Better by Bus?

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Abstract:

This case study uses datasets from Reading Buses' electronic ticketing system to gain insights into the reactions of public transport passengers to the disruption to bus and rail services in Reading, UK during Storm Doris on 23 February 2017. The analysis generally supports previous research that there are fewer public transport trips in adverse weather conditions. However, an increase in bus trips on services parallel to the more severely disrupted train services, suggests that some travellers respond flexibly by using the bus as an alternative, more resilient mode.

Better by Bus?: Insights into public transport travel behaviour during Storm Doris in Reading, UK

1. Introduction

On 23 February 2017, "Storm Doris" hit the British Isles with rain, snow, and high winds. The strong winds felled trees and displaced signs, roof materials, and other objects, which in turn severed power lines, blocked transport networks, and caused substantial disruption. Alongside the physical damage, the cost of this event includes the extent to which it may have reduced economic productivity or impacted on personal welfare, which is in turn determined by individual response to first the risk, and then the reality of the disruption. Although Reading was only issued amber warnings and gusts reached no more than ~60mph, transport infrastructure and services were significantly affected by Storm Doris. This paper explores how ticketing data from Reading Buses offers insights into the reactions of bus, and indirectly, rail passengers.

The UK Met Office coordinates with other agencies, including emergency responders, to issue severe weather warnings based upon expected impacts, such as travel disruption or flooding, rather than absolute levels of precipitation or wind speed (Met Office, 2016a). On 21 February 2017, the Met Office issued yellow and amber warnings relating to an approaching storm, which by the 22nd, covered almost all of the country (Met Office, 2017). It became Storm Doris, as the practice of naming storms with at least amber warnings had been successfully piloted the previous winter season in order to improve communication to the public (Met Office, 2016b). After Storm Doris passed, the national news reported that the damage caused by "winds of up to 94mph" had indeed been severe, including one death from fallen debris, power outages from East Anglia to Northern Ireland, cancelled flights and ferries, and closed train lines and bridges (BBC, 2017).

2. Wind Impacts on Rail Transport

Such impacts caused by severe weather events of short duration are not surprising. Research into climate change risks suggests that transport infrastructure is more vulnerable to the increasingly frequent severe weather events than to the relatively gradual climatic changes in average temperature or precipitation (Dawson, 2016; Jaroszweski *et al.*, 2010). The most significant risks to transport and other infrastructure in the UK is indirectly from rain storms, and directly from flooding (Dawson, 2016). Although carrying rain and snow, Storm Doris did not result in noteworthy flooding; rather high winds caused the majority of problems. Strong winds during storms are a recognised risk, which is why the Met Office focused on wind impacts in its trial of storm naming (Eysenck, 2016). Also, although climate change risk assessments do not predict increased wind effects and damage on the country's road network in the long term, the rail network is more susceptible, due to 2.5 million trees alongside the tracks (Dawson, 2016).

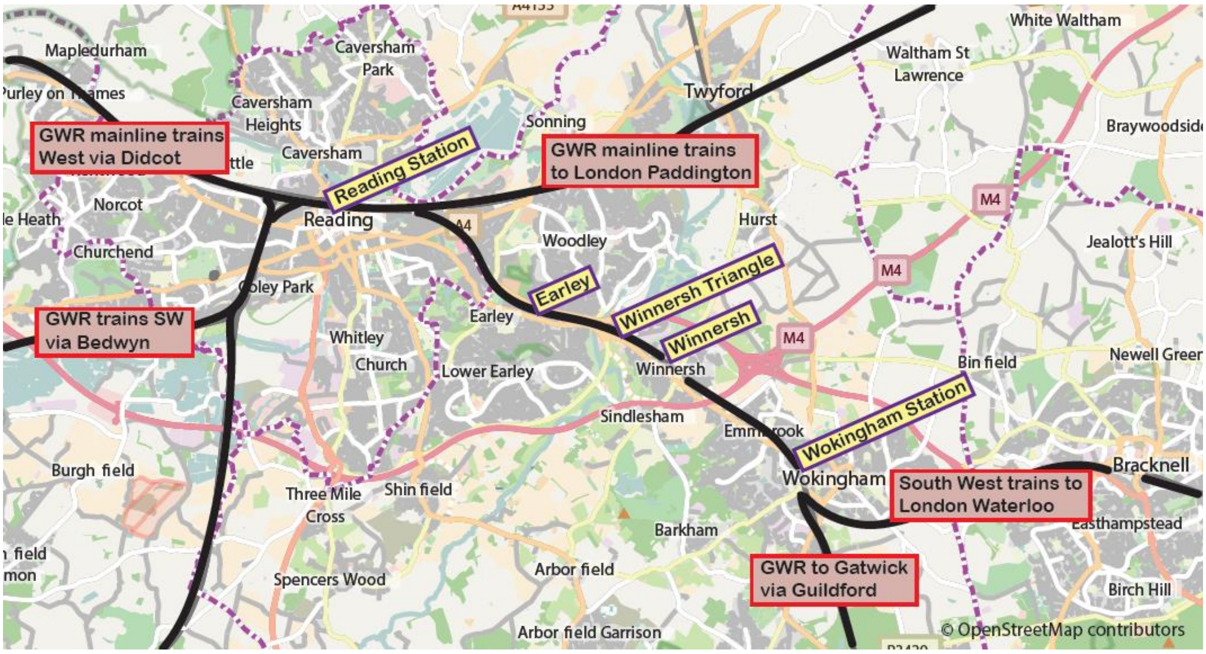
For example, high winds during the winter 2013-14 storms caused bridge closures on the country's Strategic Road Network, but operation returned to normal soon afterwards; conversely the resource available for clearing trees blocking various rail lines was deemed insufficient, delaying recovery

(Brown *et al.*, 2014). This difference in recovery time is reflected not in the total estimated costs of the 2013-14 storms to the road and rail networks, but in the proportion calculated as “welfare costs” to passengers: £1.3 million [strategic roads in England only] and £56 million [England and Wales] respectively (Chatterton *et al.*, 2016). Welfare costs are included in the totals in an attempt to reflect how much time is lost by travellers due to cancellation, delay, and lost productivity, based upon the assumption that a normal number of users are on the roads or the rails (Chatterton *et al.*, 2016). Yet whilst storms do have an impact on people travelling, and that impact may affect people’s lives and routines, welfare cost calculations do not consider how people respond to risk and what actions they may take to avoid any impacts.

