Association of American Railroads
Research and Test Department

Economic Analysis - Des Plaines Tie Configurations

Report No. R-774

D. D. Davis

December, 1990

AAR Technical Center
Chicago, Illinois

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13. ABSTRACT

This report discusses the economic performance of the eight combinations of tie spacings, sizes, and lengths tested at the AAR/RTA/C&NW Des Plaines, Illinois test site. A life cycle cost analysis of each test section was conducted. Tie replacement schedules were projected from test section performance using the AAR Tie Renewal Model. Tie Installation costs were gathered from industry sources.

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EXECUTIVE SUMMARY

For the conditions of the Des Plaines, Illinois test site, the most economical tie configurations are those with the widest ties spacings (or fewest ties/mile). This is a natural consequence of the relatively long life of the tie; initial costs tend to dominate the total Net Present Value (NPV) costs.

The effect of tie spacing on tie life is not as great as can be expected in track with high grades and curvature. The effects of tie length and tie size (cross section) on tie life were relatively small. Thus, the shortening of tie life caused by using smaller ties or wider spacings was more than offset by the lower initial cost.

The effect of other parameters such as: interest rate, tie installation cost, and surfacing costs have relatively little effect on the preference rank of the eight sections. They do however, have some effect on the life cycle costs shown.

Many potentially significant factors are not adequately covered in this economic analysis. These items are listed in the report and fall under the category of failed tie costs. These items are currently being explored in detail by the AAR Track Maintenance Research Committee and many individual railroads. Several of these items are significant enough to alter the results of the analysis for a particular situation.

ACKNOWLEDGEMENTS

This report was prepared under the sponsorship of the AAR Track Research Division's Tie Life project. Dr. A. J. Reinschmidt is the Director of Track Research. John Choros is the Manager of Track Engineering. Their guidance is greatly appreciated.

The Des Plaines tie test is a joint project of AAR, C&NW Transportation Company, and the Railway Tie Association. The good work of many individuals was needed to begin this tests.

The vigilance of many was also required to maintain the test until meaningful results can now be seen. The author is particularly grateful to previous Des Plaines test report authors:

G. Magee

C. Somogy

V. Shafarenko

S. Chrismer

TABLE OF CONTENTS

LIST OF EXHIBITS

1.0 INTRODUCTION

The quest for a more economical track structure has led to many innovations. Some are tremendous leaps in technology, while others are small adjustments to existing materials and methods. The Des Plaines tie test is an example of the latter.

This test is a collaboration of researchers (AAR), suppliers (RTA) and railroads (CNW) to look for ways to improve the performance of track (through crossties). The test has produced enough tie performance information since 1967 to perform a life cycle cost analysis of the various configurations of tie spacing, size and length.[1-7]*

2.0 METHODOLOGY

Determination of the most economical tie configuration requires consideration of tie performance (life), tie installation costs, and tie maintenance costs (i.e. subsequent tie replacements). This information will be used to determine the most economical or lowest cost tie configuration for the conditions at this test site: Tangent track, 20-40 MGT/YR, FRA Class 4, Midwest climate. Both installation costs and 100 year Net Present Palue (NPV) tie replacement costs are calculated for each test section. All cost calculations are performed on a per mile basis.

The tie performance predictions are based on the tie renewal records from the site. Average tie lives were calculated from these records; to be used as input to the AAR Tie Renewal Model.

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* Numbers in brackets [ ] indicate references in section 5.0.

The resulting tie failure predictions were then used to project a tie renewal schedule for 100 years.

Tie purchase, shipping and installation costs were derived from industry-wide surveys. These costs were applied to derive the tie installation and 100 year period replacement costs. Variation of key parameters, such as: interest rate and installation costs were employed to judge the sensitivity of the result to these parameters.

2.1 Site Description

The test site is located on the Chicago & NorthWestern railroad in the Chicago suburb of Des Plaines, Illinois. Exhibit 1 is a map of the test site. It is located in the West bound track on a freight-only double track line. Recent tonnage rates have been 30-40 MGT/YR. Exhibit 2 lists the eight test section configurations.

The site was installed in 1967 and has been monitored by the various parties involved since that time. AAR has issued several reports on the site. The most relevant ones are listed in the references section.

The ties at the site are mostly oak species with 100 to 200 "mixed" hardwoods scattered in sections 5 and 6. Tie species was not a test variable in the original plan; the introduction of the mixed hardwoods was a construction error. The ties in the first six sections are solid sawn one piece timbers. The ties in sections 7 and 8 are two piece (6x7 inch) dowel-laminated ties. All test ties have 13 inch tie plates. 115RE welded rail was installed during

Exhibit 1. Des Plaines Tie Test Location.

