Appendix 4.3
Supply interruptions supporting evidence

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Overview

As set out in chapter 4 section 4.2.2 we have accepted the Upper Quartile supply interruption target of 3 minutes by 2024/25 but have included a 3 minute deadband. The evidence is presented in this appendix.

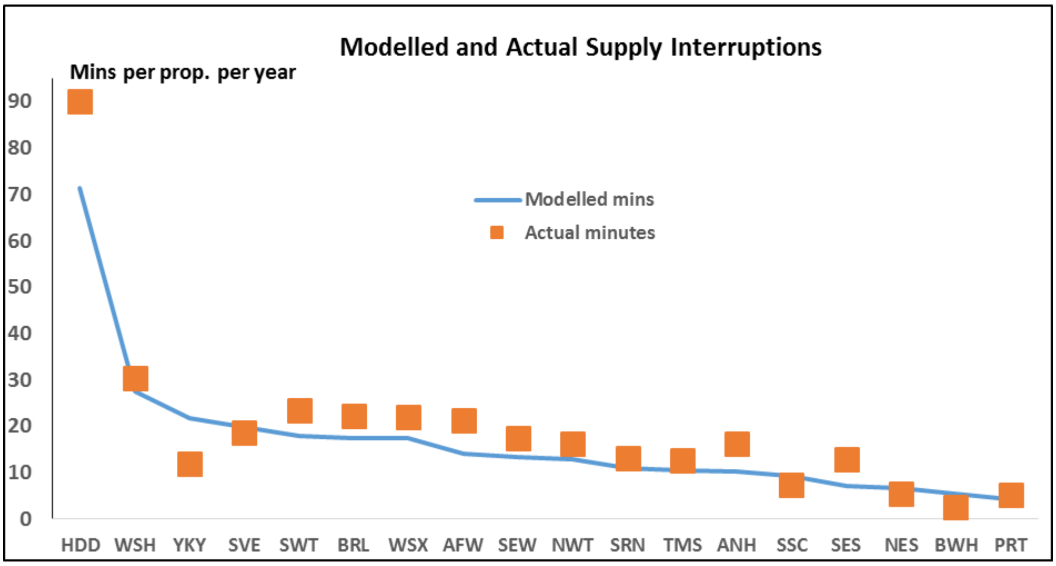
We have examined industry and company data and present the analysis in two ways:

1. Using econometrics to look for industry wide relationships between supply interruptions performance and physical characteristics such as population density and topography (represented by pumping head); and
2. By reviewing historic events using hydraulic models and GIS, to determine the extent to which the local system characteristics in HDD (for example rurality, lack of rezone options, mains materials and density of valves) impact performance by benchmarking it against performance in ST England.

We have been developing this analysis since the acquisition of Dee Valley to ensure we have a comprehensive understanding of the risks within our network and to help us prioritise events in our Control Room.

We are in the process of rebuilding Wrexham area hydraulic models to a specification that enable us to analyse that area as well, but a higher proportion of the population can be rezoned and supply interruptions are broadly in line with the industry upper quartile, so the analysis focuses on performance in Powys.

The analysis we have done shows that there is a clear relationship between population density, topography and supply interruptions performance, which explains why HDD performance is not as good as the rest of the industry. In section 2 below we interrogate these relationships to understand the drivers and extent to which the drivers can be influenced by management decisions.



Our bottom up analysis shows that due to the characteristics of our operating area in Powys the overall performance (after taking account of factors that are within management control) is **3 customer mins/ year** higher than the average performance across the wider Group. The impact of each stage is summarised in the table below. This is the basis of our plan which includes a 3 minute penalty deadband which tracks the upper quartile target. The analysis is set out in section 1 below.

