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TARQUIN: Assessment Review

Paper contributed by Dave Brooks BEng (Hons), CEng, MPWI, MICE, Associate Member IRO (david.brooks@mottmac.com)

Introduction

In order to optimise the innovative assessment process known as TARQUIN (Track and Ride Quality Investigation), an assessment of the results has been carried out, comparing the original TARQUIN recommendations and the current track quality data of a number of selected areas of a route section previously assessed.

Therefore, further to the published paper *TARQUIN: Mott MacDonald's Track and Ride Quality Investigation*, (PWI Journal Volume 121, Part 4, 2003 [pages 381 to 391, inclusive]¹), this paper reviews the recommendations TARQUIN produces.

Last year, TARQUIN was used to generate recommendations for formation treatment works on Route Seven (Crewe North to Cheadle Hulme²) of the West Coast Route Modernisation project. This process can produce a complete Track Renewal scope of works, including a Value Engineering (VE) option; Route Seven only required the formation treatment recommendations.

This paper will review the original Route Seven TARQUIN recommendations, with regards to selected parts of the route. These recommendations will then be compared with the current High Speed Track Recording Coach (HSTRC)³ data, to assess whether the original recommendations were accurate and whether the treatments implemented have made a difference to the overall track quality for the selected review sites in question. As the current HSTRC data is only available for the fast lines, only these lines will be reviewed against the original assessment.

The selected areas will cover sections of the route where TARQUIN originally recommended a formation treatment. By reviewing these sections, a valid assessment of the TARQUIN process will be achieved.

Since the recommendations for Route Seven were issued, there has been a change in the formation treatment standard. Network Rail now uses RT/CE/C/039, Issue 2, Formation Treatments, Company Code of Practice, Network Rail, December 2003⁴. In order to accurately assess the TARQUIN process, Mott MacDonald has referred to the previous standard (Issue 1A⁵). The TARQUIN process has subsequently been amended to take into account the new standard.

What is TARQUIN?

TARQUIN is a qualitative track renewal and formation risk assessment process intended to determine the track renewal, formation treatments and drainage work required on a railway. The process is divided into five main phases:

PHASE ONE: Desk Study;

PHASE TWO: Non-Intrusive Geotechnical Investigation;

PHASE THREE: Intrusive Geotechnical Investigation;

PHASE FOUR: Final Outputs; and

PHASE FIVE (Optional): Value Engineering Review of Final Output.

A description of each phase is given in detail within the paper, *TARQUIN: Mott MacDonald's Track and Ride Quality Investigation* (PWI Journal Volume 121, Part 4, 2003 [pages 381 to 391, inclusive]).

Why is TARQUIN Useful?

The easiest way to describe how useful and cost effective TARQUIN is would be to quote from Network Rail's Track Engineering Policy, RT/ENGP/01⁶:

"Investigation is a small proportion of the cost of doing the work. Getting the right specification and extent of work saves many times the cost of the investigation."

RT/ENGP/01, paragraph 5v.

"Consistent ballast and formation which distributes the loads and allows good drainage provides long lasting and low maintenance geometry. Also extends component life."

RT/ENGP/01, paragraph 5s.

The following review of the TARQUIN process, will illustrate how these exacting requirements are met.

Original Recommendations

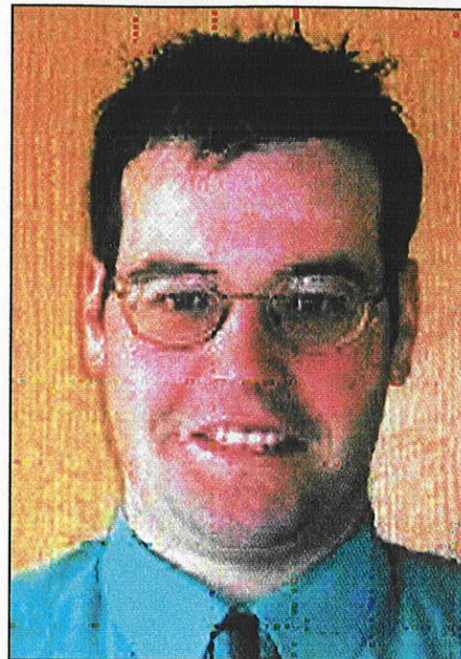
During 2003, Mott MacDonald carried out a formation assessment of Routes Seven. Following from the previous paper, Route Seven will be used as the case study for this paper. Therefore, this paper concentrates on the assessment and formation work carried out on the Route Seven project, between Crewe North and Cheadle Hulme (Engineer's Line Reference: CMP1).

