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**Rail network resilience and operational responsiveness during  
unplanned disruption: A rail freight case study  
Woodburn, A.G.**

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1 **Abstract**

2

3 This paper focuses on the resilience of rail freight operations when affected by extreme  
4 weather events. Such events, most likely linked to climate change, are becoming more  
5 common and it is vital to mitigate their effects on freight transport activity. Based on a British  
6 case study of rail network disruption resulting from a key line closure in early-2016, the  
7 analysis considers the impacts on rail freight service provision and the wider supply chains.

8

9 Following a review of the relevant literature, the case study is analysed using data from a  
10 combination of sources including an annual rail freight database, open access real-time train  
11 running data, observation surveys and stakeholder interviews. This reveals widespread  
12 consequences of the disruption, with fewer freight trains operated than normal, and longer and  
13 less punctual journeys for those which ran. However, despite the considerable disruption  
14 during the period of the line closure itself, there has been no discernible long-term impact on  
15 the rail freight flows which were impacted by the closure. The insight provided by the analysis  
16 is used to make a series of recommendations to the rail industry and policy makers.

17

18

19 **Keywords:** rail freight; weather-related disruption; transport network resilience; disruption  
20 impact analysis

## 21 1. Introduction

22

23 Transport infrastructure plays a fundamental role in facilitating the movement of people and  
24 goods but routes and nodes can suffer from planned or unplanned unavailability, disrupting  
25 transport flows and causing economic and social problems. Extreme weather events, most  
26 likely linked to climate change, are becoming more prevalent across Europe (and elsewhere)  
27 (IPCC, 2013), with consequent disruption to transport activity. Despite this, transport network  
28 resilience is insufficiently understood. Jaroszweski et al. (2010) found that surprisingly little  
29 research had been conducted, in the United Kingdom (UK) at least, investigating transport  
30 vulnerabilities to climate change.

31

32 This paper is based on a case study from 2016 of the lengthy unplanned closure of a key rail  
33 freight route in Britain. The aim of the paper is to analyse the rail industry's collective  
34 responsiveness and to assess the impacts that the closure had on the rail freight flows that  
35 were affected. Rail has a 9% share of the freight market in Britain (DfT, 2018) and it is  
36 estimated that goods valued at more than £30 billion per annum are moved by rail, including  
37 considerable volumes of time-sensitive and/or high-value traffics such as automotive products  
38 and consumer goods which require high levels of service performance (RDG, 2018). Despite  
39 being focused on a single British case study, the findings offer insight more generally since  
40 the impacts of rail network vulnerabilities on freight (and wider supply chain) activity are  
41 inadequately understood. A global survey by BCI (2018) found that adverse weather, supply  
42 chain disruption and transport network disruption were all ranked in the top 10 of 30 specified  
43 organisational threats. The case study (set out in Section 4) combines these three factors,  
44 with the specific research questions (RQs) addressed in this paper being:

45

- 46 • RQ1: To determine the impacts of the line closure on rail freight traffic levels and  
47 capability
- 48 • RQ2: To assess the wider supply chain implications of the line closure

- 49       • RQ3: To make recommendations for improving the resilience of rail freight operations,  
50           on the basis of the evidence from the case study

51

52 The paper is structured as follows. Section 2 reviews the relevant literature, highlighting the  
53 importance of the topic and the need for further empirical research such as that presented in  
54 this paper. Section 3 provides details of the research methods adopted to satisfy the research  
55 aim, followed in Section 4 by contextual information regarding the case study upon which the  
56 paper is focused. Section 5 presents the relevant data for RQ1, then Section 6 addresses  
57 each of the three research questions in turn. Section 7 concludes the paper with a discussion  
58 of the wider implications of the research findings.

59

60

## 61 **2. Literature review**

62

63 This review of the relevant literature starts by contextualising the topic of freight transport  
64 resilience (Section 2.1). Section 2.2 then concentrates on transport network resilience for rail  
65 freight operations, followed in Section 2.3 by an assessment of the growing body of literature  
66 demonstrating the vulnerability of transport infrastructure and operations to extreme weather  
67 events, the specific focus of this paper's subsequent original analysis.

68

69

### 70 *2.1 What is freight transport resilience?*

71

72 In broad terms, resilience is defined as 'the capacity to recover quickly from difficulties' (Oxford  
73 Dictionaries, n.d.). In the transport literature, the investigation of resilience is typically related  
74 to network (or system) vulnerabilities and the manner in which consequent unplanned  
75 disruption is handled (see, for example, Fikar et al., 2016; Mattsson and Jenelius, 2015;  
76 Tamvakis and Xenidis, 2012). In this context, the British government has defined resilience

77 as 'the ability of the transport network to withstand the impacts of extreme weather, to operate  
78 in the face of such weather and to recover promptly from its effects' (DfT, 2014a, 8).

79

80 Freight transport resilience is a prime consideration for well-functioning supply chains and, by  
81 extension, the economy of a country or region. Low resilience inhibits those providing freight  
82 services from satisfying customer requirements (Chen and Miller-Hooks, 2012), with  
83 potentially far-reaching economic consequences. McKinnon (2006) predicted rapid disruption  
84 to economic activity in the UK should there be a week-long cessation of road haulage activity.  
85 Waters (2011) stated that, while there is understandable concern about terrorist attacks, 'the  
86 flow of materials is much more likely to be disrupted by an unreliable supplier or difficulty with  
87 transport' and argued that the availability of parallel transport links can help to add operational  
88 resilience and mitigate freight transport disruption. A distinction can be made between  
89 frequent, but typically low-level, disruption leading to variability in everyday operating practices  
90 and major, but generally rare, events which cause widespread disruption (Li et al., 2016).

91

92

## 93 *2.2 Network resilience for rail freight operations*

94

95 Rail is commonly perceived as being less resilient than road haulage (Directorate-General for  
96 Internal Policies, 2015) so, to meet the European policy objective of shifting freight from road  
97 to rail (European Commission, 2011), it is important to make improvements. To achieve a  
98 considerable increase in freight mode share, rail needs to attract more flows of consumer  
99 goods and other time-sensitive freight but there are concerns over rail's capabilities in dealing  
100 with the requirements of such traffic (AECOM, Arup and SNC Lavalin, 2016). Based on a  
101 review of the academic literature, Reis (2014) found that the attributes consistently identified  
102 as being key for freight mode choice decision making are reliability, transit time, flexibility and  
103 price. Patterson et al. (2007) found that freight customers tend to trust rail less than road  
104 haulage, with service performance being a critical factor, a view reinforced by the Freight

105 Transport Association (FTA, 2014) which advocated better service flexibility and availability  
106 for rail. Rich et al. (2011) argued that rail freight faces greater challenges than road haulage,  
107 its main competitor, since the former mode tends to have a much less dense network and  
108 fewer alternative routes than the latter, so is generally less resilient. Specifically, there is a  
109 perception that rail needs to be better at coping with unplanned issues such as route  
110 blockages (RSSB, 2012), extreme weather events being a major cause. In the 2012 Freight  
111 Customer Survey (ORR, 2012), the (lack of) flexible service/recovery strategy was cited as  
112 the second biggest barrier to using rail in Britain. When considering rail's performance,  
113 'flexible service/recovery strategy' was highly ranked for importance but was the worst ranked  
114 attribute for performance. This suggests that resilience is important for customers, but that  
115 rail falls short on delivery during periods of disruption. Uncertainty over the extent and duration  
116 of disruption is a particular concern for customers. A high-profile media example affecting the  
117 UK was the Channel Tunnel disruption at Calais caused by migrants and strike blockades  
118 (FTA, 2015) which led to the cessation of some rail flows.