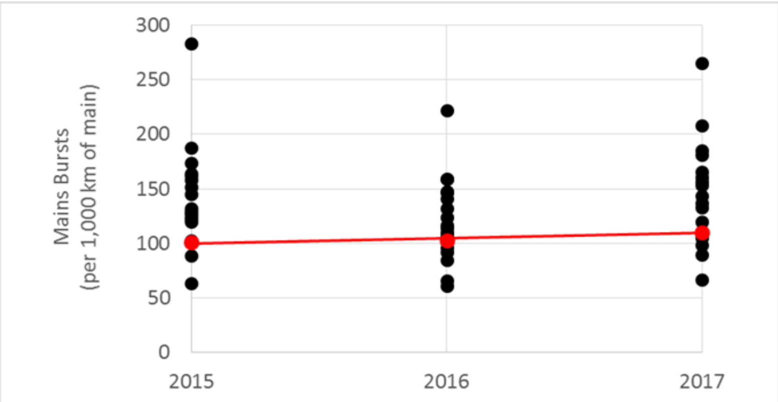
Table 1 Average impact on individual Powys supply interruptions events compared to typical SVE events

	Initiation	Pin-point cause	Isolate	Rezone / alternate supply	Repair	Recharge
Factors influencing interruption likelihood, extent and duration	Mains failure rates (material, age, ground and pressure variance)	Connection density, rurality, remoteness from depot	Valve frequency, volume to drain down	Rezone constraints	Repair type, complexity, Health and Safety	Frequency and number of valves, volume to re-charge
Average impact on each event HDD Powys vs SVE	Covered in other factors	+ 32 mins (includes 23min for travel time)	+7 mins	11% less customers can be rezoned	+22 mins	+4 mins

1.0 Benchmarking of historical supply interruption events

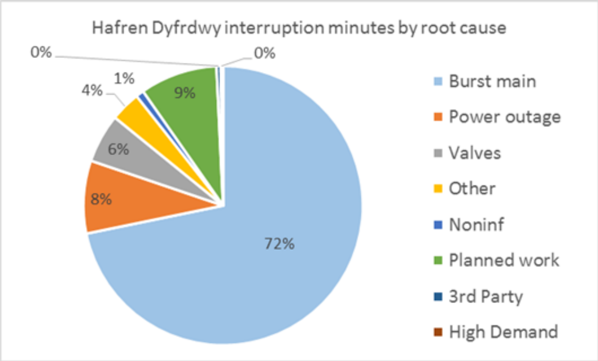
Instigation

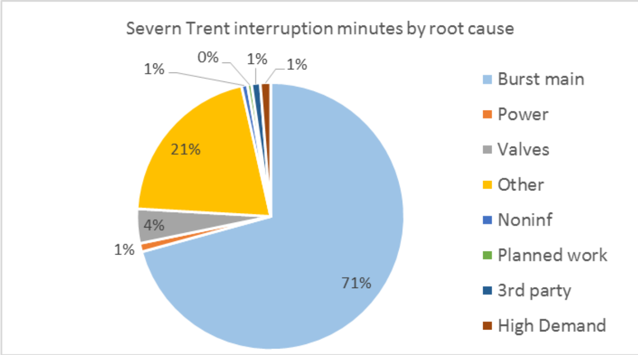
At a company level the numbers of mains failures in HDD are comparable to the rest of the industry – our burst rate is just above industry average, but this is masking a higher burst rate in Powys compared to Wrexham.



Due to the topography of the supply area and the need for more booster stations along the valleys in Powys. Analysis using hydraulic models indicates that average pressure and pressure variation are more than 10% higher in HD. It is known that systems operating at higher pressures are more likely to burst and tend to lead to supply interruptions more quickly.

We wanted to further examine the root cause of supply interruptions to understand if they can be influenced by management decisions. The chart below shows that although most interruptions are caused by mains bursts (72%), a higher proportion of interruptions in HDD Powys result from power failures due a greater proportion of the supply being boosted and the vulnerability of the power supply network in rural areas. Investment has been made previously in generators and connection points to mitigate this risk.





We have not made any assumptions about how the root cause of the burst affects the overall supply interruptions target as the impact manifests later on in the process. The section below on repair time discusses the impact of different mains materials on the duration of an interruption.