Table 1 shows the total yardages of the original Route Seven TARQUIN assessment, the actual implemented yardages, and the yardages of treatment deferred. The original recommendations referred to the treatment types given in RT/CE/C/039 Issue 1A. Prior to commencement of work on site, Treatment Type 1 was amended, in the majority of cases, to include a permeable membrane. This variation of the treatment became known as Treatment 1a.

Treatments deferred from implementation during the 2004 blockade were assessed on site during the construction phase of the project by Network Rail Field Engineers. This engineering judgement was based on the site information they had at the time. This paper will not be discussing any issues regarding the deferral of formation works. This paper is intended only to assess the accuracy of the TARQUIN process.

Selection of Review Test Sites

A sample of 10% of the total sites has been chosen for this review. The basis of the sample



was largely random, covering sections of route where formation treatments were originally recommended and either implemented or deferred. The only exception is the Control Site [Test Site No.1]. Refer to Table 2.

The Control Site is a section of the route where no recommendations for formation treatment were made, which, when compared with the current HSTRC data, should still have no requirement for formation treatment (within normal deterioration limits).

In total eight sites, including the Control Site, have been selected to check the validity of TARQUIN.

Original 2003 TARQUIN Assessment

To successfully review the original TARQUIN recommendations, it is necessary to understand the reason behind the original recommendations. Therefore, for each of the selected review sites, listed in Table 2, the original findings were as illustrated in Table 3.

Table 3 illustrates the original recommendations and where there were concerns regarding:

- **HSTRC:** Whether the site, at the time of the assessment, had poor track quality;
- **IMPACT⁷:** Whether the site had a history of poor track quality;
- **Ground Penetrating Radar (GPR):** Whether the site shows signs of erosion, migration of fines, and/or interface issues between the ballast and subgrade;
- **Topography:** Whether the site is located in a cutting, embankment, has standing water, wet beds, and/or an active drainage system.
- **Subgrade:** Whether the subgrade is classed as granular, stiff cohesive or soft cohesive; and
- **Ballast Condition:** Classification condition of the ballast prior to treatment/renewal.

Review Assessment Process

For a successful review of the original recommendation assessment, the same criteria and data should be up-dated and reapplied to the TARQUIN process. The original TARQUIN assessment referred to a variety of information sources including, but not limited to:

- **HSTRC;**
- **GPR;**
- **Automatic Ballast Sampling (ABS);**

ROUTE SEVEN				
	Treatment (in accordance with RT/CE/C/039)	Original TARQUIN Assessment	Implemented	Deferred
Up Fast	No Treatment	-	-	-
	Treatment 1 (Ballast replacement with geotextile)	11,000	220	3,300
	Treatment 1a (Ballast replacement without geotextile)	-	6,820	660
	Treatment 2 (Ballast replacement with 100mm sand blanket)	1,760	1,100	660
	Treatment 3 (Ballast replacement with 150mm sand blanket)	3,740	1,760	1,980
	Treatment 4 (Reinforced ballast with sand blanket)	220	0	220
	Totals	35,860	19,800	16,060
Down Fast	No Treatment	-	-	-
	Treatment 1 (T1)	12,540	880	1,320
	Treatment 1a (T1a)	-	6,820	3,520
	Treatment 2 (T2)	2,860	1,540	1,320
	Treatment 3 (T3)	3,520	660	2,860
	Treatment 4 (T4)	220	0	220

Table 1 (above): Summary of Yardages*1

NOTE:

*1. Please note that the Implemented and Deferred yardages are approximate, taken from the Approved for Construction drawing⁸.

• Figures presented are in yards and excludes slow lines.

• Treatment 1 original TARQUIN recommendation values should be compared to Implemented and Deferred values for Treatments 1 and 1a.