The Met Office claims that its severe weather warnings encourage more people to stay at home (Met Office, 2013). Academic studies demonstrate that even normal weather variations cause some travellers to change mode, route or departure time, i.e. leaving early or postponing (Cools, Creemers, 2013; De Palma, Rochat, 1999; Khattak, De Palma, 1997; Kilpelainen, Summala, 2007; Sabir *et al.*, 2010). Alternatively, they may alter their destination, cancel, or access their activities remotely (Koetse, Rietveld, 2009; Marsden *et al.*, 2016). Furthermore, travellers who anticipate disruption and delay are more likely to look for information on alternatives, and the more alternatives with which they are already familiar, including remote access, e.g. telecommuting, the more likely they are to switch to those alternatives in current and subsequent periods of disruption (Chorus *et al.*, 2006; Marsden *et al.*, 2016). There is also evidence that travellers are more concerned about the reliability of journey time for different modes or routes when used regularly, rather than cost or total journey time (Lyons, 2006). Weather events are a well-known risk to such reliability, particularly if infrastructure already operating close to design capacity is affected during busy periods such as morning and evening peaks (Koetse, Rietveld, 2009). Storm Doris struck on a Thursday, outside a holiday period, affecting various congested urban areas at one or both peak periods.

In Reading, rail capacity was predictably most affected. Rail is most sensitive to the sort of high winds experienced during Storm Doris, and trains are disproportionately important to the Reading conurbation. The population of Reading Borough was 155,700 in the 2011 census (Office for National Statistics, 2013), and even the wider urban area can count no more than double that number, yet Reading Station handled 20.7 million passengers entering, exiting or changing trains in 2015-16 (Office of Rail and Road, 2016). This puts it in the top five busiest stations in England outside of London, and seventh overall for interchanges with almost 4 million passengers logged changing between services (Office of Rail and Road, 2016). Great Western Railway operate most trains serving Reading Station. South West Trains, Cross Country, and many freight trains also use the facilities.

Figure 1: Rail network around Reading, UK (http://www.openstreetmap.org/copyright)



Over the course of the day, the online local news, *getreading*, reported trees or other obstructions blocking trains to London Paddington, Didcot, Bedwyn, and Wokingham / Guildford, whilst all South West Trains, including those between Reading and London Waterloo, ran under speed restrictions that delayed journeys from late morning through most of the afternoon (Fort, Perryman, 2017). Of about thirty updates on their website over the course of the day, all but three were about rail disruption (Fort, Perryman, 2017). A Twitter search for "#stormdoris Reading" showed a similar ratio (Twitter, 2017). So many trees fell across the tracks on the line between Reading and Guildford that Great Western Railways reported on its social media page: "An earlier large tree blocking the line has been cleared away… but response teams have now found several other fallen trees in the area" (Great Western Railway, 2017).

Thus, many trains were delayed or cancelled, but that may not mean their passengers were too. Panel surveys of travellers affected by three major, recent weather and roadworks events indicate that commuters most often start journeys slightly later in response to disruption, although over time compressing the work week and increasing the frequency of telecommuting become common coping responses (Marsden *et al.*, 2016). Online interactions between individuals and the train operators confirmed that a few passengers re-routed along other train lines during Storm Doris (Twitter, 2017), but other reactions were not so announced. Some may have stayed home when they heard the severe weather warnings. Yet if they postponed, their outbound journey may have been disrupted, but if they left early, they may have been stranded for hours trying to make an early return – unless they improvised by changing route or mode. The evidence from Reading Buses supports the latter hypothesis: Some travellers adjusted their travel behaviour to the changing circumstances.

