The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost

SUSTRAIL

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1. INTRODUCTION

The objective of Work Package 1 is to provide a benchmark of the current freight 'system' to establish the existing 'zero state' for subsequent comparative and enhancement activities. The benchmark is designed to provide information to support evaluation of the key system parameters which will ultimately influence and determine improvements towards freight sustainability and competitiveness.

Task 1.4 Infrastructure has details of track and infrastructure sites of the selected routes, and identification of known trouble spots. Deliverable 1.4 should be read in conjunction with Deliverable D1.2 which provides an overview of the selected routes in the UK, Spain and Bulgaria, and selected route characteristics (e.g., number of tracks, electrification, statistics on track curvature); also, the test track in Romania is described in detail in Deliverable D1.6. The present report is focussed more on infrastructure characteristics, and includes a summary of the availability of economic data required for LCC and RAMS analysis later in Work Package 5.

Table 1.1 lists the data to be collected to describe the points of interest selected on the routes. Section §2 looks at the Spanish route, Section §3 looks at the UK routes, and Section §4 looks at the Bulgarian route.

Table 1.1 Data to be collected at key locations

P.K. 000.000	
Maintenance problem	Type
Track type	Single or double track, gauge Ballast, embedded Electrified
Track geometry	Radius Gradient Cant
Sleeper type	Timber, concrete, steel
Rail size	UIC 54, 60
Maximum speed	km/h
Geological structure	Embankment, tunnel, bridge
Traffic	Number of freight trains Number of passenger trains
Track quality	good
Maintenance history	Sleepers change Rail change Tampers (levelling gravel) Investments

2. SPANISH ROUTE: MEDITERRANEAN CORRIDOR

2.1 Historical background

The Mediterranean Corridor name became popular to describe the line partially built in 1990 from Alicante, Valencia and Barcelona, arising from the refurbishment of the existing classic line.

This renewal was planned in the National Rail Plan of 1987, which provided between Barcelona and La Encina, 75 km from Alicante, a two-track path capable of supporting speeds of 200 km/h suitable for all types of traffic. The construction consisted of the modernization and duplication of existing infrastructure, and in some places the construction of major variants with a path different from the classic line. The work was carried out by sections, which entered service on different dates, being remodelled along almost the entire route between La Encina (Alicante) and Valencia and Castellón-Vandellós (Tarragona). Amongst sections not renewed, the highlight is the Vandellós-Tarragona section, about 40 km, where the Mediterranean Corridor is again a classic line, single track with a top speed of 160 km/h. The section Tarragona-Barcelona is also a classic line which was not renewed, but has double track.

The maximum speed along the renovated sections was 220 km/h which is above the limit of 200 km/h with the Spanish conventional signalling. To allow for 220 km/h a new type signalling system ATP, called EBICAB, was installed. Some trains do not use this system and limit their speed to 200 km/h.

Later it was decided to integrate these sections with other new and modernised sections (where the geography and populations required) to form what came to be called the Mediterranean Corridor high-speed route.

This document aims to create a background of critical points founded in the infrastructure, which will form the base for the planned studies performed on this project.

For this preliminary analysis of the critical infrastructure points, the collaboration of different areas of the company was required, especially to the maintenance department of the line and the civil engineering department.

The details of critical points found on the Mediterranean Corridor are described below.

2.2 Actual situation

Tables are given below with details of a number of sections along the route:

Table 2.2 includes the data from p.k. (kilometre point) 3.765 – p.k. 7.238 located in the Cabañal tunnel.

Table 2.3 summarises the data from p.k. 15.132 located in Massafassar station.

Table 2.4 summarises the data from p.k. 48.000 – p.k. 69.000 located between Moncofar and Castellón.

Table 2.5 summarises the data from p.k. 82.100 – p.k. 90.700 located between Benicassim and Oropesa.

Table 2.6 includes the data from the p.k. 110.000 – p.k. 119.000 located between Torreblanca and Alcalá de Chiver. There is a signal in the middle of an incline that frequently stops trains which are climbing the incline. When freight trains are stopped at the signal and then have to start on this rising gradient, this causes the

locomotives' wheels to spin. The resulting high tension in the rails increases the chance of rail breaks.

Table 2.7 summarises the data from the p.k. 147.000 located in the area of Vinaroz.

Table 2.8 summarises the data from p.k. 214.900 – p.k. 276.000 located between Bifurcación Calafat and Tarragona.

Table 2.9 summarises the data from p.k. 275.100 located in Tarragona Clasificación.

A histogram of age of rail, sleepers and ballast is given in **Figure 2.1**.

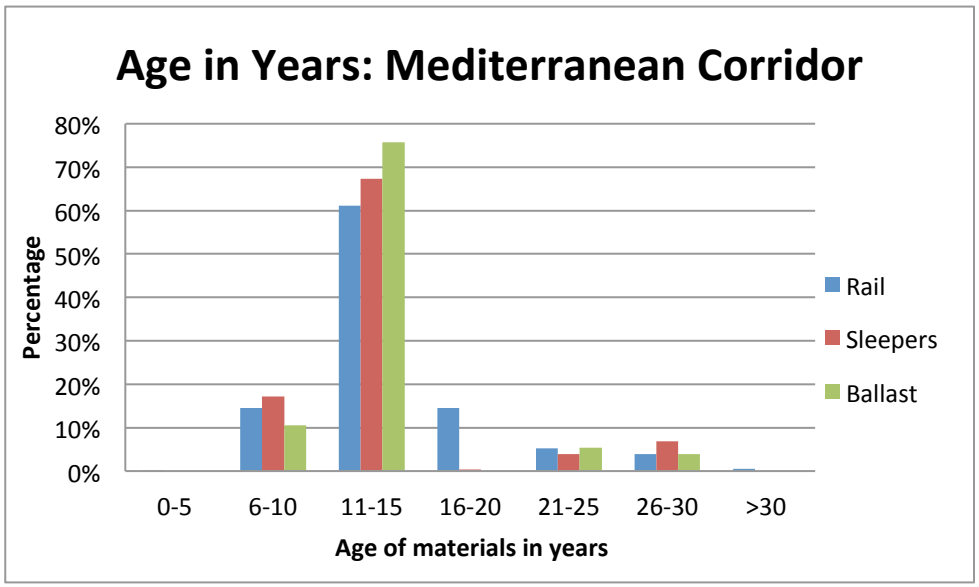


Figure 2.1 The age of the materials (rail, sleepers and ballast) of the Mediterranean Corridor

More than 60% of the materials have an age between 11 and 15 years. This data agrees with the fact that significant renewals happened in 1997 and in 2000.

- In 1997 was the major renewal of Mediterranean Corridor to increase the speed limit up to 220 km/h.
- In 2000 the line between Calafat and Tarragona was renewed.

The small peak between 6 and 10 years agreed with two renewals:

- In 2002, there was a renewal of 18 km between Sagunto p.k. 30.000 and Moncofar p.k. 48.000.
- In 2002-2003 was a renewal of 15 km between Les Palmes p.k 75.000 and Oropesa p.k. 90.000.

Two other small peaks appear between 21 to 30 years:

- Between p.k. 48.000 – p.k. 68.000 on track 2, there was renewal in 1990.
- Between p.k. 48.000 – p.k. 68.000 on track 1, there was renewal in 1984.

Table 2.1 shows the number and type of switches.

Table 2.1 Number and type of switches

Switch type	*no*	*Sleeper type*	*Max Direct Track Speed*	*Max Diverted Track Speed*	*Rail welding*
A	11	Timber	140	30	No
C	52	Timber	160 - 200	45 - 60	Yes
V	24	Timber	200	100	Yes
P	6	Concrete	200	100	Yes

Figure 2.2 summarises the quality of Mediterranean Corridor route.

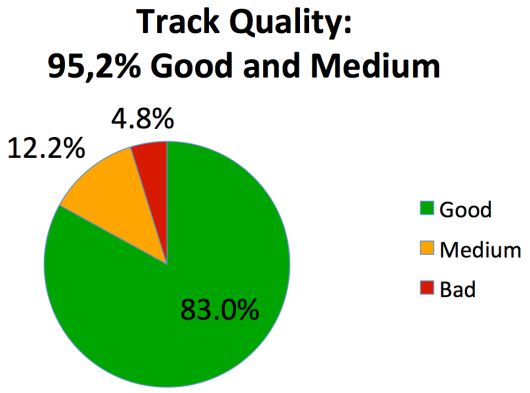


Figure 2.2 Track quality of the Mediterranean Corridor

The quality of track is determined through the quality indices of the data obtained from analysis of each 200 m track section. Bad parameters appear in track switches and turnouts, especially in points or sections that are described below.

Table 2.2 p.k. 3.765 – p.k. 7.238 located in the Cabañal tunnel

P.K. 3.765 - P.K. 7.238	
Maintenance problem	Draining and water sub-pressure problems (fresh water), with corrosion of track and elements and dynamic clearance problems
Track type	Double track, Gauge 1668 mm Ballastless track Electrified 3000DC
Track geometry	Radius curve: 2735 m, Straight; Radius curve: 900 m and straight Gradient: 1.3% Max cant: 160 mm
Sleeper type	Embedded in concrete Twin-block Stedef concrete sleepers with elastic boots
Rail size	UIC 60 (1990)
Maximum speed	80 km/h
Geological structure	Tunnel is located as a quaternary geomorphological unit, which has been formed by slits
Traffic	No freight trains: 102 per week No passenger trains: No commuter trains: 477 per week No long-distance trains: 317 per week
Track quality	good
Maintenance history	Excessive corrosion in all the materials because there are fresh water leaks. Periodic inspections increased The clearance problems are due to the existence of an overpass at the upper end of the tunnel. This supposes a speed limit of 80 km/h The overpass is expected to be modified

(P.K. = kilometre point)

Table 2.3 p.k 15.132 located in Massafassar station.

