Office of Rail Regulation

Comparison of North American Rail Asset Life

Report

Document
ORR/RP/442/NATSLC

FINAL

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Report

April 2008

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Job number 97074-00

ARUP

Job title	Comparison of North American Rail Asset Life	Job number 97074-00	
Document title	Report	File reference	
Document ref	ORR/RP/442/NATSLC		

Revision	Date	Filename			
Draft 1	03/25/08	Description	Final draft		
			Prepared by	Checked by	Approved by
		Name	Ben Voelker and Steve Clark	Steve Clark	Steve Clark
		Signature			
Issue	04/15/08	Filename	97074-00 Final Report.doc		
		Description			
			Prepared by	Checked by	Approved by
		Name	Ben Voelker	Steve Clark	Steve Clark
		Signature	BV	SLC	Steve Clark
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
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			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

1 Introduction

Arup Texas, Inc., (Arup), is pleased to provide this report to the Office of Rail Regulation (ORR) comparing Network Rail's Track Service Life Assumptions with North American data. We understand that the ORR will use this important work to assist in its assessment of Network Rail's track renewals forecast for Control Period 4 (2009 -2014).

This work considers average service lives of rail, sleeper, ballast, and switches & crossings through a high-level desk study analysis using readily available published data from North American railroads, and data on Network Rail (NA) asset lives provided by the ORR, combined with professional experience and knowledge of the North American (NA) Class 1 and British railway environments.

2 Track Asset Analysis Input

2.1 Analysis Approach

The analysis of track asset life based on NA Class 1 data was completed in the following manner:

- The required data was identified and compiled to allow the analysis to be completed.
- A number of assumptions were made that allowed the analysis to be completed and ensure reasonable results.
- Asset analysis was completed based upon the aforementioned data and assumptions to develop asset life relationships for the different rail components.
- Conversion of Class 1 rolling stock and transports information was completed to allow a suitable comparison of typical Class 1 traffic density with existing British traffic density metrics.
- A discussion is provided on the results of the analysis.

2.2 Selected Track

We analyzed the three top categories of running track, as defined by the United States Surface Transportation Board (STB), and reported by a selection of US Class 1 freight railroads in their annual R-1 Reports to the STB [1]. These are:

- Category A (track with over 20 million gross short-tons of traffic per year)
- Category B (track with over 5 and up to 20 million gross short-tons of traffic per year)
- Category C (track with over 1 and up to 5 million gross short-tons of traffic per year)

These track categories carry approximately 90 percent of annual freight traffic on the operating freight railway track in the United States, based on R-1 information.

It is worth providing a context with British traffic density. The East Coast Main Line, West Coast Main Line, and Brighton Main Line, can all be considered relatively high-density track in Great Britain. Based on previous work, these tracks carry on the order of 15 to 25 million gross tonnes (long) per annum [2].

All data for each category was averaged over the five year period of 2002-2006 to provide a more appropriate estimate of asset life.

In order to provide better granularity than can be obtained by considering a single railroad or aggregate values, we disaggregated these values by using individual railroad data. The five railroads for which data was extracted for analysis are presented in Table 1, along with the average traffic density in million gross short-tons per annum (MGTPA) over the various categories.

Data was compiled from all five railroads in Table 1 and averaged for each track category, resulting in a maximum of 15 data points for rail, sleepers and ballast.

Table 1: Railroads for Analysis and Average Traffic Density

Class 1 Railroad	Category A (MGTPA)	Category B (MGTPA)	Category C (MGTPA)
BNSF	58.4	11.6	2.9
CSXT	41.8	12.1	2.8
Norfolk Southern	28.3	12.1	3.6
Kansas City Southern	41.1	12.6	2.7
Union Pacific	60.7	11.2	2.5

2.3 Key Assumptions

The following assumptions have been made to complete the analysis of Class 1 rail asset lives:

2.3.1 General

- The following average speeds have been assumed for each track category:
  - Category A: 45 mph
  - Category B: 35 mph
  - Category C: 25 mph

- Life limiters were assumed on the various assets because on lower density track, replacements can be driven more by environmental factors rather than traffic factors. These are presented in Table 2. Network Rail life limiters are noted for comparison [3].

Table 2: Component Life Limiters

Component	Class 1 Life Limit (years)	NR Life Limit (years)
Timber Sleepers	36	40 (softwood only)
Concrete Sleepers	55	75 (includes hardwood)
CWR Rail	70	100
Jointed Rail	60	60
Ballast	60	65

- All replacement assets were assumed to always replace an equivalent asset (i.e., CWR replacement rail always replaces CWR rail, etc.).

2.3.2 Equivalent Units Conversion

- For the development of a standard Class 1 freight train, each train was assumed to be composed of cars consisting of the top seven commodities listed by tons originated as reported by the AAR, with proportional number of cars assumed for each commodity based upon total tons of commodity [4]. These top seven commodities account for approximately 80 percent of all tons originated.

- For the development of a standard Class 1 freight train, it was assumed that half the cars are empty and half are full, thereby running full in one direction, and empty in the other. This is appropriate because many of the commodities considered operate in this capacity, e.g., coal, minerals, and agricultural products.
- The number of cars for the "average" Class 1 freight train is sourced from the 2007 AAR Railroad Facts.

2.3.3 Sleepers

- No distinction was made between hardwood and softwood sleepers because R-1 data is reported solely as timber with no distinction between wood types. (The majority of sleepers installed in mainline track in North America are hardwood, with softwood used primarily in yards and on some structures. Approximately 60 percent of hardwood sleepers are red or white oak and hickory, with the remaining 40 percent comprised of mixed hardwoods (deciduous trees). Very little tropical hardwood is imported into North America for sleepers [5].)
- The following use breakdown was assumed for sleepers for different track categories:
  - Category A: 80% Timber, 20% Concrete
  - Category B: 95% Timber, 5% Concrete
  - Category C: 99% Timber, 1% Concrete
- It was assumed that there are 3,250 sleepers per track mile.

2.3.4 Rail

- Only new rail was explicitly considered in the evaluation of rail asset life.
- Relay (cascaded) rail was assumed to have half the asset life of the new rail. Within the scope of this work, this cannot be confirmed; however, it is a reasonable assumption because many railroads cascade rail, and transpose rail from the high side of a curve to the low side in order to extend service life.
- Based on R-1 data, welded rail accounts for almost 100 percent of new rail installations on the Class 1 network. A value of the amount of welded versus bolted rail in the installed inventory is not readily available. Given the overwhelming application of welded rail, particularly in main lines, a split of 99 percent welded and one percent bolted is assumed for the track categories being considered.

2.3.5 Ballast

- It was assumed that all track categories have 4,224 yd^3 of ballast per mile of track. This provides approximately 12 inches of ballast and 12 inches of sub-ballast in the formation typically found on many Class 1 mainline tracks.
- Ballast cleaning was not considered because this is not reported within the R-1 data. However, the cleaning of ballast is a practice applied on North American railroads to remove fines from fouled ballast, and restore the capacity of ballast to properly drain and provide track stability [6]. The policies for when to clean ballast are set by the individual railroad engineering departments.

2.3.6 Excluded Data

- Kansas City Southern rail replacements on Category C track were not considered in the analysis as only relay rail was reported in that year.

- BNSF ballast data from 2005 and 2006 was disregarded for all track categories due to an unexplained sharp increase in replacement rate for track categories B and C, and an unexplained sharp decrease for track category A.
- Steel sleepers are not considered in this analysis. According to R-1 data, NA sleeper replacements for materials other than timber or concrete (i.e., steel, plastics, and composites) account for less than one percent of all sleeper replacements, and there is not adequate data to make an assessment.

2.4 Asset Analysis Methodology

2.4.1 Standard Assets

Data is provided to the STB in the form of R-1 reports, required by the individual Class 1 railroad companies at the end of each calendar year. These reports include financial, operational, and asset information. Asset information includes a summary of total track owned in each category, average traffic density and a summary of all replacement data for the applicable track components. Rail, sleeper and ballast replacements are included in these reports.

Replacement data was averaged over a five year period (2002-2006) for five railroads (BNSF, CSXT, KCS, Norfolk Southern, and Union Pacific) and for each track category (A, B, and C).

While the R-1 reports provide much of the information required to complete an analysis of asset life, there is some data that is not available. Most importantly, there is no data provided concerning the assets that were in-place at the beginning of the year. To bridge gaps and develop a meaningful analysis model, some assumptions were required, which have been described in detail in Section 2.3.

The average annual replacements coupled with the analysis assumptions provide an estimate of the percentage of rail, sleepers, and ballast replaced within each track category for a given traffic density per year. This in turn provides an asset life estimate, in years and traffic density, of the respective asset. The analysis of multiple railroads and track categories allows the resulting asset life estimates to be plotted and a relationship established between traffic density and asset life. Multiple plots were created for each asset to compare traffic density to asset life by total tonnage and years.

The ORR provided existing information on various asset lives based upon existing data from NR. This information was plotted along with the R-1 data for the appropriate assets to allow comparison between the different data sets. The ORR data on asset life was provided in years only, so the comparison between R-1 and NR data was made as such.

All asset lives and density were initially calculated in million gross short-tons (MGT) and million gross short-tons per annum (MGTPA). Short-tons were converted into long-tonnes, and then gross tonnages into equivalent million gross tonnes (EMGT) and equivalent million gross tonnes per annum (EMGTPA). The conversion is discussed in detail in Section 3.

2.4.2 Special Track Work

Switches and Crossings (S&C) present a different set of challenges because there is no regular reporting mechanism for this within the public domain and data is limited. No information is required by the STB regarding the replacement of special track work, and it is not included in a railroad's annual R-1 report.

Because there is no formal information available regarding special track work in the public domain for NA rail, an effort was made to find useful data through a brief literature search, and contacting industry experts and suppliers. Unfortunately, this was not particularly successful.

Because data on special track work is not as prevalent or detailed as for standard track components, the resulting analysis was more broad based in nature than the analysis completed for standard assets. Some data was collected on S&C from the AAR and is presented to allow broad life estimates.

3 Traffic Density Conversion (North American to UK Units)

To generate comparable approximate and representative traffic density data in the analysis of Class 1 assets, it was necessary to convert representative NA Million Gross Short-Ton Miles (MGTM) into Equivalent Million Gross Tonne Miles. To complete this conversion, EGTM Factors for speed, wagon type, and axle load were used as developed by Booz Allen Hamilton (BAH) in the Usage Cost Model developed for the ORR in 1999/2000 [7].