119

120 There are few studies in the academic literature specifically considering the resilience (or  
121 otherwise) of rail networks and the impacts on freight activity. Focusing on the Brenner Pass  
122 rail route, a critical link in the European rail network, Fikar et al. (2016) substantiated a decision  
123 support system to understand the impacts of an unexpected closure of the route. Disruption  
124 scenarios lasting 24 and 72 hours were simulated, with diversion of flows to other rail routes  
125 or to road. Delay time was calculated at a strategic level, providing guidance on how to  
126 manage unplanned disruption but not taking into account detailed operational characteristics.  
127 In practice, the European Court of Auditors (2016) identified that, at times of network  
128 disruption, priority is given to passenger services, exacerbating the delays to freight trains. If  
129 this leads to a transfer of traffic from rail to road, either temporarily or permanently,  
130 improvements in freight transport sustainability may be jeopardised (RSSB, 2016a). As RSSB  
131 (2016b) notes, there is currently no recognised method for calculating the overall economic  
132 impacts of the disruption to rail freight services. In particular, Feo-Valero et al. (2011)

133 highlighted the limited extent of understanding of the value of time for freight flows, unlike their  
134 passenger counterparts. They found that the wide range of different flow characteristics and  
135 requirements, together with a lack of consistency over who is responsible for freight mode  
136 choice decisions, make establishing a standardised freight value of time almost impossible.

137

138 In a rare study focused specifically on actual disruption to rail freight operations caused by  
139 weather-related damage to the infrastructure, Ludvigsen and Klæboe (2014) modelled the  
140 effects of key weather elements on aggregate rail freight delays in five European countries,  
141 finding that severe weather events severely impacted on infrastructure availability and  
142 accounted for considerable delays and a loss of business. There can be significant economic  
143 impacts resulting from unplanned rail freight disruption, although it is rare for calculations to  
144 be made public. One recent example was that of the closure of the Rhine-Alpine rail freight  
145 corridor at Rastatt (Germany) for almost two months in 2017 following the collapse of a tunnel  
146 being constructed beneath the existing alignment (Railway Gazette, 2017). This caused major  
147 disruption to rail freight flows: just one third of scheduled freight trains operated during the  
148 closure, with major disruption to those that did run. A subsequent analysis estimated  
149 economic losses of just over €2 billion to the rail industry and wider supply chain activities  
150 (HTC, 2018).

151

152 It is evident from the literature that the challenges associated with resilient rail freight service  
153 provision are recognised, but there is limited understanding of the detailed impacts of  
154 unplanned disruption either directly on rail freight operations or more widely on supply chain  
155 activity. There is some commonality in the identification of concerns about the extent to which  
156 it is possible to run the planned rail freight services during times of disruption, together with  
157 service performance issues for those services which are able to operate. This paper therefore  
158 makes an original contribution to the topic.

159

160

161 *2.3 Vulnerability of rail infrastructure and operations to extreme weather events*

162

163 While there are many other reasons for unplanned rail network disruption, such as that at  
164 Rastatt identified in Section 2.2, there is a growing body of evidence demonstrating that  
165 transport infrastructure is increasingly vulnerable to the effects of extreme weather, with  
166 consequent risks across supply chains and to economic activity in general. Recent high-profile  
167 weather-related examples in the UK of sustained rail disruption include at Dawlish (Devon) in  
168 2014 (BBC, 2014), the Dover to Folkestone line (Kent) for nine months from late-2015  
169 (Network Rail, 2016a), the West Coast Main Line (WCML) in southern Scotland in early-2016  
170 (Network Rail, 2016b) and the closure for more than a year of the Settle and Carlisle line in  
171 Cumbria (Network Rail, 2017a). Similar disruption has been experienced in other European  
172 countries, such as in Germany on the Hannover to Berlin high speed line in 2013 (Briginshaw,  
173 2013).

174

175 More broadly, several policy-focused reports have emerged recently (e.g. European  
176 Commission, 2012; EWENT, 2012; RAIN Project, 2015) and common disruption causes which  
177 emerge include temperature changes, changes in rainfall and flooding, and sea level rises and  
178 sea surges. Disruption which is severe and of a long duration, sometimes including a  
179 considerable period of uncertainty as to the extent and duration of the disruption, is especially  
180 problematic (Mattsson and Jenelius, 2015). Assessments of the impact of climate change and  
181 associated weather impacts on freight transport operations vary in their outcomes. A common  
182 theme which emerges is that, without a determined effort, more frequent disruption is  
183 expected, even if there is no general agreement on the estimated extent of impact.  
184 Researchers and policy makers have been increasingly active in developing strategies both  
185 proactively to reduce the likelihood of weather events impacting on transport operations and  
186 to better react to events which do have operational impacts (see, for example, EEA, 2014;  
187 MOWE-IT, 2014). As such, actions to improve transport resilience broadly fall in to two  
188 categories: reducing the vulnerability of infrastructure to disruptive events, and mitigation of



189 the effects of unplanned infrastructure disruption. The former is less disruptive to transport  
190 activity, but is often impractical or not cost-effective, so growing attention is focusing on the  
191 ways in which the effects of disruption can be minimised. The potential for disruption is  
192 considerable: focusing on the Dawlish example mentioned above, Dawson et al. (2016) found  
193 that the number of days where the train service would be disrupted could increase by up to  
194 1170% by 2100 in the worst-case scenario.

195

196 In the UK, concerns have been expressed about the growing number of severe weather  
197 events. Major disruption during winter 2013/14 led the government to instigate the  
198 independent Transport Resilience Review (DfT, 2014a), to which it provided a response (DfT,  
199 2014b). The most relevant recommendations were that a critical network of routes of national  
200 economic significance be designated to be maintained to a higher level of resilience and for  
201 contingency rail timetables to be produced to allow alternatives to be quickly implemented  
202 when disruption occurs. The latter recommendation seemed only to apply to passenger  
203 operations, however. Rail network vulnerability, and the need for greater resilience, had  
204 already been recognised (Network Rail, 2013). A Weather Resilience and Climate Change  
205 programme has been implemented and regional weather resilience and climate change  
206 adaptation plans have been produced (Network Rail, 2015a). There are no freight-specific  
207 actions, but infrastructure maintenance, contingency planning and timetabling flexibility all  
208 form a part of the programme and should benefit passenger and freight users alike. RSSB  
209 (2016b) emphasised the increasing likelihood of extreme weather events resulting from  
210 climate change and set out a range of recommendations on how to deal with their impacts on  
211 the rail network. Their research identified that there is currently a limited understanding of the  
212 nature of infrastructure damage caused by such events and, particularly, little insight into the  
213 operational impacts on rail flows.

214

215 As a result of these growing weather-related vulnerabilities, and the limited attention thus far  
216 devoted to rail freight when key routes are unexpectedly blocked, it is necessary to better

217 understand how unplanned network disruption affects freight activity in order that negative  
218 impacts can be minimised.

219

220

### 221 **3. Research methods**

222

223 This is an empirical study using a mix of quantitative and qualitative methods to analyse a  
224 specific case study of an unplanned 53-day closure of a strategic railway line; the  
225 characteristics of the case study are set out in Section 4. As the literature review established,  
226 there is a dearth of detailed evidence regarding the effects on rail freight activity of unplanned  
227 network disruption. Specifically, the analysis is based on the range of methods and source  
228 material summarised in Table 1 and justified in the following text.

229

230 *Insert Table 1 here (see end of document, due to landscape formatting)*

231

232 The major part of the data collection related to freight train service provision during the case  
233 study disruption period. Given its online availability at an individual train level from an open  
234 access data source (Method 1 in Table 1), information was collected for the entire population  
235 of diverted freight trains. This allowed the total number of trains operated to be identified,  
236 together with the planned schedule, routing and actual timings of each train. Direct  
237 observation surveys of train composition and loadings (Method 2a) took place on five of the  
238 53 days, supplemented by online train composition data from throughout the time period  
239 (Method 2b). In combination, train composition details were obtained for 21% of all services  
240 during the closure period; in itself, this coverage is not sufficiently representative to allow  
241 robust analysis but has proved useful in combination with other information.