P.K. 15.132	
Maintenance problem	Track fault
Track type	Double track, 1668 mm of gauge Ballast Electrified 3000DC
Track geometry	Straight Gradient: 0 Cant: 0
Sleeper type	Concrete monoblock DW-7
Rail size	UIC 60 (1997)
Maximum speed	220 km/h
Geological structure	Embankment is located as a quaternary geomorphological unit, which has been formed by slits
Traffic	No freight trains: 86 per week No passenger trains: No commuter trains: 470 per week No long-distance trains: 240 per week
Track quality	good
Maintenance history	Massalfassar station, repaired with track heavy machinery: Tampers (levelling and aligning)

Table 2.4 p.k 48.000 – p.k. 69.000 located between Moncofar and Castellón.

P.K. 48.000 – P.K. 69.000	
Maintenance problem	Excessive maintenance of old infrastructure Old metallic bridge at p.k. 58.700
Track type	Double track, 1668 mm of gauge Ballast Electrified 3000DC
Track geometry	Straights, radius curves: 800, 6000, 900 Gradient: 0.36% Max Cant: 140 mm
Sleeper type	Concrete bi-block RS
Rail size	UIC 54 (1984 track 1, 1990 track 2)
Maximum speed	160 km/h 90 km/h Nules station 200 m 110 km/h Burriana station 400 m
Geological structure	The area is located as a quaternary geomorphological unit, which has been formed by alluvial fans erosions
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 477 per week No long-distance trains: 260 per week
Track quality	medium
Maintenance history	Track 1 was renewal in 1984-1985 Track 2 was renewal in 1990 Old layout of both tracks Excessive maintenance of old infrastructure. Sleepers renewal Rail renewal Ballast renewal Bridge inspections Drainage maintenance

Table 2.5 p.k. 82.100– p.k. 90.700 located between Benicassim and Oropesa.

P.K. 82.100 – P.K. 90.700	
Maintenance problem	Unstable cutting
Track type	Double track, 1668 mm of gauge Ballast Electrified 3000DC
Track geometry	Radius curve: 2800 m, straights Gradient: 0.7% Max Cant: 130 mm
Sleeper type	Concrete monoblock sleepers PR-90
Rail size	UIC 60 (2003)
Maximum speed	220 km/h
Geological structure	Cuttings is located as a quaternary geomorphological unit, which has been formed by colluvial settlements
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 0 per week No long-distance trains: 245 per week
Track quality	Good
Maintenance history	Special Treatment of the soil and cuttings

Table 2.6 p.k. 110.000 – p.k. 119.000 located between Torreblanca and Alcalá de Chiver.

P.K. 110.000-119.000	
Maintenance problem	Rail breaks (2 times in 15 years). High gradients.
Track type	Double track, 1668 mm of gauge Ballasted Track Electrified 3000DC
Track geometry	Radius curve: 1300, 1100, Straights Gradient: 1.4% Max Cant: 160 mm
Sleeper type	Concrete monoblock PB-90
Rail size	UIC 60 (1997)
Maximum speed	160 km/h
Geological structure	Embankment is located as a quaternary geomorphological unit, which has been formed by cretaceous materials like chalk and loam
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 0 per week No long-distance trains: 233 per week
Track quality	Good
Maintenance history	Track renewal performed in 1997 with new materials Every broken rail was repaired with a new rail and welded.

Table 2.7 p.k. 147.000 located in the area of Vinaroz.

P.K. 147.000	
Maintenance problem	Flooding area
Track type	Double track, gauge 1668 mm Ballasted Track Electrified 3000DC
Track geometry	Straight Gradient: 0 Cant: 0
Sleeper type	Concrete monoblock sleepers PR-90
Rail size	UIC 60 (1990)
Maximum speed	220 km/h
Geological structure	Embankment is located as a quaternary geomorphological unit, which has been formed by colluvial materials
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 0 per week No long-distance trains: 247 per week
Track quality	Good
Maintenance history	Excessive corrosion in all the materials and embankment washed away because of the flooding. Periodic drainage revisions increased.

Table 2.8 p.k. 214.900 – p.k. 276.000 located between Bifurcación Calafat and Tarragona

P.K. 214.900 – P.K. 276.000	
Maintenance problem	More and difficult maintenance
Track type	**Single** track, 1668 mm of gauge Ballast Electrified 3000DC
Track geometry	Straights and curves (minimum 800 m) Gradient: 1.1% Max Cant: 160
Sleeper type	Concrete monoblock PR-90
Rail size	UIC 60 (2000)
Maximum speed	140 km/h 130 km/h L´Hospitalet de L´Infant 400 m 160 km/h 120 km/h p.k. 250.000. 400m 140 km/h
Geological structure	Embankment is located as a quaternary geomorphological unit, which has been formed by colluvial materials
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 0 per week No long-distance trains: 332 per week
Track quality	good
Maintenance history	The single track is a higher maintenance section because the high traffic in the only track. The embankments and subbase have already been built for track duplication.

Table 2.9 p.k. 275.100 located in Tarragona Clasificación

P.K. 275.100	
Maintenance problem	Excessive freight traffic. 223 m of left rail wear
Track type	Double track, 1668 mm of gauge Ballast Electrified 3000DC
Track geometry	Straight Gradient: 0 Cant: 0
Sleeper type	Concrete monoblock PR-90
Rail size	UIC 60 (2000) UIC 60 (2010)
Maximum speed	140 km/h
Geological structure	Embankment is located as a quaternary geomorphological unit, which has been formed by colluvial materials
Traffic	No freight trains: 56 per week No passenger trains: No commuter trains: 0 per week No long-distance trains: 245 per week
Track quality	Good
Maintenance history	The wear of the left rail at one end of Tarragona station is generated because of the forced location of the switch to Tarragona Clasificación station A total length of 223 m of rail installed in 2000 had to be renewed in 2010

2.3 Conclusions of Spanish Route

In the case of the Spanish route (Valencia-Tarragona), after studying the maintenance data and contrasting them with the technical track, we have reached the following conclusions about what are the critical points in the infrastructure:

- The problem of clearance happens because of an overpass at the exit of the Cabañal tunnel and can be solved by **moving the two crossover Alboraia blocking points**, substituting them for other switches type P1 on concrete bearers, and moving its location about 200 meters in the way to Castellón

- Between p.k. 48.000 and 69.000, where the infrastructure is old (rail profile type UIC 54 mounted on twin-block sleepers renewed between 1984 and 1990), we can find **switch types A on timber bearers** that have become to need more maintenance, especially in the area of the frog and fish plates.

- The optimal solution for the maintenance of these switches would be its replacement for another ones of type P1 (on concrete bearers), that are the most suitable for type A1 sub-network type of lines like this one (high speed and very high rate of freight traffic).

- The unstable cuttings need some specific **soil treatment**. The treatment could be decreased in amount with a proper geological inspection that could generate specific diagnosis and solutions.

- The signals in ramps with high gradients generate several stops that increase the wear and fragility of the rail in the track. Moving the **signal** to other **flat areas,** if possible could decrease the maintenance works needed.

- In flooding areas it is necessary a permanent **control of the drainage system**.

- The **single track** is a critical section in this study. In the Spanish case we find a clear example between Calafat and Salou. The logical solution to this problem is the duplication of the existing track. The embankments and subbase have already been built.

- The track and switch **near to a logistic area (Tarragona Clasificación) and small radius curves** have important wears, that need more maintenance in all their components like switches blades and frogs, fastenings, sleepers and ballast, but specially in rails and check rails.

3. U.K. ROUTE

3.1 Historical background

The UK's railways have approximately an 11% share of surface freight transport and the amount of rail freight carried has generally been increasing since the mid-1990s[1]. Along the two UK corridors studied in the SustRail project, from Felixstowe and Southampton to Nuneaton and then up the West Coast Main Line (WCML), around 75% of the total rail traffic is freight trains, the remaining 25% being passenger trains. This ranges from 96% freight on the line near Felixstowe to 42% on the mainline between Southampton and Basingstoke.

Much of the UK railway was built very quickly in the Victorian era, and hence most structures and earthworks along NR's 15,800 route-km are between 100 and 150 years old. NR has 7,861 route-km of embankments, 850 route-km of rock cuttings and 5,475 route-km of soil cuttings as well as 23,981 underbridges. 6% (664 km) of the embankments and cuttings are considered to be in a poor condition whilst 44% have been graded as marginal. It has been estimated that 'poor' earthworks will have 1 failure per 25 km per year and account for 90% of all failures. 'Marginal' earthworks are estimated to have 1 failure per 270 km per year and account for 9% of all failures; half of these are due to wash out and drainage problems.

The Ely to Peterborough line (the 45.4 km long EMP section between Felixstowe and Nuneaton) was built in ten months despite the problems with the soft fenland soils; it opened to goods traffic in 1846 and to passengers in 1847. This Victorian zeal for rapid expansion has left the modern UK railways with problems to resolve, especially when contemplating very high tonnages and increased speeds on poorly constructed trackbeds and embankments.

InnoTrack Deliverable D1.4.6 [7] showed that for Network Rail in 2006 the maintenance costs were 24% main line tamping, 19% inspection, 18% rail changing and 15% S&C maintenance. Of course, maintenance is only half the renewals budget. NR figures per track-km for 2009/10 (at 2011/12 prices) for maintenance and renewals only was 92,360 Euro/track-km. Maintenance was 28,720 Euro/track-km and renewals were 60,960 Euro/track-km.

3.2 Actual situation

Two sections provide the data for each of the two strategic freight routes from Southampton in the south and Felixstowe in the east to Nuneaton in the Midlands. A third section is then provided of the common route section heading north up the slow line of the WCML.