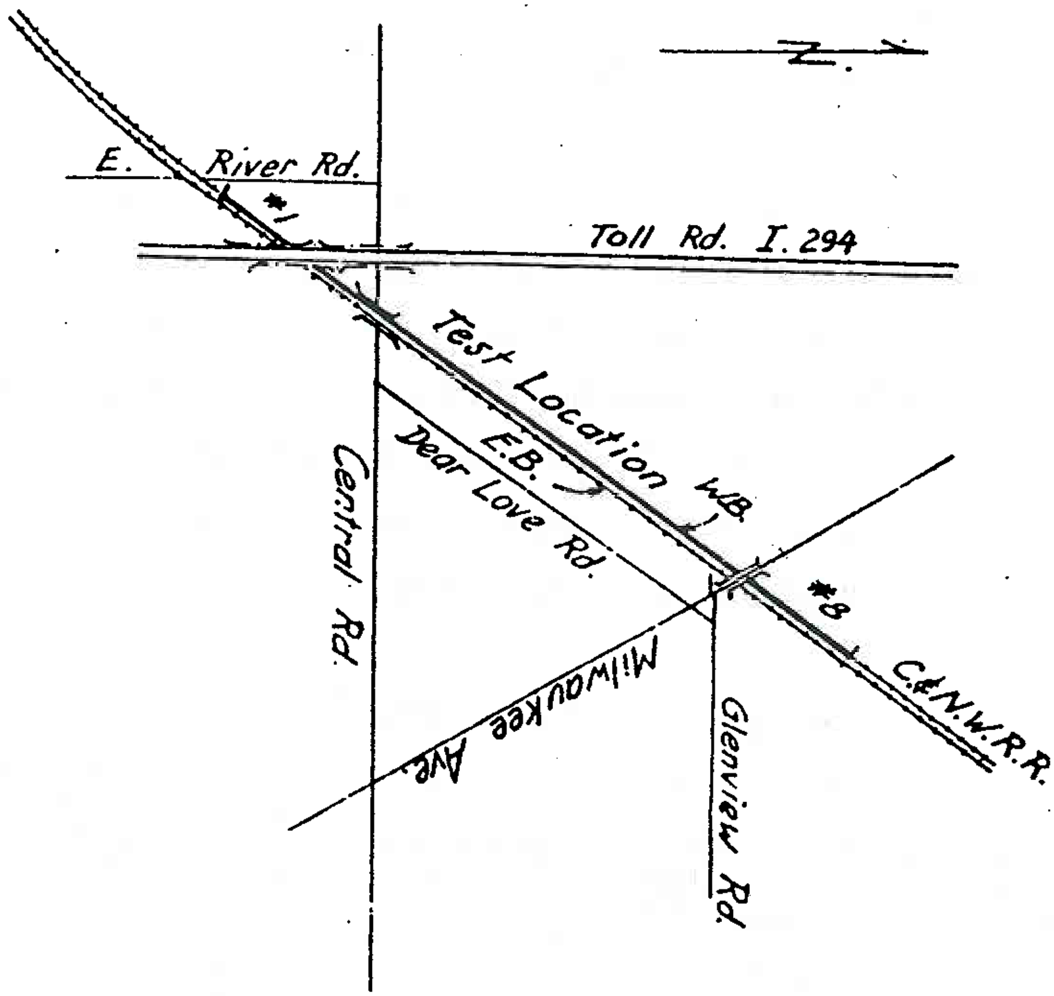


Exhibit 2. Test Tie Configurations.

SECTION NUMBER	TIE SIZE X SECTION (in.xin.)	TIE LENGTH (ft.)	TIE SPACING (in.)	TIES/ MILE	SECTION LENGTH (ft.)
ONE	6 x 8	9	19.5	3249	706
TWO	7 x 9	10	19.5	3249	618
THREE	7 x 9	9	19.5	3249	775
FOUR	7 x 9	8.5	19.5	3249	778
FIVE	7 x 9	8.5	23.4	2711	628
SIX	7 x 9	8.5	27.5	2304	738
SEVEN	7 x 12	8.5	29.3	2166	778
EIGHT	7 x 12	8.5	23.4	2711	684

construction of the test site in 1967. The rail anchor pattern is: box anchor every other tie in open track and box anchor every tie near joints, crossings, bridges, etc.

2.2 Tie Life

Tie replacement records indicate some differences in tie performance.[8] Exhibit 3 is a compilation of the tie replacements made in 1988. Estimates of average tie life were then made from the data using the U.S.D.A. Forest Products Curve.[9] The Forest Products curve has been shown to be applicable to modern railroad conditions by the AAR Track Maintenance Research Committee.[10]

Exhibit 3. 1988 Tie Replacement Summary.

SECTION NUMBER	NUMBER OF TIES	NUMBER FAILED	PERCENT FAILED	PERCENT AVE LIFE	F.P.C. PROJECTED AVE LIFE	LINEAR PROJECTED AVE LIFE
1	435	182	42	88	24	25
2	377	63	17	71	30	62
3	477	116	24	77	27	44
4	479	166	35	85	25	30
5	396	152	38	87	24	28
6	322	146	45	91	23	23
7	319	89	28	80	26	38
8	351	27	8	60	35	131
ALL	3156	941	30	81	26	35

The validity of using the curve to estimate tie life for an out-of-face installation, such as the test site, is unclear. The curve was developed from tie replacement records of hundreds of miles of track. Replacements were done on an as-needed basis, not out-of-face tie renewals. There is an unsubstantiated theory that the life of a tie is dependent on the condition of adjacent ties. This theory is undoubtedly true for ties which fail by mechanical means. However, the magnitude of this effect is unknown. It does suggest that the out-of-face tie renewal site may produce ties with a longer average life and less variation about the average. The condition of the ties and track surface will be much more uniform with an out-of-face renewal than a failed tie renewal.

To the extent that this effect is true, the average tie life predictions and the economic analysis on which they are based are in error (the average life predicted in this analysis would be larger than the actual). The average life predictions are based on the tie life distribution of the Forest Products Curve. The Forest Products Curve was developed from records of cyclically maintained track. If the out-of-face ties fail according to a different life distribution, the predictions made by the Forest Products curve will be in error. In the case of the out-of-face ties the presumed narrower life distribution will result in a Forest Products Curve prediction of tie life which is longer than the actual. Evaluation of this effect must wait for several more years until a sufficiently large number of the original test ties have been replaced.

The AAR Tie Renewal Model[11] was used to predict the tie replacement schedule for each test section. The model uses tie installation history, average tie life, and tie maintenance policy to determine how many ties will fail in each year and, to schedule renewals according to maintenance policy. Exhibits 4 and 5 show tie renewal schedules for two maintenance threshold levels: 700 ties/mile and 25% of the ties/mile (the number varies by section).

The 700 ties/mile renewal threshold is typical for cyclical, as-needed tie replacements performed in North America with large mechanized gangs. For mainline track with about 3250 ties per mile, this level of maintenance allows for an uninterrupted high level of track performance. However, application of this level of maintenance to track with larger tie spacing may be unconservative; because there will be fewer good ties in track.

The "25 percent" maintenance criteria may be more applicable to this analysis. This would reduce the number of bad ties in track for the wider spacing sections. This would reduce the number of bad spots or failed tie clusters in track; thus reducing track damage and safety risk. It is likely that clustering will be a more important issue with wider spacing track.

Exhibit 4. 700 Tie Renewal Schedule (100 years).