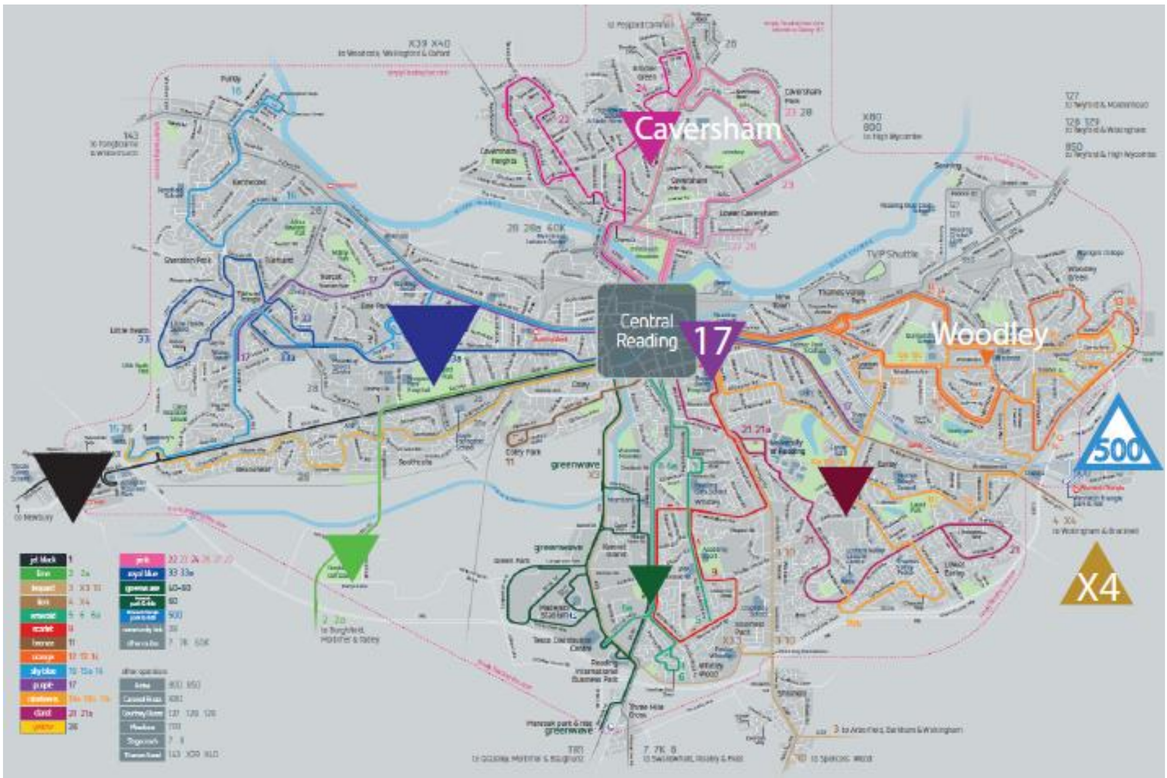
3. Impacts on Bus Travel

Reading Buses is a municipal bus company, which operates over 95% of services in Reading Borough, and the majority of services in neighbouring boroughs (Ottewell, Hyde, 2016). The dataset from their electronic bus ticketing system is thus a practically complete record of bus patronage in the area for the period of analysis. Buses also hold a greater and growing share of the transport market in

Reading compared to most other urban areas in the UK, with 20.4 million trips in 2015/16, the 3rd highest rate of bus use per capita in England outside of London (Ottewell, Hyde, 2016). About 50% of trips are estimated to be made by commuters (Pettitt, 2017). For this research, Reading Buses provided summary data from their ticketing system of 303,000+ trips taken on Thursday, 23 February 2017, during Storm Doris, and Thursday, 2 March 2017, an 'average' day.

The most obvious result from the summary data is that bus passenger trips were 4-8% lower on most services on 23 February than on an 'average' Thursday, except for the orange Woodley services, down by 1.5%, and the southeast Park and Ride route and inter-town services, which saw increases.

Figure 2: The triangles are scaled to match the % changes in daily passenger numbers on the colour-coded clusters of services during Storm Doris compared to an 'average' Thursday. The size of the triangles does not reflect the differences in popularity or patronage of different services. (Base Map from: http://www.reading-buses.co.uk/files/maps/current/Reading%20network%20map.pdf)