ROUTE SEVEN					
	Up / Down Fast Lane	Mileage		Yardage	Test Site Reference **
		Start	End		
Control Site	Down	164m 1320yds	165m 0 yds	440	1
Recommended: Implemented					
Treatment 1 / 1a	Down	164m 220yds	164m 660yds	440	2
Treatment 2	Down	166m 0 yds	166m 440yds	440	23
Treatment 3	Up	171m 0 yds	171m 440yds	440	4
Treatment 4*2	N/A	N/A	N/A	N/A	-
Recommended: Deferred					
Treatment 1 / 1a	Up	167m 880yds	167m 1100yds	220	5
Treatment 2	Down	175m 1320yds	175m 1540yds	220	6
Treatment 3	Up	170m 1100yds	171m 0 yds	660	7
Treatment 4	Down	165m 880yds	165m 1100yds	220	8
Line Totals	Down Up	- -	- -	1,760 1,320	- -
Total Yardage				3,080	-

Table 2 (above): Selected Sites for TARQUIN Review

NOTE:

*1. Arbitrary number for easy reference within this paper; not project specific.

*2. Only 220yards of Treatment 4 was originally recommended, which was deferred.

CATEGORY	DESCRIPTION
1	Correct Original TARQUIN Results
2	TARQUIN Failed to Correctly Recommend
3	TARQUIN Over Recommended
4	TARQUIN Under Recommended / Construction Issues
5	Deferred Works

Table 5 (above): 2004 Review Assessment Criteria Categories

OVERVIEW	CATEGORIES					
	1		2	3	4	5
Original Recommendation	✓	X	X	✓	✓	✓
Treatment Implemented	✓	X	X	X	✓	X
Treatment Deferred	X	✓	X	✓	X	✓
Treatment Still Required	X	X	✓	X	✓	✓

Table 6 (above): 2004 Review Assessment Criteria

ROUTE SEVEN				
Treatment Recommended	Up Fast GPR Factor (%)	Down Fast GPR Factor (%)	Up Fast Total (recommended total+GPR %)	Down Fast Total (recommended total+GPR %)
Nil	-27	-31	103	108
1	125	190	63	38
2	150	0	18	7
3	325	366	60	14
4	0	100	0	0
Total			37	50
%Total			21%	28%

Table 7 (above): Ground Penetrating Radar Percentage Factors.

NOTE:

"Nil" treatment percentage is subtracted from the total result, as this figure is likely to reduce after the route has been surveyed with GPR

ROUTE SEVEN					
Test Site No.	Original TARQUIN Recommendation ²	Treatment Implemented ⁸	Treatment Deferred ⁸	Current Result ¹⁰ (i.e. Still Requires)	Category* ¹
1	Nil	Nil	-	Nil	1
2	1	1	-	Nil	1
3	2	2	-	Nil	1
4	3	3	-	Nil	1
5	1	-	1a	1	5
6	2	-	2	2	5
7	3	-	3	3	5
8	4	-	4	Nil	3

Table 8: Original Site Conditions at the Selected Review Sites

NOTE:

*1. Refer to Figure 1: 2004 Review Assessment Criteria Categories.

ROUTE SEVEN						
Test Site No**	Treatment Recommendations	Concerns Regarding:				
		Poor Track Quality (inc. HSTRC & IMPACT)	Issues Found by Ground Penetrating Radar **2	Poor Topography**3	Subgrade Type**4	Ballast Condition**5
1	Nil	No	No	No	Stiff Cohesive	Dirty
2	T1 / 1a	Yes	Yes	Yes	Stiff Cohesive	Dirty
3	T2	Yes	Yes	Yes	Stiff Cohesive	Clean
4	T3	Yes	No	Yes	Stiff /Soft Cohesive	Dirty
5	T1 / 1a	No	Yes	Yes	Granular	Dirty
6	T2	No	Yes	Yes	Soft Cohesive	Very Dirty
7	T3	Yes	Yes	Yes	Soft Cohesive	Dirty
8	T4	Yes	Yes	Yes	Soft Cohesive	Very Dirty

Table 3: Original Site Conditions at the Selected Review Sites

NOTE:

*1. Refer to Table 2.