The BAH equation was developed for the purpose of assessing track variable usage costs for the various types of rolling stock operating on the railway, and provides a method to harmonize North American MGT data into relevant British units. The BAH equation has the following form:

$$\text{EGTM} = \text{K} \times \text{C}_t \times \text{A}^{0.49} \times \text{S}^{0.64} \times \text{USM}^{0.19} \times \text{GTM}$$

Where:

K = spillage of fines factor (1.0 for closed hoppers, 1.2 for open hoppers)

C_t = bogie type factor, and is equal to 1.0 for all wagon types

A = Axle Load (in Tonnes)

S = Speed ÷ 75 (in MPH)

USM = unsprung mass per axle (kg) ÷ 2000

GTM = gross tonne miles ÷ 1000

A representative Class 1 freight train was developed by using proportional representation of the top seven categories of Total Tons Originated (coal, ores, agricultural products, metals, etc.) for the Class 1 freight railroads, as reported by the AAR. The top seven commodities transported by the Class 1's in 2006 are presented in Table 3.

Table 3: Top Seven Commodities Transported by Rail in the United States in 2006 by Tons Originated

Commodity Group	Tons Originated (1,000 Short-Tons)	% of Total
Coal	852,061	43.5
Chemicals & Allied Products	168,275	8.6
Farm Products	149,392	7.6
Non-metallic Minerals	140,871	7.2
Miscellaneous Mixed Shipments	125,880	6.4
Food & Kindred Products	105,443	5.4
Metals & Products	62.256	3.2
Total	**1,604,168**	**82.0**

Conversion factors were calculated by the BAH method for all seven car types and typical six-axle locomotives, at six speeds: 10 MPH, 20 MPH, 30 MPH, 40 MPH and 50 MPH.

The factors for each car type were combined based on an "average" Class 1 freight train to create an average conversion factor for each of the six speeds. The representative Class 1 freight train was developed by assuming it is made up of a proportional number of total cars based upon the tons originated, and the average train length as reported by the AAR in 2007, plus two six-axle locomotives.

Linear interpolation was used to calculate the appropriate EGTM conversion factor for the speeds assumed for each of the three track categories.

A summary of the calculated conversion factors is presented in tabular form in Table 4 and in graphical form in Figure 1.

Table 4: Gross Tonne to Equivalent Gross Tonne Multipliers for a Typical North American Class 1 Freight Train

	GTM to EGTM Conversion Factor					
	Speed					
Traffic Mix	10	20	30	40	50	60
Class 1 Mix	1.36	2.12	2.75	3.30	3.81	4.28

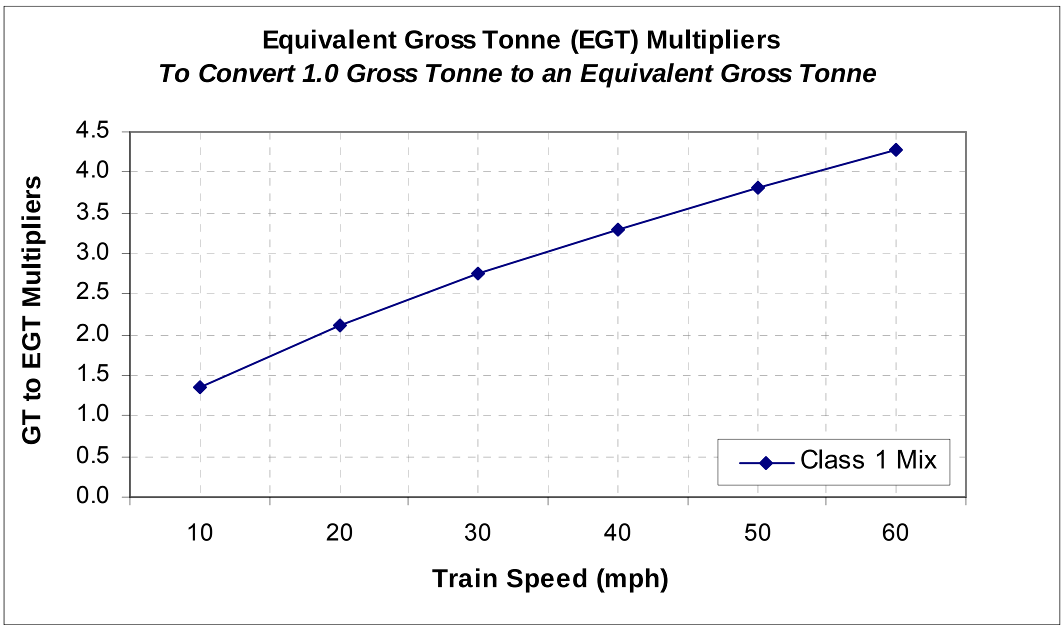

Figure 1: Gross Tonne to Equivalent Gross Tonne Multipliers for a Typical North American Class 1 Freight Train

4 Data Presentation and Discussion on Asset Lives

As was described in Section 2.4, the asset life of sleepers, rail and ballast were all developed based upon available railroad asset data. The following are the results of the analysis of each asset type.

4.1 Sleeper Asset Life

The asset life of sleepers for North American freight rail was considered for two different types of sleepers: timber and concrete. It is important to note that the UK asset life data for sleepers combines both hardwood timber and concrete sleepers. Because the R-1 data is segregated between timber and concrete, both sleeper types are presented in a summary chart. However, R-1 data does not segregate hardwood and softwood sleepers.

A summary of the NA concrete sleeper asset life data are presented in Table 5 and Figure 2. Table 5 clearly shows that only some of the Class 1 railroads use concrete sleepers extensively. In addition, where they are used sparingly, such as on the UP Category C track, there is not enough data to make a sensible calculation of asset life and this data has not been included in the analysis.

Table 5: Concrete Sleepers Replacements

Concrete Sleeper Replacement					
Rail Company	**Track Category**	**Number of Replacement Crossties (5 year average)**	**Time for Full Replacement (years)[1]**	**EMGTPA**	**EMGT**
BNSF	A	142,318	55	189	10,405
	B	19,444	55	32	1,748
	C*	0*	n/a*	6*	n/a*
CSXT	A	37,923	55	135	7,433
	B	14,218	55	33	1,834
	C*	0*	n/a *	6*	n/a *
KCS	A*	0*	n/a *	91*	n/a *
	B*	0*	n/a *	33*	n/a *
	C*	0*	n/a *	8*	n/a *
NS	A*	0*	n/a *	133*	n/a *
	B*	0*	n/a *	35*	n/a *
	C*	0*	n/a *	6*	n/a *
UP	A	328,391	41	196	7,994
	B	17,003	55	31	1,699
	C*	3,723*	n/a*	n/a*	n/a*
*	Data that was not considered in the development of the NA asset life due to very limited or no data.				
1)	Life limit for concrete sleepers is 55 years. See Section 2.3.1				

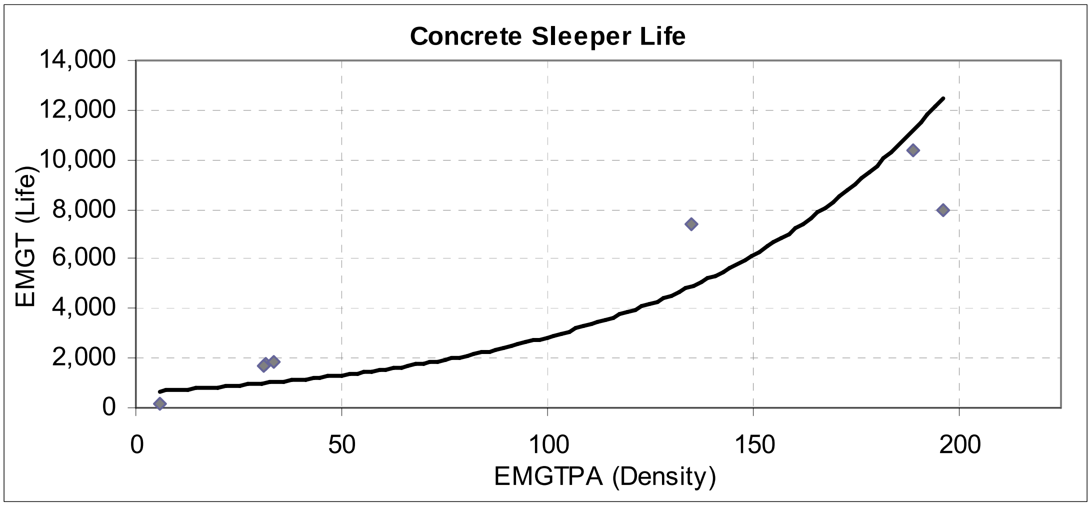

Figure 2: Concrete Sleeper Asset Life (EMGT)

A summary of the NA timber sleeper asset life data are presented in Table 6 and Figure 3

Table 6: Timber Sleeper Asset Life Data Summary

Timber Sleeper Replacement					
Rail Company	**Track Category**	**Number of Replacement Crossties (5 year average)**	**Time for Full Replacement (years)[1]**	**EMGTPA**	**EMGT**
BNSF	A	1,615,481	33	189	6,261
	B	451,359	36	32	1,144
	C	72,835	36	6	230
CSXT	A	1,622,723	19	135	2,560
	B	673,239	28	33	934
	C	170,676	36	6	226
KCS	A	146,231	17	91	1,590
	B	143,572	27	33	898
	C	1,169	36	8	290
NS	A	1,501,518	16	133	2,147
	B	705,856	30	35	1,037
	C	109,100	36	6	216
UP	A	2,294,283	23	196	4,577
	B	1,004,686	24	31	753
	C	141,545	36	6	202
1)	Life limit for timber sleepers is 36 years. See Section 2.3.1				

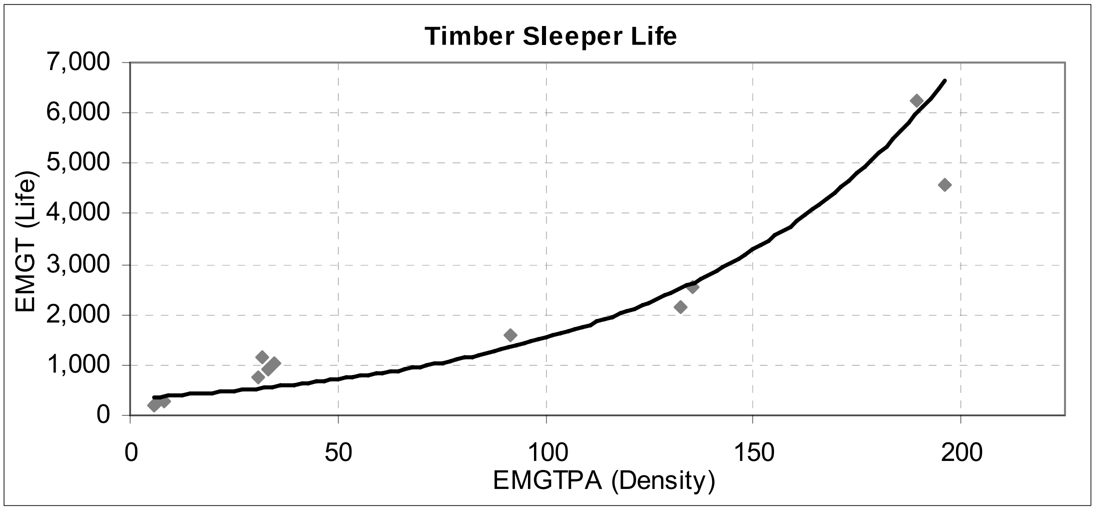

Figure 3: Timber Sleeper Asset Life (EMGT)

The conversion of EMGT life to life in years and the comparison with NR data is presented in Figure 4.