242

243 To assess the level of disruption to service provision, it was necessary to establish the  
244 baseline (i.e. that expected in normal, non-disrupted, circumstances), with which the case

245 study could be compared. The author's annual rail freight database (Method 3) provided this  
246 baseline. The database uses a consistent data collection method each year, with information  
247 from a range of published and online rail industry and rail enthusiast sources. Its construction  
248 is a bottom-up exercise leading to a comprehensive record of regular freight train service  
249 provision, with a set of characteristics relating to each service as set out in Table 1. Databases  
250 for subsequent years were used to assess any longer-term impacts arising from the line  
251 closure. More detailed information about the database can be found in Woodburn (2006).  
252 Since that time, the database coverage has expanded to cover all commodities (i.e. including  
253 the previously excluded mail and coal services) and additional data sources, most notably  
254 open access data (Method 1), have been used to corroborate the information from the long-  
255 established sources. For the period relating to this case study, there were no changes to  
256 either database coverage or sources, so there are no data consistency issues. The database  
257 covers 100% of regular freight train services using the case study route, though service  
258 frequency for some is on an 'as required' basis depending on customer demand. This last  
259 aspect is discussed further in Section 5.1.

260

261 Finally, these data sources were supplemented by in-depth semi-structured interviews  
262 (Method 4) with key individuals from four organisations, representing both the rail industry and  
263 its customers, involved in the disruption; the interviews took place between one and three  
264 months after the line reopened. The interviews each had a duration of between 30 and 90  
265 minutes, with tailored discussions relating to the nature and extent of the disruption and the  
266 measures taken in response.

267

268 In combination, the research methods set out in Table 1 offer considerable scope to conduct  
269 an in-depth analysis of the case study and compare the disrupted period with the normal  
270 situation. The analytical framework recognises that different flow types can have specific  
271 characteristics and requirements. Reflecting the flows affected in the case study, the rail  
272 freight market has been divided for analysis as follows:

273

- 274 • Intermodal (with sub-divisions for domestic intermodal and port intermodal)
- 275 • Trainload bulk (with sub-divisions for cement, china clay, metals, nuclear waste and
- 276 petroleum)
- 277 • Wagonload (i.e. shared-user services)
- 278 • Mail

279

280 The analysis is structured around three key measures which allow quantification of the impacts  
281 of the disruption when compared with the baseline, in line with the service performance issues  
282 raised in the literature review. The measures are freight train service provision, scheduled  
283 journey times (and associated diversionary routings) and train punctuality. The train  
284 composition data and interview discussions provide additional information to enrich the  
285 analysis. To assess any longer-term impacts on rail freight activity (i.e. beyond the disruption  
286 period itself), the information gathered from the interviews has been supplemented by data  
287 from the rail freight database relating to service provision in January 2017 and January 2018,  
288 respectively one and two years on from the unplanned line closure.

289

290

#### 291 **4. Case study: unplanned closure of Lamington Viaduct**

292

293 While the effects of rail network disruption on freight flows exhibit similarities no matter where  
294 they occur, some aspects of a specific event are influenced by the characteristics of the rail  
295 system and associated policy environment. This section therefore briefly sets out the salient  
296 features of the British rail system and its links to disruption management, then explains the  
297 specific context for the case study that forms the focus of this research.

298

299

300 *4.1 The structure of the British rail system and responsibility for disruption*

301

302 Britain's rail network has been vertically separated since rail privatisation in the mid-1990s,  
303 exceeding the European Union (EU) requirement that 'a distinction should be made between  
304 the provision of transport services and the operation of infrastructure' to encourage  
305 liberalisation and competition (Council Directive 2012/34/EU, 1). Network Rail is the state-  
306 owned national infrastructure manager (IM) with responsibility for maintaining the rail network  
307 and generally making it available for traffic; it also coordinates the timetabling process. In  
308 formal terms, Network Rail is in charge of the Network Code, covering the rules, procedures  
309 and contractual relationships governing network access (ORR, 2016a). The train services  
310 themselves are provided by (passenger) train operating companies (TOCs) and freight  
311 operating companies (FOCs). While the overwhelming majority of passenger services are  
312 franchised by the government, with limited direct competition 'on the rails', rail freight activities  
313 were sold off and the market is openly competitive with six active FOCs (Woodburn, 2014).

314

315 The Delay Attribution Guide forms a part of the Network Code, with the vision 'for all parties  
316 to work together to achieve the core objective of delay attribution – to accurately identify the  
317 prime cause of delay to train services for improvement purposes' (Delay Attribution Board,  
318 2016, 3). Delays on the national rail infrastructure caused by severe weather are the  
319 responsibility of Network Rail, regardless of whether it could have been expected to prevent  
320 the delays through its maintenance programme, and it pays compensation to the FOCs based  
321 on the contractual arrangements in place. There is a specific delay code (X2) for 'severe  
322 flooding beyond that which could be mitigated on Network Rail infrastructure'.

323

324

325 *4.2 Case study: Lamington Viaduct*

326

327 The case study analysed in this paper relates to an unplanned closure for 53 days of part of  
328 the West Coast Main Line (WCML). The WCML is the most important rail freight artery in the  
329 UK, with 40% of all freight trains using at least some of its length at some point in their journey  
330 (DfT, 2015). A bridge (known as Lamington Viaduct) over the River Clyde between Carlisle  
331 and Glasgow/Edinburgh sustained considerable damage to its structural supports as a result  
332 of exceptionally high water levels and fast flow caused by Storm Frank on 29/30 December  
333 2015 (Network Rail, 2016b; RAIB, 2016). The line was closed to traffic from 08:53 on  
334 Thursday 31 December 2015 after maintenance staff witnessed unusual track movement  
335 during the passage of a passenger train and spotted a large crack in the viaduct structure  
336 (RAIB, 2016). There had been unusually high rainfall in the weeks leading up to the closure,  
337 with winter 2015/16 being the wettest on record for Scotland (Met Office, 2016). Short-term  
338 line closures as a result of flooding had occurred elsewhere on the northern part of the WCML  
339 during December (Network Rail, 2015b, 2015c). The subsequent accident investigation found  
340 that previously agreed Flood Action procedures for monitoring at-risk structures such as  
341 Lamington Viaduct were no longer being implemented within Scotland, resulting in ineffective  
342 management of the effects of high river flow (RAIB, 2016).