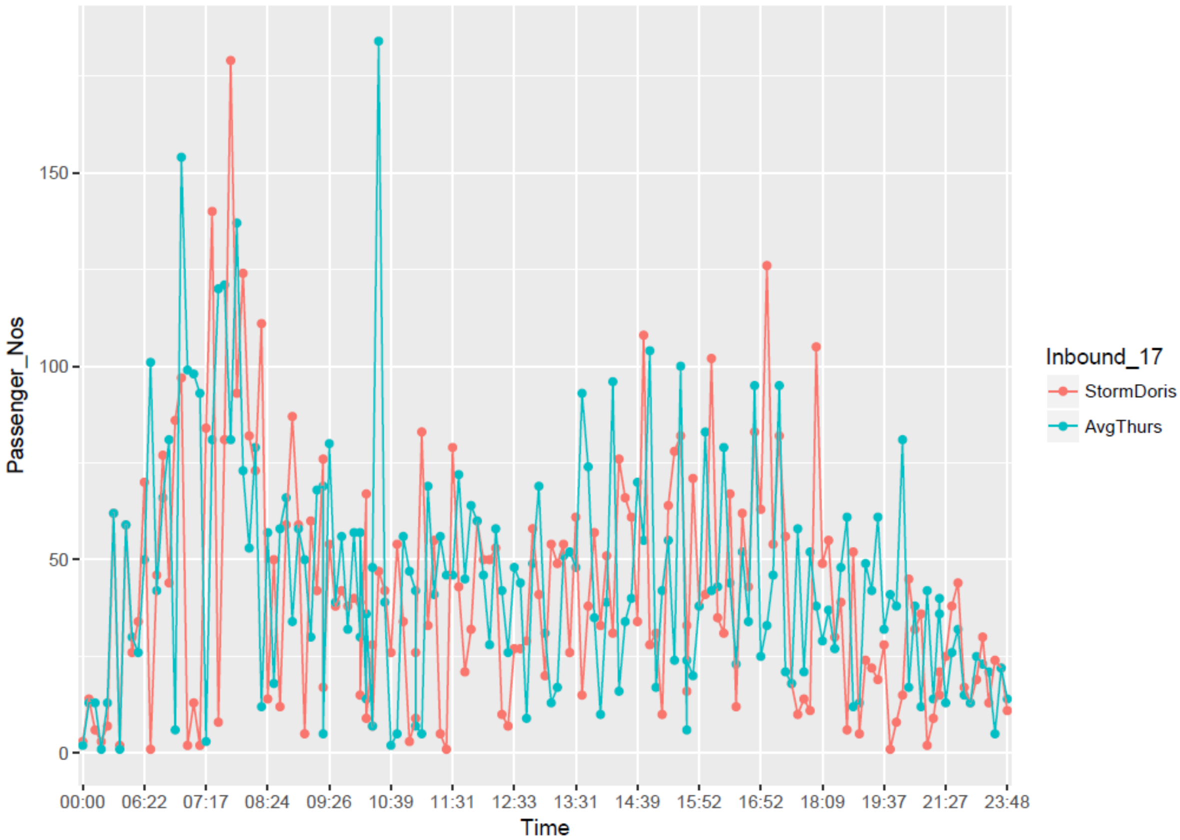


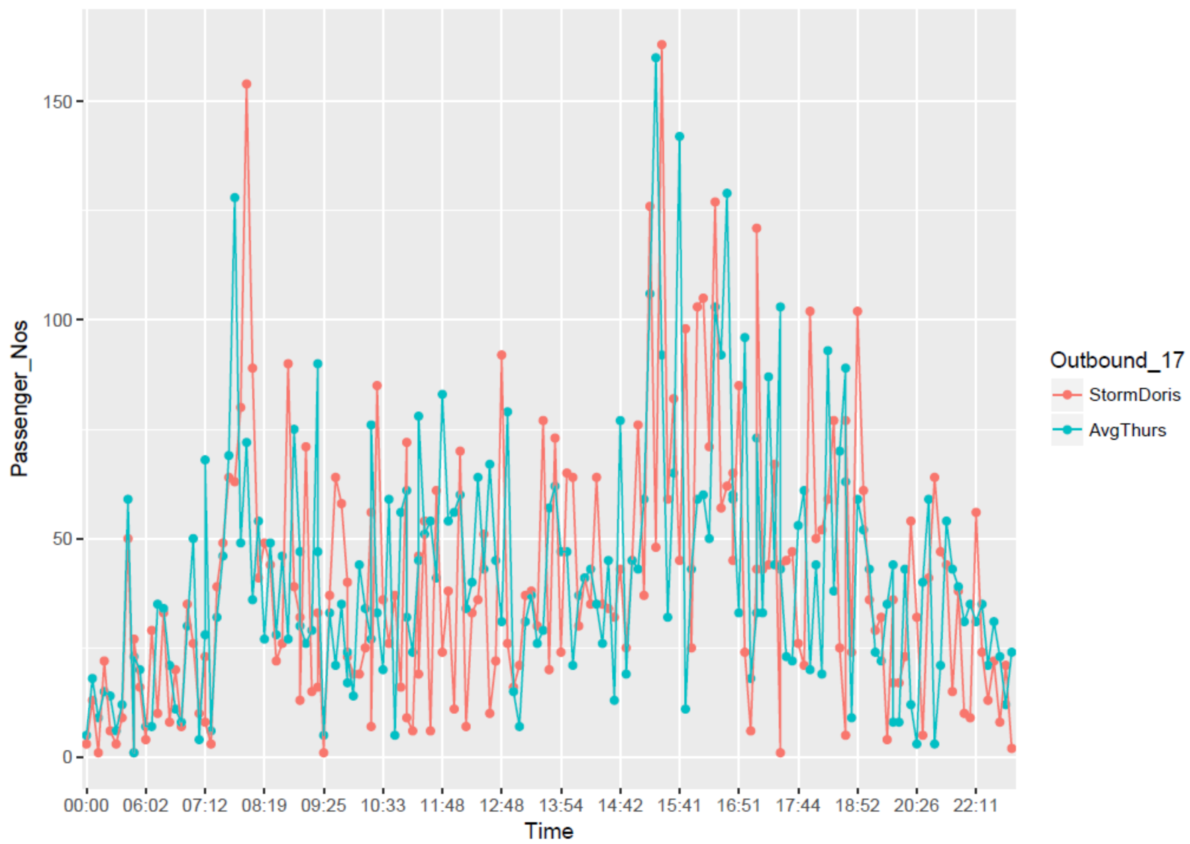
Lower patronage is expected, as studies of ticketing data in various cities over periods of up to two years conclude that ridership usually decreases in 'bad' weather and increases in 'good' weather; even with small percentage changes, many tests have had statistically significant results (Guo *et al.*, 2007; Kalkstein *et al.*, 2009; Singhal *et al.*, 2014; Stover, McCormack, 2012). Public transport passengers are thought to respond to a range of direct and indirect weather impacts (Adler, Van Ommeren, 2016; Guo *et al.*, 2007). People may decide not to travel by bus on rainy days because they would get wet walking to the bus stop, because their stop lacks a bus shelter, or because the bus is likely to be delayed by typically slower speeds on the road network (Guo *et al.*, 2007; Stover, McCormack, 2012). They may also choose to postpone or cancel a weather-affected activity, and thus the trip to access the activity does not occur (Sabir *et al.*, 2008).

Postponement or cancellation is most common for discretionary journeys, whilst far fewer people cancel their commuting or business journeys (Sabir *et al.*, 2010). This conclusion appears to apply to the reduction in journeys around Reading. A majority of those using concessionary bus passes as tickets are not in work or education, as these passes are part of the national scheme only available to those of pensionable age travelling after 9:30AM or with certain recognised disabilities. Therefore, excluding trips taken using concessionary bus passes, the percentage change in passenger numbers on the pink routes in Caversham falls to less than 1%, and in Woodley rises to 3% more passengers on 23 February. Other major service clusters still show decreases of 2-6%.

Reviewing when fewer trips occurred provides further evidence of how few commuters cancelled trips. The following graphs show when and on which bus the almost 28,000 trips were taken on the eastern half of the crosstown, flagship Route 17 on the two successive Thursdays (Reading Buses, 2017).

Figure 3: Route 17 a) Inbound and b) Outbound





Whilst Route 17 saw 6.5% fewer trips during the day Storm Doris hit the UK, and 4.1% fewer trips excluding concessionary bus pass holders, that drop in passengers was spread throughout the day, inbound and outbound. Research suggests that mobility and activities are most consistent, no matter the weather, between 0800 h and 0900 h on weekdays: the morning rush hour (Horanont *et al.*, 2013). In the dataset shown above, there were actually 155 more passengers travelling on 23 February in this hour than on the following Thursday. If passengers during the entire peak period, 0600 h to 1000 h, are included, there were 196 more AM peak trips on 2 March. Considering that the most common response to bad weather is for commuters to change the start time of a journey (Cools, Creemers, 2013; De Palma, Rochat, 1999; Khattak, De Palma, 1997; Kilpelainen, Summala, 2007; Marsden *et al.*, 2016), the data suggests that a small number of commuters probably stayed home on 23 February, but most travelled, some slightly later during the morning peak. Overall, therefore, this case study is consistent with the results of previous research: In severe as in merely 'bad' weather, most commuters will continue travelling.