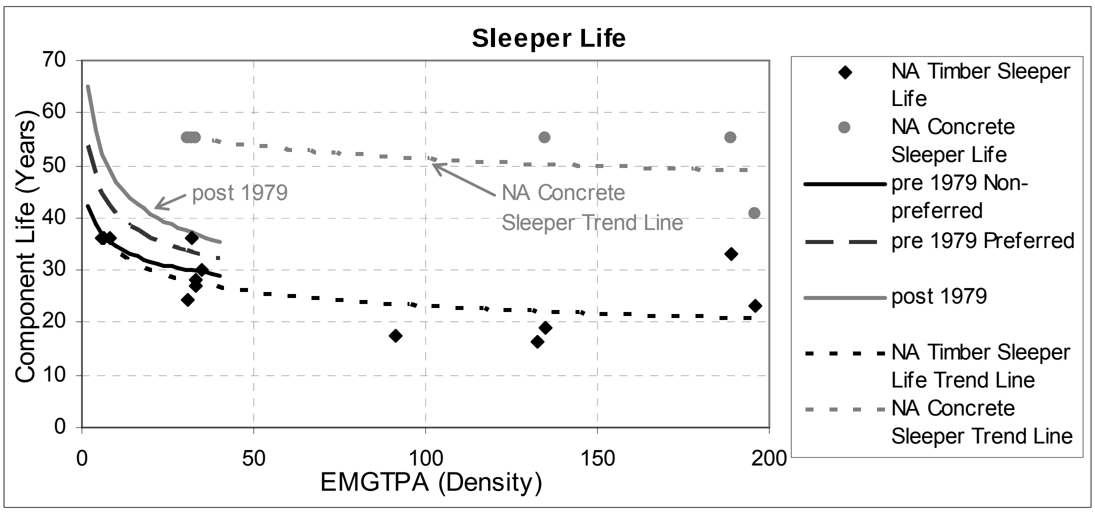

Figure 4: Comparison of NA Sleeper Life to NR Sleeper Life

As can be seen in Figure 4, the NA Class 1 concrete sleeper life appears to be significantly higher than the combined concrete/timber sleeper life reported by NR, and the NA Class 1 timber sleeper life appears to be significantly lower than the combined timber/concrete sleeper life reported by NR.

This result is not surprising, as concrete sleepers are expected to have a greater asset life than timber sleepers, and it is expected that with separation of the NR rail data, there would result in a reduction in asset life for timber sleepers, and an increase in asset life for concrete.

The results also show that concrete sleeper lives reach the life limiter of 55 years in all but the most heavily used track. This supports the general assumption that concrete sleepers are a highly durable component, and suggests that when used in lower density track will be life limited by environmental factors as opposed to failing from traffic related degradation mechanisms.

4.2 Rail Asset Life

The asset life of rail for Class 1's was considered for two different types of rail: continuously welded rail (CWR) and bolted rail. Only new rail has been considered in the analysis of asset life. A factor has been developed to allow an increase in asset life based upon the amount of relay rail that is used by the railroad. This was done to take account of the shorter asset life of relay rail, which requires a greater number of total replacement rails to be laid.

A summary of the tabular CWR rail asset life data is presented in Table 7. Graphical summaries of North American CWR rail in EMGT and years are presented in Figure 5 and Figure 6, respectively.

Table 7: CWR Rail Asset Life Data Summary

CWR Rail Replacement							
Rail Company	**Track Category**	**Miles of Replacement Rails (5 year average)**	**Relay Lifespan Factor**	**Total Miles of CWR Rail**	**Time for Full Replacement (years)[1]**	**Track Density (EMGTPA)**	**Estimated Life (EMGT)**
BNSF	A	807.47	1.08	40,769	55	95	5,174
	B	151.92	1.09	13,759	70	16	1,113
	C	27.54	1.09	4,599	70	3	224
CSXT	A	577.40	1.01	23,441	41	68	2,768
	B	100.15	1.11	12,107	70	17	1,167
	C	13.19	1.12	4,716	70	3	220
KCS	A	24.32	1.04	1,940	70	46	3,198
	B	29.17	1.10	2,491	70	17	1,163
	C*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
NS	A	248.23	1.10	18,517	70	66	4,645
	B	71.68	1.14	13,545	70	17	1,214
	C	10.33	1.13	5,686	70	3	210
UP	A	817.58	1.07	40,806	53	98	5,217
	B	391.16	1.17	15,728	47	15	728
	C	34.57	1.19	5,514	70	3	197

*	Data that was not considered in the development of the NA asset life.
1)	Life limit for CWR rail is 70 years. See Section 2.3.1

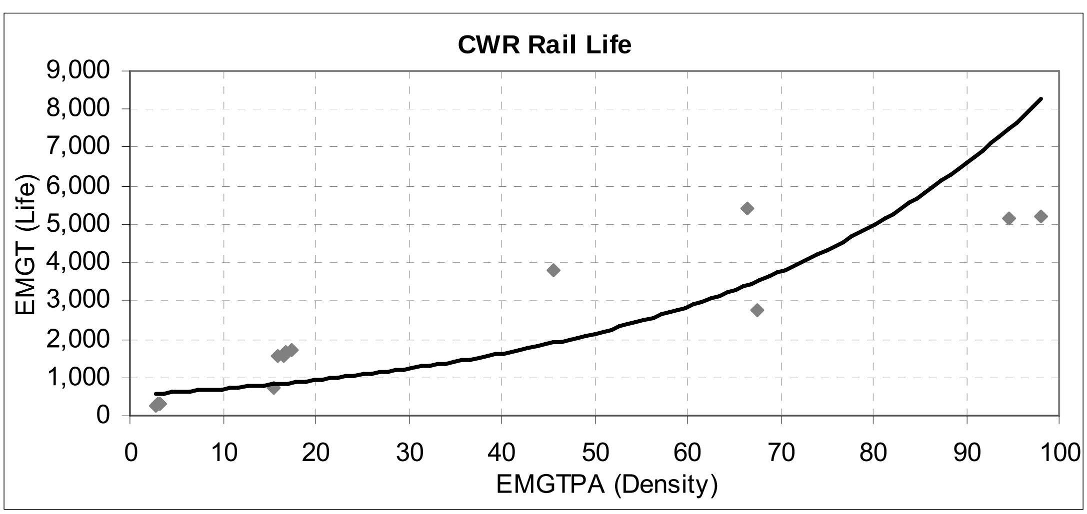

Figure 5: CWR Rail Asset Life (EMGT)

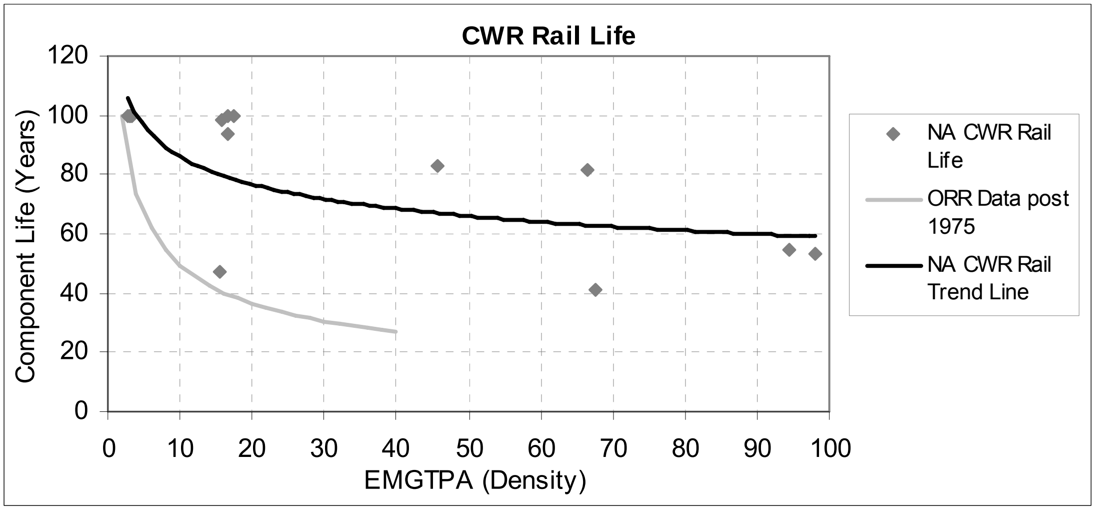

Figure 6: CWR Rail Asset Life (Years)

Figure 5 shows the relationship between traffic density and asset life in EMGT. Although a general trend line clearly shows the expected behavior of rail life, the reasons for scatter between railroads is not precisely known, but is expected to be from different rail maintenance practices as well as material selection. Several of the data points indicate rail reaching its 70 year life limit assumption. This suggests that the wear due to rail traffic and usage is less significant in determining CWR asset life on lower density tracks.

A summary of the tabular bolted rail asset life data is presented in Table 8. Graphical summaries of Class 1 bolted rail in EMGT and years are presented in Figure 7 and Figure 8, respectively.

The analysis indicates significantly longer rail lives on Class 1 track than in Great Britain for both welded and bolted rail.

Table 8: Bolted Rail Asset Life Data Summary

Bolted Rail Replacement							
Rail Company	**Track Category**	**Miles of Replacement Rails (5 year average)**	**Relay Lifespan Factor**	**Total Miles of Bolted Rail**	**Time for Full Replacement (years)[1]**	**EMGTPA**	**EMGT**
BNSF	A	5.66	1.36	370	60	95	5,676
	B	1.15	1.34	125	60	16	954
	C	0.19	1.36	42	60	3	192
CSXT	A	6.05	1.03	213	36	68	2,438
	B	1.40	1.35	110	60	17	1,000
	C	0.27	1.40	43	60	3	189
KCS	A	3.42	1.25	18	6	46	295
	B	1.52	1.43	23	21	17	353
	C*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
NS	A	2.97	1.39	168	60	66	3,982
	B	0.86	1.42	123	60	17	1,041
	C	0.10	1.43	52	60	3	180
UP	A	5.72	1.31	371	60	98	5,886
	B	2.31	1.41	143	60	15	927
	C	0.24	1.38	50	60	3	169
*	Data that was not considered in the development of the NA asset life.						
1)	Life limit for jointed (bolted) rail is 60 years. See Section 2.3.1						