Pinpointing location

We have analysed historical events to assess the typical times to become aware of and pin point a burst main causing an interruption in various types of location. This analysis indicates that it is quicker to locate a mains burst in urban areas with more customers, street lighting and access to fittings. Mains bursts in rural areas, especially those across agricultural land, take longer to track down. We used ArcGIS to apply these typical times to all mains in SVE and HDD Powys to estimate the average impact of differences in location. This revealed that it takes on average **9 minutes** longer to locate an issue in HDD Powys rather than in SVE.

The greater distance between communities in HDD Powys compared to SVE means that it takes longer for our inspectors to travel to the area where the interruption is detected or reported. Using a mapping system we estimated the time to travel to each post code in HDD Powys and SVE containing a water main from the nearest depot. The average travel time in HDD Powys was **23 minutes** longer than in SVE. Management action, for example creating new depots, recruiting more local staff and increasing home based working, may mitigate this impact somewhat. We have taken account of this in the conclusion section below.

Isolating repair

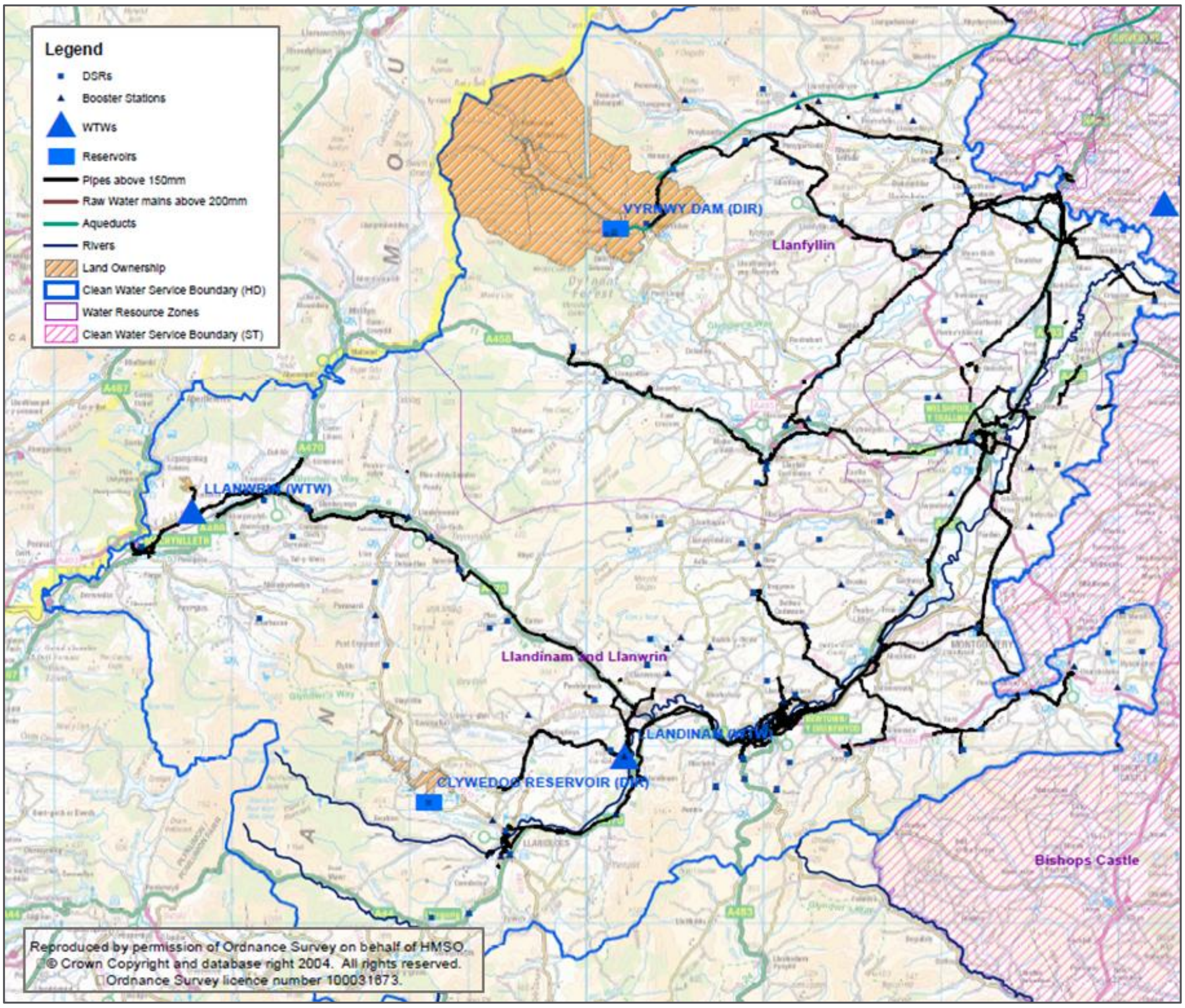
We used ArcGIS and our hydraulic modelling software to analyse the number of valves that need to be shut, the distance between valves and the number of turns required (derived from mains diameter) and drain down volume/time in order to isolate a main for repair for each length of water mains in HDD Powys and SVE.