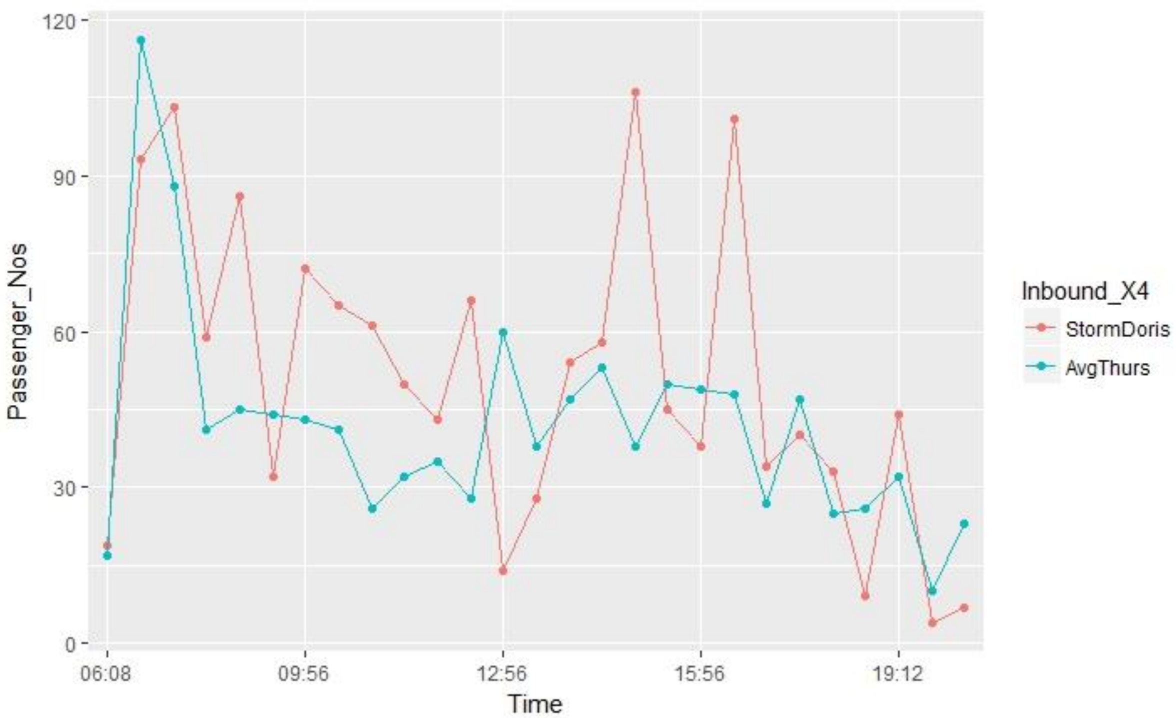
Another question is whether those who do not travel, commuters or otherwise, are responding to weather parameters like rainfall and wind speeds, the focus of most previous research, or to weather impacts on network performance, e.g. bus routing, timetable adherence. From the company's operational summaries and its Twitter feed, it is known that falling trees and debris did affect a number of Reading Buses' services during the day of storm, causing delays and diversions. Yet the operator attributed far more lost mileage to ongoing roadworks than it did to the weather. For example, the 17 was diverted for almost 2 hours as a fallen billboard closed the road on which it normally runs along a bus lane, yet the redundancy built in to bus service delivery meant minimal lost mileage. (Reading Buses, 2017) Also, the difference in passenger numbers during that period outbound was negligible and inbound only about 100, a small loss on such a popular service. Therefore, bus passengers appear to respond more to severe weather warnings and associated risks than to the resulting impacts as they occur.

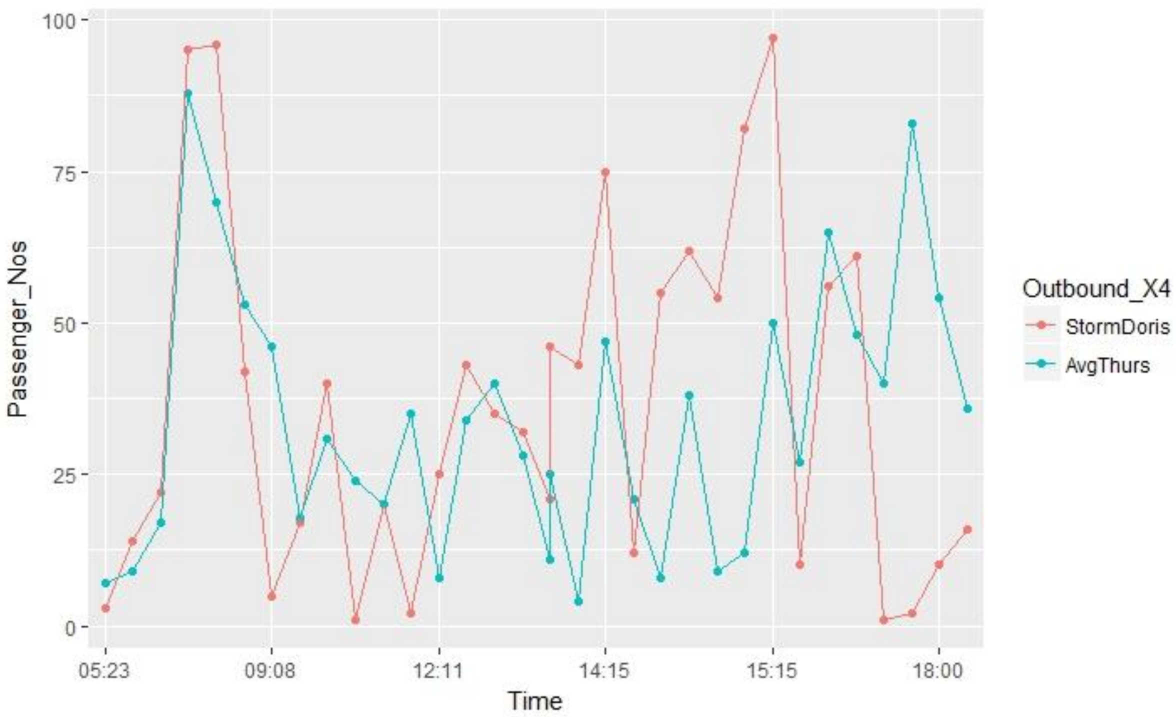
4. Impacts on Bus Travel parallel to Rail Services

It is less certain that rail passengers, dependent upon much less resilient services, respond likewise. The summary data above revealed a clear aberration to the expected decrease in bus passengers. Routes serving the adjacent towns of Wokingham, Bracknell, and intermediate areas with small railway stations recorded substantially more trips. These routes only carry about 7,000 passenger trips combined on an 'average' Thursday, but between them, they carried over 550 more passengers on the day of Storm Doris (Reading Buses, 2017). It is not only a significant change, but merits further investigation of the differences in trip patterns.