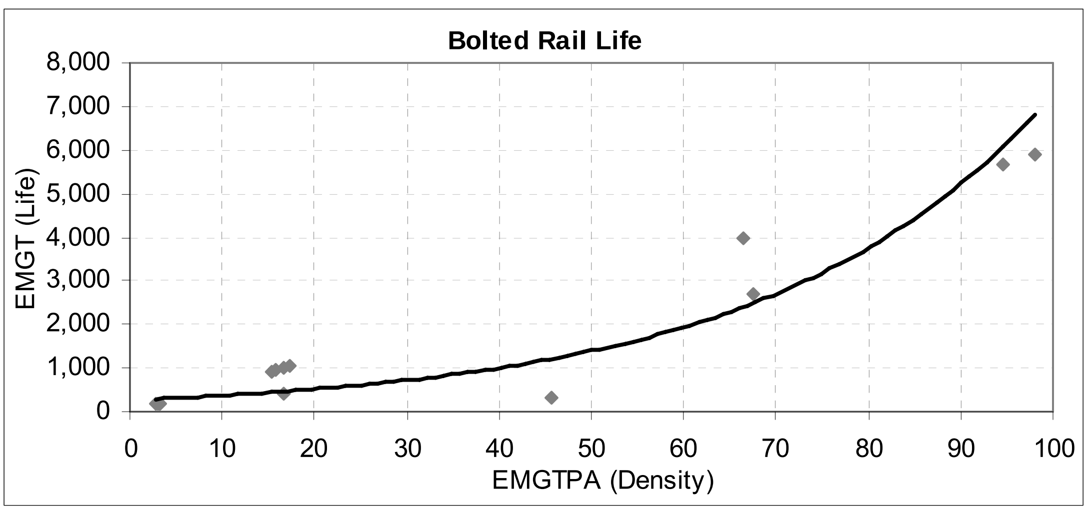

Figure 7: Bolted Rail Asset Life (EMGT)

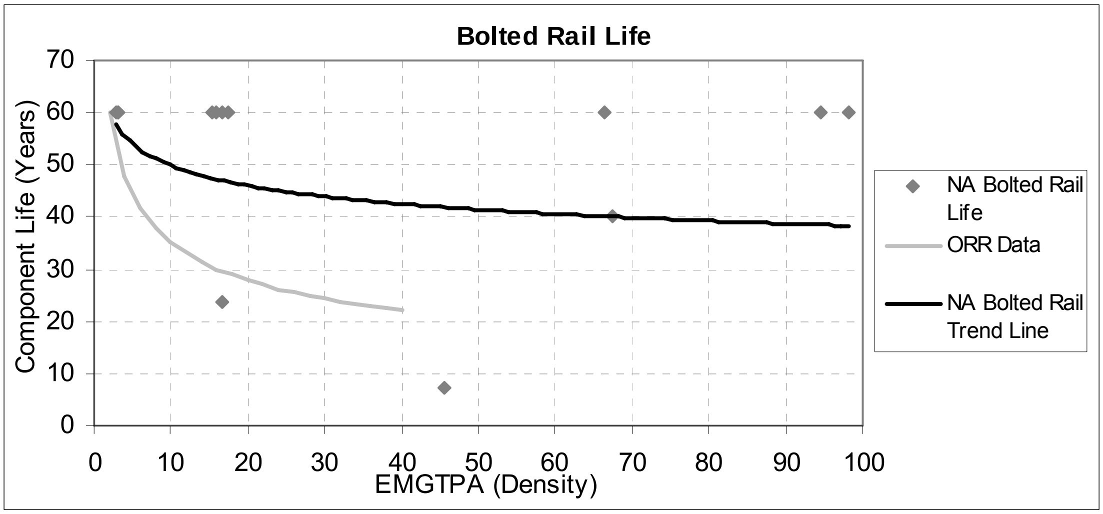

Figure 8: Bolted Rail Asset Life (Years)

4.3 Ballast Asset Life

The asset life of ballast was considered based on the assumptions presented in Section 2.3. It has been assumed that all track categories require the same amount of ballast (4,224 yd^3 /mile). A summary of the tabular ballast asset life data is presented in Table 9. Graphical summaries of North American ballast in EMGT and years are presented in Figure 9 and Figure 10, respectively.

Table 9: Ballast Asset Life Data Summary

Ballast Replacement						
Rail Company	**Track Category**	**Volume of Ballast Replacement, yd^3 (5 year average)**	**Total Volume of Ballast**	**Time for Full Replacement (years)[1]**	**Traffic Density (EMGTPA)**	**Estimated Life (EMGT)**
BNSF	A*	1,177,489*	84,077,312*	60*	189*	11,351*
	B	301,890	30,702,848	60	32	1,907
	C	61,693	10,873,984	60	6	384
CSXT	A	1,336,211	49,956,403	37	135	5,053
	B	440,774	25,802,726	59	33	1,952
	C	97,880	10,051,430	60	6	377
KCS	A	213,491	4,134,451	19	91	1,770
	B	208,248	5,308,723	25	33	847
	C	38,298	2,831,770	60	8	483
NS	A	1,449,464	39,462,298	27	133	3,613
	B	466,823	28,867,661	60	35	2,082
	C	67,403	12,116,966	60	6	360
UP	A	3,498,335	86,965,402	25	196	4,878
	B	709,886	33,519,974	47	31	1,459
	C	109,307	11,751,168	60	6	337

*	This data point was a significant outlier for which clarification was not obtained, and was therefore excluded from the analysis.
1)	Life limiter for ballasts is 60 years. See Section 2.3.1

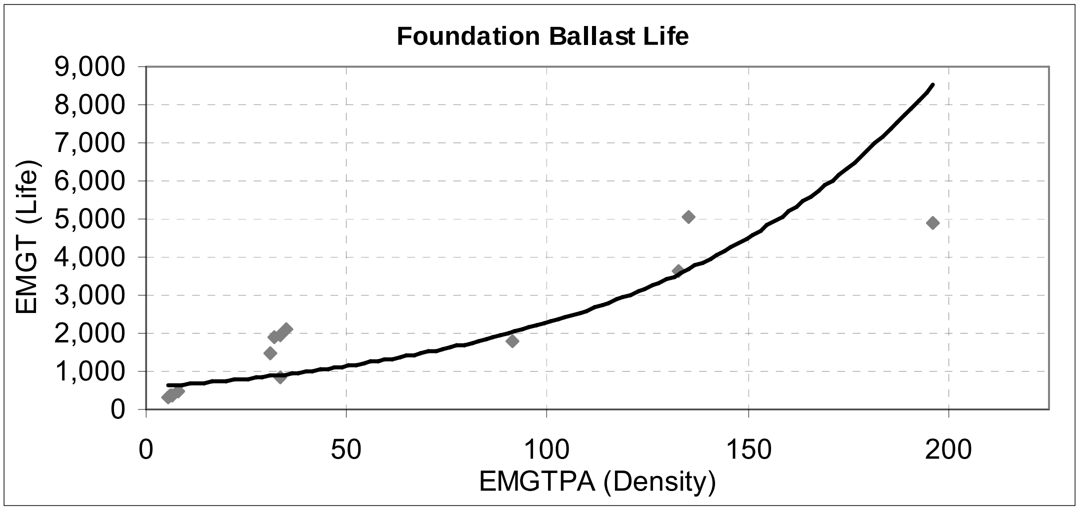

Figure 9: Ballast Asset Life (EMGT)

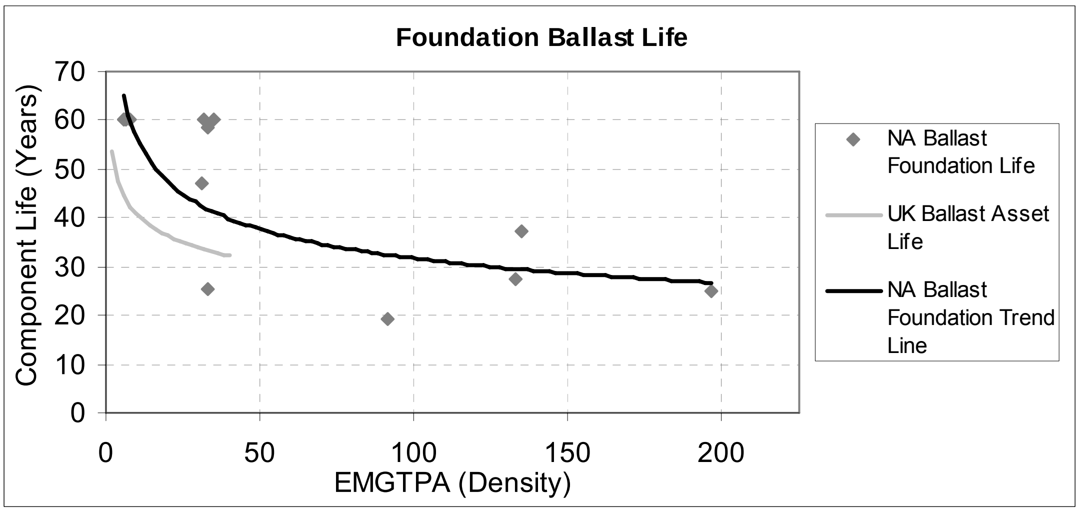

Figure 10: Ballast Asset Life (Years)

The EMGT ballast data has been fit to an exponential trend line, similar to the other track assets, and shows expected behavior.

The data indicate higher asset life for ballast on Class 1 track, than on NR, and suggest that the minimum asset of life would be about 25 years, regardless of the traffic density considered. At lower density track, the ballast would reach its full life-limited age.

4.4 Special Track Work Asset Life

Special track work generally consists of all track work associate with turnouts that is not used in normal track conditions. More specifically, this typically refers to the switches, which allow the path of a train to be switched to a different track, and crossings, which are the special track that is used at the crossing track's intersection to allow traffic to pass it in both directions. In general special track work is subjected to higher loads than typical track due to the concentration of forces caused by the turnout.

Little information is available regarding special track work asset life in the public domain. Transportation Technology Center (TTCI) has completed some research on special track work, including switches and crossings. Research was summarized in the TTCI research report R-954 entitled "Results from Special Track Work Experiment at FAST" [8]. This report summarizes the completion of physical testing on special track work at TTCI's Facility for Accelerated Service Testing (FAST). The experiment used actual trains over a controlled section of track to allow evaluation of actual service lives of track work.

The study focused on the evaluation of economic and physical performance of a variety of switches and crossings, focusing on improvement due to new technology. In general, a very conservative test setup was used to evaluate services lives and economic impact. This included 35 tonne axle load wagons, which is somewhat higher than the average traffic used in the assessment of R-1 data. It would be reasonable to expect somewhat better performance under normal operating conditions.

It is stated in the report that diverging traffic travelled through the turnouts at 40 MPH, which can be assumed to be the speed of all traffic. While no specific information on the train type was provided, a conversion to EMGT was provided based upon the representative Class 1 train discussed in Section 3.

Performance of switches in the FAST testing was monitored on two different types of No. 20 switches. These included a low entry angle switch and a standard AREMA switch for both curved and straight switches.

The resulting lives of the four types of switch points, including conversions to EMGT, are presented in Table 10.

Table 10: Switch Asset Life Based on FAST Testing

Switch Type	Straight Switch		Curved Switch	
	Asset Life (MGT)[1]	Asset Life (EMGT)[2]	Asset Life (MGT)[1]	Asset Life (EMGT)[2]
Low Entry Angle Switch	173	570	68	224
AREMA Switch	177	585	105	347

1) Asset life has been converted from short tons to tonnes.