3.2.1 Southampton to Nuneaton

A summary of the route between Southampton and Nuneaton is given in Table 3.1. The age of rails, sleepers and ballast on this route is indicated in Figure 3.1 and Table 3.2. Defect rates are indicated in Table 3.3; these include RCF, lipping, side wear, wheel burns, but most are either squats or weld defects. The high level of rail defects on the DCL section between Anyho and Leamington Spa are due to the age of the rail; Figure 3.2 shows how defect rate may be related to life used. Renewals work has started to replace these rails. A breakdown of the defects between Anyho and Leamington Spa is given in Table 3.4. However, less than 1% of these defects cause any delay to the railway. For the network as a whole, there are only about 0.36 track failures per 100 km per year leading to a delay (see Table 3.5).

[1] Based on data from ORR National Rail Trends Yearbook 2010-11.

Table 3.1 Route summary: Southampton to Nuneaton

Route length	211.2 km
Track type	Double track, gauge: 1435 mm Ballast Electrified: the first 48 km is electrified at 750V dc; but there is no power on the rest
Track geometry	Minimum Radius: 300 m on LSC2 near Coventry Max Gradient: 1.22% for 2 km near Kenilworth on LSC2 Max Cant: 160.5 mm
Sleeper type	Most sections have between 90-98% concrete with most of the remainder in hardwood. However the northern part of DCL route section only has 56% concrete and 44% hardwood
Rail size	From Southampton to Warrington 67% is UIC54 equivalent; 17% is UIC 60; 14% is unknown.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 160 km/h
Structures	From Southampton to Warrington: 46% of route is embankments; 26% cuttings; 2% viaducts; and only 101metres of tunnels
Ground Conditions	Along the coast is the "Hampshire Basin", an area of relatively non-resistant Eocene and Oligocene clays and gravels; the Southern England Chalk Formation of the South Downs The escarpment and plateau of the Cotswold Hills dominates the north-west of Oxfordshire through which DCL passes. These are formed in Jurassic shallow coastal limestones, shales and sands. The plateau surface gradually shelves southwards to Oxford, which is floored by the heavy clays of the Jurassic Oxford Clay. South of Oxford there is a low ridge of Upper Jurassic limestones and clays.
Traffic	Varies significantly along the route with between 40-70% of the traffic being freight. That is between 133 and 147 freight trains/week Freight tonnages: 6.9 - 7.7million tonne/yr (or 12 – 14 EMGTA) Passenger tonnages: 3.4 – 10.7 million tonne/year (or 5 to 17 EMGTA) (or between 200 and 774 trains/week)
Track quality	good

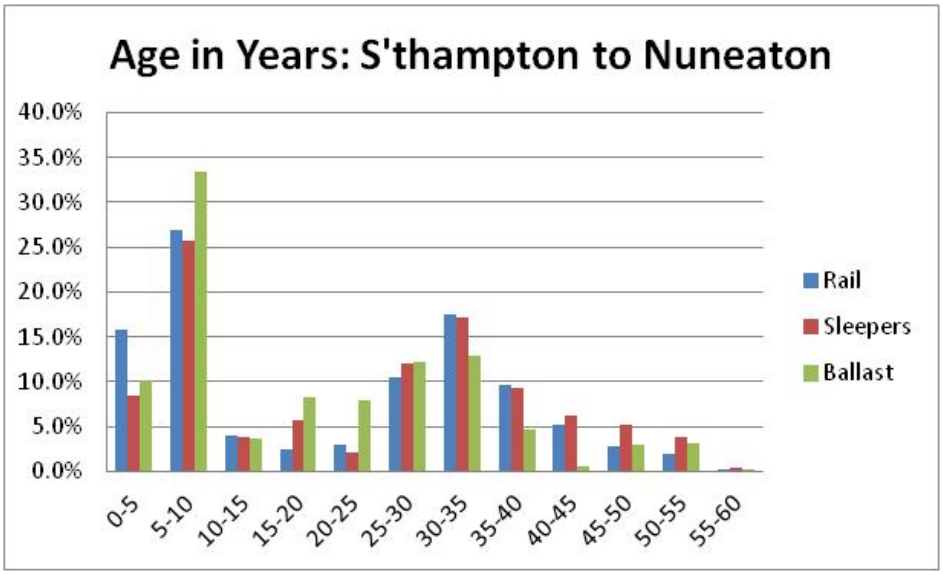


Figure 3.1 Age in years: rail, sleepers and ballast.

Table 3.2 Used life of rails and sleepers.

Rail used life	0-25%	25-50%	50-75%	75-100%	Extended
DCL: Anyho to Leamington Spa	18%	3%	31%	31%	17%
DCL: Chester Line to Anyho	41%	6%	14%	10%	30%
EMP: Ely North to Peterborough	30%	45%	19%	6%	1%
BML1: Northam to Basingstoke	42%	12%	16%	27%	3%
WCML: Nuneaton to Crewe	58%	6%	16%	11%	9%

Sleeper used life	0-25%	25-50%	50-75%	75-100%	Extended
DCL: Anyho to Leamington Spa	23%	12%	14%	45%	6%
DCL: Chester Line to Anyho	33%	3%	9%	22%	34%
EMP: Ely North to Peterborough	7%	24%	42%	16%	11%
BML1: Northam to Basingstoke	33%	11%	20%	30%	6%
WCML: Nuneaton to Crewe	47%	5%	24%	16%	8%

Table 3.3 Defect rates, based on defects found in 2009/10 and 10/11.

	Defect rate per 100 km / year	
Route	**Actionable**	**Serious + breaks**
DCL: Anyho to Leamington Spa	333.7	6.2
DCL: Chester Line to Anyho	95.9	2.8
EMP: Ely North to Peterborough	78.1	3.3
BML1: Northam Short to Basingstoke	59.7	9.3
WCML: Nuneaton to Crewe	42.9	1.0
Network average	*73*	*5.1*

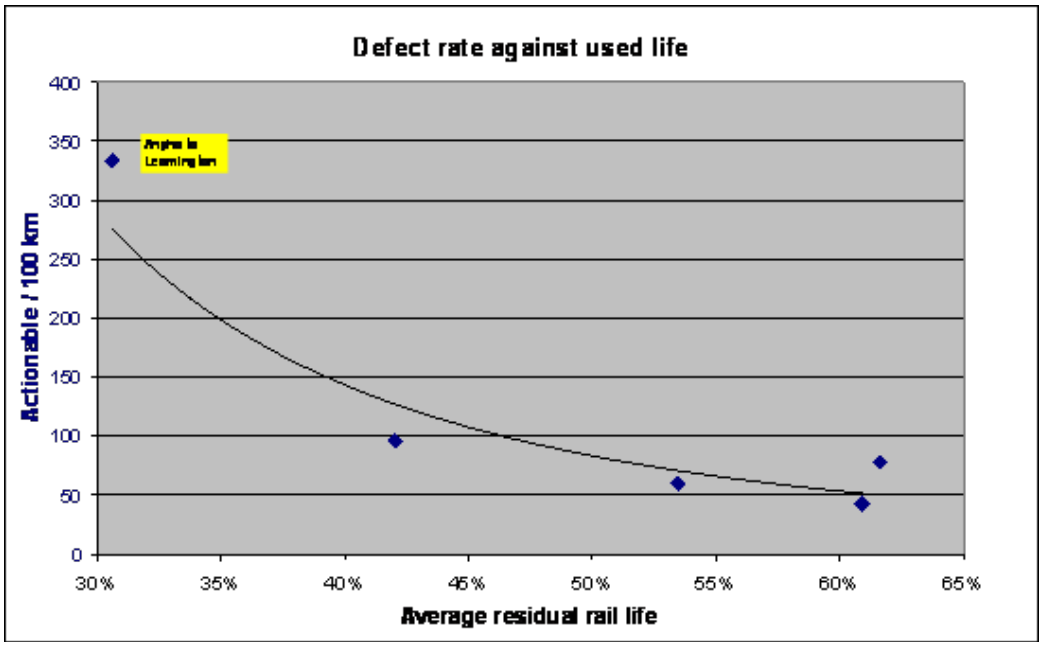


Figure 3.2 A possible relationship between average residual life of the rail and the number of defects.

Table 3.4 Breakdown of the defects over the 32.3 km of route between Anyho and Leamington Spa.

Defect Group	2009	2010
Lipping & sidewear	1	3
Other	8	8
RCF	2	
Squat	81	59
Tache Ovale	1	
Weld	32	20
Wheelburn	1	
Grand Total	**126**	**90**

Table 3.5 Failures causing a delay.

Failures causing a delay	
	No. per 100km route/yr
Track	0.36
Points	0.32
Signalling	1.37

3.2.1.1 BML1 Section from Southampton to Basingstoke

There is a large amount of new rail on this route, primarily as a result of rail defects caused by rolling contact fatigue (RCF). Class 444 and 450 Desiro units with stiff lateral suspension have been initiating RCF on curves. The heavy freight trains then cause these small cracks to grow into '1A' defects which are more than 50 mm long and 15 mm deep and require immediate remedial action. Sections of MHH, a low-alloyed pearlitic heat-treated rail, have been installed on these curves to try to mitigate matters. Analysis of the benefits of MHH on this route is still awaited. It is interesting that the route section north of Basingstoke, which has the same passenger train traffic initiating cracks but very few freight trains, has far fewer incidents of '1A' RCF defects.

This section of the route is summarised in Table 3.6. The age of rails, sleepers and ballast is indicated in Figure 3.3.