The service carrying the most inter-town passengers is the X4. On 23 February, during Storm Doris, these buses served 14.5%, or about 325 more trips than on 2 March. Unlike on Route 17, the difference in trips do not appear to have been distributed randomly throughout the day or by direction. Most of the additional passengers were on two mid to late afternoon services, just before the typical evening peak hour, and 73% of the additional trips were inbound.

Figure 4: Route X4 a) Inbound and b) Outbound





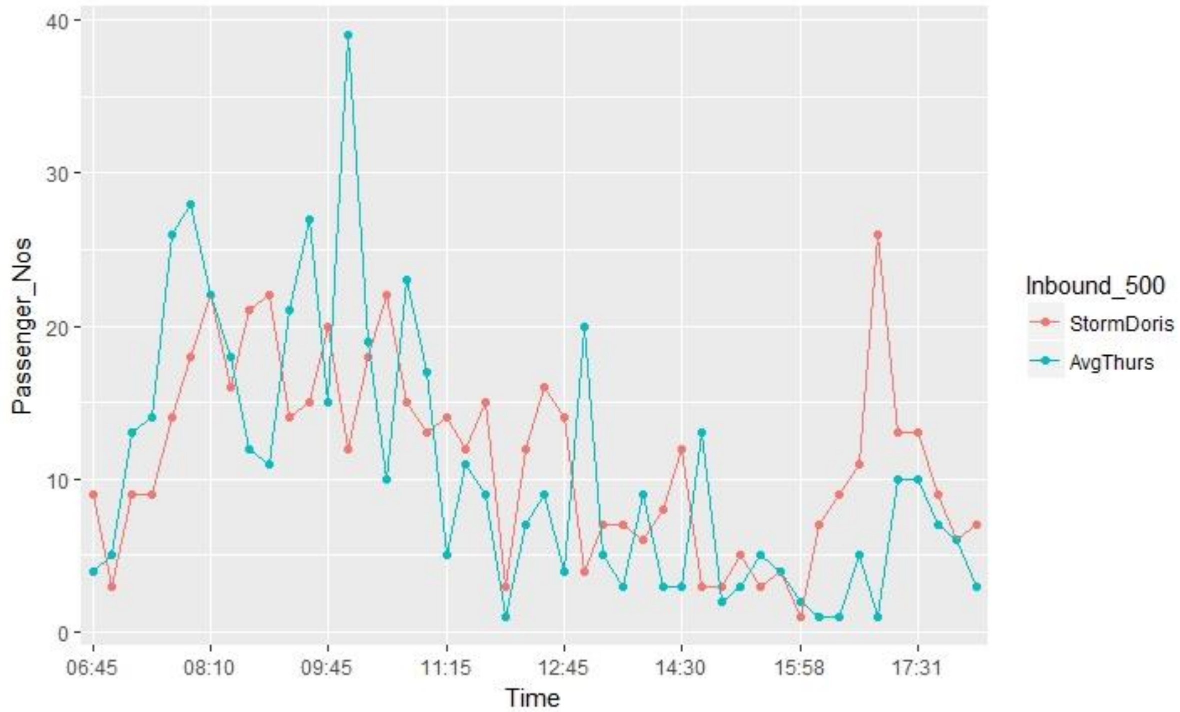
Although the reason for these extra trips cannot be confirmed from the data available, the parallel train lines suffered from severe disruption. Rail services between Reading and Guildford via Wokingham were delayed or cancelled on and off for about two hours in the morning starting at the tail end of the rush hour, and throughout most of the afternoon (Fort, Perryman, 2017; Great Western Railway, 2017). A limited bus replacement service was only offered at around 1600 h (Fort, Perryman, 2017), and the train operator's Twitter feed estimated that the line would not be open until 1730 h at the earliest and that tickets would be accepted on other operators' routes (Great Western Railway, 2017). According to *getreading*, the line reopened at 1717 h, although delays continued for some time afterwards (Fort, Perryman, 2017).

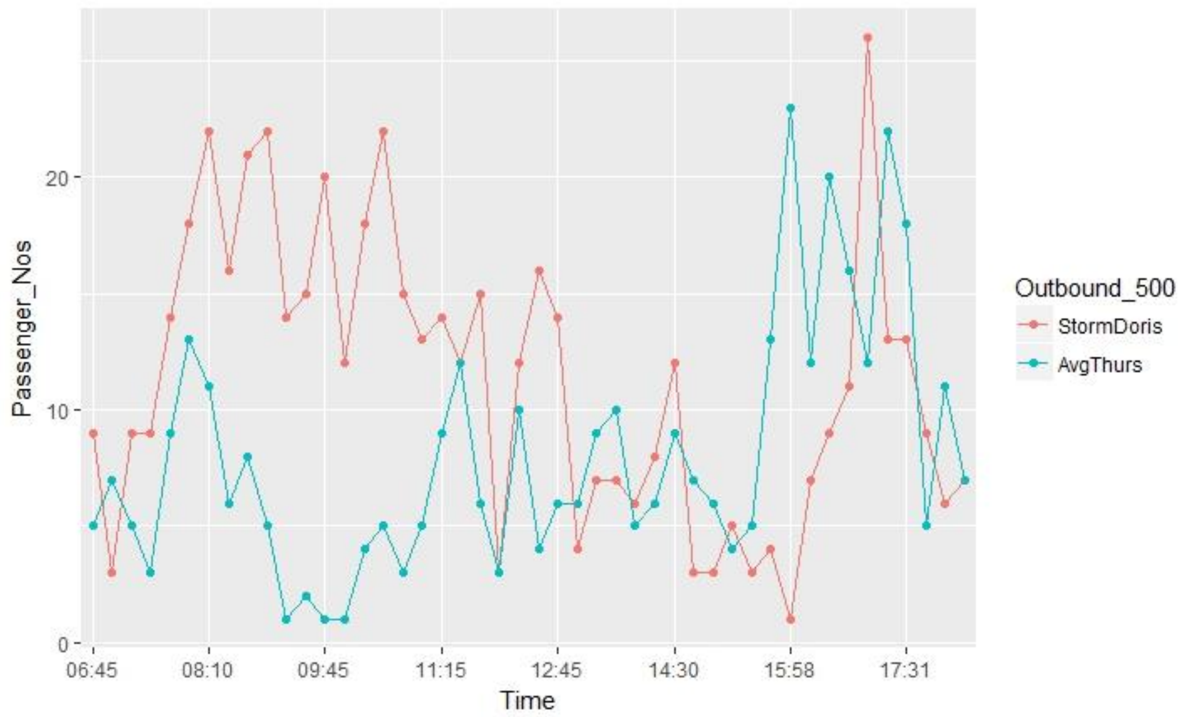
It is not unreasonable to speculate that some of the additional bus passengers were commuters and students who took trains in the morning, kept an eye on events and the uncertain extent of rail disruption, and improvised accordingly. Students often travel at that time, but commuters too were likely among the extra passengers, as their presence would better explain why so many trips were inbound. There are employment sites all along this corridor, but the majority of selective and specialist schools are in Reading, so more students would travel outbound in the afternoon. Furthermore, with interchange centralised in Reading, more employees working along this corridor would need to travel inbound to access multiple residential neighbourhoods, whilst employees in central Reading would only travel outbound if they live in that direction.