*2. Issues regarding erosion, migration of fines, and/or interface between ballast and subgrade.

*3. For example, site in a cutting, standing water present, and/or no positive drainage present.

*4. Refer to BS 5930:19999.

*5. Taken from Automatic Ballast Sample logs in the vicinity of the selected site, carried out by Fugro Ltd., on behalf of Route 7 Alliance in 2002/03, in accordance with RT/CE/C/039 Issue 1a.

Site No.	1/8th Miles (From - To)				Up Fast		Up Fast		Up Fast		Up Fast		Up Fast		Up Fast		Up Fast	
					Dec-02		20-Nov-03		1-May-04		20-May-04		16-Jun-04		18-Aug-04		15-Sep-04	
	Miles	Yards	Miles	Yards	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst
5	167	880	167	1100	4	4	1.9	1.9	0.8	0.8	0.8	0.8	0.8	0.8	1	1	1	1
	171	220	171	440	3	3	2.4	2.4	1.5	1.5	2.5	2.5	3	3	1.9	1.9	3.1	3.1
4	171	440	171	660	5.1	5.1	4.9	4.9	5	5	4.6	4.6	4.2	4.2	4.5	4.5	3.7	3.7
	170	1100	170	1320	1.8	1.8	2.1	2.1	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.6
7	170	1320	170	1540	4	4	2.8	2.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1	1
	170	1540	171	0	3	3	1.5	1.5	1.8	1.8	1.8	1.8	1.8	1.8	2	2	2.1	2.1

Site No.	1/8th Miles (From - To)				Down Fast		Down Fast		Down Fast		Down Fast		Down Fast		Down Fast		Down Fast		Down Fast	
					Dec-02		20-Nov-03		1-May-04		20-May-04		16-Jun-04		17-Aug-04		14-Sep-04		28-Sep-04	
	Miles	Yards	Miles	Yards	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst	SP 35m V Value	Worst
1	164	1320	164	1540	1.8	1.8	1	1	0.8	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9
	164	1540	165	0	1.8	1.8	1.5	1.5	0.8	0.8	0.5	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
2	164	220	164	440	4	4	2.2	2.2	2.1	2.1	1.1	1.1	1	1	1	1	1.1	1.1	1.1	1.1
	164	440	164	660	1.8	1.8	1.5	1.5	1.2	1.2	1.1	1.1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
3	166	220	166	440	4	4	4.3	4.3	0.9	0.9	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	175	1320	175	1540	3	3	2.2	2.2	1	1	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8
8	165	880	165	1100	3	3	2.8	2.8	1	1	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9

Table 4. Track Quality Data from original TARQUIN runs.
NOTE:
December 2002 values are approximate for category, i.e., derived from VG, G, S, P and VP ratings.

	Very good/good value
	Satisfactory value
	Poor value
	Very poor value

- Topographical survey;
- Walk over survey; and
- Drainage survey.

There follows a brief description of the review assessment process¹⁰.

Review Assessment Assumptions

The review of the original TARQUIN assessment was based on the current information for the following items:

- HSTRC data (fast lines only)³;
- Drainage data¹¹; and
- Formation works carried out or deferred⁸.

This provided an estimated overall accuracy result of the original assessment and indicated where the fast lines still required formation work.

The review of the track quality assumed that the ballast conditions remained unchanged from the original assessment. In other words, if a section of the route had no outstanding track quality issues, then it was assumed that the condition of the ballast was having a negligible affect on the overall track quality. Ballast condition only becomes a contributing factor when there is a combination of poor track quality and soft cohesive subgrade.

Review Assessment Limitations

The review of the original TARQUIN assessment did not contain up to date information for GPR, ABS, or walkover surveys.

Drainage Work

Drainage work implemented appears to have had a positive affect on track quality throughout the entire route.

Formation Work

This paper cannot comment on the quality of the formation work implemented. Where sections of the route are still indicating a requirement for formation work despite the implementation of a treatment type, this paper assumes one of two possible reasons:

- The original TARQUIN assessment underestimated the requirements of the section affected; or
- Construction issues.