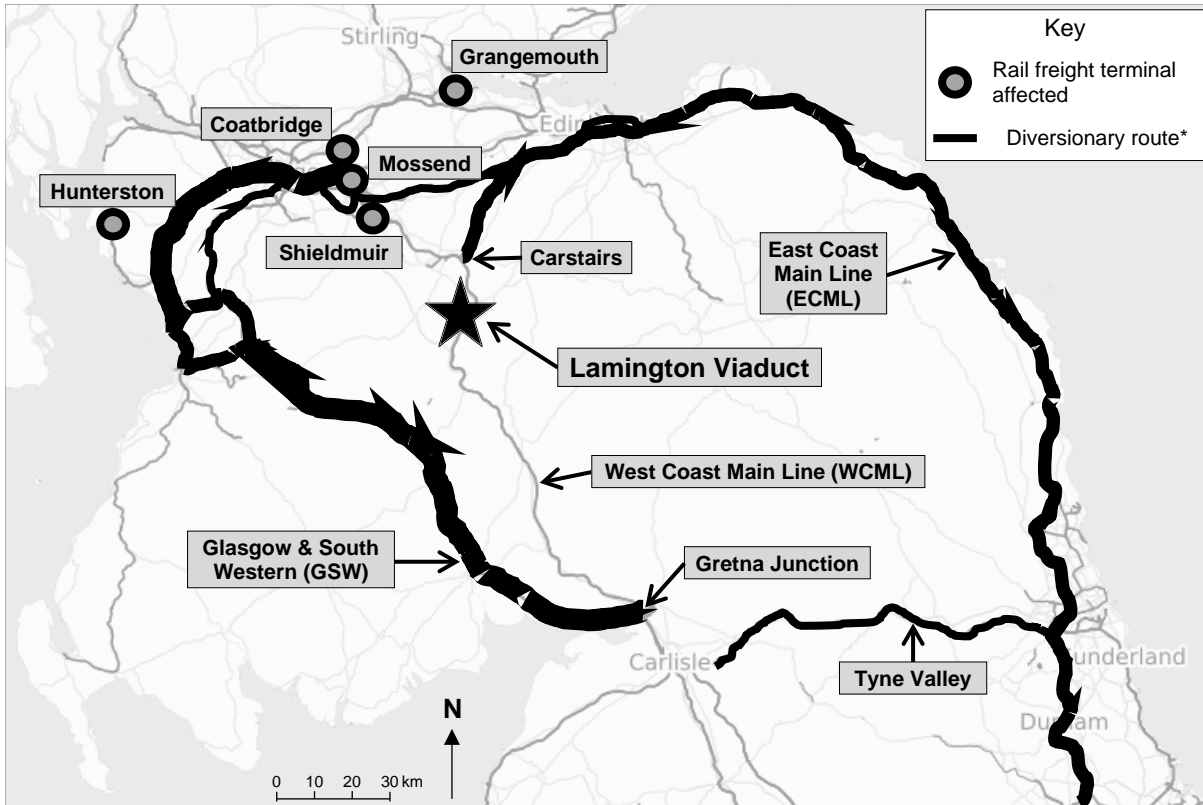
343

344 As a consequence of the failure of Lamington Viaduct, the section of line from Gretna Junction  
345 (north of Carlisle, near the England/Scotland border) to Carstairs, a distance of 104 kilometres,  
346 was closed to freight traffic. This necessitated lengthy diversions via a range of alternative  
347 routes. Figure 1 shows the location of the affected section of line, along with the diversionary  
348 routes used by freight trains to serve the terminals affected.

349

350 Figure 1: Location map showing Lamington Viaduct and diversionary routes

351



352  
353  
354  
355  
356

Source: adaptation of base map from openstreetmap.org (© OpenStreetMap contributors); \* line thickness is representative of the number of diverted trains by that route (see Section 5.2)

357 Despite the section of line affected being located at the quieter end of the WCML, in southern  
 358 Scotland, it caters for considerable rail freight activity. According to the author’s annual rail  
 359 freight database, at the time of the disruption this section would normally have handled an  
 360 average of 146.5 freight trains in a typical week. This accounts for more than three-quarters  
 361 of rail freight services between England and Scotland, including almost all intermodal traffic  
 362 since at the time of the disruption the East Coast Main Line (ECML) had not yet been gauge-  
 363 enhanced to allow the carriage of 9’ 6” height containers on standard height wagons (Network  
 364 Rail, 2016c).

365

366 There was considerable uncertainty over the anticipated duration of the line closure and the  
 367 estimated date for reopening was revised several times. The timeline of updated estimates  
 368 from the IM, Network Rail, is shown in Table 2, demonstrating how it initially lengthened but  
 369 then contracted. The line eventually reopened in the early hours of Monday 22 February

370 (Network Rail, 2016g). Network Rail spent £4 million on renewing Lamington Viaduct and  
371 paid out around £10 million in Schedule 4 payments to train operators to compensate them  
372 for the disruption (ORR, 2016b), though the distribution between passenger and freight  
373 operators has not been published.

374

375 Table 2: Timeline of reopening estimates from Network Rail

376

<b>Date</b>	<b>Estimated timescale for reopening</b>
3 January 2016	Work 'likely to continue until end of January', with reopening expected on 1 February 2016
18 January 2016	'Further damage delays opening until first week in March 2016'
12 February 2016	'Works...are progressing ahead of schedule'; new date for reopening to be confirmed
15 February 2016	Confirmed reopening date of Monday 22 February 2016

377

378 Source: Network Rail (2016b, 2016d, 2016e, 2016f)

379

380 The duration of the closure of such a vital rail freight route, together with the uncertainty over  
381 just how long the closure would last, provide the circumstances for an interesting and insightful  
382 case study into how the disruption was managed for rail freight customers and to identify  
383 lessons to be learned for future disruptive events given the likely increase in the frequency of  
384 their occurrence.

385

386

### 387 *4.3 Limitations of the case study*

388

389 As is often the case with the analysis of 'real world' situations, the conditions for investigation  
390 were not ideal. Three specific study limitations have been identified:

391

392 1. The damage to Lamington Viaduct occurred during a holiday period, so caution is needed  
393 when interpreting the early response to the line closure. Some traffic, notably domestic  
394 intermodal, tends to be little affected by holiday periods, while other flows generally would



395 not be expected to operate. Friday 1 January was a UK-wide holiday and Monday 4  
396 January was a Scottish holiday. It was therefore Tuesday 5 January at the earliest before  
397 some flows would have been expected to operate in normal circumstances. Also, the Tyne  
398 Valley route, one of the possible diversionary routes (see Figure 1) was itself closed from  
399 6 January until 8 February. Its loading gauge restrictions and detour length meant that it  
400 is unlikely it would have been used much in any case, which was confirmed in discussions  
401 with interviewees and was borne out by the very few trains diverted that way during the  
402 times it was open. These issues are discussed as appropriate throughout the following  
403 analysis.

404 2. Most freight service provision on the affected line operates with a high degree of  
405 predictability, but certain smaller flows are more erratic in nature and cannot be recorded  
406 reliably in the database. The effects of this are discussed in the results presented in  
407 Section 5.1.

408 3. Changes in diversionary capabilities during the closure period meant that the train  
409 composition survey data (see stages 2a and 2b in Table 1) were not sufficiently  
410 representative to allow rigorous analysis of the different phases that became apparent in  
411 the analysis supporting RQ1 (see Section 6.1). However, in combination with material  
412 gathered from the interviews, some pertinent findings did emerge, albeit of a more general  
413 nature than anticipated.

414

415

## 416 **5. Rail freight traffic levels and service performance during the line closure**

417

418 In this section, the data relating to freight train service provision (Section 5.1), diversionary  
419 routings and associated schedules (Section 5.2) and train punctuality (Section 5.3) are  
420 presented. These key measures are key to the subsequent analysis of the impacts of the line  
421 closure, which follows in Section 6.

422

423

424 5.1 Freight train service provision

425

426 Table 3 reveals that just over 80% of the number of trains that would have been expected to  
427 run had the line not been closed actually did so. The expected number of trains was calculated  
428 on the basis of a seven week closure, given the holiday weekend at the start of the period  
429 (see Section 4).

430

431 Table 3: Expected and actual number of freight trains (full closure period), by  
432 commodity/train type  
433

<b>Commodity/train type</b>	<b>Expected no. (baseline)</b>	<b>Actual no. (WCML closure period)</b>	<b>Actual as % of expected</b>
Intermodal, of which:	630	529	84
<i>Domestic intermodal</i>	420	399	95
<i>Port intermodal</i>	210	130	62
Trainload bulk, of which:	150.5	137	91
<i>Petroleum</i>	77	69	90
<i>Cement</i>	49	34	69
<i>Nuclear waste</i>	14	16	114
<i>Metals</i>	7	9	129
<i>China clay</i>	3.5	9	257
Mail	140	71	51
Wagonload	105	99	94
<b>Total</b>	<b>1,025.5</b>	<b>836</b>	<b>82</b>

434

435 Source: based on data from realtimetrains.co.uk and author's annual rail freight database; n = 836

436

437 While it may seem odd that there were more services than expected for three of the five  
438 trainload bulk commodities in the table, this is largely a function of the fact that they operate  
439 infrequently on an 'as required' basis. In calculating the expected level of service, the default  
440 position in the database analysis is that a train which operates on, for example, a Thursday  
441 as required will operate on 50% of the possible occasions (i.e. every second Thursday); the  
442 reality may be that such a train will actually operate on, say, three Thursdays out of four, thus  
443 appearing to be over-represented. This may have been the case with nuclear waste and  
444 metals. It may also be true to some extent of china clay, but the dramatic over-representation  
445 largely reflects the changed nature of provision during the line closure. In the main, during the  
446 line closure the empty china clay services generally ran direct to Carlisle as dedicated trains;

447 under normal circumstances, the empty wagons would be combined at Mossend with other  
448 flows and thus be categorised as wagonload. An additional two northbound wagonload trains  
449 were terminated at Carlisle with no onward schedule over a diverted route. It is likely that any  
450 Scottish traffic on these trains was added to other services in order to complete its journey.