2) MGT multiplied by a 3.3 factor based on 40 MPH traffic and assumption of standard NA train as presented in Section 3.

Performance of crossings was also monitored for two different types of hardware. These crossings included a standard rail bound manganese (RBM) fixed crossing (which would be similar to the manganese casting used in the UK without the outer rail structure) and a spring crossing. The resulting service lives of the two crossings are presented in Table 11.

Table 11: Crossing Asset Life Based on FAST Testing

Crossing Type	Asset Life (MGT)[1]	Asset Life (EMGT)[2]
RBM Crossing	305	1,005
Spring Crossing	273-318	900-1,050

1) Asset life has been converted from short tons to tonnes.

2) MGT multiplied by a 3.3 factor based on 40 MPH traffic and assumption of standard NA train as presented in Section 3.

It is important to note that the data presented in Table 10 and Table 11 are the asset lives of the switches considering only the traffic that actually used the components. For example, the curved switch data only considers diverging traffic, as this is the only traffic that actually uses the curved switches. Crossings see all traffic irrespective of traffic direction.

The low entry angle switch results in lower asset life for the curved switches. The AAR report stated that this was due to a very thin section of the switch blade, necessary to generate the low entry angle, but susceptible to chipping from wheel-rail forces. The benefit of the low entry angle switch is reduced train forces through the turnout.

There was little difference in asset life between the two crossing types.

These results have been normalized to the EMGTPA traffic densities, and plotted against NR trends on S&C life. This is shown in Figure 11. It is understood that the NR data aggregates switches and crossings into single trend lines, although the individual component lives are expected to be significantly different.

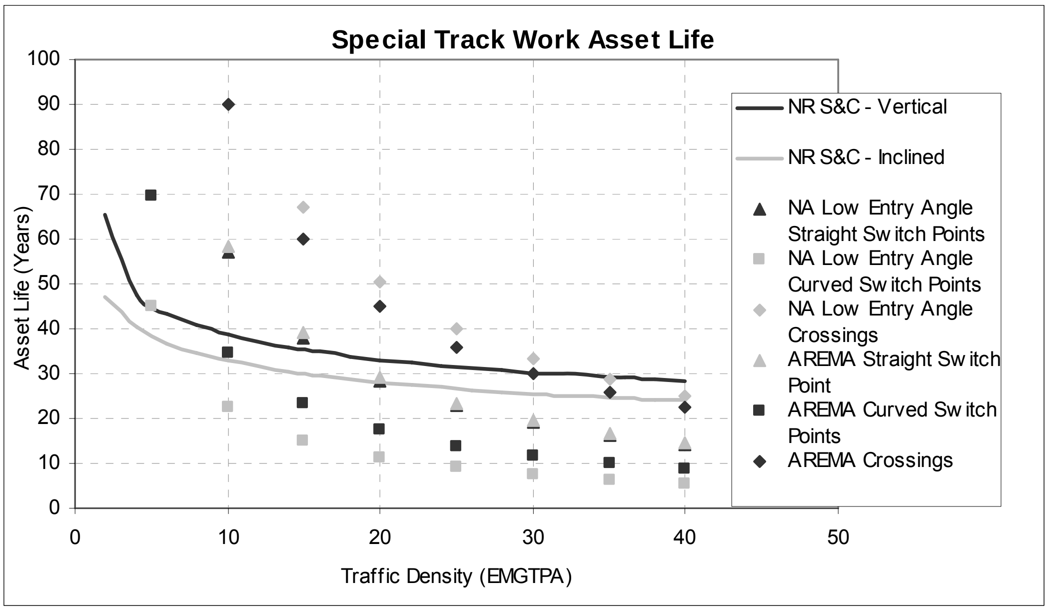

Figure 11: Special Track Work Asset Life

The general trend shows NA curved switch point lives below the composite NR S&C lives, NA crossing lives higher than the composite NR S&C lives, and NA straight switch lives approximately in the range of the composite NR S&C lives.

5 Discussion of Results

There are some differences between track engineering practices and policies on the Class 1 and British networks that affect component life between them. These include rail section, rail hardness, rail grinding, ballast selection, ballast tamping, and overall track design.

This section presents the general conclusions, and a discussion that compares and contrasts some of the practices and policies between the NA Class I system, which is designed to be a heavy-haul freight railway, and British railway system, which is designed to be a mixed service railway.

Table 12 presents some typical representative track sections that have been previously used to analyse the differences between NA and British track degradation. It is presented here to provide a side-by-side comparison of how the different track sections might look. These are track sections that might be commonly found on each respective railway system.

It is understood that around year 2000, Network Rail began using CEN-60 rail that is slightly larger in rail section and slightly harder than the BS-113A rail section. The Class 1 railroads are now moving towards RE-141 rail with a larger rail section and similar hardness to the 136RE rail section. While these track designs are only representative of track that might be commonly found in each of the systems, the heavier and harder rail sections are becoming more prevalent and will likely lead to greater rail life in both systems.

The important "take away" point from Table 12 is that the Class 1 track section is designed for heavier traffic, and is generally stronger with heavier components, and would therefore be expected to generally have greater durability with longer asset life.

Table 12: Representative Track Designs

Input	Track Name and Design Criteria			
	UK-1	**UK-2**	**NA-1**	**NA-2**
Rail Section	BS113A	CEN60	136RE	141RE
Rail Hardness	240-260	260	300-340	300-340
Tie Spacing (qty/60 ft)	28	30	38	36
Tie Spacing (mm)	653	610	483	508
Tie Material	Concrete	Concrete	Hardwood	Concrete
AREA Ballast Grade	AREA No. 4	AREA No. 4	AREA No. 3	AREA No. 3
Ballast Depth (mm)	254	300	305	457
Subballast Layer (mm)	127	76	152	152
Ballast Abrasion Number	60	45	45	45
Typical Axle Load (tonne, maximum)	25.0	30.0	32.5	32.5

5.1 Sleepers

The analysis of sleeper life indicates that Class 1 timber sleeper life is at or below the composite Network Rail sleeper lives, and that the Class 1 concrete sleeper life is substantially above the composite Network Rail sleeper lives.

As discussed previously in this report, the Class 1 railroads use either hardwood or concrete sleepers in their mail lines. Network Rail has previously used a combination of softwood and hardwood timber, and concrete sleepers, but now specifies concrete sleepers for their main line tracks [9, 10]. Both systems use steel sleepers, and the Class 1's are starting to use some plastic sleepers. But the use of "alternative" sleeper materials (steel, plastics, composites) still comprise less than one percent of sleeper replacements on the Class 1 system, whereas NR is understood to be using a substantial number of steel sleepers where economics support this, but only for moderate load conditions.

All renewals on Category 1 British mainline track consist of CEN60 rail on concrete sleepers at a tighter sleeper spacing of 30 sleepers per 60-foot length, on 300mm of ballast [10]. Based on NR's asset policy, this increases the maximum standard axle load to 30 tonnes from the previous limit of 25 tonnes. This compares with Class 1 mainline track which has a maximum standard axle load of 32.4 tonnes.

In terms of durability and stability, concrete sleepers are considered to be superior to timber, elastic fasteners are superior to spikes, and hardwood timber sleepers are superior to softwood timber sleepers [6]. Tighter sleeper spacing provides greater load distribution and lateral stability, which increases the maximum axle load the track can handle.

An estimate used by the AAR in their research assessments indicates that approximately 87 percent of all Class I track is timber, mostly hardwood. Softwood sleepers are reported to have a life approximately 20 percent less than the life of hardwood sleepers [11, 12].

The durability of steel sleepers is dependent on the service environment, with tests at TTCI indicating poor lateral stability of track and ballast life with steel sleepers under heavy axle loads [13]. The author is aware of some negative experiences with steel sleepers installed on a British freight line (Settle and Carlisle), and it is understood that this was due to the high-axle load application on somewhat weak formation. As mentioned above, steel sleepers are used by NR for moderate and light load conditions. Plastic sleepers are relatively new to the railroad market and are showing very promising results in vertical and lateral durability [14].

Because timber and concrete sleepers have substantially different degradation mechanisms, it is difficult to make an assessment when the data is combined for the two types, as it is for the NR data.

If the NR data were disaggregated to separate timber from concrete, it is difficult to suggest precisely what the result might be, but it is expected that the NR trend lines would move towards the Class 1 trends for concrete and timber, respectively.

It is understood that NR used timber sleepers sparingly in mainline track, and that in the mix of concrete and hardwood sleepers, concrete may account for approximately 95 percent. On this basis, sleeper life for NR aggregated concrete/sleeper would expect to be skewed towards the life of concrete sleepers. Consequently, the NR concrete sleeper life appears to be significantly less than the Class 1 concrete sleeper life.

5.2 Rail

The analysis of rail life indicates that with the exception of very low tonnage track, where rail reaches an imposed "life limit" value, the Class 1 rail achieves significantly higher rail life than NR rail. This holds true for both welded and bolted rail. The section size and hardness of rail used between the two systems is perhaps one of the greatest differences. The following sections explain why there is, and continues to be a difference between rail life between the two systems.

5.2.1 Rail Size Hardness

The US uses primarily 132-, 136-, and 141-pound rail sections. The number denotes the pounds of steel per 3-foot length of rail. Consequently, 132-pound rail will be a lighter rail section than 141-pound rail. Much of the installed rail inventory is of 132- and 136-pound sections, with the 136-pound section being more commonly installed in the recent past. The 141-pound section appears to be the newly accepted standard, primarily because it provides about 20 percent more available vertical head wear at an incremental cost of about five to seven percent at the time of the assessment [15].

The British railway system has traditionally used a 110- or 113-pound rail section [9]. A new CEN-60 rail section is now being used in the UK and has a weight of 60 kilogram per meter [10]. This profile and cross-section is almost equivalent to the 113-pound rail section, but it is slightly heavier at about 120 pounds per 3 foot length. NR is also using CEN56 rail in secondary lines.

Heavier rail sections are appropriate for higher axle loads as well as higher wear rates. This is appropriate for the NA system because lighter rail sections are not as durable under heavy axle load traffic as heavier sections and do not have the cross-sectional area to provide a long wear life. British axle loads are lighter, and the British BS-113a rail profile matched with the P-8 wheel profile produced what was considered as low-wear railway [16].

Harder rails are more resistant to wear and the initiation of surface fatigue cracking than softer rails. Harder rail steel is more expensive to purchase, can require more careful handling and welding procedures, and surface fatigue cracks may grow more rapidly once they have started to develop.

In North America, the normal practice is for a minimum hardness of 300 HB [15]. This rail hardness is normally used in straight track and curves up to about 1,800 meters of radius. Curves less than 1,800 meters of radius will typically be supplied with treated rail with hardness of 340 HB to 360 HB. Some railroads are using rails with hardness values of 400 HB and greater.