On average there is a greater distance between valves in rural areas means that on average it takes an additional **7 minutes** to isolate an equivalent main for repair in HDD Powys compared to SVE.

Re-zoning customers

In Powys the rezone options are limited because the distribution network follows the topography and serves the small communities that stretch along the river Severn valley and its tributaries. The Figure below illustrates how the Powys supply network follows the river valleys. The supply to the main communities of Llanidloes, Newtown and Welshpool are supplied from Llandinam borehole along the river Severn valley over a distance of 30 miles with limited ability to interconnect.

Powys supply trunk main network showing



We have quantified our ability to rezone by using extensive and in depth analysis using hydraulic models. The software allows us to virtually break each individual section of pipe, operate valves to try to rezone and then count the number of customers that can be supplied by another source, or from the same source via another pipeline route.

This analysis shows that on average 11% less customers can be rezoned in HDD Powys than in SVE meaning that for a burst on a similar size and type of asset more customers will be interrupted.

	Proportion of customers that can be rezoned	Proportion of customers that can be rezoned
HDD Powys	72%	27%
average of all zones in SVE	84%	16%

Repair time

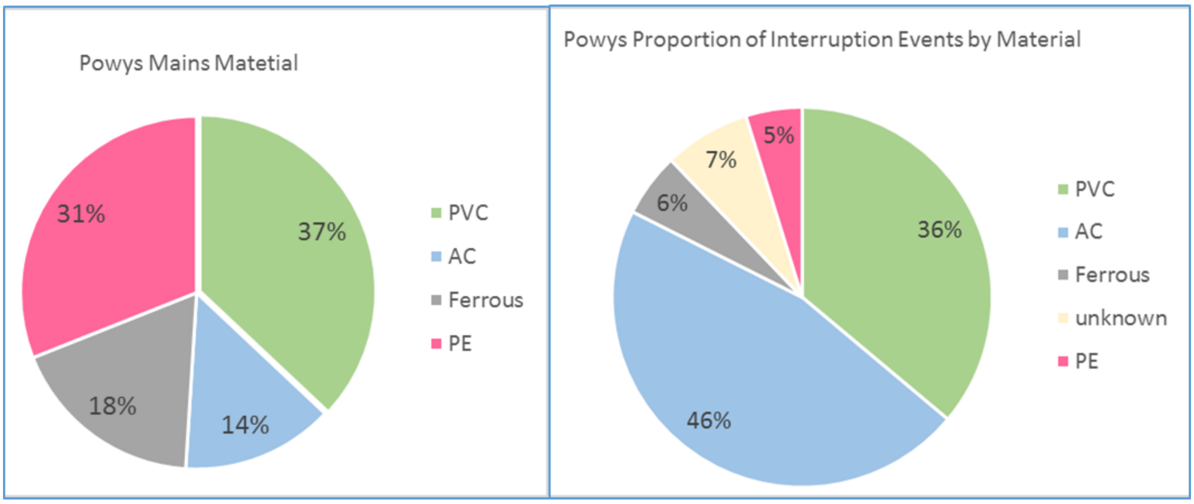
PVC and Asbestos Cement (AC) mains have a disproportionate impact on interruptions as they often require a full length repair that takes longer to implement because;

- AC mains present a health and safety risk if they are cut into, meaning that a quicker 'piece repair' (used commonly on ferrous mains) is not unavailable; and

- PVC mains have a tendency to split longitudinally due to the structure of the polymer

We have proportionally more AC and PVC mains as these were laid in rural areas in preference to ferrous mains between the 1940s and 1980s in Powys.