RENEWAL SCHEDULES (yrs)
700/MILE

RENEWAL NUMBER	CUMMULATIVE TIES	SECTION NUMBER ONE	TWO	THREE	FOUR	FIVE	SIX	SEVEN	EIGHT
1	700	19	24	19	20	20	20	23	29
2	1400	23	28	26	24	24	25	28	35
3	2100	26	32	29	27	28	30	37	41
4	2800	30	37	33	31	37	42	49	65
5	3500	39	47	41	40	45	48	57	73
6	4200	45	55	49	46	50	56	67	82
7	4900	49	61	55	51	57	65	77	93
8	5600	54	67	60	57	65	72	86	
9	6300	60	74	73	62	71	80	96	
10	7000	66	82	79	69	78	88		
11	7700	72	89	85	74	85	96		
12	8400	77	95	91	80	92			
13	9100	82		97	86	98			
14	9800	88			92				
15	10500	98			97				
16	11200	99							

Exhibit 5. 25 Percent Tie Renewal Schedule (100 years).

RENEWAL SCHEDULES (yrs)
25 PERCENT

RENEWAL NUMBER	ONE 812	TWO 812	THREE 812	FOUR 812	FIVE 678	SIX 576	SEVEN 542	EIGHT 678
1	20	25	22	21	20	19	22	29
2	24	30	27	25	24	23	26	34
3	27	34	31	29	28	27	30	40
4	35	43	39	39	35	34	39	50
5	44	55	49	46	44	45	48	63
6	49	61	56	52	49	50	54	71
7	55	68	62	58	55	56	60	79
8	62	77	70	66	62	64	68	90
9	69	86	78	73	69	72	76	
10	75	94	85	79	76	78	82	
11	82		95	86	82	85	89	
12	88			94	88	93	97	
13	95				96			
CUMULATIVE NUMBER TIES	10556	8120	8932	9744	8814	6912	6504	5424

Track Surfacing is generally required after a large scale tie renewal. A conventional track surfacing with no new ballast applied costs about $2000.00 per mile.[12] Both the no surfacing and surfacing options were used in the analysis.

2.3 Tie Installation Costs

Tie installation costs can be divided into two main categories. These are: material costs (i.e. costs associated with procurement of a treated crosstie) and installation costs (i.e. costs associated with the installation of the tie in track). Industry-wide surveys[13] were used to obtain representative values and, where possible, site specific values.

Exhibit 6 contains a list of estimated test tie costs. Also listed is the shipping costs for a 300 mile move. Other materials include fasteners (AREA #13 tie plates and cut spikes) and rail anchors (2 per tie average). The costs of these items are also listed in Exhibit 6.

Exhibit 6. Tie Installation Costs.

SECTION NUMBER	TIE SPACING INCHES	TIES/ MILE	EST. AVE. LIFE YEAR	BLACK TIE COST	TIE TRANS. COST	TIE INSTALLATION COST	COST/ MILE	OTM/ MILE
ONE	19.5	3249	24	$16.21	$2.67	$14.00	$106,835	$42,240
TWO	19.5	3249	30	$23.82	$3.90	$14.00	$135,558	$42,240
THREE	19.5	3249	27	$21.81	$3.51	$14.00	$127,760	$42,240
FOUR	19.5	3249	25	$20.66	$3.05	$14.00	$122,528	$42,240
FIVE	23.4	2711	24	$20.66	$3.05	$14.00	$102,216	$35,238
SIX	27.5	2304	23	$20.66	$3.05	$14.00	$ 86,884	$29,952
SEVEN	29.3	2166	26	$32.30	$4.64	$14.00	$110,344	$28,160
EIGHT	23.4	2711	35	$32.30	$4.64	$14.00	$138,077	$35,238

Tie installation costs are more variable than new tie costs because there are many methods of installation. An industry-wide average of $14.00 was used for the analysis. A $20.00 cost was also used to examine the sensitivity of the results.

Beyond the initial installation, tie replacements consisted of ties, spikes and two percent of the plates and anchors to account for breakage and loss.

3.0 DISCUSSION

The results show that for long-lived products, such as crossties, the initial cost is the determining factor in life cycle costs. Exhibit 7 lists the NPV cost for a 100 year period for each test section under various factor values. One can see that initial cost is the dominant factor. In this test, the most economical sections are the ones with the fewest ties/widest spacings. The reduction in tie life experienced is less costly than the addition of more ties at construction. For the industry-wide average cost case shown, the most economical section is section 6. The rankings of the eight sections are given in Exhibit 8.

An implicit assumption in this analysis is that all track sections will give the same level of service between tie replacements. This assumption is based on the belief that tie replacement criteria are objective, or performance based. It was also assumed that all sections will require the same amount of routine maintenance. The railroad stated that all test sections have received the same maintenance. However, this may be due to the small size of the test sections (600-700 ft) and not indicative of actual, in-practice maintenance requirements.

Exhibit 7. Parametric Study of Tie Life Costs.

RESULTS: TOTAL COST

Replacement Amount=700 ties Surfacing Cost= $0

Installation Cost= $14.00/tie

SECTION NUMBER	INTEREST RATE (%) 4	6	8	10	12
1	$211,542	$181,812	$167,900	$160,547	$156,341
2	$233,115	$204,962	$192,306	$185,975	$182,579
3	$232,108	$202,571	$188,612	$181,235	$177,045
4	$231,713	$199,485	$184,464	$176,592	$172,140
5	$195,146	$167,548	$154,659	$147,869	$144,003
6	$167,055	$143,200	$131,987	$126,036	$122,638
7	$190,049	$164,498	$152,812	$146,826	$143,527
8	$209,105	$190,044	$181,771	$177,799	$175,770

Replacement Amount=700 ties Surfacing Cost= $0

Installation Cost= $20.00/tie

SECTION NUMBER	INTEREST RATE (%) 4	6	8	10	12
1	$241,952	$207,027	$190,685	$182,047	$177,107
2	$260,297	$228,232	$213,817	$206,607	$202,738
3	$260,742	$226,858	$210,846	$202,384	$197,577
4	$261,463	$224,298	$206,976	$197,898	$192,764
5	$220,247	$188,421	$173,558	$165,728	$161,270
6	$188,572	$161,063	$148,121	$141,269	$137,351
7	$208,948	$180,471	$167,447	$160,776	$157,099
8	$229,467	$208,224	$199,003	$194,576	$192,314