Table 3.6 Route section summary: BML1 from Southampton to Basingstoke

Route length	48.42 km out of 211.2 km
Track type	Double track, gauge: 1435 mm Ballast Electrified: for this 48 km at 750V dc
Track geometry	Minimum Radius: 1300m Max Gradient: 0.46% but ascending for 27 km from Southampton up the South Downs Max Cant: 100 mm
Sleeper type	98% concrete; 1% hardwood; 1% softwood
Rail size	89% is UIC54 equivalent; 6% is UIC 60.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 160 km/h
Ground Conditions	Along the coast is the "Hampshire Basin", an area of relatively non-resistant Eocene and Oligocene clays and gravels; the Southern England Chalk Formation of the South Downs
Traffic	42% freight: 58% passenger Freight: 7.7million tonne/yr (14 EMGTA) 151 freight trains/week Passenger: 10.7 million tonne/year (17 EMGTA) max of 673 trains/week
Track quality	good

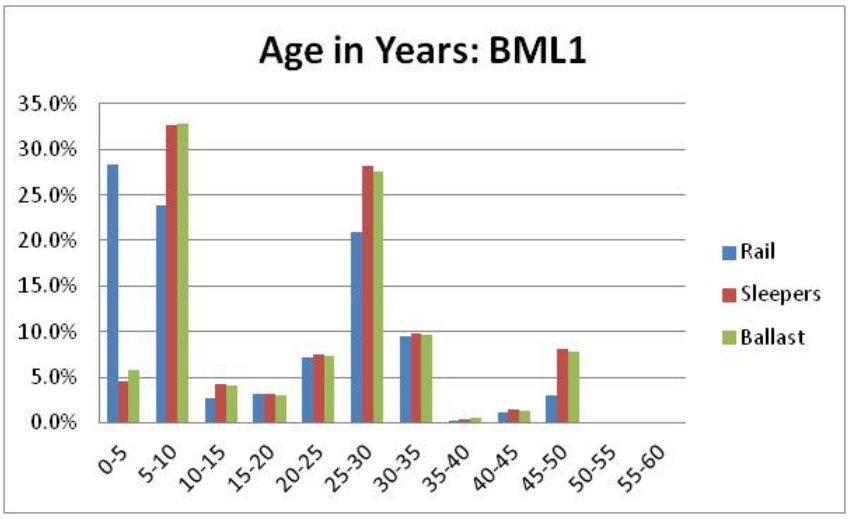


Figure 3.3 Age of rails, sleepers and ballast (BML1).

3.2.1.2 DCL Section from Didcott to Leamington Spa

This section of the route is summarised in Table 3.7. The age of rails, sleepers and ballast is indicated in Figure 3.4.

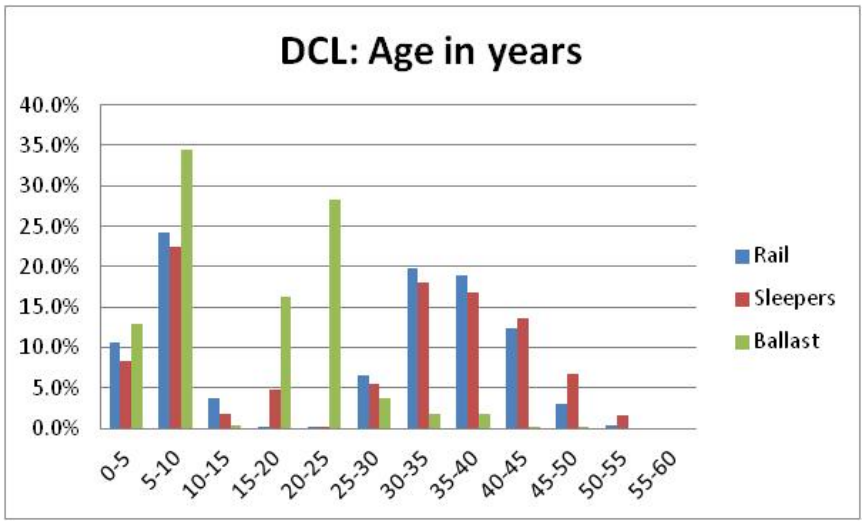


Figure 3.4 Age of rails, sleepers and ballast (DCL).

Table 3.7 Route section summary: DCL Section from Didcott to Leamington Spa

Route length	85.5 km out of 211.2 km
Track type	Double track, gauge: 1435 mm Ballast Not electrified;
Track geometry	Minimum Radius: 400 m Max Gradient: 0.89% Max Cant: 150 mm
Sleeper type	South of Anyho: 90% concrete; 9% hardwood; North of Anyho: 55% concrete; 43% hardwood
Rail size	72% is UIC54 equivalent; 16% is UIC 60.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 144 km/h
Ground Conditions	The escarpment and plateau of the Cotswold Hills dominates the north-west of Oxfordshire through which DCL passes. These are formed in Jurassic shallow coastal limestones, shales and sands. The plateau surface gradually shelves southwards to Oxford, which is floored by the heavy clays of the Jurassic Oxford Clay. South of Oxford there is a low ridge of Upper Jurassic limestones and clays.
Traffic	42% freight: 58% passenger Freight: 7.2million tonne/yr (13 EMGTA) 137 freight trains/week Passenger: 3.4-5.8 million tonne/year (5.1 -7.8 EMGTA) 315 to 745 trains/week
Track quality	good

3.2.2 Felixstowe to Nuneaton

This route is summarised in Table 3.8. The age of rails, sleepers and ballast is indicated in Figure 3.5.

Table 3.8 Route summary: Felixstowe to Nuneaton

Route length	256.6 km
Track type	Double track except for 13 km of single track at the port and 7 km of single track between Soham and Ely on SOB section, gauge: 1435 mm Ballast Electrified: the first 30 km is electrified at 25kV ac; but there is no power on the rest except for a short section of the East Coast Main Line that the route crosses
Track geometry	Minimum Radius: 400 m on SOB2 near Ely North Junction Max Gradient: 1.25% near Westerfield Junction near FEL 76.5 miles Max Cant: 153.7 mm on 1500 m curve on LTN1 81 miles
Sleeper type	Varies along the route with 30-40% concrete 50-60% hardwood; 10% softwood.
Rail size	From Felixstowe to Warrington 72% is UIC54 equivalent; 20% is UIC 60; 8% is unknown.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 216 km have a max speed of 120 km/h; 38 km at 96 km/h or less; 2.6 km at 140 km/h
Structures	From Felixstowe to Warrington: 39% of route is embankments; 32% cuttings; 1% viaducts; and 1.2 km of tunnels
Ground Conditions	Much of the route near Ely has clay and glacial deposits making it quite soft along the way and prone to weak embankments and soft spots. The route west of Peterborough includes more solid rock as it climbs up to Melton Mowbray
Traffic	Averages around 22% passenger; 78% Freight along the route; Intermodal wagons are currently 85% of total traffic near Felixstowe and 11% near Narborough. That is between 81 freight trains/week at Narborough and 303 freight trains / week at Trimley on FEL near Felixstowe. Freight tonnages: 5.2 – 16.5 million tonne/yr (or 8 – 26 EMGTA) Passenger tonnages: 0.6 – 1.9 million tonne/year (or 0.8 to 2.2 EMGTA) (or between 224 and 256 trains/week)
Track quality	good

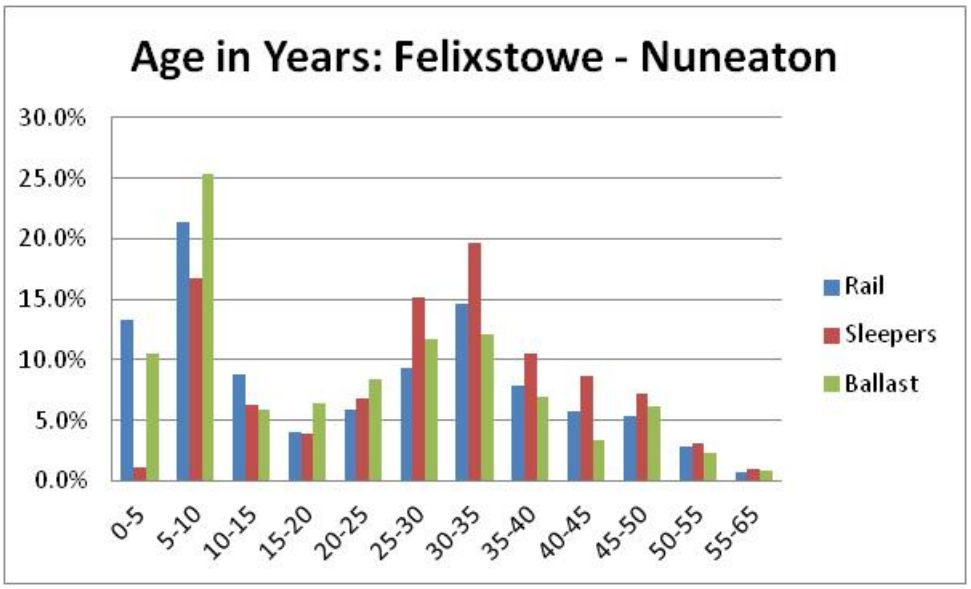


Figure 3.5 Age of rails, sleepers and ballast: Felixstowe to Nuneaton.

3.2.2.1 EMP Section from Ely to Peterborough

This problems facing this section of the route are the soft clay on which the embankments were built and the large number of level crossings. There are 7 Automatic Half Barrier (AHB) Crossings in the 12 km between Eastrea and March and at Ramsey Road there are two AHB crossings 300 m apart. Drainage problems require frequent maintenance and renewals. Work is to be carried out in 2012/13 on 40 m of embankment at Ramsey Road (EMP 93 m 32 ch) and 120 m of embankment at EMP 96 m 3 ch. Road embankments also suffer in these areas from weaknesses due to drainage problems and the soft clay ground.

This route section is summarised in Table 3.9. The age of rails, sleepers and ballast is indicated in Figure 3.6.