In the UK, rail hardness was typically 220 HB to 240 HB, although some treated rails with hardness of 340 HB to 360 HB were being used in curves [9]. Following Hatfield, there was a moratorium on treated rails while the industry determined the extent and causes of rolling contact fatigue (RCF) on the railway system [16]. Experience from other railways suggested that using harder rails was a method to mitigate the incidence of RCF on the system [17, 18].

A study was performed by Massachusetts Institute of Technology to analyze the effects of improved technology on railroad track costs, which included improved rail steels [19]. Utilizing rail wear and defect modelling, the researchers estimated a decrease in rail maintenance and renewal costs of 58 percent through the replacement of old 248 BHN and 270 BHN rail steels with newer 300 BHN and 340 BHN steels. In their study, total rail costs were estimated at 55 percent of total maintenance of way (MOW) costs using the older rails versus 37 percent of total MOW costs using newer rails.

In 2005, Network Rail (NR) commissioned work to assess the economic feasibility of using harder rail steels on the British railway network [2]. The analysis demonstrated that the long-term economic benefits are positive and would lead to long-term rail savings for the railway. Because those savings would not be realized within the relatively short-control periods applied within in the UK regulatory framework, there was not an economic incentive for using higher performance rail steels on a network-wide basis in the UK. Even though using harder rail steels would reduce long-term costs, NR would suffer an initial efficiency penalty because of the higher short-term costs. It is understood from the ORR that whole life costs are now important considerations to asset investments. The recent NR policy specifies the use of harder rails in curves with exceptionally high rates of wear, and where an appropriate rail grinding program can be implemented [10].

5.2.2 Welded and Jointed (Bolted) Rail

The Class I railroads lay both welded and jointed rail, although welded rail is much more common than jointed rail, and very little jointed rail is used on high density mainline routes. Based on R-1 data, 99 percent of all new rail installed on Class I railroads is welded rail.

The Class I railroads also cascade rail in order to extract the longest economic service life from rail. Rail from higher tonnage lines will be cascaded down as “relay” rail to lower tonnage lines. In very low tonnage branch lines and yards, such rail can serve for an indefinite length of time.

It is understood that in recent history, very little rail on the British network was cascaded from high density lines to low density lines. The reason for this was understood to be the high costs associated with removing, storing, transporting, and reinstalling old rails outweighed the potential savings. This seems reasonable from the perspective that installation costs in the UK are approximately 50 percent of the total installed cost [2], whereas in North America the installation cost is 30 to 35 percent of the total installed cost [20]. With the changes in rail pricing, the economics may have shifted.

The current percentage of jointed rail on the British railway network is understood to be about 20 percent, with most of this on secondary routes. The amount of jointed rail on primary routes is about five percent [10]. NR is moving away from using jointed rail in favor of CWR.

For many years now, Class I railroads have moved away from jointed rail to welded rail because of the damage incurred to joints by what are called P1 and P2 forces, which result from wheel impacts at the discontinuities in the running surface of the rail created by joints.

The form of these equations is presented in Equation 1 and Equation 2 [21].

Equation 1: The P1 Force Equation

$$\boxed{P_1 = P_0 + 2\alpha V \sqrt{\frac{h\,M_{T1}}{1 + M_{T1}/M_u}}}$$

Equation 2: The P2 Force Equation

$$\boxed{P_2 = P_0 + 2\alpha V \sqrt{K_{T2} M_u}}$$

Without going into great detail, three terms are important in these equations

- P_0, which is the static wheel load
- α, which is the angle of the dip at a rail joint
- V, which is the train velocity

Among other factors, the magnitudes of P1 and P2 forces are a function of axle load, the size of a discontinuity at a rail joint, and the speed of the train. Not only do P1 and P2 forces cause problems to the rail joints themselves, but they also increase damage to ballast and sleepers in the vicinity of the rail joint. Rail joints must also be inspected to ensure proper bolt torque and bolt-hole integrity.

This is important because properly maintained welded rail eliminates P1 and P2 forces that occur at rail joints. In short, jointed rail is a source of ongoing maintenance and increased costs that properly installed welded rail is not.

5.2.3 Rail Grinding

Rail grinding is a practice that is performed to remove the fatigued layer of metal off the running surface of the rail to eliminate surface cracks and to restore the desired rail profile to reduce contact stresses and improve steering.

Rail grinding is an established practice on most Class I railroads. Although some Class I railroads' grinding programs are more evolved than others, it is safe to say that all Class I railroads have some sort of planned rail grinding program.

The British railway industry traditionally performed only selective grinding on a small scale to correct rail surface corrugations, but not to extend rail life [16]. Beginning in 2002, Railtrack and then NR began to acquire and put into service the grinding equipment necessary to implement a preventive grinding program.

It is understood that over the past several years, Network Rail has significantly increased their application of grinding on the British network, although the author has no hard data to confirm or quantify this. Assuming such progress has been made, this should lead to longer rail lives and lower rail costs than previously experienced by the British railway network.

Figure 12 shows an example of rail life benefits from implementing rail grinding on the Canadian Pacific [22].

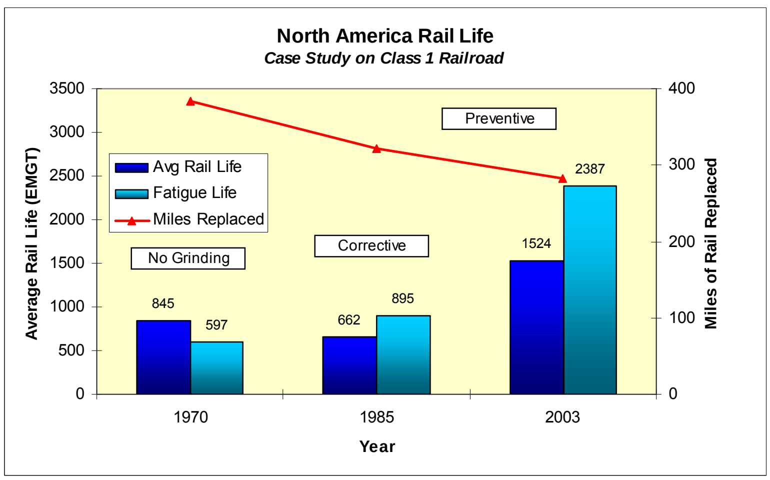

Figure 12: Improved Rail Life Case Study *(Canadian Pacific Railway)*

There are three basic rail grinding strategies: (1) corrective, (2) preventive-gradual, and (3) preventive [22]. Corrective grinding is performed on rail that has significant surface defects or cracking. This practice removes a significant amount of surface metal and is costly and time consuming. Sometimes this is necessary to salvage rail that would otherwise not be serviceable for an extended period of time. Railroads avoid this type of grinding because of its cost, and because the life remaining in the ground rail may not warrant the expense. It might be cheaper just to replace the rail.

Preventive-gradual grinding is a common treatment for rails that require corrective treatment, but are worth salvaging. Grinding is performed in cycles with the removal rate larger than the surface defect or crack growth rate, so that each cycle more and more of the damaged layer is removed until finally, the rail surface is free of defects.

Preventive is the desired goal of an optimized grinding program. Grinding is conducted at frequent intervals, but can be performed quickly with little metal removal. The benefit of preventive rail grinding is greatly improved rail life through lower wear rates and longer fatigue lives.

5.2.4 Friction Management

It is understood that significant effort was made to improve rail lubrication on the British railway network beginning in about year 2001. Friction management, and particularly gauge face lubrication, is a standard practice on most Class 1 railroads.

Although there are likely some differences between traditional rail lubrication practices on the two networks, the author is not currently aware of the status of current rail friction management practices in the UK, and cannot comment on major differences that may contribute, or take away from the relative rail lives experienced between the two systems. That being said, NR's asset policy clearly establishes gauge face lubrication practices using modern track-based equipment [10].

Because of the relatively light curvature, it is expected that traditional gauge face lubrication plays a lesser role in the overall life of rail on the British railway network, relative to materials selection, grinding, and wheel-rail interaction behavior.

The management of friction on Class 1 railroads is advancing past the practice of gauge-face lubrication. The practice of "total friction management" is taking form on at least one major Class 1 railroad [23]. Total friction management is a practice in which state-of-the-art application and monitoring combine gauge face lubrication with top-of-rail friction modification to provide continuous management of the coefficient of friction between the wheels and rails at all contact points where significant wheel-rail degradation forces are in action.

The technology of total friction management is developing and may be an opportunity for significant benefits, particularly on heavily used track.

5.3 Ballast

The analysis indicates that ballast life is higher on Class 1 railroads when compared to the NR ballast life trend. It is suspected that this is due primarily to the selection of ballast size by Class 1 railroads, and possibly due to more widespread use of harder materials, although the latter cannot be confirmed in relation to the British network without further study. In addition, the track geometry standards indicate that the British mixed-service network should be maintained to tighter geometric limits than the Class 1 freight system, and may require more frequent ballast maintenance. More frequent ballast maintenance increases ballast degradation.

5.3.1 Ballast Size and Type

Ballast is an important part of the railway track structure. It provides energy absorption and attenuation of vertical, lateral, and longitudinal forces imparted to the rail/sleeper/fastener system, maintains the vertical and lateral alignment of the rails, provides a flexible medium to adjust misalignments that do occur, and provides support and distributes the loads to the subgrade that otherwise could not withstand the high forces imparted by trains.

The ballast size, material, and depth are driven by the type of railway it needs to serve. The minimum ballast depth for British track is 300 millimetres for Category 1A and 1 (the highest speed and traffic density), and 250 millimetres for track Category 2 [10, 24], for concrete and timbered sleeper, welded rail track, on good quality subgrade.

Ballast depth for NA Class I track will range from 12 to 24 inches (305–610 mm), with 18 inches (457 mm) providing adequate depth for heavy axle load service on good quality subgrade [25].

Typical preferred ballast materials include granite, slag, and limestone, with limestone being the least durable of the three. Other less used ballast materials include crushed rock, sandstone, and trap rock. Crushed granite and slag are the preferred ballast materials for Class I operations [6].

Ballast size is based on AREA grades. Typical British track has used ballast sizes equivalent to AREA No. 5 (3/8 inch to 1 inch) and AREA No. 4 (3/4 inch to 1 1/2 inch), with the larger size being preferred. Class I track has used ballast sizes of AREA Nos. 4, 3, and 24, with No. 24 becoming a more favored size for heavy axle load traffic [6]. Table 13 shows the sizes of the ballast grades.

Table 13: Selected Ballast Grades and Sizes

Ballast Grade No.	Size (in.)	Preferred
AREA 5	⅜ to 1	UK
AREA 4	¾ to 1½	UK
AREA 3	1 to 2	NA
AREA 24	¾ to 2½	NA

The actual distribution of ballast depth, size, and material for either the NA or British railway systems is not known by the author. Consequently, no direct assessment is made on whether one system has ballast better suited for its purpose than the other. In general terms, it is correct to say that all things being equal, of the sizes and materials discussed here, larger ballast of stronger materials in depths of 300 to 500 millimeters will likely have greater durability to freight traffic than smaller ballast of weaker materials at shallower depths.