Exhibit 7. Parametric Study of Tie Life Costs. (Continued)

RESULTS: TOTAL COST

Replacement Amount=25% of total   Surfacing Cost =0

Installation Cost= $14.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$210,168	$181,076	$167,390	$160,161	$156,040
2	$231,001	$203,646	$191,432	$185,382	$182,172
3	$229,566	$200,261	$186,726	$179,762	$175,912
4	$227,941	$197,291	$183,055	$175,650	$171,496
5	$195,155	$167,569	$154,629	$147,817	$143,948
6	$165,640	$143,098	$132,228	$126,356	$122,940
7	$192,085	$165,668	$153,552	$147,321	$143,867
8	$214,288	$192,159	$182,656	$178,185	$175,946

Replacement Amount=25% of total   Surfacing Cost=0

Installation Cost= $20.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$240,338	$206,163	$190,086	$181,593	$176,753
2	$257,889	$226,733	$212,821	$205,931	$202,276
3	$257,826	$224,209	$208,683	$200,694	$196,277
4	$257,113	$221,768	$205,351	$196,813	$192,022
5	$220,258	$188,446	$173,523	$165,668	$161,206
6	$186,940	$160,944	$148,410	$141,639	$137,699
7	$211,217	$181,775	$168,273	$161,328	$157,479
8	$235,243	$210,581	$199,989	$195,006	$192,510

Exhibit 7. Parametric Study of Tie Life Costs. (Continued)

RESULTS: TOTAL COST

Replacement Amount=700 ties Surfacing Cost= $2000.00

Installation Cost= $14.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$216,739	$184,536	$169,467	$161,502	$156,946
2	$236,775	$206,760	$193,266	$186,516	$182,895
3	$236,460	$204,853	$189,916	$182,023	$177,539
4	$236,596	$202,017	$185,900	$177,454	$172,677
5	$199,355	$169,743	$155,914	$148,629	$144,481
6	$170,718	$145,123	$133,082	$126,707	$123,062
7	$192,859	$165,915	$153,592	$147,280	$143,801
8	$211,056	$190,957	$182,232	$178,043	$175,904

Replacement Amount=700 ties Surfacing Cost= $2000.00

Installation Cost= $20.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$247,149	$209,751	$192,251	$183,002	$177,711
2	$263,957	$230,029	$214,777	$207,148	$203,071
3	$265,093	$229,140	$212,150	$203,171	$198,071
4	$266,346	$226,830	$208,413	$198,761	$193,302
5	$224,455	$190,616	$174,813	$166,488	$161,747
6	$192,235	$162,986	$149,226	$141,940	$137,775
7	$211,758	$181,889	$168,227	$161,230	$157,373
8	$231,418	$209,136	$199,464	$194,820	$192,448

Exhibit 7. Parametric Study of Tie Life Costs. (Continued)

RESULTS: TOTAL COST

Replacement Amount=25% of total Surfacing Cost=$2000.00

Installation Cost= $14.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$214,548	$183,371	$168,703	$160,956	$156,540
2	$234,035	$205,120	$192,209	$185,814	$182,422
3	$233,163	$202,088	$187,736	$180,351	$176,269
4	$231,912	$199,335	$184,204	$176,334	$171,919
5	$199,503	$169,838	$155,923	$148,597	$144,437
6	$169,966	$145,426	$133,592	$127,200	$123,481
7	$195,861	$167,582	$154,613	$147,943	$144,245
8	$216,596	$193,221	$183,182	$178,459	$176,094

Replacement Amount=25% of total Surfacing Cost=$2000.00
Installation Cost= $20.00/tie

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$244,718	$208,458	$191,399	$182,388	$177,252
2	$260,923	$228,207	$213,599	$206,363	$202,525
3	$261,422	$226,036	$209,693	$201,283	$196,634
4	$261,084	$223,812	$206,501	$197,497	$192,445
5	$224,605	$190,715	$174,817	$166,448	$161,696
6	$191,266	$163,272	$149,774	$142,483	$138,240
7	$214,993	$183,690	$169,333	$161,949	$157,857
8	$237,551	$211,642	$200,516	$195,280	$192,658

Exhibit 7. Parametric Study of Tie Life Costs. (Continued)

RESULTS: TOTAL COST

Replacement Amount=700 Surfacing Cost=$2000.00

Installation Cost=VARIABLE

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$216,739	$184,536	$169,467	$161,502	$156,946
2	$241,305	$210,638	$196,851	$189,955	$186,255
3	$236,460	$204,853	$189,916	$182,023	$177,539
4	$236,596	$202,017	$185,900	$177,454	$172,677
5	$199,355	$169,743	$155,914	$148,629	$144,481
6	$170,718	$145,123	$133,082	$126,707	$123,062
7	$199,159	$171,240	$158,470	$151,930	$148,325
8	$217,844	$197,016	$187,976	$183,636	$181,419

Replacement Amount=25% Surfacing Cost=$2000.00

Installation Cost=VARIABLE

SECTION NUMBER	INTEREST RATE 4	6	8	10	12
1	$214,548	$183,371	$168,703	$160,956	$156,540
2	$238,516	$208,968	$195,774	$189,239	$185,772
3	$233,163	$202,088	$187,736	$180,351	$176,269
4	$231,912	$199,335	$184,204	$176,334	$171,919
5	$199,503	$169,838	$155,928	$148,597	$144,437
6	$169,966	$145,426	$133,592	$127,200	$123,481
7	$202,238	$172,951	$159,520	$152,612	$148,782
8	$223,581	$199,361	$188,960	$184,066	$181,615

Exhibit 8. Average Cost Case Results.