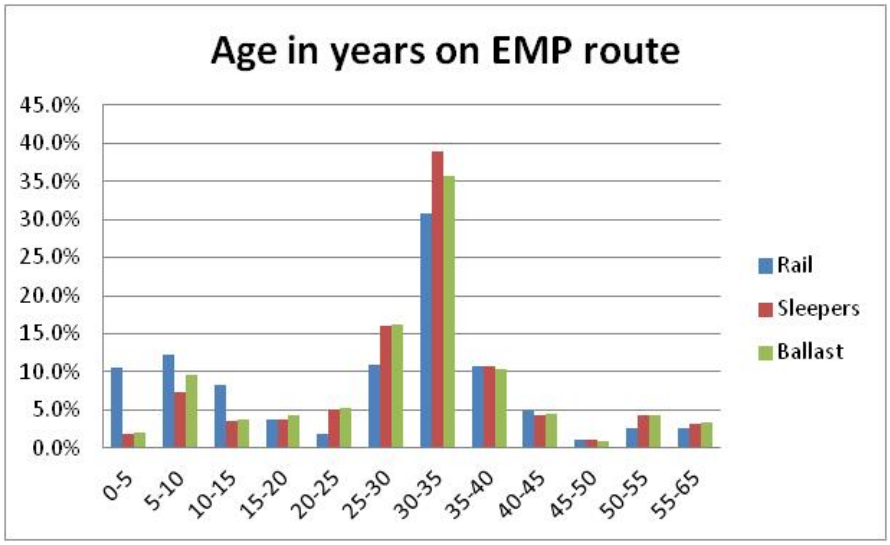


Figure 3.6 Age of rail, sleepers and ballast (EMP).

Table 3.9 Route section summary: EMP Section from Ely to Peterborough

Route length	45.4 km out of 256.6 km
Track type	Double track, gauge: 1435 mm Ballast Electrified: No
Track geometry	Minimum Radius: 600 m near March Max Gradient: 0.71% on the approach to Peterborough Max Cant: 106.9 mm at a 1000 m curve near Ely
Sleeper type	36% concrete; 54% hardwood; 10% softwood
Rail size	52% is UIC54 equivalent; 0% is UIC 60.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 120 km/h
Ground Conditions	Much of the route has clay and glacial deposits making it quite soft along the way and prone to weak embankments and soft spots.
Traffic	76% freight: 24% passenger Freight: 5.3 million tonne/yr (8.6 EMGTA) 100 freight trains/week Passenger: 1.6 million tonne/year (1.9 EMGTA) 256 passenger trains/week
Track quality	good

3.2.3 Nuneaton to Crewe – Slow line of the West Coast Main Line

There has been significant upgrade work on the West Coast Main Line over the last 10 years; this is shown by the high percentages of new rails, sleepers and ballast on this route (see Figure 3.7). The route is summarised in Table 3.10.

Table 3.10 Route summary: WCLM

Route length	101.6 km
Track type	Four-track but freight is on the two slow lines, gauge: 1435 mm Ballast Electrified: at 25kV ac overhead;
Track geometry	Minimum Radius: 600 m at 132 miles 35 ch near Trent Valley Junction Max Gradient: 0.56% between 150 milepost and 153 milepost Betley Road Max Cant: 154.4 mm on 1550 m curve on LEC2 112 miles 4 ch
Sleeper type	62% concrete 35% hardwood; 2% softwood.
Rail size	50% is UIC54 equivalent; 37% is UIC 60; 13% is unknown.
Maximum speed	Max Freight train speed: 120 km/h Max Passenger train speed: 120 km/h to 160 km/h on slow line
Structures	From Felixstowe to Warrington: 39% of route is embankments; 32% cuttings; 1% viaducts; and 1.2 km of tunnels
Ground Conditions	The geology of Staffordshire comprises a swathe of Permian and Triassic sandstones and mudstones, which occupy much of the central and southern part of Staffordshire and older Carboniferous rocks which outcrop in the Potteries area of Stoke and form the south-west corner of the Peak District. In south and east Staffordshire the landscape becomes more undulating and is dominated by arable farming on the fertile floodplain soils of the upper Trent River. To the North of this, Cheshire covers a boulder clay plain. The bedrock of the northern region is almost entirely Triassic sandstone.
Traffic	Averages around 14% passenger; 86% Freight along the route; Intermodal wagons are currently 58% of total traffic. Freight tonnage: 6.1 million tonne/yr (111 freight trains/week) (or 10.3 EMGTA) Passenger tonnage: 1.1 million tonne/year (or 1.8 EMGTA) (or 95 passenger trains/week)
Track quality	good

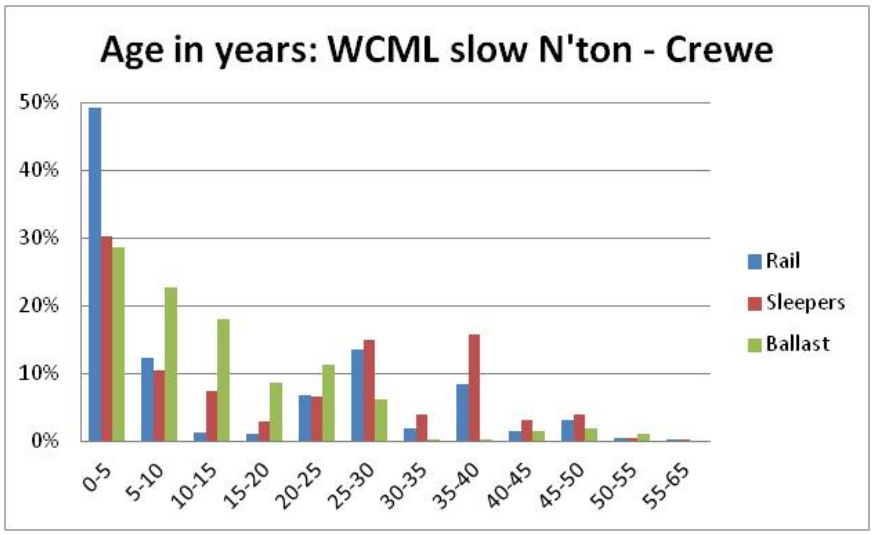


Figure 3.7 Age of rail, sleepers and ballast (Nuneaton to Crewe).

3.3 Conclusions from the U.K. Routes

The two U.K. routes consist of many different route sections crossing different types of traffic and a range of geological conditions. The overall U.K. railways defect statistics for Network Rail's 31,000 track-km or 16,000 route-km for 2010 are given in Table 3.11. These show that in many areas significant progress has been made in reducing track and infrastructure defects such as in Gauge Corner Cracking, earthworks and structures, and track faults (including rail breaks), and in reducing points defects.

Table 3.11 Defect statistics for Network Rail's 16,000 route-km for 2008-2010.

	National		
	this	previous	older
* Points failures	4628	5380	6513
Level crossing failures	1634	1681	1901
# TSRs due to Condition of track	549	778	998
# Track faults (including broken rails)	4084	4247	4608
# Gauge corner cracking	39	54	122
Civil Engineering structures, earthworks & buildings	253	322	386
Other infrastructure failures	3352	2923	3206
Track Patrols & related possessions	1733	2064	2458
Mishap - Infrastructure causes	1602	1342	1263
Fires starting on Network Rail infrastructure	231	227	175
OLE/Third Rail faults	1070	1104	1080
Signal failures	4290	4349	5365
* Track circuit failures	3756	3981	4539
* Axle Counter failures	575	564	810
Signalling system and Power supply failures	3551	3837	3485
Other signal equipment failures	1421	1470	1414
Telecoms failures	1041	1056	1170
Cable faults (Signalling & Coms)	472	469	458
Bridge strikes	944	1068	974

Key issues identified for the freight traffic along the two strategic freight routes have been:

- Soft spots and embankment destabilisation due to water and poor sub-structure with clay and sand along parts of the Anglian route– some key sections of the EMP section are to be included in renewals projects by 2014 but tamping of soft spots along the routes can be a very expensive and ineffective remedy. Recent studies have shown how cost effective stabilising the ballast and the track foundations can be.
- Frequency of level crossings, such as Automatic Half barriers along rural stretches of the route between Felixstowe and Nuneaton.
- The growth of rolling contact fatigue cracks in rails through the loading by freight trains where the cracks have initially been initiated by passenger trains – between Southampton and Basingstoke. Projects have been carried out to install heat-treated MHH rail and to improve the dynamic characteristics of the passenger trains. Much work has also been carried out to refine the grinding strategy to improve the transverse rail profile, remove localised misalignment at welds and other track features and remove RCF defects. The above statistics show that significant improvements have been achieved in recent years.
- Higher levels of rail defects due to having older rails on lines which have been subject increases in traffic in recent years – renewals programmes have been replacing older rails on lines where capacity has increased.
- Single track sections on the Felixstowe to Nuneaton route: 13 km at the port and 7 km between Soham and Ely. There are plans in place to double track this latter section which would provide an essential increase of capacity and allow a service to continue whilst maintenance was taking place on one line.

4. BULGARIAN ROUTE

4.1 Overview

The selected route in Bulgaria runs between Kalotina, at the Serbian border, to Svilengrad, at the Turkish border.

There are two marshalling yards on the route, one at Podujane by Sofia (see Figure 4.1) and one at Plovdiv (see Figure 4.2). Domestic rail freight has been dying out in recent years, and Podujane is no longer operational, although a feasibility study is under way to establish an intermodal yard near Sofia. At Plovdiv, 6-7 trains are received each day for disassembly in the hump yard. Some additional trains are received, and disassembled by shunting, and 11-12 trains are assembled each day. The marshalling yard in Plovdiv is well-sited for intermodal activity, and a feasibility study is being carried out regarding this.

The route sees international container traffic (27 in each direction, each day; see Table 3.4 in Deliverable D1.2). The possibility of a new rail bridge over the Danube at Vidin in the north-west is being studied, and a decision is expected by end-2012. If this goes ahead, this will open a direct route between Sofia and Budapest, crossing Romania in the west and avoiding Buchurest. Although the quality of the infrastructure is poor along this route, the traffic through Serbia is expected to diminish significantly.

