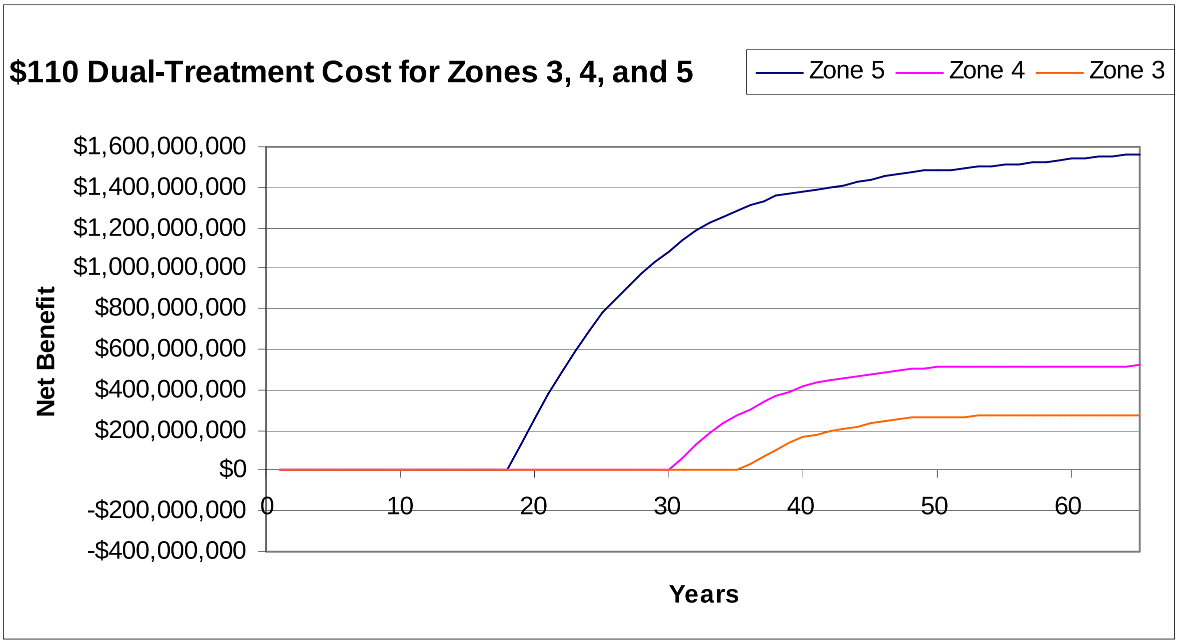

Figure 17: Net Benefit of $110 Dual-Treatment Installed Cost and 6% Interest Rate

For the case of a dual-treatment tie having equivalent cost to a creosote-only tie ($110), there is no longer a period of negative net benefit. In these cases (for all zones and interest rates), the net benefit is zero during the years where the creosote-only ties are being replaced. Once that period ends, the net benefit quickly turns positive for all three zones with the Zone 5 benefit clearly being the most significant gain. This is illustrated in Figure 17.

9. Summary and Conclusions

This analysis looks at the extension in tie life that can be achieved through the use of dual treatment with both creosote and borate. The analysis segments the wood crossties in the United States into five Climate Zones according to the Wood Decay Deterioration Map (Figure 1). Using available railroad data, ties in the US are categorized not only by Climate Zone but also by annual tonnage and curvature. Using ZETA-TECH's *TieLife*, the average new tie lives for creosote-only ties is calculated for each zone (using weighted averages to account for tonnage and curvature variations).

Ties are further distinguished by their 'treatability' with four groups ranging from 'Difficult to Treat' to 'Easy to Treat'. The prevalence of each group in the industry is used together with the expected life extension achieved using dual treatment, as determined by several studies performed by the Railway Tie Association in recent years[4]. Applying these life extension factors and a limit on increased life (to account for the effect of mechanical wear), the overall effect on tie life was found for each zone and for the United States as a whole.

The largest effect was found in Zone 5 where environmental wood decay is the most severe. In this zone, average new tie life is found to increase from 18.1 years to 38.6 years. In Zone 4, dual treatment results in an extension from 30.7 to 39.9 years. In Zone 3 the extension is from 35.9 to 39.9 years. Overall, if dual treatment were applied to all ties in Zones 3, 4, and 5, the aggregate increase in US wood tie life in all five zones would be from a system average of 35.2 years to 40.4 years. This is an increase in tie life of 14.8% for all wood ties throughout the US.

With these increases in tie life, the net economic benefit of dual treatment was also examined. This analysis looked at dual treatment in Zones 3, 4, and 5. In addition, three cases of interest rates were used in order to express all future savings (and expenditures) in terms of 'today's dollars' (i.e. net present value). Interest rates of 3%, 6%, and 10% were used in all economic calculations, with 6% considered to be the best value given today's economic climate.

One final variable in the analysis was the cost difference between creosote-only treatment and dual treatment. For all cases, the creosote-only cost was taken to be $110.00 per tie (this is the installed cost of one tie). Dual-treatment installed costs of $115.00, $112.50, and $110.00 were examined for the study. In the latter two cases, it is anticipated that the cost differential can be minimized (possibly to zero) by making slight reductions to the amount of creosote in a dual treated tie as compared with creosote-only treatment.

[4] Tie life extension data and projections are provided by the Railway Tie Association based upon the 1987 AAR/RTA/MSU research on ties dual treated at the Atchison, Topeka and Santa Fe Railroad wood preserving plant in Somerville, TX.

Economic benefit analysis shows that there is a substantial gain in Zone 5 for all cases (i.e. for all three interest rates and all three dual-treatment costs). A significant gain is also found in Zone 4 provided the interest rate is less than 10% or the dual-treatment installed cost is below $115.00. In Zone 3, the net benefit is more mixed. A positive benefit is obtained for a very low interest rate (3%) or a minimum difference in treatment cost. For other combinations, the benefit may be negative or very small.

In conclusion, this report demonstrates the significant extension of wood tie life that can be achieved through dual treatment with creosote and borate. Overall wood tie life can be extended by 14.8% in the US with system average tie life increasing from 35.2 years to 40.4 years. The use of dual-treatment ties in Zones 4 and 5 can lead to a net present economic benefit on the order of one to five billion dollars over the next 65 years. Expressed in actual dollars (not "today's dollars"), this would be a benefit of 13 to 15 billion dollars.

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