HSTRC Data

To review the accuracy of the original assessment, the track quality data from the HSTRC was used; including a review against the original assessment track quality data, the most recent data run and seven previous data runs. This then provided a comparison between the original track quality data, the current condition of the track, and highlight any trends towards poor track quality since the formation works were completed. Table 4 illustrates the track quality data for the original assessment, a data run just prior to the formation works, and a data run several months after completion of all formation work. Experience has shown that the 35m Vertical filter gives the best values to assist the assessment of formation issues.

Improvements in Track Quality

A review of the current HSTRC data for each of the selected review sites over the last eight runs highlights where there has been an improvement in the track quality. Generally, throughout the entire route there appears to be a long-term improvement in track quality, for example Test Site No.2. This is probably due to the formation, drainage, and the track renewals work implemented.

It should be noted that although some sections of route show recent improvements in track quality, there are still large sections of these areas which show a future trend towards poor track quality. In other words, between the HSTRC runs prior and after completion of the formation works, the track quality initially improved, however, the long-term track quality shows a trend towards deterioration.

It is these sections, where a trend is present, which are likely to deteriorate in quality back to the original condition prior to any works carried out. These trends towards poor track quality are expected on an operational railway.

Deterioration in Track Quality

Up Fast

There were several areas on the Up Fast where the track quality has deteriorated. There are three possible reasons for this:

1. The formation work implemented has not provided a path for water to escape in accordance with the relevant standard, resulting in the "canal of ballast" effect;
2. Any transverse drains implemented, feeding the outfall water into the drainage system, might not be of sufficiently recurrent to be fully effective; or
3. The outfalls for this drainage system have not been fully cleared.

Several areas of the route with an apparent trend towards track deterioration, for example Test Site No. 4 [Chelford Loops] shows a continuing trend towards poor track quality despite formation treatment implemented as recommended in the original TARQUIN assessment. This suggests that TARQUIN has either underestimated the severity of the conditions or there is a construction issue with the formation work carried out.

Down Fast

There were a number of areas on the Down Fast where the track quality has deteriorated since the initial run prior to completion of the formation works.

Test Site No. 8 shows a trend towards track quality deterioration. There is a clearly an initial improvement since the original TARQUIN assessment, and it appears that the renewal works completed around 1 May 2004 have had an impact. However, the track quality is slowly deteriorating again. The original TARQUIN assessment recommended Treatment Type 4, which was deferred. The initial improvement is probably due to palliative tamping works.

No Change in Track Quality

There are numerous sections where there has been little or no change in the track quality, for example Test Site No. 1. Generally, this is an indication of the good condition of the track. However, there are several sections where the track quality remains unchanged, or has changed very little, yet the track quality was poor to begin with.

Trackbed Assessment

The review assessment looked at the following aspects:

1. The original recommended treatments;
2. Illustrating where formation work is still required;
3. Actual implemented and deferred treatments; and
4. The comparison of results.

The formation work still required uses the same criteria as the original 2003 TARQUIN assessment, without current GPR data.

Also indicated, against the relevant eighth of mile section, is whether the recommended formation treatment was implemented or deferred.

Table 5 illustrates the criteria categories used in determining the percentage accuracy, whether the original 2003 TARQUIN Assessment was correct, and whether the

ROUTE SEVEN		
2004 Review Assessment Criteria Category	Category Description	Percentage Result for Test Sites (%)
1	Correct TARQUIN Results	50
2	Failed TARQUIN Results	0
3	TARQUIN Over Recommended	12.5
4	TARQUIN Under Recommended	0
5	Deferred Works	37.5
CORRECT TOTAL [Category 1 + Category 5]		87.5

Table 9 (above): Percentage Accuracy of Original TARQUIN Assessment

		OVERVIEW					Accuracy of Original TARQUIN Assessment: Test Site	Accuracy of Original TARQUIN Assessment: Total Route Without GPR	Accuracy of Original TARQUIN Assessment: Total Route With GPR
		A	B	C	D				
PERCENTAGES	Original Up Fast	100	43	40	22		99.90%	78%	95%
	Up Fast	62	9	20	16				
	Test Sites	33.3	0	0	0	66.6			
		1	2	3	4	5			
		CATEGORY							