451

452

## 453 *5.2 Freight train diversionary routings and schedules*

454

455 Analysis of the revised schedules for the 836 diverted trains revealed a diverse and complex  
456 set of routings to avoid Lamington Viaduct, though with two core diversionary routes. Figure  
457 1 showed the revised routings in southern Scotland and part of northern England. The majority  
458 (77%) of trains used the WCML as normal to the south of Gretna Junction, with the GSW route  
459 being used north thereof. The other 23% of trains used the ECML, with diversionary routings  
460 generally extending much further south. Most ECML-routed trains ran cross-country to/from  
461 the Midlands via Yorkshire using a number of different routes, but mail trains between  
462 Shieldmuir and London remained on the ECML to/from London. A small number of trains  
463 used the Tyne Valley route but, as mentioned previously, it itself was closed by a landslip for  
464 much of the duration of the study period. In total, there were 32 diversionary routes,  
465 discounting some very short distance (i.e. 10 km or less) deviations on sections of route further  
466 south than shown in Figure 1. The GSW formed the core of 10 of the diversionary routes, with  
467 the remainder using the ECML. A small number of these diversionary routes accounted for  
468 the majority of trains: the two most common routes each accounted for 28% of the trains, the  
469 top six routes combined saw 91% of the trains, while the remaining 26 routes saw just 74  
470 trains (9%) in total.

471

472 Table 4 summarises the difference between the schedules for the disruption period and the  
473 baseline for each of the commodity/train types and in total. As a consequence of the  
474 disruption, some schedules bore little resemblance to those in the normal operating period,

475 for example with very different train reporting numbers and origin departure times. Where  
 476 possible, schedules were matched based on train reporting number and/or on the closest  
 477 origin-destination pair and commodity/train type. A small number of trains (4% of the total)  
 478 were excluded because no equivalent service in the baseline could be identified, resulting in  
 479 800 train schedules being compared between the baseline and the disruption period. For  
 480 information, Table 4 displays the number and percentage of trains excluded per  
 481 commodity/train type.

482

483 Table 4: Impact on schedules: disruption period vs baseline, by commodity/train type  
 484

Commodity/train type	Revised scheduled journey time per train as % of baseline	Trains excluded	
		No.	As % of type
Intermodal, of which:	130	21	4
<i>Domestic intermodal</i>	133	18	5
<i>Port intermodal</i>	124	3	2
Trainload bulk, of which:	111	9	7
<i>Petroleum</i>	109	1	1
<i>Cement</i>	121	2	6
<i>Nuclear waste</i>	105	0	0
<i>Metals</i>	123	0	0
<i>China clay</i>	70	6	67
Mail	99	0	0
Wagonload	121	6	6
<b>Total</b>	<b>124</b>	<b>36</b>	<b>4</b>

485

486 Source: based on data from realltimetrains.co.uk; n = 800  
 487

488 It is evident that scheduled journey times for comparable services were extended considerably  
 489 during the disruption. The average revised schedule was 24% longer than normal, though  
 490 china clay trains had much faster schedules than normal, owing to the revised method of  
 491 working outlined in Section 5.1, and mail trains had schedules which were little changed from  
 492 normal: however, as discussed later (see Section 6.1), these services were unable to serve  
 493 their key intermediate terminal en route to/from London so the capability was much reduced.  
 494 The schedules for intermodal services, particularly domestic intermodal ones, experienced the  
 495 greatest journey time lengthening. For china clay, cement, wagonload and domestic  
 496 intermodal, at least 5% of services were excluded from the analysis because of the inability to

497 match them to an equivalent service in the baseline. Of these, china clay was once again the  
498 extreme example, for the aforementioned reason.

499

500

### 501 5.3 Freight train punctuality

502

503 An important measure of service performance which is quantifiable from the real-time data  
504 relates to train punctuality, specifically the extent to which trains arrive at the destination 'on  
505 time'. For this analysis, on-time arrivals are defined as trains arriving at their destination up to  
506 (but not including) 15 minutes after their scheduled arrival time. This matches the current  
507 industry standard, the Freight Delivery Metric (FDM), although this measures only delays  
508 caused by Network Rail (ORR, 2018). Table 5 reveals that 77% of trains arrived at their  
509 destination 'on time' during the line closure. At the national level, 94% of freight trains arrived  
510 on time in 2015/16 Q4 (ORR, 2018), this being the period within which the case study  
511 disruption occurred. This national performance was very considerably better than that shown  
512 in Table 5 for the case study, though the basis of the two calculations is too dissimilar to be  
513 regarded as particularly insightful.

514

515 Table 5: Train punctuality during disruption period, by commodity/train type

516

<b>Commodity/train type</b>	<b>'On-time' arrivals (%)</b>
Intermodal, of which:	77
<i>Domestic intermodal</i>	74
<i>Port intermodal</i>	87
Trainload bulk, of which:	80
<i>Petroleum</i>	75
<i>Cement</i>	88
<i>Nuclear waste</i>	88
<i>Metals</i>	89
<i>China clay</i>	67
Mail	68
Wagonload	83
<b>Total</b>	<b>77</b>

517

518 Source: based on data from realtimetrains.co.uk; n = 830

519

520 Of the four main train types, wagonload and trainload bulk displayed the best ‘on-time’  
521 performance, at 80% or greater, with mail trains performing particularly poorly at just 68% on  
522 time. Within intermodal and trainload bulk, there was considerable variation between the sub-  
523 groups with, for example, port intermodal outperforming domestic intermodal by a margin. It  
524 should be remembered that all of these punctuality statistics relate to the revised scheduled  
525 arrival time. As Section 5.2 revealed, this was generally at the end of a far longer journey than  
526 would be the case under normal circumstances.

527

528

## 529 **6. Analysis and key findings**

530

531 Building on the key measures presented in Section 5, this section focuses on the three inter-  
532 related research questions (RQs) which form the basis for the paper, allowing the overall  
533 research aim to be satisfied. Section 6.1 incorporates findings from the interviews to the data  
534 already presented, allowing the direct impacts of the line closure on rail freight service  
535 provision to be established. Section 6.2 then adopts a broader supply chain perspective as  
536 well as identifying any longer-term impacts. Finally, Section 6.3 takes the available evidence  
537 from this case study and makes recommendations for improving the resilience of rail freight.  
538 It should be remembered that the main focus of this analysis is on operational and policy  
539 issues. Attempts were made to examine in detail the cost implications of the line closure on  
540 both the rail industry and its customers, but insufficient information was forthcoming from the  
541 interviewees to allow this.