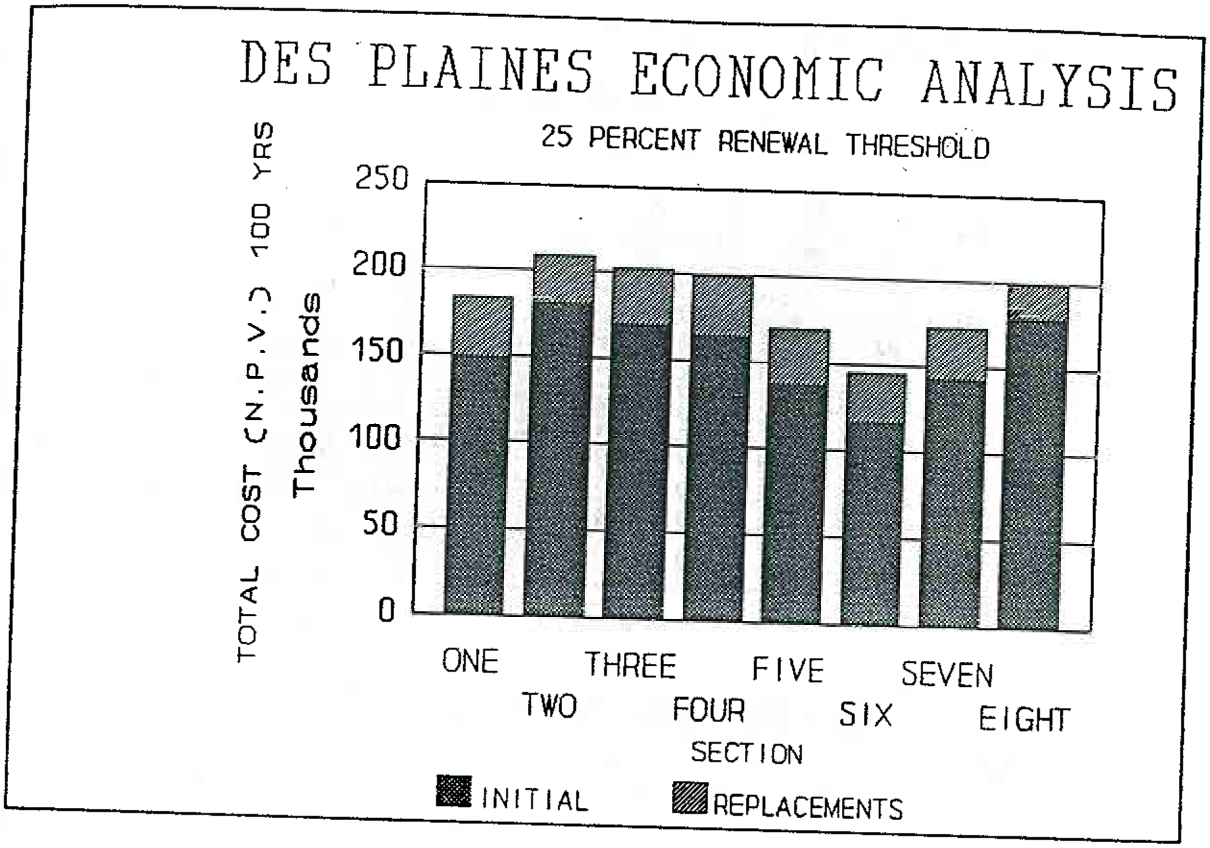
Tie Installation Cost - $14.00/tie
Discount Rate = 6%
Renewal Amount = 700 ties/mile
Surfacing Cost = $2,000/mile/tie renewal

SECTION NUMBER	NPV COST	RANK	PERCENT DIFFERENCE
1	185,000	4	27
2	207,000	8	42
3	205,000	7	41
4	202,000	6	39
5	170,000	3	17
6	145,000	1	0
7	166,000	2	14
8	191,000	5	32

The dominance of the initial costs may be seen in Exhibit 9. Over 100 years, two to three times the initial number of ties will be installed in all sections. But, the long life of the tie pushes the first renewals 20 or more years into the future. The net present value of these renewals becomes relatively small.

The effect of interest rate on the net present value of the costs is significant. Higher interest rates lead to lower net present value costs. For all cases a range of interest rates from 4 to 12 percent were used. AAR has determined that the current discount rate for railroads is 6 percent.[14] Exhibit 10 illustrates the effect of discount rate for one case. Varying the discount rate in some cases does change the ranking of some of the sections. However, it does not affect the rankings of the three highest rated sections in any case.

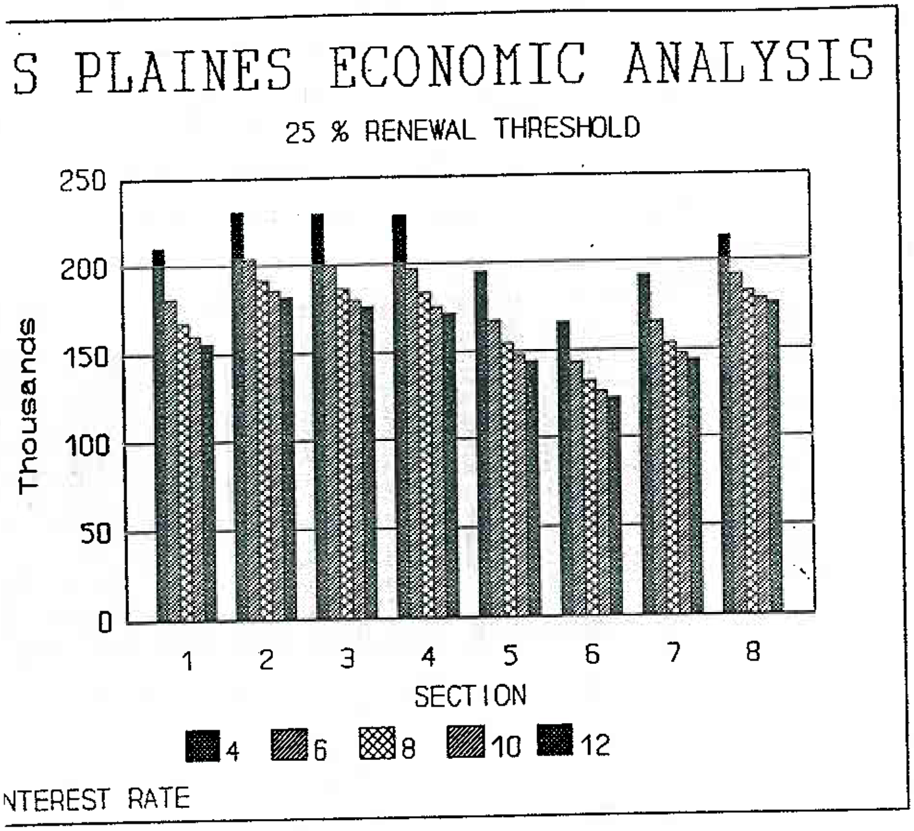
Exhibit 9. NPV Cost Components - 100 Year Life.