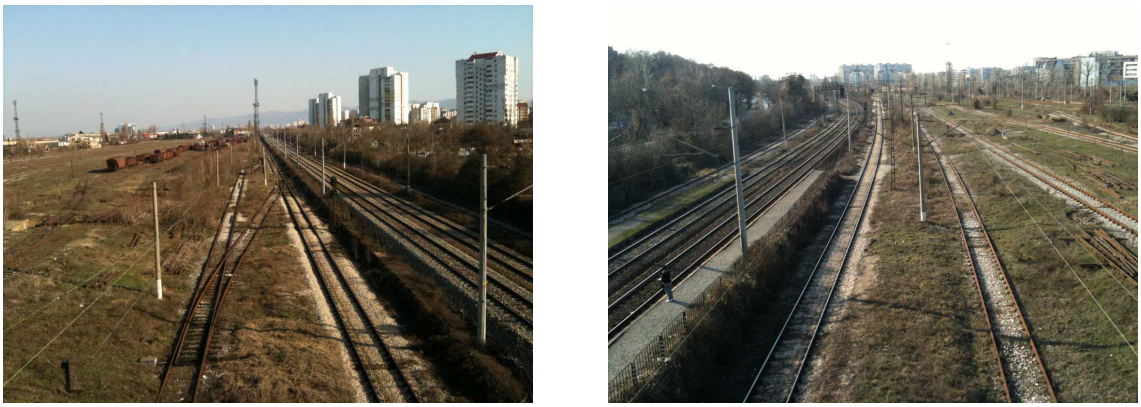


Figure 4.1 Podujane marshalling yard, Sofia, no longer active.

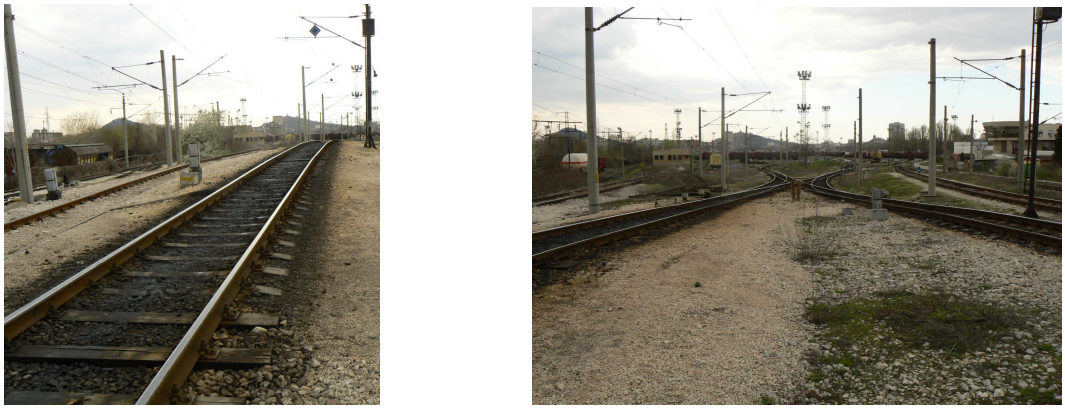


Figure 4.2 Plovdiv marshalling yard. Left: View of the hump. Right: View of the assembly area from the hump.



Figure 4.3 Container traffic at Dragoman (left) and Pazardjik (right), including tanks in intermodal frames.



Figure 4.4 Container traffic at Dragoman: Flatbed wagons with stanchions carrying two containers.



Figure 4.5 Locomotive and coaches at Ihtiman.

Examples of containers and tanks in intermodal frames can be seen in Figure 4.3, and a flatbed with stanchions holding two short containers can be seen in Figure 4.4. Just discernable in Figure 4.3 is a track maintenance / renewal vehicle; sections of assembled track are piled at various locations including Pazardjik station.

The route is mixed traffic, and a typical passenger train can be seen in Figure 4.5, although there are a number of newer vehicle types operating on the line also.

Kalotina is a village close to the Serbian border and the border control point. Freight trains are stopped at nearby Dragoman for customs checks. Kalotina station itself is on a branch line north of the main route (see Figure 4.6). The branch line leads to a coal mine; the ore trains travel from Stanjantsi through Kalotina to join the main line at Dragoman until Volujak where they head south to Bobov Dol.

Ballasted track on the approach to Dragoman, and the steel viaduct where the mainline crosses the road between Dragoman and the Serbian border, can be seen in Figure 4.7. The route between Dragoman and the Serbian border is characterised by tight curves, down to 300 m radius, and gradients as steep as 20‰ (see Table 3.6 in Deliverable D1.2).



Figure 4.6 Kalotina station on the branch line to the coal mine.



Figure 4.7 Left: Stretch of track west of Dragoman. Right: Steel bridge between Dragoman and the Serbian border.

The route is undergoing extensive renewal. The older sections track on the mainline have concrete sleepers, while the branch line has wooden sleepers (see Figure 4.8). Wooden sleepers are sometimes used on the mainline track, usually where there is an unusual feature, such as a joint, or a switch and crossing, or a stream running under the railway line. Four-bolt fish-plated joints are supported by a double wooden sleeper; in newer jointed track sections, a six-bolt fish plate is used to join rails between sleepers. Ballast is typically limestone since this is locally available. In newer sections, the Vossloh W 14 rail clamp (see Figure 4.9) is used instead of the traditional tie-plate fastening with pressing clamp.

Where track is being renewed, tougher ballast material (e.g., granite) has been specified, and the track is laid to specification for CWR. The rail section is UIC 60 in plain line and UIC 62 in S&C. Concrete sleepers of length 2600 mm are spaced at 600 mm (1680 sleepers / km), and the rail fastened using Vossloh W 14 rail clamps.



Figure 4.8 Track with 'tie-plate fastening with pressing clamp': on wooden sleepers at Kalotina on the branch line (left), and on concrete sleepers at Ihtiman (right).



Figure 4.9 Vossloh W 14 rail clamps on concrete sleepers west of Dragoman (left) and at Pazardjik (right).

The line from Plovdiv to Svilengrad is undergoing renewal, and electrification should be completed by 2015. Currently the line is single track. The new line will be double track, and work to date has progressed a few kilometres east of Sadovo. (See Figure 4.10.)



Figure 4.10 Left: Newly laid double track with CWR and electrification at Sadovo east of Plovdiv. Right: Close-up of welds and Vossloh W 14 rail clamps.

4.2 Section Characteristics

The Bulgarian route has been split into ten sections. The characteristics of each section are summarised in the following tables.

Table 4.1 Bulgarian route section characteristics: Kalotina Zapad – Slivnica.

From	Kalotina-Zapad	
To	Slivnica	
Maintenance problem	*Type*	Rockfall between Kalotina and Dragoman
Track type	*Single or double track, gauge*	Single
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	Several tight curves, approx. 300 m radius
	Gradient	Very steep, exceeding 2% in places
	Cant	-
	Jointed / CWR	CWR between Aldomirovci and Slivnica
	Signalling	Relay semi-automatic block system; colour light
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4) with some wooden sleepers
Rail size	*UIC 54, 60*	UIC 49 (older track); UIC 60 (renewed track)
Maximum speed	*km/h*	60-70 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	26-27 international and 2-4 other (each way)
	Number of passenger trains	5 international and 6-7 other (each way)
Track quality		Poor between Kalotina and Dragoil, and on the third line at Dragoman station
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Mechanized renewal in 2009 between Kalotina-Zapad and Dragoman; renewed in 1983 between Dragoman and Slivnica

Table 4.2 Bulgarian route section characteristics: Slivnica – Volujak.

From	Slivnica	
To	Volujak	
Maintenance problem	*Type*	
Track type	*Single or double track, gauge*	Single, 1435 mm, 22.5 t axle load
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	725 m minimum
	Gradient	Less than 1.1%
	Cant	-
	Jointed / CWR	CWR between Slivnica and Petarch
	Signalling	Relay semi-automatic block system; colour light
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4) with some wooden sleepers
Rail size	*UIC 54, 60*	UIC 49
Maximum speed	*km/h*	80 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	27 international and 4 other (each way)
	Number of passenger trains	5 international and 6-7 other (each way)
Track quality		-
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed in 1983

Table 4.3 Bulgarian route section characteristics: Slivnica – Sofia.

From	Slivnica	
To	Sofia	
Maintenance problem	*Type*	
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	550 m minimum
	Gradient	Less than 1%
	Cant	-
	Jointed / CWR	Jointed
	Signalling	Relay semi-automatic block system; colour light
Sleeper type	*Timber, concrete, steel*	Concrete (CT-4T)
Rail size	*UIC 54, 60*	UIC 49
Maximum speed	*km/h*	70 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	20-21 international (each way) and 6 other (one-way)
	Number of passenger trains	5 international and 17-18 other (each way)
Track quality		-
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed in 1961

Table 4.4 Bulgarian route section characteristics: Sofia – Podujane.

From	Sofia	
To	Podujane	
Maintenance problem	*Type*	
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	650 m minimum
	Gradient	Less than 1%
	Cant	-
	Jointed / CWR	Jointed
	Signalling	Direct connection with interlocking; colour light; cab radio
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4) with some wooden sleepers.
Rail size	*UIC 54, 60*	UIC 49
Maximum speed	*km/h*	65 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	20-21 international and 2-6 other (each way)
	Number of passenger trains	4 international and 21-22 other (each way)
Track quality		-
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed in 1980

Table 4.5 Bulgarian route section characteristics: Podujane – Elin Pelin.

From	Podujane	
To	Elin Pelin	
Maintenance problem	*Type*	Switches in poor condition
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	1000 m minimum
	Gradient	Less than 1%
	Cant	-
	Jointed / CWR	Predominantly CWR
	Signalling	Automatic block system; colour light; cab radio
Sleeper type	*Timber, concrete, steel*	Concrete (predominantly CT-4, some CT-6)
Rail size	*UIC 54, 60*	UIC 49
Maximum speed	*km/h*	70-80 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	19 international and 4-6 other (each way)
	Number of passenger trains	4 international and 21-22 other (each way)
Track quality		CWR in bad technical condition between Kasichene and Elin Pelin
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed in 1978-79

Table 4.6 Bulgarian route section characteristics: Elin Pelin – Septemvri.