542

543

### 544 *6.1 RQ1: Impacts of the line closure on rail freight traffic levels and capability*

545

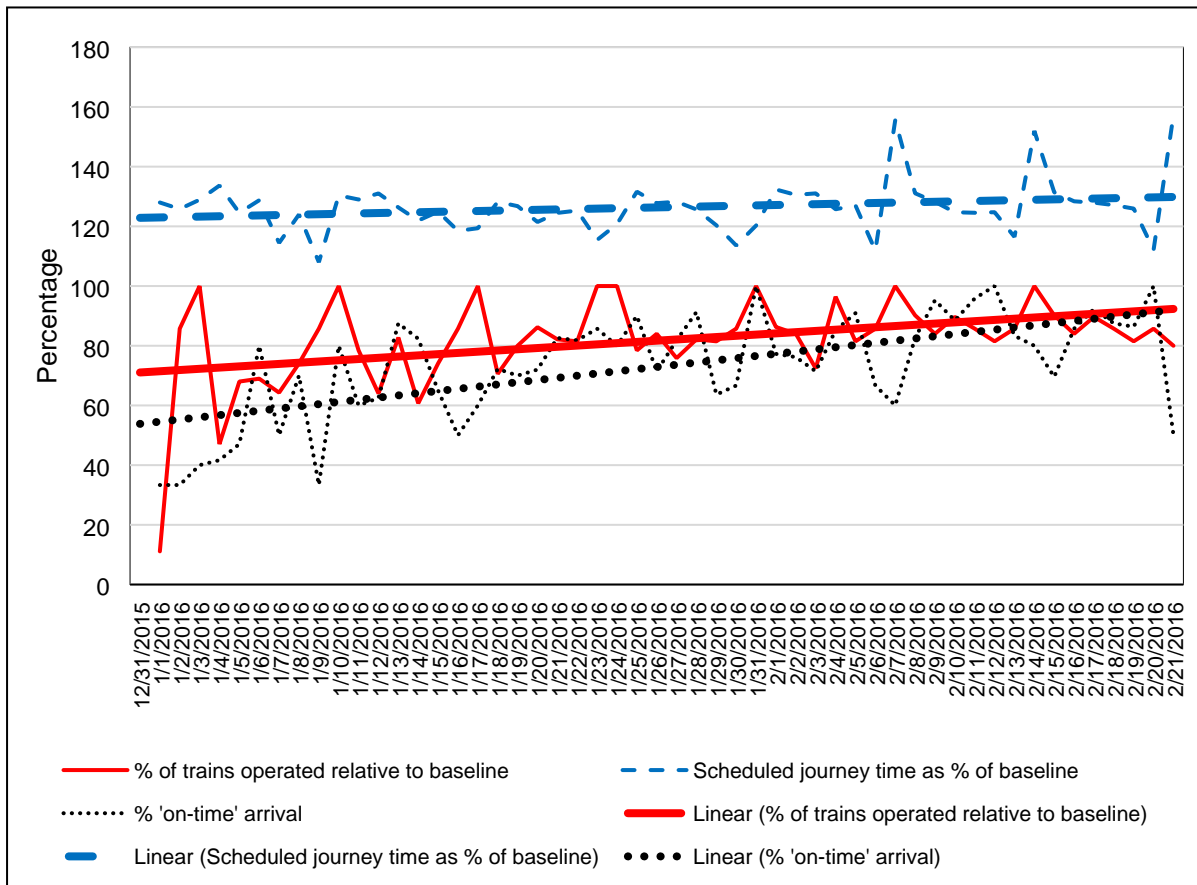
546 A common theme that emerged from the interviews was that the response to the closure  
547 improved over time, perhaps not unexpectedly. Building on the data presented in Section 5,

548 Figure 2 shows the three key service provision measures on a daily basis throughout the  
 549 closure period, plus the smoothed (linear) trend for each measure. While there is considerable  
 550 day-to-day variability, each trend line is evidently upward. For two of the three measures (i.e.  
 551 % of trains operated and % on-train arrival), an upward trend is unambiguously positive. For  
 552 the third, reflecting the change in scheduled journey times, a downward trend would be  
 553 preferable, since that would show journey times converging with those in the baseline. The  
 554 very slightly upward trend in this measure was influenced by the spikes on the three final  
 555 Sundays where scheduled journey times were extended beyond that experienced at any other  
 556 time during the closure.

557

558 Figure 2: Daily performance of key service provision measures

559



560  
 561  
 562  
 563

Source: based on data from Tables 3 to 5; 'baseline' refers to the non-disrupted period

564 Two of the four interviewed organisations made specific reference to the closure period being  
565 divided into three distinct phases, with the situation improving with the progression from one  
566 phase to another:

567

- 568 • Phase 1: from line closure (31 December 2015) until around 5/6 January 2016
- 569 • Phase 2: from 5/6 January 2016 until 17 January 2016
- 570 • Phase 3: from 18 January 2016 until line reopening (22 February 2016)

571

572 Post hoc analysis of the key service provision measures in line with these phases provides  
573 supporting evidence for this division, as Table 6 demonstrates. The comparison of revised  
574 and baseline journey schedules showed no noticeable difference between the phases, but  
575 Phase 2 showed considerable improvements over Phase 1 in both the proportion of services  
576 operated and the punctuality of those trains which ran. From Phase 2 to Phase 3, the changes  
577 were less marked but still showed improvements in these two measures. However, the  
578 difficulties of quantifying fully the effects of the disruption on the key measures in Phase 1  
579 need to be borne in mind since the New Year holiday period would have resulted in a reduced  
580 level of service provision in any case. That said, punctuality of the relatively small proportion  
581 of trains which did run in Phase 1 was particularly poor and, according to one interviewee, the  
582 limited timetabling resource available in this phase meant that trains were running without  
583 workable schedules, compounding delays.

584

585 Table 6: Summary statistics for key service provision measures, by phase

586

<b>Service provision measure</b>	<b>Phase 1</b>	<b>Phase 2</b>	<b>Phase 3</b>
No. of freight trains operated (as % of baseline)	48	73	84
Revised scheduled journey time (as % of baseline)	128	125	127
Punctuality (% 'on time' arrival)	39	68	82

587

588 Source: based on data from Tables 3 to 5

589



590 In the interviews, concerns were raised about the limited number of train paths available on  
591 both the Glasgow and South Western (GSW) and East Coast Main Line (ECML) diversionary  
592 routes to cater for the displaced freight traffic, leading to sub-optimal schedules which were  
593 less customer-friendly. Pre-planned engineering work on the ECML meant that this route was  
594 not available at all over three of the weekends, while the additional freight traffic over the GSW  
595 route led to limited time available for infrastructure maintenance. The strict industry  
596 requirements for driver route knowledge presented challenges in resourcing the revised  
597 schedules, particularly for the ECML since few freight trains normally travel by that route. The  
598 fragmented and competitive nature of freight train service provision created extra resourcing  
599 challenges than would have been likely under a unified operational structure. From the  
600 observation surveys and industry interviews, several additional impacts were identified which  
601 particularly affected intermodal services:

602

- 603 • revised schedules for some of the domestic intermodal services did not allow for the  
604 usual 24-hour wagon rake rotations, so either additional wagon rakes were required or  
605 fewer services could operate
- 606 • additional diesel traction had to be found, as a consequence of the longer end-to-end  
607 journey times and the need to substitute the electric traction normally used on the  
608 majority of intermodal trains, since diversionary routes generally were not electrified
- 609 • loading gauge restrictions, particularly affecting the key GSW diversionary route: until  
610 Phase 3, there was a 9' 2" height restriction which meant that around two thirds of the  
611 normal intermodal units could not be moved by rail on this route. The increased gauge  
612 clearance to allow 9' 6" intermodal units to be carried on the GSW route at the start of  
613 Phase 3 resulted from urgent gauging checks carried out by Network Rail in the first  
614 two weeks of the disruption
- 615 • restrictions on train length due to diversionary route infrastructure constraints: the  
616 dedicated Tesco train was worst affected, with a 22% reduction in the maximum

617 number of units per train compared to normal, with other intermodal services impacted  
618 to a lesser extent

- 619 • challenges at intermodal terminals: extended journey times often led to less terminal  
620 time for train loading and unloading, plus most terminals handle several trains per day  
621 and the disrupted schedules led to problems in dealing with out-of-course arrivals

622

623 Two specific factors which led to the disruption being lower than it could have been were  
624 identified from the data analysis and confirmed in the interview phase:

625

- 626 • the timing of the line closure, during a relatively quiet period for intermodal traffic in  
627 particular; had it occurred in the September to December period, in the build up to the  
628 retailing peak, the impacts on supply chains (see Section 6.2) would have been more  
629 severe

- 630 • the reduction in coal traffic in the five years preceding the line closure, since this had  
631 freed up freight train paths on the key GSW route (see Figure 1)

632

633 Turning to possible longer-term impacts on the rail freight market, Table 7 compares the typical  
634 weekly rail freight service provision at the time of the disruption (i.e. January 2016) with that  
635 in the following two years. Small year-on-year reductions can be seen, but these changes are  
636 explained by factors unrelated to the line closure, such as amended flow requirements and  
637 the rationalisation of wagonload rail freight services.

638

639  
640

Table 7: Weekly rail freight service provision in each January (2016, 2017 and 2018)

Commodity/train type	Expected no. of trains per week in:		
	January 2016	January 2017	January 2018
Domestic intermodal	60	60	60
Port intermodal	30	30	30
Mail	20	20	20
Wagonload	15	14	0
Petroleum	11	10	10
Cement	7	6	6
Nuclear waste	2	2	2
Metals	1	1	1
China clay	0.5	1	3
Automotive	0	0	10
Ministry of Defence (MoD)	0	0	0.5
<b>Total</b>	<b>146.5</b>	<b>144</b>	<b>142.5</b>

641  
642  
643

Source: author's annual rail freight database

644 The analysis has demonstrated that there were very considerable impacts on rail freight traffic  
645 levels and capability, albeit with evidence of improvements in service provision and train  
646 punctuality as the closure period progressed. There is no evidence that the closure has had  
647 any long-term impacts on rail freight service provision.