The effect of varying the renewal threshold/renewal amount on the NPV costs and section rankings was almost nil. Exhibit 11 illustrates this for the nominal case. The relatively small effect of renewal threshold again illustrates the dominance of initial costs on total costs.

The effect of track surfacing after tie renewals is shown in Exhibit 12. At 10 percent of the cost of a tie renewal ($2,000 for surfacing vs. $20,000-30,000 for 700 ties) the effect is minimal. The effect on NPV costs is about one percent. The effect on section ranking is nil.

10. Effect of Discount Rate on NPV Cost.



11. Effect of Renewal Amount on NPV Cost.

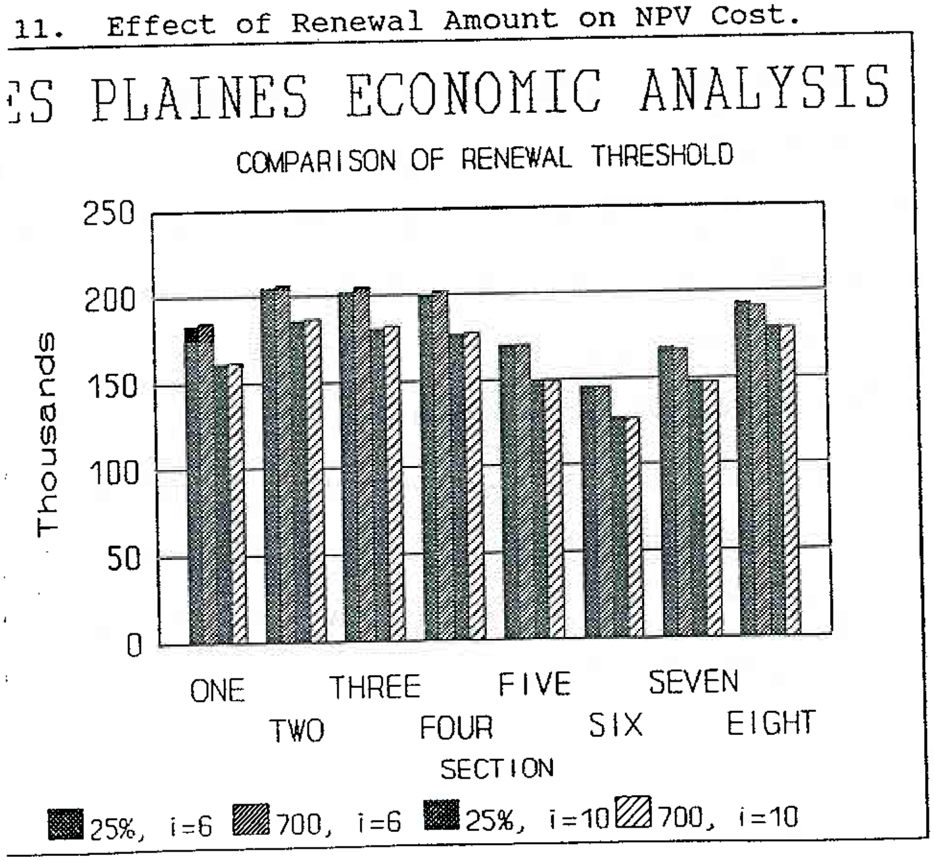


Exhibit 12. Effect of Surfacing Cost on NPV Cost.