There are also some general rules regarding ballast life that merit comment and are related to track alignment management.

- Ballast grade and the nominal particle size affect ballast degradation. All things being equal, large ballast will last longer than smaller ballast.
- Abrasion number is a number with a magnitude inversely proportional to the breakdown durability of the ballast and is similar to the Wet Attrition Value grading used by British Rail. Ballast with a high abrasion number will break down more rapidly than ballast with a low abrasion number.
- Sleeper spacing affects vertical and lateral stability of the track, as well as degradation of the ballast. Fewer sleepers provides less distribution of forces onto the ballast. Greater sleeper spacing increases ballast degradation, while closer sleeper spacing decreases ballast degradation.

Sleeper material also affects ballast degradation and track stiffness. Concrete sleepers provide a stiffer track with greater stability than timber sleepers and can slightly increase ballast degradation. The benefits from increased track stiffness tend to override the costs of increased degradation, and for the most severe conditions in passenger and freight service, railroads tend to prefer concrete sleepers.

5.3.2 Ballast Maintenance

Surfacing, or ballast tamping, is the activity of maintaining the lateral and vertical alignment geometry of the railroad. In its simplest terms, specifications are typically given based on allowable lateral and vertical offsets for unit longitudinal lengths. Although not affected by the surfacing activity, gauge (the distance between the rails) can also be considered as part of the track geometry maintenance practices.

Comparing track geometry specifications between different railway systems, such as North America and the Great Britain, can be a bit confusing and time-consuming. Each system has established track geometry standards on the basis of speed class, but the classes are not wholly consistent with one another.

Standards have been established for each system based on different units of length. The NA system has different speeds within each track class for passenger and freight trains, while the British system has adopted some of the track geometry specifications for all track, while some specifications are different for mixed-use and freight-only [21].

Table 14 presents a limited comparison of track gauge and lateral alignment specifications between the two railway systems. These are some of the more easily comparable track geometry standards and provide a good example of the basic differences between the two systems.

Table 14: Track Safety Limits for Gauge and Lateral Alignment

<table>
<tr><th rowspan="3">UK Speed Band</th><th rowspan="3">FRA Track Class</th><th colspan="4">Gauge**</th><th colspan="2">Lateral***</th></tr>
<tr><th colspan="2">UK</th><th colspan="2">US</th><th>UK</th><th>US</th></tr>
<tr><th>Min</th><th>Max</th><th>Min</th><th>Max</th><th></th><th></th></tr>
<tr><td>10-20</td><td>2</td><td>1426</td><td>1455</td><td rowspan="3">1422</td><td rowspan="3">1467</td><td rowspan="8">18</td><td>n/a</td></tr>
<tr><td>25-30</td><td rowspan="2">3</td><td rowspan="4">1429</td><td rowspan="4">1450</td><td rowspan="2">32</td></tr>
<tr><td>35-40</td></tr>
<tr><td>45-50</td><td rowspan="2">4</td><td rowspan="3">1422</td><td rowspan="3">1461</td><td rowspan="2">25</td></tr>
<tr><td>55-60</td></tr>
<tr><td>65-75</td><td>5</td><td rowspan="3">1430</td><td rowspan="3">1450</td><td rowspan="3">13</td></tr>
<tr><td>75-100</td><td rowspan="2">6-7</td><td rowspan="2">1422</td><td rowspan="2">1454</td></tr>
<tr><td>100+</td></tr>
<tr><td colspan="8">*Limits for NA track are converted at 25.4 mm/in. and rounded
**Safety (maintenance) limits for tight gauge[26, 27, 28]
***Safety limits for UK track geometry tolerances based on 10 m (32.8 ft) chord,[28]and for US based on 31 ft. (9.45 m) chord[26, 27]</td></tr>
</table>

It can be seen that the track specifications for gauge are tighter in all cases for British track. With respect to lateral alignment, only the highest speed NA FRA track, Class 5 and above have a tighter lateral alignment specification than the UK. Only about five percent of NA track falls into Class 5 and above [29].

This is important because surfacing is an important and essential part of track maintenance to maintain the quality of the track geometry. The activity of tamping the ballast has a detrimental effect on the ballast itself by breaking down the ballast. In other words, the more tamping that is performed, the shorter the ballast life will be. Consequently, if more ballast tamping is required to maintain a higher quality of track geometry, ballast cleaning and renewal will be required more often.

5.4 Switches and Crossings (Special Trackwork)

Because the NR trend data are not segregated between S&C components, it is difficult to make a meaningful assessment of differences in component lives. This is compounded by limited hard data available in the public domain on North American switch and crossing component life.

The general trend shows NA curved switch point lives below the composite NR S&C lives, NA crossing lives higher than the composite NR S&C lives, and NA straight switch lives approximately in the range of the composite NR S&C lives.

The results are not surprising if the composite NR data average curved switch, straight switch and crossing lives. If this is the case, and the NR data were disaggregated, it is likely the component life trends would move in the direction of the NA counterparts, but it is not certain precisely how they would compare.

The drivers of degradation in points and crossings are the number of axle passes, the axle loads of the vehicles, and the speeds of the vehicles. In fact, vehicle speed and number of axle passes play a major part in the wear and degradation of S&C components, and on a tonnage density basis, it is possible that many passes of low axle load vehicles at high velocities can cause greater damage than the same given tonnage of fewer passes of heavier axle load vehicles at lower speeds.

To understand degradation of points and crossings, it is important to know the traffic traveling through the turnout. Figure 13 shows the four possible directions of traffic through a turnout: Facing Straight, Facing Divergent, Trailing Straight, and Trailing Divergent. It is intuitive that all things being equal, Facing Straight and Trailing Straight will be the least damaging to the turnout components as no change in traffic direction is required. The next most damaging traffic is Trailing Divergent in that the traffic must converge with the straight track, but it has already begun to change direction, either from some previous turnout (in the case of a crossover) or a converging track. The Facing Divergent traffic is the most damaging traffic in that it must be fully directed off the straight path.

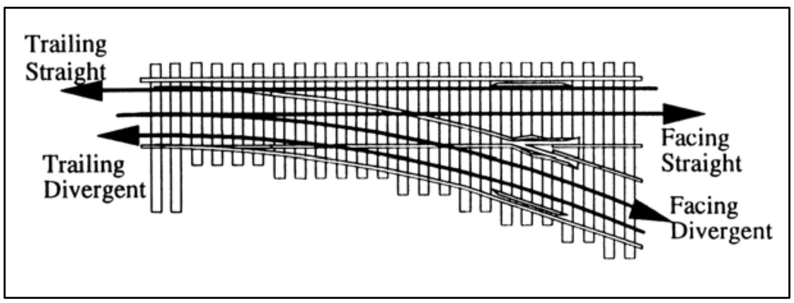

Figure 13: Traffic Directions in Turnouts

Changing the direction of rail vehicles generates considerable forces on the track structure. By design, switch points have a small cross-sectional area at the entry of the point. Consequently, with less metal, the effects of forces are more pronounced in this region. This is even more pronounced on the curved switch point which has the added duty of diverting all facing traffic as well as carrying trailing traffic from the curved direction to the straight track.

The curved point will only see traffic in a diverging move, and the straight point will only see traffic in the straight moves, but the crossing will see traffic in every move.

5.4.1 Research by TTCI on S&C Sensitivity

Research was conducted by TTCI using numerical analysis models to study the effects of speed and axle load [30].

The numerical model used by TTCI was calibrated based on actual track data to confirm results. While the report is generally focused on the development of the model for use in future studies, there are two model application examples which evaluate asset life of special track work and are quite useful in understanding turnout and component life.

The impact of an increase in axle load was analyzed using trains with 30-tonne axle loads and 35-tonne axle loads. The following traffic characteristics were assumed for the model:

- Each train consisted of three locomotives, and 100 wagons with 30-tonne axle load wagons, and then 87 wagons with 35-tonne axle loads, respectively.

- Traffic mix was 100 trains a week, with 50 loaded and 50 unloaded.
- Straight path trains travel through the turnout operating at 45 MPH, while divergent trains operate through the turnout at 25 MPH.
- Five percent of loaded trains take the diverging route and 25 percent of empty trains take the diverging route.
- Traffic density for both cases was 38.6 MGTPA (tonnes).

The data is presented in years and North American units of MGT (converted to tonnes), for both car weights in Table 15.

Table 15: Special Track Work Asset Life for NUCARS Model Evaluating Axle Load

Component	Axle Load = 30-tonnes		Axle Load = 35-tonnes		Difference
	Asset Life (MGT)	Asset Life (years)	Asset Life (MGT)	Asset Life (years)	
Crossing	114	2.9	79	2.0	-31%
Straight Switch[1]	302	7.8	212	5.6	-28%
Curved Switch[1]	254	6.6	227	6.0	-9%

1. This is the approximate actual traffic over the component, based on the ratios of full and empty trains travelling through the straight and diverging paths.

This analysis shows that the straight switch and crossing are more sensitive to axle loads than the curved switch. This makes sense because curved switches already have lower life that other components, and the train forces from diverging traffic are likely to exert significant wear and damage above that of the static axle load itself.

A second analysis evaluated the impact of an increase in train speed through the turnout in a diverging direction. All initial assumptions for the 30-tonne axle load sensitivity were the same, but the trains traveled at 25 MPH and 40 MPH. The resulting asset lives for the train speed sensitivity are presented in Table 16.

Table 16: Special Track Work Asset Life for NUCARS Model Evaluating Train Speed

Switch Type	Diverging Traffic at 25 MPH		Diverging Traffic at 40 MPH		Difference
	Asset Life (MGT)	Asset Life (years)	Asset Life (MGT)	Asset Life (years)	
Crossing	137	3.5	129	3.3	-6%
Straight Switch	329	8.5	329	8.5	0%
Curved Switch	253	6.56	184	4.8	-27%

In this case, it is of interest to note that the increase in speed over the diverging route does little to change the asset life of the crossing, or the straight switch, but has a significant effect on the curved switch point asset life.

The conclusions of the sensitivity analysis conducted by the AAR indicated the following within the ranges of conditions studied:

- Curved switch points are more sensitive to train speed than axle load

- Straight switch points and crossings are more sensitive to axle load than train speed

5.4.2 Differences between Class 1 and British S&C Life

The drivers of degradation to S&C are very complex. It is not a simple matter to identify reasons for differences, and the traffic and track make-ups between the British railway system and the North American Class 1 system are substantial.

At lower traffic densities (below 20 EMGTPA), the NA straight switch point and crossing life trends are significantly higher than NR S&C lives. The precise reasons for this are not clear, but could be determined through further analysis. It is strongly expected that S&C life is influenced by materials and traffic, but discussions with the ORR suggest there could be at least one other reason.