648

649

## 650 *6.2 RQ2: Assessment of the wider supply chain implications*

651

652 Information provided by the interviewees provided insight into wider supply chain implications  
653 resulting from the line closure. No such implications were identified for any of the trainload  
654 bulk commodity flows, for which the transport requirements tend not to be particularly  
655 demanding. On the other hand, there were considerable implications for the intermodal traffic.

656

657 The interview findings made clear that the extended journey schedules posed particular  
658 challenges for domestic intermodal traffic, since much of this is highly time-sensitive. Journey  
659 time extensions of several hours proved problematic, particularly where the arrival time at the  
660 destination rail terminal was later than normal. This was especially challenging for services  
661 delayed against their revised schedule but was also an issue where services arrived 'on-time'

662 against the revised schedule though still hours later than would usually be the case. Under  
663 normal circumstances, the transfer of domestic intermodal loads from road to rail for onward  
664 movement takes place very rapidly. One example offered by the logistics service provider  
665 (LSP) interviewee was of a three-hour time window after the train's arrival where the loads  
666 would be taken from the rail terminal to local distribution centres for re-working/cross-docking  
667 and departure en route to retail outlets. The extended rail schedule during the line closure  
668 meant that this time window disappeared, so the consignments that were most time-sensitive  
669 and/or needed the most re-working at the local distribution centre had to switch to road. The  
670 fact that the domestic intermodal traffic is controlled by LSPs helped to limit the overall impact  
671 on the ultimate customers, generally retailers, since they had flexibility to divert the most  
672 critical traffic to their road haulage operations. Despite this, there was disruption to some  
673 Anglo-Scottish retail supply chain activity. Evidence from both the interviews and the train  
674 composition information showed that train lengths were shorter than normal because of  
675 infrastructure limitations on the diversionary routes, though this was not identified as a  
676 particular constraint given the transfer to road of the most critical consignments.

677

678 Port intermodal traffic was also badly affected, with just four of the six daily services operating  
679 for most of the period. Although port intermodal train lengths show some variability ordinarily,  
680 those services which did operate also had a reduced maximum train length compared to  
681 normal. Two interviewees believed it likely that the relatively quiet period for deep-sea  
682 container traffic had limited the impacts of the reduced capacity, though one of the two  
683 reported that some of the traffic had switched from rail to short-sea feeder services using the  
684 ports of Grangemouth and Greenock.

685

686 While the other flows were able to serve their usual rail freight terminals, albeit with disrupted  
687 schedules, the main diversionary route used for the mail trains meant that intermediate mail  
688 traffic between northern England and Scotland also reverted to road during the closure period  
689 because the Warrington terminal could not be served. These trains were diverted along the

690 full length of the ECML to/from London, preserving end-to-end journey times between London  
691 and Scotland and vice versa (see Table 4) and allowing the specialist electric trains to continue  
692 to be used. The intermediate Warrington traffic was therefore sacrificed to road to allow the  
693 London traffic to continue with as little disruption as possible.

694

695

### 696 *6.3 RQ3: Recommendations for improving the resilience of rail freight operations*

697

698 Using the evidence base provided by the preceding analysis, a series of recommendations  
699 has been developed. These have been separated into managerial recommendations and  
700 policy recommendations, though this distinction is somewhat artificial given the considerable  
701 overlap between the two. Those that are managerial in nature are ones assumed to be able  
702 to be implemented by the rail (or wider logistics) industry, while the policy-related ones are  
703 aimed primarily at government. In the UK context, Network Rail (as the public sector  
704 infrastructure manager) essentially straddles the rail industry and government, accentuating  
705 the overlap. The discussion focuses on those recommendations supported by the evidence  
706 from the case study. Table 8 presents an overview of the recommendations, with the detailed  
707 discussion around the managerial aspects in Section 6.3.1 and for wider policy issues in  
708 Section 6.3.2. While the main focus of this research has been on the impacts on rail freight  
709 service provision during the line closure itself, the interview process also identified a number  
710 of wider issues relating to strategic rail network resilience. In line with the themes raised in  
711 the literature review, the recommendations based on this case study analysis are divided into  
712 two groups: strategic network resilience, to prevent or limit disruptive incidents, and  
713 operational response to incidents which cannot be prevented. This structure is in line with the  
714 recommendations set out in the Transport Resilience Review (DfT, 2014a) and, as can be  
715 seen in the following discussion, there is commonality between the recommendations arising  
716 from that review and from the analysis in this paper. That said, the Transport Resilience  
717 Review did not produce freight-specific recommendations (see Section 2.3), so the

718 recommendations here are targeted at minimising the impacts on rail freight. Considering the  
 719 overall list of recommendations, it is evident that the rail industry itself bears primary  
 720 responsibility in almost all cases.

721

722 Table 8: Overview of recommendations

723

Nature of recommendation	Primary responsibility
<b>A. Strategic network resilience</b>	
A1. Preventative maintenance	Rail industry
A2. Understanding the needs of freight customers	Rail industry
A3. Improved freight resilience: network investment	Government/rail industry
A4. Contingency planning	Rail industry
A5. Rail industry coordination	Rail industry
<b>B. Operational response to incidents</b>	
B1. Contingency plan implementation	Rail industry
B2. Understanding the needs of freight customers	Rail industry
B3. Communication with freight customers	Rail industry
B4. Rail industry coordination	Rail industry

724

725

726 *6.3.1 Managerial recommendations*

727

728 Many of the managerial (i.e. rail industry) recommendations are aimed at Network Rail, as  
 729 infrastructure manager, covering both strategic network resilience and the operational  
 730 response to incidents. The number and impact severity of disruptive incidents is influenced  
 731 by the extent to which preventative maintenance takes place across the rail network. Despite  
 732 the high river flow, this particular line closure may well have been avoided had the agreed  
 733 Flood Action procedures been implemented (RAIB, 2016). An interviewee raised other  
 734 examples of situations where considerable disruption was caused by a lack of preventative  
 735 maintenance such as vegetation clearance and embankment management, and this is  
 736 something raised by the Transport Resilience Review (DfT, 2014a) as a particular issue. To  
 737 reduce the chances of extreme weather events causing line closures, it is vital to have sound  
 738 preventative maintenance procedures and for them to be implemented and monitored  
 739 (Recommendation A1).

740

741 There is a need for better coordination and communication within the rail industry (i.e. between  
742 Network Rail and the FOCs) (Recommendations A5 and B4) and between the rail industry  
743 and its customers (Recommendations A2 and B2). Industry coordination is particularly  
744 important in a fragmented rail industry such as in the UK, where infrastructure and operations  
745 are separate and where there are multiple freight train operators, but other European rail  
746 networks also share some of these characteristics. To date, however, the freight perspective  
747 in relation to coordination and communication has not been adequately recognised in the  
748 literature from government or the rail industry.

749

750 Recommendations A2 and B2 relate to the level of understanding within the rail industry of the  
751 requirements of customers and their flows. On a mixed traffic rail network such as in the UK,  
752 as elsewhere in Europe, the requirements of the different freight flows are often poorly  
753 understood. Recognition of the demanding requirements of some of the freight flows,  
754 particularly domestic intermodal and mail, could be higher and both strategic and operational  
755 planning could better deal with these requirements. Network Rail's newly implemented  
756 devolved organisational structure is as yet unproved when it comes to the focus on freight  
757 requirements. Many freight services cross multiple routes, although there is a national 'route'  
758 tasked with the requirements of rail freight. This leads in to Recommendation A3, which  
759 relates to ensuring that the rail network is fit for purpose for the various freight flows using it,  
760 both now and in the future. This recommendation is focused primarily on policy makers (see  
761 Section 6.3.2), but there is a need for the rail industry to contribute to the planning process.