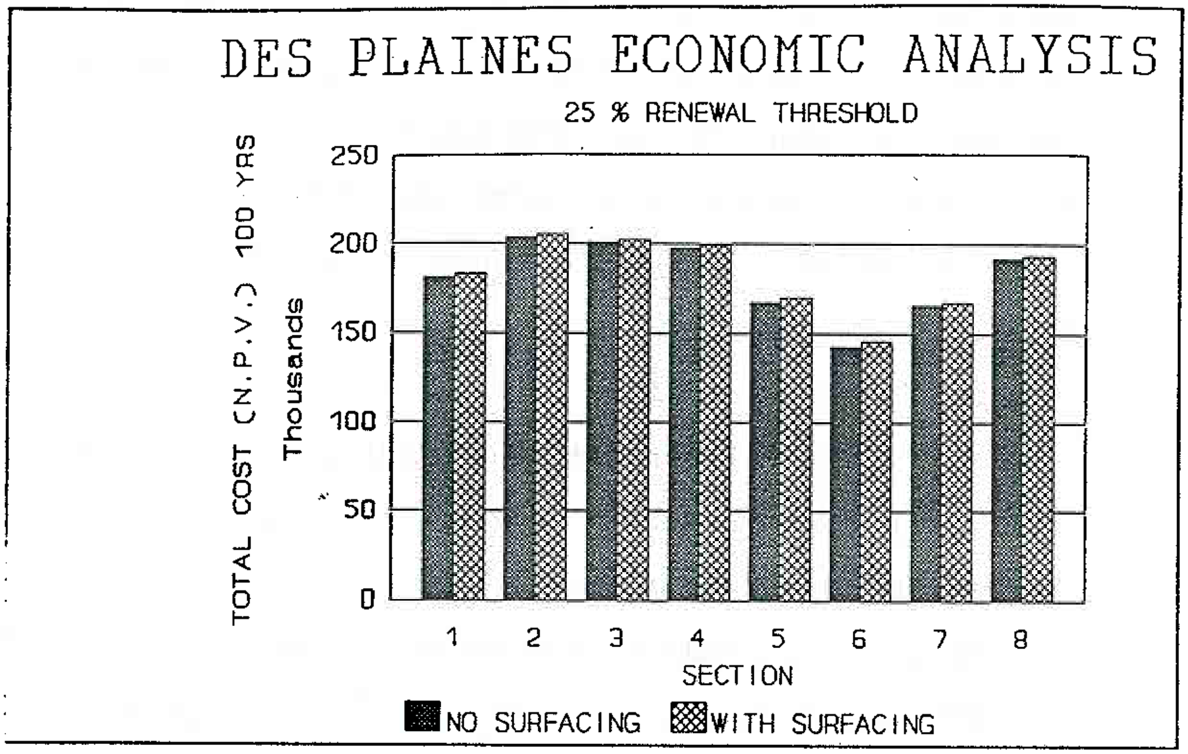
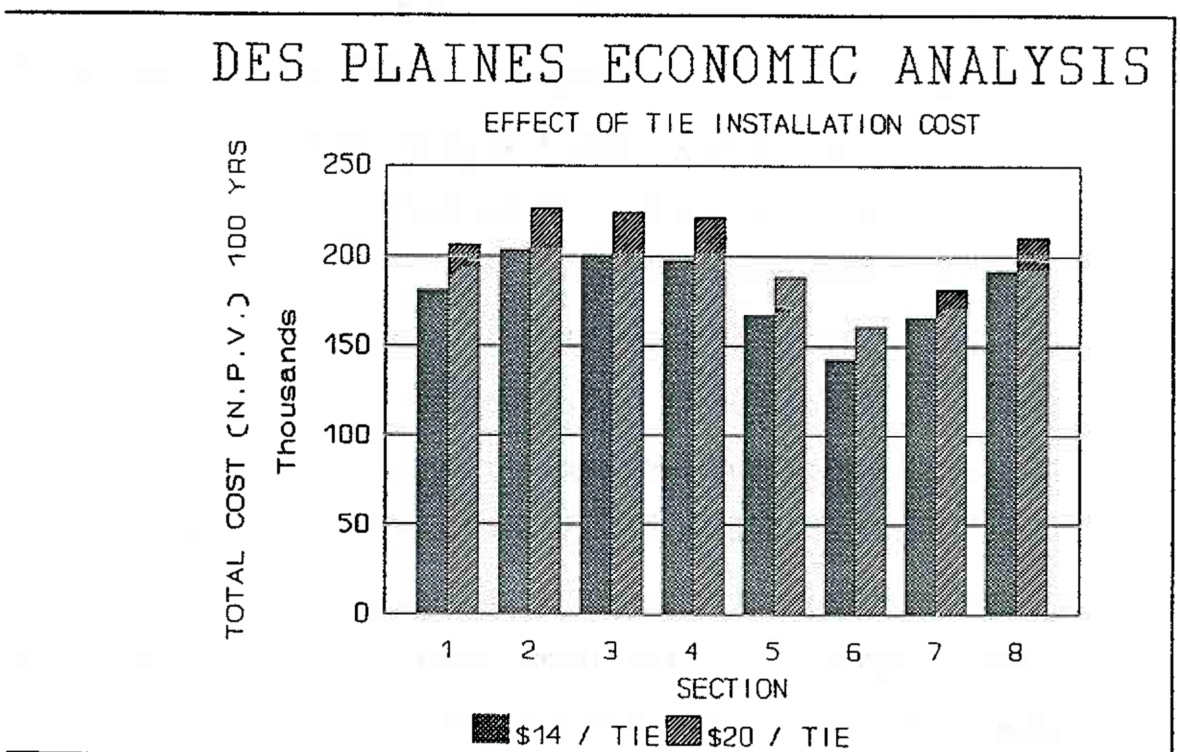


Exhibit 13. Effect of Installation Cost on NPV Cost.



The effect of tie installation cost is significant. Installation costs can be 25 to 40 percent of the initial construction costs. Raising the installation cost from $14 to $20/tie increases the NPV Life costs by about 10 percent. Raising installation costs (from $14 to $20) has no effect on section ranking. Exhibit 13 shows the effect of raising installation costs.

3.1 Cost of a Failed Tie

Factors beyond tie installation and replacement costs should be considered. The costs of having failed ties in track can be significant. The existence of failed ties in track is a result of the methods used to maintain track. The use of large, high production tie gangs leads to heavy tie renewals on long (time) cycles. Between the renewals, a large number of tie failures accumulate in track.

Failed ties in track add to the railroad operating cost in several ways. Items which may be affected include:

- train delay caused by slow orders
- increased fuel consumption
- increased lading damage
- decreased car life
- decreased track component life
- increased derailment risk

Initial estimates of these costs range from $5.00/tie/year to $30.00/tie/year depending on the number and severity of slow orders imposed.[15] The lower figure is considered to be representative of the costs experienced on a well maintained railroad with virtually no tie-related slow orders.

To illustrate the effects of considering failed tie costs, the average cost case listed in Exhibit 8 was run again with failed tie costs added. The $5.00 per failed tie cost was adjusted for the tie spacing variations in the test sections according to Exhibit 14.

Exhibit 14. Bad Tie Annual Costs vs. Tie Deflection Rating.

TEST SECTION	DEFLECTION RATING	ANNUAL BAD TIE COST ($/TIE)
ONE	1.04	5.20
TWO	1.00	5.00
THRE	1.00	5.00
FOUR	1.00	5.00
FIVE	1.11	5.55
SIX	1.33	6.65
SEVE	1.13	5.65
EIGH	0.99	4.95

These costs were then applied to each section according to the predicted annual bad tie counts provided by the Tie Renewal Model. Exhibit 15 lists a portion of the prediction. Exhibit 16 lists the 100 year NPV failed tie cost total for each section. Exhibit 17 is a plot of this data.

Exhibit 15. Yearly Bad Tie Counts From AAR Tie Renewal Model.