The dataset for Route 500 also revealed a significantly different pattern on 23 February compared to 2 March. Route 500 is the express service into Reading from a Park and Ride site immediately adjacent to Winnersh Triangle railway station. Passengers may walk to the Park and Ride and ride Route 500 like any bus, or they may Park their car at the Park and Ride site, or they may be dropped off and picked up. Park and Ride offers less flexibility than the other choices, as passengers are expected to return to their car at the end of the day. Taking an alternative mode home, such as other public transport, would involve abandoning their personal vehicle. Getting a lift to/from the Park and Ride offers the most flexibility, as the passenger could be picked up at a different place from where they were dropped off.

Reading's Winnersh Triangle Park and Ride carried 22%, or almost 200 fewer passengers on 2 March than on 23 February. In contrast to the X4, 81% of those additional passengers were on outbound services.

Figure 5: Route 500 a) Inbound and b) Outbound





Park and Ride sites are purposefully built to encourage daily commuters to use remote parking facilities and an express bus service as an alternative to parking in the centre of an urban area. Thus, they are designed for a high proportion of inbound trips in the morning and outbound in the evening. This was the pattern on 2 March, a 'typical' day. On 23 February, many more passengers were using the Park and Ride outbound in the morning. As it is unlikely they had left their cars the day before, their trips must have been made to access the business park and surrounding area where the Park and Ride facilities are located. Yet there are not enough inbound passengers recorded on Route 500 for those people to have returned home by that means in the afternoon.

The train delays at the end of the morning peak were between Reading and Wokingham, thus affecting both the South West trains that stop at Winnersh Triangle on their way to London Waterloo, and trains towards Guildford. In contrast, the speed restrictions on South West trains were lifted by mid-afternoon, even if those trains did still suffer delays, whilst the trains on the Reading- Guildford line weren't running at all until a couple hours later. Thus commuters who arrived at work at the tail end of the rush hour and left later in the evening could have been on the 500 in the morning, then taken the train home. Or they could have found the timetables of the heavily laden X4 buses more convenient in the afternoon.

In conclusion, the X4 and 500 attracted significantly more passengers on the day of Storm Doris. These services also lost concessionary trips during the storm, but non-concessionary trips more than made up for the loss. Thus, the evidence supports the hypothesis that those making non-discretionary journeys, i.e. commuters and students, were not cancelling their trips, but rather were seeking alternative, more resilient modes of travel such as the bus when faced with severely disrupted train services. The datasets from the slower, less direct Routes 4 and 10 also bolster this argument. Both carried more passengers on 23 February, although this applies to Route 4 only if concessionary trips are excluded. Route 10, which serves a number of smaller settlements, carried more passengers using all ticket types.

5. Conclusions

The above analysis demonstrates that the travel patterns of bus passengers in Reading changed significantly as a result of the storm. The overall reduction in passenger numbers on most services provides further evidence that public transport ridership tends to decrease in adverse weather conditions, despite previous studies often excluding the most severe weather events (Guo *et al.*, 2007; Hofmann, O'Mahony, 2005; Kalkstein *et al.*, 2009; Singhal *et al.*, 2014; Stover, McCormack, 2012). It may be bus passengers drive in bad weather, but it seems more likely that many discretionary journeys, particularly as measured by concessionary trips, are cancelled. Furthermore, as the Route 17 dataset demonstrated, the fall in trips is spread throughout the day, rather than tied to specific storm-related impacts on performance. This suggests that the Met Office weather warnings and publicity, including storm naming, is effective in encouraging people not to take risks and travel in severe weather (Met Office, 2013).

Conversely, commuters cancel fewer trips due to weather warnings, so their productivity may well be affected by disruption as measured by 'welfare costs'. Surveys suggest that if possible and acceptable to their employers, telecommuting increases during prolonged periods of travel disruption, (Kaufman *et al.*, 2012; Marsden *et al.*, 2016), yet there is no such evidence for a single-day event. The empirical analysis above suggests that evasive action, such as travelling later or switching between rail and bus, may reduce the costs of delay, but without complete, clean and accessible datasets reflecting all modes of transport in an urban area, the exact mode shift or level of cancelled trips cannot be determined. Non-transport, geographical data, such as from mobile phone companies, could also enable quantitative analysis of reactive travel behaviour. Nevertheless, Reading Buses' ticketing data does reveal patterns of travel behaviour change in response to Storm Doris. As the risk and impact is unequal for bus and rail services operating on parallel routes, the data suggests both mode switch, and also a flexibility and opportunism in the services used, direction, and time of travel. The case study thus provides insights into the complex relationship between non-discretionary travel behaviour and weather, and what this means for costing resilience and recovery planning.