762

763 Of particular importance to the findings from this analysis, better contingency planning at both  
764 the strategic and operational levels is required (Recommendations A4 and B1). The UK  
765 government has recognised the importance of this (DfT, 2014b) and expects Network Rail to  
766 overcome the weaknesses of the prevailing situation. However, it is not evident that sufficient  
767 awareness of the particular characteristics of freight exists. Specifically, when developing  
768 contingency plans to cope with the unplanned closure of key rail freight arteries, it is important

769 to holistically consider the capabilities of diversionary routes. In the case study examined in  
770 this paper, during Phases 1 and 2 the rail industry was very much exploring options owing to  
771 a lack of detailed contingency planning beforehand. The greater complexities of intermodal  
772 wagon and loading unit combinations meant that this took time to resolve for these flows.  
773 Contingency plans should be refreshed regularly, particularly for intermodal traffic, given the  
774 frequent changes in train operating characteristics. This creates a heavier planning workload,  
775 but should reduce the work needed to minimise disruption when unplanned line closures  
776 occur. As the rail network has got busier the effects of disruption are magnified, with less  
777 slack in the system and more secondary impacts, further strengthening the arguments for  
778 thorough contingency planning. Such contingency planning must take account of the varied  
779 characteristics of rail freight flows including, for example, train weights, loading gauge  
780 requirements and use of electric traction.

781

782 In addition to the lack of coordination within the rail industry (see Recommendations A5 and  
783 B4 above), concerns were raised about the lack of 'real-time' updating of customers about the  
784 number of freight trains that could be operated, together with their planned schedules and any  
785 restrictions on what could be carried. To date, attention has focused on the importance of  
786 keep rail passengers informed (DfT, 2014b) but, to retain freight customers' trust in rail, it is  
787 vital to ensure good, pro-active communications with them too (Recommendation B3), so that  
788 they can better plan their businesses and implement their own contingency plans where  
789 necessary.

790

791

### 792 *6.3.2 Policy recommendations*

793

794 Most of the managerial recommendations set out in Section 6.3.1 will need government  
795 support to enable them to maximise their potential. In particular, the increased likelihood of  
796 disruptive weather events strengthens the argument for investment in key freight corridors,



797 together with appropriate diversionary routes, to provide better network resilience  
798 (Recommendation A3). The government acknowledges the need for a 'critical network' (DfT,  
799 2014b), though the case study came soon afterwards so there had as yet been no discernible  
800 change in investment appraisal. Despite this, the ongoing gauge enhancement works as part  
801 of the Strategic Freight Network investment programme are leading to a greater range of  
802 diversionary routes able to cater for intermodal traffic on standard wagons. Linking  
803 Recommendation A3 with others aimed primarily at the rail industry, the following policy-  
804 related aspects should be considered:

805

- 806 • when developing the strategic direction for the rail industry, through the regulatory  
807 process and the implementation of strategies (e.g. rail freight strategy, electrification  
808 strategy), government should be cognisant of the need for greater resilience to cope  
809 with disruption, both in planning and operational terms
- 810 • strengthen regulatory oversight, to mandate that Network Rail (as infrastructure  
811 manager) improves its asset register: linked with the managerial recommendation  
812 relating to contingency planning for diversionary routes, better awareness of  
813 infrastructure capability should allow a smoother transition to revised service provision  
814 when unplanned route closures take place

815

816 Finally, policy makers should ensure that their strategies and interventions take account of the  
817 growing importance of intermodal rail freight, much of which has more demanding customer  
818 requirements than does traditional rail freight. With 40% of the rail freight market, intermodal  
819 has grown to be by far the largest of the commodity groupings in the UK (ORR, 2018) and  
820 forms the backbone of growth forecasts (Network Rail, 2017b). In implementing the  
821 recommendations set out, government and the rail industry should work together to ensure  
822 resilient intermodal service provision.

823

824

## 825 **7. Wider implications of the research findings**

826

827 Despite being based on a single case study, this in-depth empirical investigation of the nature  
828 of rail freight disruption resulting from the unplanned closure of a key railway line has broader  
829 relevance, both in terms of the research methods adopted and in the ability to generalise from  
830 the case study findings to other geographical areas.

831

832 Methodologically, the application of disaggregated data relating to key rail freight operational  
833 measures to assess the rail freight impacts in this way is believed to be novel, and the findings  
834 provide considerable insight into the effects of the disruption. Specifically, the availability of  
835 open access train running data covering all individual freight trains operated in Britain allowed  
836 this detailed analysis to be conducted, and the annual rail freight database provided the  
837 opportunity to compare the service provision during the disruption with that expected in the  
838 baseline (non-disrupted) period. It would be beneficial to replicate the study's methodology to  
839 analyse similar cases of network disruption in other spatial settings, to identify common  
840 themes as well as areas of divergence. Access to the necessary disaggregated data would  
841 likely be challenging unless provided by the rail industry, however, since no other country is  
842 believed to provide comprehensive open access freight train running data at the present time.

843

844 Despite the lack of similar studies based on an equivalent methodological approach, and  
845 recognising that each rail network has its own structure and operational practices, the research  
846 findings are not limited to the UK context, since many of the issues and recommendations  
847 have relevance elsewhere. In particular, there is commonality with the (limited) rail freight  
848 literature identified earlier relating to experience elsewhere in Europe, where mixed traffic rail  
849 networks predominate and where weather patterns are broadly comparable. In the five  
850 countries analysed by Ludvigsen and Klæboe (2014), a similar lack of contingency planning  
851 led to widespread service disruption and a recognition of a need for greater preparedness if  
852 existing customers were to be retained and new ones attracted from road haulage. Despite

853 being part of a strategic European rail freight corridor, the unplanned closure at Rastatt in  
854 2017 (Railway Gazette, 2017; HTC, 2018) also revealed a lack of resilience and consequent  
855 widespread disruption. In general terms, it is important to recognise that freight flows are not  
856 homogenous, with different flows having varying network and scheduling requirements.  
857 Specifically, efforts must be made to support resilient intermodal rail freight service provision,  
858 a major existing and potential growth area across Europe (and beyond). The fact that severe,  
859 disruptive weather events are likely to become more frequent, and that it is impractical to  
860 prevent all instances of major network disruption from occurring, adds urgency to the  
861 implementation of recommendations to increase resilience and minimise the implications for  
862 rail freight and associated supply chain activity.

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Table 1: Overview of case study research methods

<b>Method</b>	<b>Purpose</b>	<b>Details</b>	<b>Sampling coverage</b>
1. Open access real-time information for freight train services (from realltimetrains.co.uk)	To collect route and schedule data for freight trains diverted as a result of the line closure	The following information was captured for each specific train: date/day of operation; train origin; scheduled and actual departure time; route; train destination; scheduled and actual arrival time; freight operating company (FOC)	n = 836 (100% of freight trains diverted during the period of the line closure)
2a. Observation surveys	To gather additional details about train composition and loadings	Direct observation of diverted trains, collecting details of train composition, on-train capacity, load factor, heights of unitised loads, etc. as appropriate	n = 38 (5% of freight trains diverted during the period of the line closure)
2b. Online information relating to train composition	To supplement the observation surveys	Using an approach adopted in previous research (see Woodburn, 2015), train composition information for additional trains was gathered from reliable online sources	n = 134 (16% of freight trains diverted during the period of the line closure)
3. Author's annual rail freight database	To determine the baseline 2016 service provision as a comparator for the disrupted period, and to identify changes in subsequent years (2017 and 2018)	Compiled from a range of sources, for each January since 1997 the database contains information about each service, including: days of operation; scheduled departure and arrival time; commodity; FOC	The database provides national (i.e. Great Britain) coverage of regular freight train services operating each January
4. Industry interviews	To augment methods 1, 2a and 2b and to provide qualitative information about the impacts of the disruption and how it was handled	In-depth, semi-structured interviews with key individuals from relevant organisations, representing the infrastructure manager, a FOC, a logistics service provider (LSP) and the rail freight users group	n = 4 organisations (5 individuals)