Table 10 (above): Up Fast 2004 Review Assessment Percentages

		OVERVIEW					Accuracy of Original TARQUIN Assessment: <i>Test Site</i>	Accuracy of Original TARQUIN Assessment: <i>Total Route Without GPR</i>	Accuracy of Original TARQUIN Assessment: <i>Total Route With GPR</i>
		A	B	C	D				
PERCENTAGES	Original Down Fast	100	36	52	12				
	Down Fast	54	3	15	17				
	Test Sites	60	0	20	0	20			
		1	2	3	4	5	80%	71%	97%
CATEGORY									

Table 11 (above): Down Fast 2004 Review Assessment Percentages

OVERVIEW	DESCRIPTION	CATEGORY	DESCRIPTION
A	Original Recommendation	1	Correct Original TARQUIN Results
B	Treatment Implemented	2	TARQUIN Failed to Correctly Recommend
C	Treatment Deferred	3	TARQUIN Over Recommended
D	Treatment Still Required	4	TARQUIN Under recommended / Construction Issues
		5	Deferred Works

Table 12: Titles for Overview and Category Sections

construction implemented/deferrals were also correct. The criteria details are given in Table 6.

Brief Description of Each 2004 Review Assessment Criteria Category¹⁰

1. Correct Original TARQUIN Result

This criterion assesses:

- Whether the original recommended treatments implemented and whether there is now good track quality; or
- Whether there was no treatment originally recommended and whether the current track quality still requires no formation treatment.

2. TARQUIN Failed to Correctly Recommend

This criterion assesses whether the current track quality recommends formation treatment, whilst the original TARQUIN assessment made no recommendations for formation work.

3. TARQUIN Over Recommended

This criterion assesses whether the original treatment recommendation was deferred and whether the review assessment recommended formation treatment.

4. TARQUIN Under Recommended / Construction Issues

This criterion assesses whether the original recommended treatment was implemented and whether the review assessment recommended formation treatment is still required.

5. Deferred Works

This criterion assesses whether the original treatment recommendation was deferred and whether the review assessment recommends formation treatment is still required.

Percentage Accuracy

The percentage is obtained from the combination of correct TARQUIN results and where deferred the original treatment sections have been re-assessed and still require formation work.

Ground Penetrating Radar Factors

As the review assessment only included current HSTRC data, the overall results were limited and can not be assumed to be 100% accurate. If the route was surveyed with GPR again, and the results from this included in the assessment,

the accuracy of the review would be improved.

In order to estimate the degree at which GPI would amend the assessment results, the difference made by GPR on the original 200 TARQUIN Assessment is quantified. Therefore the percentage difference between each treatment recommended, including where no treatment is required, was obtained. A summary of these percentages, taken from the total route review assessment carried out for Route Seven in 2004, is presented in Table 7. These percentages can then be added to the current recommended treatments, to obtain an estimate for the quantities of treatment required including GPR data. A full GPR survey of the route would be required to verify this assumption. With regard to the test site reviewed in this paper, GPR has not been considered because of the small number of results. The figures in Table 7 however do reflect the importance of carrying out GPR as part of a total trackbed assessment.

2004 Review Assessment Results

Test Site and Total Route Results

Table 8 shows the overall summary of results for the test sites. Table 9 gives the percentage accuracy for the test sites, based on the 200 Review Assessment Category Criteria as shown in Table 5.

Tables 10 and 11 show the percentage result for the review assessment test sites, as well as the official Route Seven Review figures for the whole route. Table 12 gives the Overview and Category descriptions.

Overall, the accuracy of the original TARQUIN assessment, according to the test sites, is circa 87.5% with regards to the categories illustrated in Table 9.

This is a very reasonable degree of accuracy especially as GPR data has not been included in the review. The official Route Seven assessment had a total route average without GPR of approximately 75%.

Up Fast

The Up Fast appears to have a high degree of accuracy for the original 2003 TARQUIN assessment, currently estimated at 99.9% based on HSTRC data only for the test site. The total route accuracy without GPR is approximately 78%.

Taking the assumptive percentage values for GPR, as described previously, this degree of accuracy could increase to approximately 95%. See Table 10 for a summary of these results.