The impact of these longer repair times is illustrated below where the AC forms 14% of the material but causes 46% interruption events. A similar pattern is seen in SVE (9% of the material and 28% of events)



The predominance of these mains materials, circa 50% in HDD Powys compared to circa 20% in SVE, means that there is a notable impact on interruptions performance in HDD.

Using ArcGIS we have assessed the repair time for all mains in HDD Powys and SVE by considering;

- likely repair type (collar, piece or length) due to mains characteristic (diameter and material); and
- location (proximity to other services and likely traffic management requirements)

The analysis indicates that on average a main in HDD Powys would take 22 minutes longer to repair than a main in SVE.

Increasing the renewal rate of Asbestos Cement mains would seem a sensible long term proposition (renewing at the industry average rate of approximately 0.5% per annum would take over 20 years.) We intend to fully consider the cost and benefits of different renewal strategies for the PR24 Business Plan submission.

Recharge time

We used GIS and our hydraulic modelling software to analyse, for each water main in HDD Powys and SVE, the number of valves that need to be opened, the distance between valves and the number of turns required, recharge volume, water pressure and time to chlorinate.

Our analysis indicates that on average it takes an additional **4 minutes** to recharge an equivalent main in HDD Powys compared to SVE. This is because;

- on average there is a greater distance between valves
- a greater volume of water has to be Chlorinated; mains have proportionately larger diameters in order to overcome greater headloss over the long distances between communities.

Conclusion

Overall we estimate that an average interruption event will be 65 minutes longer in HDD Powys compared to SVE. We have applied these impacts to individual historic events with a burst main cause in Powys to work out the effect on annual performance (i.e. how much is performance affected by the topography, asset types and system configuration).

	Initiation	Pin-point cause	Isolate	Repair	Recharge	Total
Average impact on each event HDD Powys vs SVE	Covered in other factors	32	7	22	4	65

Note: pinpointing the cause includes 23 minutes for travel time

However travel time may be addressed by changes to working practices and work base locations, so we have therefore analysed the potential impact of management decisions that could be changed.

Impact on supply interruptions performance (minutes) due to company specific characteristics

	all travel time impact included	management action reduces travel time impact	
		By 50%	Fully
2013/14	4.4	3.7	3.2
2014/15	2.9	2.7	1.6
2015/16	3.4	2.9	2.5
2016/17	1.4	1.1	0.8
2017/18	1.0	0.6	0.5
2018/19 to 28.02	2.5	2.1	1.6
Average	**2.6**	**2.2**	**1.7**

We believe that we should be able to eliminate a proportion of travel time issues and have assumed that a **two minute** impact should be assumed, this is a judgment based on a average between 1.7 and 2.2.

The impact on the rezone constraints has been assessed by reducing the numbers of properties affected in each individual Powys event from previous years by 11%. This has an average impact of **one minute** on overall company performance.

Our analysis confirms that achieving this level of performance is extremely challenging due to the inherent characteristics of our network that we are not able to address through management intervention or increased investment over the next five years. We are committed to achieve upper quartile performance but believe is appropriate to use this analysis to create a 3 minute deadband.

We will also use this analysis to inform our AMP7 interruptions improvement plan.