From the materials perspective, on the main lines, Class 1 railroads almost exclusively use rail bound manganese (RBM) cast crossings that are explosively hardened to a range of 352 BHN to 390 BHN, and switch points that are machined from head hardened rail stock, with a range of 360 BHN to 390 BHN [31]. Both crossings and points are weld-reparable. NR's most recent asset renewal policy calls for weldable points to eliminate bolted joints and cast crossings to eliminate fabricated crossings in main line [10]. The hardness of the materials is not stated. It is expected that as NR rail increased the application of weldable points and cast crossing, the overall S&C life would trend upwards.

Traffic on British railways typically travels at higher speeds. The degradation of S&C is highly influenced by speed and wheel passes. Consequently, on a purely tonnage basis, the damage per million gross tonnes on British track may be greater than on a Class 1 track.

In addition, it was suggested by the ORR that for a number of years on the British railway there may have been a disconnect between the cycles of maintenance and renewals. It is suggested that the track maintenance staff replace iron work when needed, without awareness of planned renewals. Then, when planned renewals were performed, there were instances when iron work that was replaced under maintenance was replaced, but prematurely. The author has no hard data to confirm this; but, if it were the case, this would cause a significant downward trend in the NR S&C asset lives.

6 Conclusions and Recommendations

The author has been involved in previous studies comparing North American Class 1 railway asset lives with British railway asset lives. These past studies were based on aggregated Class 1 information derived from R-1 reports. This work was based on individual railroads for the purpose of generating a wider distribution of data points across a broader range of traffic densities.

The behavior trends are similar to previous studies and present no surprises, but there is some unexplained scatter within some of the asset types and traffic densities between the various Class 1 railroads. A better understanding of the reasons behind the data scatter in the North American data could be an area of consideration for future investigation. It is expected that the answers would lie behind different maintenance practices and materials selections that are not readily apparent on the surface. Such information could, however, be somewhat difficult or time-consuming to obtain.

The results of the analysis indicate the following, primarily related to main line track:

- Timber sleeper life on Class 1 railroads is less than that for the composite concrete/timber sleeper life reported by NR. This is consistent with NR sleeper life values being comprised of mostly concrete sleepers. Concrete sleepers typically have longer lives than timber sleepers.
- Concrete sleeper life on Class 1 railroads is greater than that for the composite concrete/timber sleeper life reported by NR. The NR rail sleeper life value will be slightly skewed below a purely concrete life, because it includes some timber sleepers. However, the Class 1 and NR sleeper lives are substantially different, and show that Class 1 concrete sleepers last longer than NR concrete sleepers. Although the precise reasons for this are not clear from the data reviewed, and beyond the scope of this study, some reasons could be the wider sleeper spacing and higher speeds on British tracks, both of which can decrease sleeper life from higher train forces.
- Rail life on Class 1 railroads is higher than rail life reported by NR. The main reasons for this may include:
    - Rail section: Class 1 railroads use heavier, larger rail than NR. As CEN 60 rail becomes more prevalent on the British network, longer rail lives will be expected because of its larger cross section than BS113A rail.
    - Rail material: Class 1 railroads use harder rail metal than NR. As CEN 60 rail becomes more prevalent on the British network, longer rail lives will be expected because of its higher hardness value from earlier BS113A rail.
    - Grinding practices: Grinding rail to extend its service life has been a standard practice on Class 1 railroads for much longer than has been in Great Britain. As NR evolves its rail grinding strategy, it is expected that longer rail lives will result.
    - Friction management: The Class 1 railroads continue to advance implementation of new and improved friction management. As NR improves its program of rail lubrication, improved rail lives will be expected. However, the opportunity for total friction management could be investigated. There may be benefits in particularly high use, high maintenance areas.
- Ballast life is slightly greater on Class 1 railroads than reported by NR. The two main reasons for this are likely ballast size, which is smaller on British tracks and has somewhat reduced durability, and track quality, which is tighter on British tracks and leads to more frequent maintenance, thus increasing maintenance-related degradation.

- Publically available S&C life data on Class 1 railroads is scarce. The limited data indicates that at lower traffic densities (below 20 EMGTPA), the Class 1 straight switch point and crossing life trends are significantly higher than NR S&C lives. The precise reason for this is not clear from the data reviewed, but could be determined through further analysis. But it is expected that materials, traffic, and maintenance are the main influencing factors.
    - Class 1 railroads have invested heavily in stronger and more durable switch and crossing components. The use of explosively hardened rail-bound cast crossings is relatively standard practice on the Class 1 railroads.
    - Traffic on British railways typically travels at higher speeds but lighter axle loads. The degradation of S&C is highly influenced by speed and wheel passes. Consequently, on a purely tonnage basis, the damage per million gross tonnes on British track may be greater than on a Class 1 track. This could be confirmed through further study.
    - In was suggested by the ORR that there may have been a disconnect between the cycles of maintenance and renewals on British track. By not coordinating maintenance activities with renewals, some S&C components may have been replaced prematurely. The author has no hard data to confirm this; but, if it were the case, this would cause a significant downward trend in the NR S&C asset lives.
- It is understood that the selection of materials may be more easily implemented than changes to maintenance practices such as rail grinding and could be accomplished under the right circumstances.
- This analysis was focused on the differences between track asset life, with little analysis regarding the detailed effects of traffic. It is well established that vehicle effects play an important role in track degradation and this cannot be disregarded from analysis of infrastructure.
- It is difficult to make meaningful assessments on the life of components with different degradation mechanisms when they are aggregated together, such as with timber and concrete sleepers, and S&C components. It is recommended that these components be considered separately in future analyses of component life.

The North American Class 1 railway network remains a heavy-haul freight dominated railway, while the British railway remains a mixed service passenger-freight network. The requirements and economic drivers are different, leading to different materials selections and maintenance and design practices, and therefore, different asset lives.

References

1. Surface Transportation Board Class I R-1 Reports., These are reports submitted to the United States Federal Surface Transportation Board on a yearly basis, and are required by all Class 1 railroads. Data was collected from reports from 1989 to 2005.
2. Clark, S., A. Doherty, and M. Dembosky. 2006. "Economic Analysis of the Application of Premium Rail Steels on British Infrastructure," World Congress of Railway Research, Montreal
3. Halcrow Group Ltd., Independent Reporter, Reporter Mandate – Variable Usage Costs Final Report, 2008, London.
4. Association of American Railroads. November 2006. *Railroad Facts*, 2007 Ed.
5. Based on a telephone call on April 10, 2008, between the author and Mr. Jim Gauntt, Executive Director of the Railway Tie Association (USA).
6. Hay, William W., 1982. *Railroad Engineering.* 2nd Edition. John Wiley & Sons, USA.
7. Booz, Allen & Hamilton. October 2000. Usage Costs: Issues Raised in the Regulator's Consultation, Final Report to the Office of the Rail Regulator R/00318, London.
8. Davis, Guillen, Singh, Robeda and Lopresti. February 2002. Results From Special Track Work Experiment at FAST. Report No. R-954, Association of American Railroads (AAR) and Transportation Technology Center, Inc. (TTCI).
9. Railtrack. 2002. Track Engineering Policy RT/ENGP/01, Issue 2. London, UK.
10. Network Rail. October 2007. Strategic Business Plan, Supporting Document, Asset Management. London, UK.
11. Jimenez, Rafael, et al. August 1999. "Major Findings of Wood Tie and Fastener Performance Under Heavy Axle Loads at FAST 1988-1999," *Technology Digest* TD99-029. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.
12. Acharya, D. 1994. "Tie Model: A Crosstie Replacement Planning and Life-Cycle Costing Mode," Research Report R-831, Association of American Railroads, Washington, D.C.
13. Jimenez, Rafael, et al. August 2000. "Final Results of Steel-Tie Testing at FAST," Technology Digest TD00-015, Transportation Technology Center, Inc., Association of American Railroads, Pueblo, CO.
14. Jimenez, Rafael, et al. October 2003. "An Evaluation of the Temperature on the Vertical Stiffness and Gage-Spreading Strength of Plastic Composite Tie Track," Technology Digest TD03-021, Transportation Technology Center, Inc., Association of American Railroads, Pueblo, CO.
15. International Heavy Haul Association. May 2001. Guidelines to Best Practices for Heavy Haul Railway Operations: Wheel and Rail Interface Issues. Virginia Beach, VA.
16. Railtrack Rail Head Checking Investigation Phase 2 Final Report, prepared for Railtrack, Arup-TTCI, September 2001.
17. Grassie, S., et. al. 1997. "Rolling Contact Fatigue of Rails: Characteristics, Causes and Treatments," 6th International Heavy Haul Conference, IHHA, South Africa.
18. Marich, Steve, Rail Services Corporation, Australia. 2000. Written communication to Malcolm Kerr, Railtrack, UK. Comments on Rolling Contact Fatigue Defects in Rails.

19. Chapman, J. and Martland, C., 1998. "The Effects of Fixed Plant and Rolling Stock Technology on Railroad Track Costs," Massachusetts Institute of Technology, Boston.

20. This is based on assumptions the author used in the economic analysis of AAR research projects, and assumptions that were prepared by the analysts where hard data was not available, but obtained anecdotally through conversations with Class 1 railway engineers.

21. Permanent Way Institution. 1993. British Railway Track Design, Construction and Maintenance, 6th Edition, Loughborough, England.

22. Sroba, P. and M Roney. 2004. Rail Grinding Best Practices, AREMA 2004 Conference Proceedings, Nashville.

23. Based on a conversation between the author and Mr. Don Eadie, Vice President of Technologies, Kelsan Technologies Corp., a developer and supplier of friction management products.

24. Cope, D.L. and Ellis, J.B. 2001. British Railway Track, Volume 4, Plain Line Maintenance, Permanent Way Institution, Loughborough.

25. Li, Dinqing. 1998. How to Design Ballast Depths for New Track Construction, Roadbed Stabilization and Ballast Symposium, AREMA.

26. Federal Railroad Administration–Office of Safety. November 30, 1998. Track Safety Standards Part 213, Subpart A to F, Class of Track 1-5, Department of Transportation, Washington, D.C.

27. Federal Railroad Administration–Office of Safety, November 15, 1998. Track Safety Standards Part 213, Subpart G, Class of Track 6, Department of Transportation, Washington, D.C.

28. Network Rail. October 2005. Inspection and Maintenance of Permanent Way, NR/SP/TRK/001, Issue 02, London.

29. Transportation Technology Center, Inc. 2002. Data received by the author from a survey conducted by TTCI for the Association of American Railroads' Strategic Research Initiatives Program on Hot Bearing Detectors.

30. Smith, Martland, Handal, Acharya, Chiang and McGovern. December 1993. Development of a Comprehensive Life-cycle Costing Model for Railroad Turnouts, Report No. R-854, Association of American Railroads (AAR) and Transportation Technology Center, Inc. (TTCI).

31. Based on a telephone call on April 10, 2008, between the author and Mr. Richard Gorcyca of Nortrak Rail Products, a division of VAE, a supplier of switch and crossing materials to the Class 1 railroads.