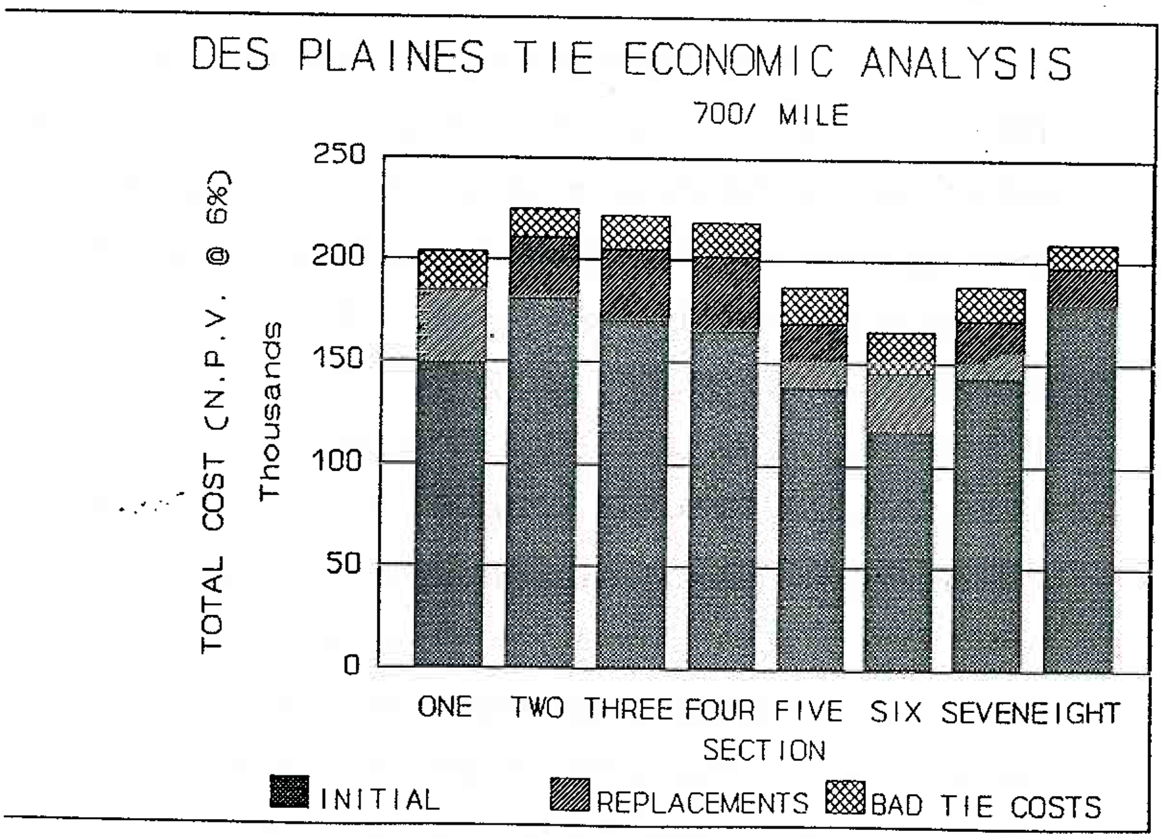
YEAR	Section Number							
	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	11	0	0	0	9	16	0	0
10	33	0	11	33	27	23	14	0
11	46	11	33	33	38	43	22	0
12	80	33	39	65	67	68	34	0
13	114	33	69	98	95	93	55	15
14	148	60	99	130	123	124	76	27
15	219	87	129	163	183	194	97	27
16	301	114	159	260	251	265	136	46
17	433	141	242	325	361	373	190	66
18	557	179	308	488	464	470	254	85
19	707	260	433	585	590	585	345	105
20	176	314	545	47	31	35	419	124
21	373	433	669	210	195	185	523	159
22	576	536	820	405	364	355	631	217
23	809	639	282	600	559	530	756	256
24	346	775	463	827	756	682	184	329
25	550	210	651	355	227	855	330	418

Exhibit 16. NPV Costs Including Bad Tie Costs.

e Installation Cost - $14.00/tie Renewal Amount = 700 ties/mile
scount Rate = 6% Surfacing Cost = $2,000/mile/tie renewal

100 YR. EPLACEMENT	INITIAL INSTALLATON	P.V. SUM	BAD TIE COSTS	N.P.V. COSTS	TOTAL MAINT.
$35,461	$149,075	$184,536	$18,900	$203,436	$54,361
$29,591	$181,047	$210,638	$14,265	$224,903	$43,856
$34,853	$170,000	$204,853	$16,803	$221,655	$51,656
$37,249	$164,768	$202,017	$16,394	$218,411	$53,642
$32,289	$137,454	$169.743	$17,533	$187,276	$49,822
$28,287	$116,836	$145,123	$20,642	$165,765	$48,929
$28,404	$142,836	$171,240	$16,333	$187,573	$44,737
$18,280	$178,736	$197,016	$11,591	$208,607	$29,871

Exhibit 17. 100 Year Failed Tie Cost.



4.0 CONCLUSIONS

For the conditions of the Des Plaines, Illinois test site, the most economical tie configurations are those with the widest ties spacings (or fewest ties/mile). This is a natural consequence of the relatively long life of the tie: initial costs tend to dominate the total NPV costs.

The effect of tie spacing on tie life is not as great as can be expected in track with high grades and curvature. The stable, well supported tangent track of the test section has largely mitigated the harmful effects of wider tie spacings. A relatively small percentage of failures are mechanically caused, even though the test section carries heavy traffic. Loaded unit coal trains make up a significant proportion of the total traffic.

The effect of other parameters such as: interest rate, tie installation cost, and surfacing costs have relatively little effect on the preference rank of the eight sections. They do, however, have some effect on the life cycle costs shown.

Many potentially significant factors are not adequately covered in this economic analysis. Among them are the items listed under failed tie costs in section 3.1. These items are currently being explored in detail by the AAR Track Maintenance Research Committee and many individual railroads. Train delay costs and service reliability are becoming topics of interest as track time for maintenance decreases. This may significantly raise the life cycle costs of the shorter lived (i.e. wide spacing) sections when train operating costs are considered.

5.0 REFERENCES

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