2.0 Econometric modelling

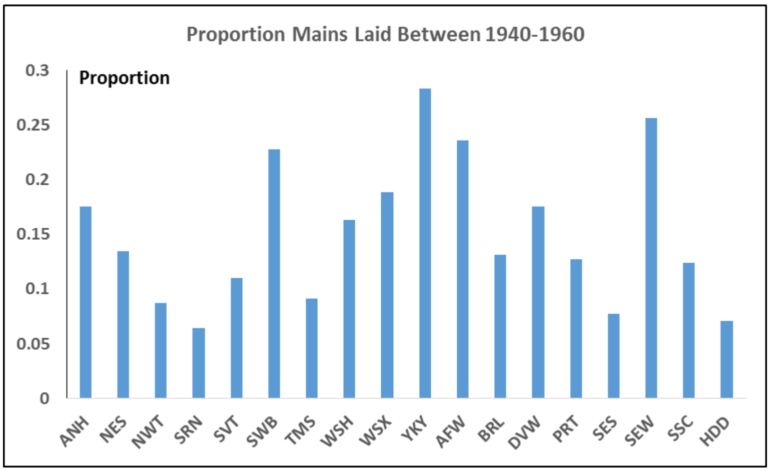
As part of this analysis we have explored an econometric modelling approach to understand the degree to which differences in performance between companies can be explained by network and geographic characteristics.

We believe that this approach has merit and we will do further research on this and are happy to engage with other companies and Ofwat. Whilst we haven't used it to derive the size of an appropriate deadband it does show a clear difference between HDD and the rest of the industry that should be taken into account.

The key factors affecting the number of supply interruptions are set out in the sections above. Our attempts to build an econometric model were restricted due to the lack of comparative data. To overcome this we tested a number of proxy variables;

- **Mains material**: weighted average age of the mains network for each company (given that asbestos cement was most commonly used in the 1940s to 1980s)

  Our analysis proved that this was not a suitable proxy as the main driver for mains length in shows that HDD are at the lower end of this range.

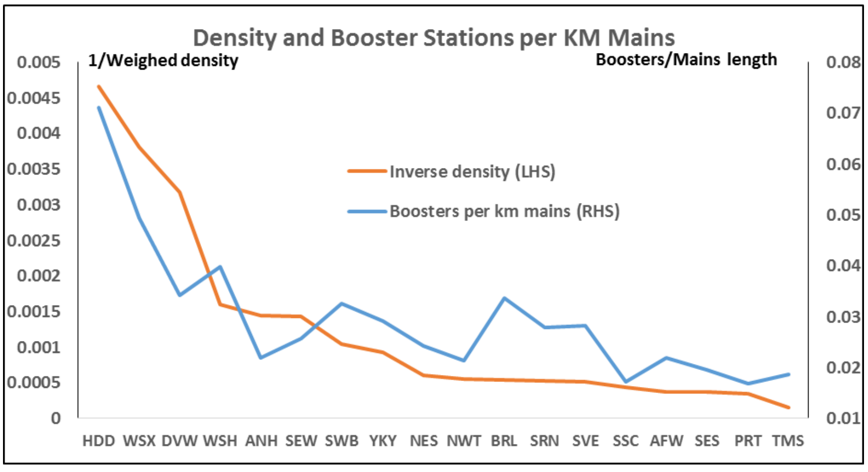


- **Mains material**: proportion of leakage which captures a broader range of factors than network age
- **Rurality**: number of properties per km mains and Ofwat's weighted average density.

  We found similar results with both metrics.

- **Topography**: average pumping head and the number of booster stations per km of main