From	Elin Pelin	
To	Septemvri	
Maintenance problem	*Type*	Sleepers in bad technical condition between Verinsko and Ihtiman; 300 m curves with short transition curves between Sestrimo and Belovo; sliding of rocks together with trees and shrubs after weathering and self-excavating of boulders between Kostenec and Sestrimo
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	275 m minimum, several less than 500 m
	Gradient	Very steep, less than 2.5%
	Cant	-
	Jointed / CWR	Half jointed, half CWR
	Signalling	Automatic block system; colour light; cab radio
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4, CT-4T, CT-6) with some wooden sleepers.
Rail size	*UIC 54, 60*	UIC 49 (older track); UIC 60 (renewed track)
Maximum speed	*km/h*	50-80 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	19 international and 3-4 other (each way)
	Number of passenger trains	4 international and 19-20 other (each way)
Track quality		CWR in bad technical condition between Elin Pelin and Pobit Kamak
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Previously renewed in 1978-80, some stretches rehabilitated in 1989-91; some stretches currently undergoing mechanized renewal

Table 4.7 Bulgarian route section characteristics: Septemvri – Plovdiv.

From	Septemvri	
To	Plovdiv	
Maintenance problem	*Type*	Dirty ballast in Septemvri station
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	1500 m minimum
	Gradient	Less than 1%
	Cant	-
	Jointed / CWR	CWR
	Signalling	Automatic block system; colour light; cab radio
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4) with some wooden and MP 94 sleepers.
Rail size	*UIC 54, 60*	UIC 49 (older track); UIC 60 (renewed track)
Maximum speed	*km/h*	80 km/h (60 km/h between Ognjanovo and Stambolijski)
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	19 international and 3-5 other (each way)
	Number of passenger trains	4 international and 24 other (each way)
Track quality		Poor between Pazardjik and Stambolijski
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed or rehabilitated since 1993; currently being upgraded

Table 4.8 Bulgarian route section characteristics: Plovdiv – Krumovo.

From	Plovdiv	
To	Krumovo	
Maintenance problem	*Type*	Dirty ballast and poor technical condition of sleepers east of Plovdiv
Track type	*Single or double track, gauge*	Double
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	25 kV / 50 Hz / 500 A
Track geometry	*Radius*	400 m minimum
	Gradient	Less than 0.25%
	Cant	-
	Jointed / CWR	Jointed
	Signalling	Automatic block system; colour light; cab radio
Sleeper type	*Timber, concrete, steel*	Predominantly concrete (CT-4) with some wooden sleepers.
Rail size	*UIC 54, 60*	UIC 49
Maximum speed	*km/h*	80 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	18-19 international and 1-2 other (each way)
	Number of passenger trains	4 international and 11-13 other (each way); 17 additional suburban trains between Plovdiv and Por
Track quality		
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Rehabilitated in 1993

Table 4.9 Bulgarian route section characteristics: Krumovo – Dimitrovgrad.

From	Krumovo	
To	Dimitrovgrad	
Maintenance problem	*Type*	Poor subgrade ('railroad bed') between Jabalkovo and Dimitrovgrad
Track type	*Single or double track, gauge*	Double between Katunica and Popovica
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	Electrification by end-2015
Track geometry	*Radius*	100 m between Skobelovo and Jabalkovo; 400 m minimum elsewhere
	Gradient	Less than 1%
	Cant	-
	Jointed / CWR	Jointed (renewal and upgrade to CWR in progress)
	Signalling	Automatic block system with axle-counters; colour light
Sleeper type	*Timber, concrete, steel*	Concrete (CT-4)
Rail size	*UIC 54, 60*	UIC 49 (older track); UIC 60 (renewed track)
Maximum speed	*km/h*	120 km/h between Parvomaj and Dimitrovgrad; 80 km/h elsewhere
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	18-19 international and 1 other (each way)
	Number of passenger trains	4 international and 11-13 other (each way)
Track quality		
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed or rehabilitated since 1986; currently being renewed and electrified

Table 4.10 Bulgarian route section characteristics: Dimitrovgrad – Svilengrad.

From	Dimitrovgrad	
To	Svilengrad	
Maintenance problem	*Type*	Bad technical condition of sleepers in Simeonovgrad station; a flat 350 m radius curve in Simeonovgrad station
Track type	*Single or double track, gauge*	Single
	Gauge, axle load	1435 mm, 22.5 t axle load
	Ballast, embedded	Ballast
	Electrified	Electrification by end-2015
Track geometry	*Radius*	345 m minimum; several at 350 m
	Gradient	Less than 1.25%
	Cant	-
	Jointed / CWR	Half jointed, half CWR
	Signalling	Relay semi-automatic block system; colour light
Sleeper type	*Timber, concrete, steel*	Concrete (CT-4)
Rail size	*UIC 54, 60*	UIC 49 (older track); UIC 60 (renewed track)
Maximum speed	*km/h*	80 km/h
Geological structure	*Embankment, tunnel, bridge*	
Traffic	*Number of freight trains*	22-23 international and 2 other (each way)
	Number of passenger trains	4 international and 4 other (each way)
Track quality		
Maintenance history	*Sleepers change* *Rail change* *Tampers (levelling gravel)* *Investments*	Renewed or rehabilitated since 1990; currently being renewed and electrified

4.3 Conclusions of Bulgarian Route

The sections between Plovdiv and Svilengrad are undergoing major renewal, upgrade and electrification[2]. The time-scale for this work is still unclear, but electrification should be complete by the end of 2015. The railway on the Turkish side is being upgraded for high-speed passenger service, and the railway was closed for one month in early 2012 as a consequence of this upgrade.

The route between Septemvri and the Turkish border is seeing extensive modernisation. The railway follows the River Maritsa closely and can be at risk when flooding occurs; the section between Xarmanli and Ljubimec was damaged in early 2012 when the nearby reservoir broke. Earthquakes present another occasional hazard.

The section between Elin Pelin and Septemvri is problematic. This section is characterised by steep gradients and tight curves, and unstable ground conditions.

Not all traffic to and from Turkey goes to Sofia. Corridor IX is a north-south railway route between Greece and Russia via Bulgaria, Romania (passing through Bucharest), Moldova and the Ukraine. This crosses the Bulgarian route (Corridor X / IV) at Dimitrovgrad, half-way between Plovdiv and the Turkish border. If the Calafat (Romania) – Vidin (Bulgaria) rail/road bridge over the Danube is built[3], this will provide an alternative path for Corridor IV from Budapest to Sofia (possibly by end-2013); this will bypass Bucharest, and take traffic away from Corridor X through Serbia.

The demand for traditional freight services has been dying out over the past twenty years[4]. The marshalling yard at Poduyane has ceased operation, and the yard at Plovdiv is used at only a fraction of its capacity. There is, however, an opportunity to invest in intermodal yards in Sofia and Plovdiv.

[2] 'Plovdiv-Svilengrad Railway Electrification and Upgrading of Corridors IV and IX,' http://www.plovdivsvilengradrailway.com/.
[3] See, e.g., http://www.hprconsult.com/vidin-calafat-case-study.php.
[4] There is, however, a possibility that the route from Kremikovski to Atolovo will be upgraded for 23 tonne axle load for ore wagons.

5. ECONOMICS: DATA FOR LCC/RAMS

5.1 Data collection methodology

A key element of the overall assessment of innovations proposed in the SustRail project is the assessment of their economic impact on the whole system (i.e., rail infrastructure, freight operations and passenger operations) and on all major system stakeholders. This will require comparative assessment of existing and novel vehicles in terms of their whole system economic impacts.

SustRail will conduct these analyses in Work Package 5, initially as part of an iterative process in which potential rail freight innovations will be proposed and screened for viability, as part of the project's overall method of identifying the best innovations, and subsequently to provide a comprehensive economic assessment and business case for those innovations that are finally selected. For such analyses, a variety of relevant approaches will be used, most notable amongst these being the Life Cycle Costing (LCC) approach and an assessment of Reliability, Availability, Maintainability and Safety (RAMS). However there will also be a comprehensive economic evaluation of the impacts of the innovation on each key stakeholder group.

RAMS assessment is fundamental to the evaluation, and information on how RAMS is conducted has been set out in SustRail Deliverable D1.3. Essentially, both LCC and RAMS analyses need to take into consideration impacts throughout the entire life cycle of the developed system 'from cradle to grave' (i.e., from conception and design, through manufacturing, testing and operation until end-of-life, disposal or recycling). In SustRail, LCC and RAMS will be conducted at an appropriate level of detail and disaggregation, and will as far as possible adhere to the EN 50126-1:1999 standard *"Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)"*. This standard entails that RAMS assessment operates at various distinct levels:

- System level (locomotive, wagon)
- Sub-system level (e.g., bogie, braking system, bodywork, engine, etc.)
- Component level (frame, wheels, springs, etc.)

For the three case study routes, an initial assessment has been conducted to determine the general availability and accessibility of relevant data. Detailed collection of data items was not felt to be advisable until Work Packages 3 and 4, relating to vehicle and track innovations respectively, are sufficiently under way such that initial suggestions for innovations are being put forward and more precise items of data required can be determined. By this stage, Work Package 5 will also have commenced and hence Work Packages 3, 4 and 5 will then be able to co-ordinate to provide the assessments of the various innovations.

The three countries in which the case study routes are located have different organisational structures and levels of vertical separation, and relevant data (if and when available) are held within diverse organisations within the rail industry, such as infrastructure operators, train operating companies, maintenance providers, wagon manufacturing and leasing companies and regulatory bodies.