Down Fast

The Down Fast appears to have a high degree of accuracy for the original 2003 TARQUIN assessment, currently estimated at 80%, based purely on HSTRC data only for the test site. The total route accuracy, without GPR, is approximately 71%.

Taking the assumptive percentage values for GPR, as described previously, then this degree of accuracy could increase to approximately 97%. See Table 11 for a summary of this result.

Overall

Individually the Up Fast and Down Fast have a high degree of accuracy, averaging 89.5% for the test sites.

For the total route the combined average is circa 75% without GPR and 96% with GPR. Therefore, it can be argued that the test site are representative of the whole route.

Conclusions

This paper demonstrates that TARQUIN is an accurate, repeatable and auditable assessment process for track renewals, formation treatment and drainage requirements in a short time scale, in an environment with limited safe access. There is also strong evidence to suggest the process is time-saving and cost effective if used to full potential. The accuracy of the process, based on the test sites, is on average 89.9%. The overall total route accuracy is approximately 74.5% without GPR; 96% with GPR (estimated).

Ground Penetrating Radar

In order to accurately assess the route and further refine the TARQUIN process, it would be beneficial if both the Up Fast and Down Fast lines are surveyed with GPR.

GPR appears to improve the accuracy by an average of 26% for total route, as illustrated in Table 7. With regards to the Test Sites, the results would be distorted if reviewed against the assumption for GPR, especially for the Up Fast which already has an accuracy of 99.9%, based on the three Up Fast test site locations.

Future Aspirations

The ideal situation would be for a process like TARQUIN to be used nationwide, and incorporated into the regular track quality surveys carried out by Network Rail.

With the advancement of technology, GPR is now capable of being used at high speed and could therefore be added to the current HSTRC vehicles throughout the rail network. Combining the HSTRC with GPR would allow the industry to bring track quality assessments to a higher

level of accuracy, using the TARQUIN process.

Routes which have been assessed by TARQUIN

TARQUIN has been successfully used on the following projects, in date order:

- **Route Twelve:** Colwich to Cheadle Hulme - blockade work in summer 2003;
- **Route Seven:** Crewe North to Cheadle Hulme - blockade work in Spring/Summer 2004; and
- **Stockport Renewal:** Heaton Norris Junction to Heaton Norris Station - blockade work in summer 2004.

TARQUIN has also carried out preliminary assessments on the following routes:

- **Route Two:** Crewe North to Weaver Junction (inclusive); and
- **Route Nine:** Weaver Junction (exclusive) to Liverpool Lime Street.

Further Developments

TARQUIN has been reviewed and amended to take into account the new Network Rail standard⁴.

For those familiar with the Guide to Railway Investment Projects (GRIP)¹² stages, the process stages of TARQUIN can be mapped to GRIP as follows:

- **GRIP STAGE 3** - Includes TARQUIN Phases One, Two and Three;
- **GRIP STAGE 4** - Includes TARQUIN Phase Four; and
- **GRIP STAGE 5 (Initial)** - Includes TARQUIN Phase Five.

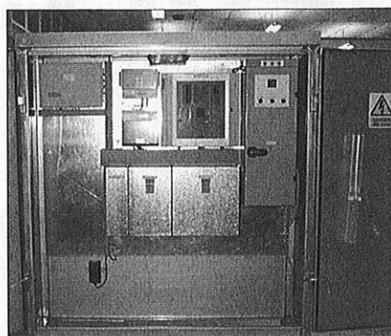
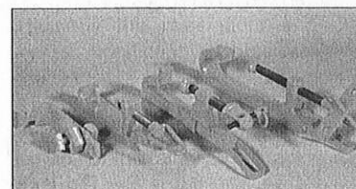
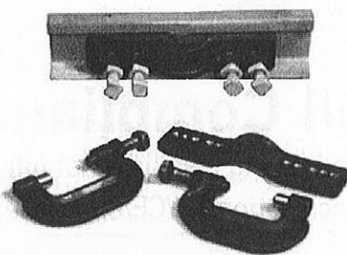
TARQUIN is also under review to take into account slope stability, ballast returns and improve the accuracy for subgrade issues at depths greater than 5m.

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