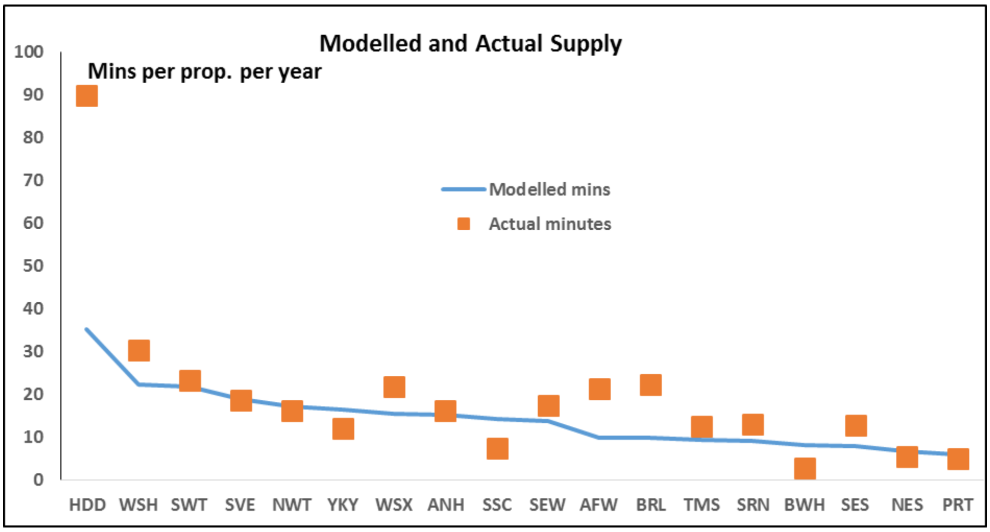
  We found that average pumping head was relatively significant but that the number of booster stations per km of mains was the most powerful driver.



The table below shows the results of two models of (ln) supply interruptions.

ln Minutes per Prop.	Model 1	Model 2
ln APH	0.29*	.32***
Prop. leakage	8.04***	4.4**
ln density	-1.48***	-.09
ln boosters/length		1.45***
Constant	6.04	6.98
R^2	0.33	0.52

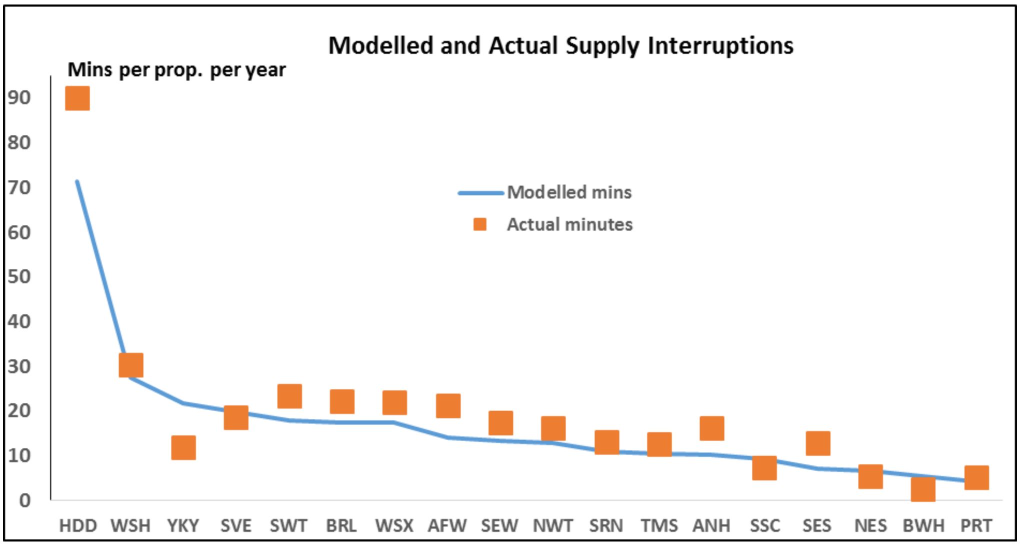
The figure below shows the relationship between model 1's forecast and the actual average supply interruptions over the period 2011-2018. For HDD we use only the period 2016-2018 as it is all that is available.



The R^2 for model 1 is 0.33 and the coefficients conform to expectations and given that extreme one-off events can have a substantial impact on supply interruptions we would not have expected to necessarily be able to explain the majority of the variance.

The figure below shows the results of model 2 which differs from model 1 only with the inclusion of the number of booster stations per km mains. The fit of the model improves an R^2 of 0.52.

Model 2 shows a clear relationship between these modelled network characteristics and achievable supply interruptions targets.



Our conclusion is that the analysis confirms that there is a clear link between network characteristics and performance and that the main driver for this is driven by density and numbers of booster stations per km of main as proxy measures for rurality.

A more appropriate way to set a challenging target for companies would be to make an upper quartile adjustment to the modelled performance or, if the company is already outperforming the model, to require a frontier shift.