The national rail infrastructure organisations are the primary points of contact within SustRail for the purposes of obtaining data. While these organisations do not themselves hold all data that will be required, by the nature of their responsibilities, their operations and their relationships with other industry stakeholders, they have a broad knowledge of which other organisations hold such data. The infrastructure organisations were therefore asked to provide information regarding availability, ownership and accessibility of the data required for

RAMS, LCC and economic evaluation of the whole system effects (infrastructure, freight operations and passenger operations), pertaining to their own country.

The responses identify that much of the data is held by a relevant organisation in the rail industry, or else that sufficient information will be available to build up some form of modelled cost estimate for the parameters that will be required. The precise location of data varies and, as might be expected, is particularly widely dispersed in countries such as the UK where vertical separation of the rail industry is more advanced. In some instances, data may be held by more than one organisation. Where the infrastructure organisation itself does not hold the data, it is not always clear at this stage how much detail and disaggregation of data can be obtained, and further investigation into this will be required. Apart from the UK case, it appears that systematic data on rail infrastructure network reliability may be difficult to obtain, as may data on specific aspects of rail environmental performance. In Work Package 5, SustRail will need to engage with a wider range of stakeholders in each country beyond the infrastructure organisation.

Table 5.1, Table 5.2 and Table 5.3 provide overviews of the availability and ownership of data required for RAMS, LCC and economic evaluations, for infrastructure operations, freight operations and passenger operations respectively, for each of the 3 case studies / countries under investigation.

Table 5.1 Availability of data for LCC/RAMS: Infrastructure

INFRASTRUCTURE		BULGARIA	SPAIN	UK
RELIABILITY				
	Failure rates	X	X	O
	Critical items and functions	X	X	Y
	Boundary conditions	X	X	Y
AVAILABILITY		Y	Y	V
MAINTENANCE				
	Preventive (either condition-based or time-based)	Y	Y	Y
	Corrective	Y	Y	Y
SAFETY				
	Incident numbers	V	Y	V
	Accident numbers	V	Y	O
LCC COST DRIVERS				
	R&D	Y	M	Y
	Investments/disposals	Y	M	V
	Maintenance costs – preventive	Y	M	V
	Maintenance costs – corrective	Y	M	V
	Operating costs	Y	M	V
REVENUE AND USER BENEFIT DRIVERS				
	Track Access Charges	Y	X	Y
	Service quality	Y	X	O
	Capacity	Y	X	Y
	Availability	X	X	O
	Demand	Y	X	O
	'Zero state' revenue	Y	X	Y
ENVIRONMENTAL PERFORMANCE				
	Noise	U	X	V
	CO_2	U	X	V

CODES

Y Infrastructure Organisation has the data
T Infrastructure Organisation advises that train operating companies possess the data
M Infrastructure Organisation advises that train operating companies *may* have the data
O Infrastructure Organisation advises that another organisation possesses the data
P Infrastructure Organisation advises that another organisation *may* have the data
X Infrastructure Organisation understands that the data does not exist
U unknown / not ascertained to date
V more than one organisation holds relevant data

Suffix /I indicates that whilst some data exists, it may be incomplete

Table 5.2 Availability of data for LCC/RAMS: Freight operations

FREIGHT OPERATIONS		BULGARIA	SPAIN	UK
RELIABILITY				
	Failure rates	M	P	V
	Critical items and functions	M	P	V
	Boundary conditions	M	P	V
AVAILABILITY		V	P	V
MAINTENANCE				
	Preventive (either condition-based or time-based)	M	P	V
	Corrective	M	P	V
SAFETY	Incident numbers	V	P	O
	Accident numbers	V	P	V
LCC COST DRIVERS				
Technical	Track standards	Y	P	V
	Maintenance regime	T	P	V
	Speeds	T	P	V
	Freight flows	T	P	V
	Timetable	V	P	Y
	Rolling stock	T	P	Y
	Train lengths	V	P	V
	Axle loads	V	P	Y
	Track/train interface	Y	P	V
	Technologies employed	V	P	V
Economic	R&D	T	P	V
	Investments/disposals	T	P	V
	Maintenance costs – preventive	U	P	V
	Maintenance costs – corrective	U	P	V
	Operating costs	T	P	V
REVENUE AND USER BENEFIT DRIVERS				
	Track Access Charges	V	P	Y
	Service quality	U	P	V
	Capacity	Y	P	V
	Availability	U	P	V
	Demand	T	P	V
	'Zero state' revenue	T	P	T
ENVIRONMENTAL PERFORMANCE				
	Noise	U	P	V
	CO_2	U	P	V

Y Infrastructure Organisation has the data
T Infrastructure Organisation advises that train operating companies possess the data
M Infrastructure Organisation advises that train operating companies *may* have the data
O Infrastructure Organisation advises that another organisation possesses the data
P Infrastructure Organisation advises that another organisation *may* have the data
X Infrastructure Organisation understands that the data does not exist
U unknown / not ascertained to date
V more than one organisation holds relevant data

Suffix /I indicates that whilst some data exists, it may be incomplete

Table 5.3 Availability of data for LCC/RAMS: Passenger operations

PASSENGER OPERATIONS		BULGARIA	SPAIN	UK
RELIABILITY				
	Failure rates	U	P	V
	Critical items and functions	U	P	V
	Boundary conditions	U	P	V
AVAILABILITY		V	P	V
MAINTENANCE				
	Preventive (either condition-based or time-based)	U	P	V
	Corrective	U	P	V
SAFETY				
	Incident numbers	V	P	O
	Accident numbers	V	P	V
LCC COST DRIVERS				
Technical	Track standards	Y	P	V
	Maintenance regime	Y	P	V
	Speeds	Y	P	V
	Timetable	V	P	Y
	Rolling stock	T	P	Y
	Track/train interface	Y	P	V
	Technologies employed	V	P	V
Economic	R&D	T	P	V
	Investments/disposals	T	P	V
	Maintenance costs – preventive	U	P	V
	Maintenance costs - corrective	U	P	V
	Operating costs	T	P	V
REVENUE AND USER BENEFIT DRIVERS				
	End User Pricing	V	P	V
	Service quality	U	P	V
	Capacity	Y	P	V
	Availability	U	P	V
	Demand	T	P	V
	'Zero state' revenue	T	P	T
ENVIRONMENTAL PERFORMANCE				
	Noise	U	P	V
	CO_2	U	P	V

Y Infrastructure Organisation has the data
T Infrastructure Organisation advises that train operating companies possess the data
M Infrastructure Organisation advises that train operating companies *may* have the data
O Infrastructure Organisation advises that another organisation possesses the data
P Infrastructure Organisation advises that another organisation *may* have the data
X Infrastructure Organisation understands that the data does not exist
U unknown / not ascertained to date
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Suffix /I indicates that whilst some data exists, it may be incomplete

6. CONCLUSIONS

The main track problems (reported at InnoTrack workshops of Infrastructure Maintenance Engineers [7]) based on frequency and listed in order of importance are:

- Track: bad track geometry
- Rail: cracks and fatigue
- S+C: switch wear
- Substructure: unstable ground
- Joints: isolation joint failure
- Rail: corrugations
- Rail: wear
- Structures: major line closures
- Fasteners: worn/missing pads
- Sleepers: renewal optimisation
- Culverts/pipes: flooding
- Ballast: stone spray
- Ballast: ballast wear
- Rail: low friction/adhesion
- Joints: weld quality
- S+C: common crossings
- S+C: Manganese crossings
- S+C: geometry maintenance
- S+C: loss of detection

Many of these have an impact on the selected SustRail routes.

- **Drainage / flooding:** Flooding can have a major impact on the substructure, causing major changes to the track geometry; problems with drainage can create minor but persistent problems, leading to corrosion of track and components and erosion of embankments.
- **Environment:** Unstable ground in cuttings, ground support and surrounding slopes (rockfall) creates a hazard; earthquakes magnify this risk.
- **Single track:** Where traffic in both directions shares a single track, this creates a capacity bottleneck. Also, the damage rate is higher so that maintenance is required more frequently, and there's no second track for the traffic to use during maintenance.
- **Old infrastructure:** Old infrastructure needs more frequent maintenance, and may lead to permanent speed restrictions. Examples: bridges; switches and crossings (S&C) on wooden sleepers; fish plates.
- **Geometry:** In mountainous regions, and sometimes in urban environments, there may be severe constraints on the track geometry, leading to high gradients, tight curves, possibly even flat curves or curves with short transitions. This leads to permanent speed restrictions and an increased rate of track faults.
- **Track faults:** Examples: wear, rolling contact fatigue (RCF), rail breaks, poor rail profile, misaligned welds, and poor technical condition of sleepers, fastenings, S&C and continuously welded rail (CWR).
- **Subgrade:** Limestone ballast degrades relatively fast and increases the rate of ballast contamination; vegetation and poor drainage also accelerate ballast contamination.

- **Signalling:** Inappropriate stopping locations, for example on steep gradients, lead to increased locomotive traction and a higher rate of track defects.
- **Level crossings:** Level crossings present a general hazard.

Many of the above relate to the track substructure. In the UK, for example, on the 664 km of track where the earthworks are categorised as 'poor', there is an estimated 1 failure per 25 km per year which account for 90% of all earthwork failures; 'marginal' earthworks have an estimated 1 failure per 270 km per year and account for 9% of all earthwork failures – half of these are due to wash out and drainage problems. Although tamping can correct track geometry temporarily in such cases, subsequent degradation can be rapid; recent studies have shown how cost-effective stabilising the ballast and the track foundations can be.

Clearly there is a strong argument for upgrading old infrastructure and moving from single to double track; renewal costs will be high, but subsequent maintenance costs will be significantly lower. The increase in system capacity and removal of speed restrictions are additional benefits.

Most importantly, track geometry and track components are a major source of faults, particularly in S&C, tight curves and steep gradients, and there is scope to improve the materials, designs and monitoring and inspection technologies.

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