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References

Adler MW, van Ommeren, JN. 2016. Does public transit reduce car travel externalities? Quasi-natural experiments' evidence from transit strikes. *Journal of Urban Economics.,* **92**: 106-119.

BBC. 2017. Storm Doris: Woman killed as UK hit by winds reaching 94mph. *BBC News.,* http://www.bbc.co.uk/news/uk-39060095.

Brown R, Curley, J, Smith, B. 2014. *Transport Resilience Review: A review of the resilience of the transport network to extreme weather events*. Department for Transport: London.

Chatterton J, Clarke, C, Daly, E, *et al*. 2016. *The costs and impacts of the winter 2013 to 2014 floods*. Environment Agency: Bristol.

Chorus CG, Molin, EJE, Van Wee, B. 2006. Use and effects of advanced traveller information services (atis): A review of the literature. *Transport Reviews*., **26**: 127–149.

Cools M, Creemers, L. 2013. The dual role of weather forecasts on changes in activity-travel behavior. *Journal of Transport Geography*., **28**: 167-175.

Dawson R. 2016. Chapter 4: Infrastructure. In: *UK Climate Change Risk Assessment 2017: Evidence Report.,* Committee on Climate Change: London.

De Palma A, Rochat, D. 1999. Understanding individual travel decisions: results from a commuters survey in Geneva. *Transportation.*, **26**: 263-281.

Eysenck J. 2016. UK weather: Why do we give names to storms? *The Telegraph.* http://www.telegraph.co.uk/news/weather/12074681/UK-storm-names.html.

Fort H, Perryman, F. 2017. Recap: Reading passengers hit by delays as Storm Doris causes problems. *getreading.* http://www.getreading.co.uk/news/reading-berkshire-news/updates-reading-passengers-travelling-guildford-12644142.

Great Western Railway. 2017. *National Rail (@NRE_GWR) | Twitter*. @NRE_GWR timeline from 23/02/17 and 02/03/17.

Guo Z, Wilson, NHM, Rahbee, A. 2007. The impact of weather on transit ridership in Chicago, Illinois. *Transportation Research Record: Journal of the Transportation Research Board*., **2034**: 3-10.

Hofmann M, O'Mahony, M. 2005. The Impact of adverse weather conditions on urban bus performance measures. *IEEE Conference on Intelligent Transportation Systems.* Vienna, Austria, 431-436.

Horanont T, Phithakkitnukoon, S, Leong, TW., *et al.* 2013. Weather Effects on the Patterns of People's Everyday Activities: A Study Using GPS Traces of Mobile Phone Users. *PLOS ONE*., **8**: 1-14.

Jaroszweski D, Chapman, L, and Petts, J. 2010. Assessing the potential impact of climate change on transportation: the need for an interdisciplinary approach. *Journal of Transport Geography*., **18**: 331-335.

Kalkstein AJ, Kuby, M, Gerrity, D, *et al*. 2009. An analysis of air mass effects on rail ridership in three U.S. cities. *Journal of Transport Geography*., **17**: 198-207.

Kaufman S, Qing, C, Levenson, N, *et al*. 2012. *Transportation During and After Hurricane Sandy*. Rudin Center for Transportation, NYU Wagner Graduate School of Public Service: New York.

Khattak AJ, De Palma, A. 1997. The impact of adverse weather conditions on the propensity to change travel decisions: a survey of Brussels commuters. *Transportation Research Part A: Policy and Practice*., **31**: 181-203.

Kilpelainen M, Summala, H. 2007. Effects of weather and weather forecasts on driver behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*., **10**: 288-299.

Koetse MJ, Rietveld, P. 2009. The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment*., **14**: 205-221.

Lyons G. 2006. The role of information in decision-making with regard to travel. *Intelligent Transport Systems*., **153**: 199-212.

Marsden G, Anable, J, Shires, J, *et al*. 2016. Travel Behaviour Response to Major Transport System Disruptions: Implications for Smarter Resilience Planning. In: Forum IT *Preparing for Major Disruptions to Transport Systems.* Leipzig: OECD, 5-27.

Met Office. 2013. *'St Jude's Day' storm - October 2013*. http://www.metoffice.gov.uk/about-us/who/how/case-studies/st-judes-day-storm-oct-2013.

Met Office. 2016a. Severe Weather Warnings. In: weather desk advisor in correspondence with the author, 25 November 2016.

Met Office. 2016b. *Name Our Storms 2016. The UK's storms will be named again this coming autumn and winter.* http://www.metoffice.gov.uk/news/releases/2016/nameourstorms2016.

Met Office. 2017. *Met Office (@metoffice) | Twitter*. @metoffice @metofficeSEENG timeline from 21/02/17 to 23/02/17.

Office for National Statistics. 2013. *Reading 2011 Census Factsheet*. Reading, UK.

Office of Rail and Road. 2016. *Estimates of Station Usage 2015-16*. Office of Rail and Road: London.

Ottewell D, Hyde, N. 2016. Reading Buses controls more than 95 per cent of town's market. *getreading.* http://www.getreading.co.uk/news/reading-berkshire-news/reading-buses-controls-more-95-12090411.

Pettitt T. 2017. Estimation of commuting passengers. In correspondence with the author, 15 May 2017.

Reading Buses. 2017. *Ticketer Reports and Operational Summaries*. Reading Buses: Reading, UK.

Sabir M, Van Ommeren, J, Koetse, MJ, *et al*. 2008. Welfare effects of adverse weather through speed changes in car commuting trips. *Tinbergen Institute Discussion Papers.* VU University: Amsterdam.

Sabir M, Van Ommeren, J, Koetse, MJ, *et al*. 2010. Impact of weather on daily travel demand. *Tinbergen Institute Discussion Papers.* VU University: Amsterdam.

Singhal A, Kamga, C, Yazici, A. 2014. Impact of weather on urban transit ridership. *Transport Research Part A: Policy and Practice*., **69**: 379-391.

Stover VW, McCormack, ED. 2012. The Impact of Weather on Bus Ridership in Pierce County, Washington. *Journal of Public Transportation*., **15**: 95-110.

Twitter. 2017. *Twitter search results for "#stormdoris Reading"*. www.twitter.com.