WLR and LLU Fault Rates Analysis

Final Report

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Ofcom

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20 November 2013

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1. Executive Summary

Project Objectives

1.1. In July 2013, Ofcom commissioned CSMG to produce a report determining the fault rates for three types of Openreach lines: Wholesale Line Rental (WLR) only lines, WLR and Shared Metallic Path Facility (SMPF) lines, and Metallic Path Facility (MPF) lines in 2011/12 and 2012/13.

1.2. In addition, if differences were found to exist between WLR+SMPF lines and MPF lines, CSMG was asked to investigate the reasons for these differences.

1.3. Finally, CSMG was asked to forecast the fault rates for the three types of line in 2016/17.

1.4. The fault rates calculated will input into Ofcom's WLR and LLU charge control for the period 2014-17.

Data Sources

1.5. For its analysis, CSMG utilised two datasets provided by Openreach, a database of faults from April 2011 to August 2013 and a database of the weekly working system size of lines for each week of the same time period. The datasets covered faults and lines in England, Scotland, Wales and Northern Ireland.

1.6. In the fault database, each fault was categorised by date, line type and if the fault occurred in early-life (EL) or in-life (IL). Early-life was defined as within the first 28 days after a transition activity.

1.7. The working system size was also categorised by week, line type and segmented into EL and IL volumes.

1.8. The analytical results are bound by the quality and sufficiency of the source data. In particular, some caution must be applied when assessing the significance of long-term trends inferred from the relatively short-run dataset (approximately two years).

Recent Fault Rates

1.9. Using these two datasets CSMG was able to calculate the 2011/12 and 2012/13 fault rates for each line type. These are shown in the table below.

Figure 1: Fault Rates by Product 2011/12 and 2012/13

Line Type	Overall Fault Rate (Faults per active line per annum)	
	2011/12	2012/13
MPF	10.3%	11.1%
WLR Only	8.1%	8.4%
WLR + SMPF	10.5%	10.8%

1.10. It should be noted that there were issues with the data in the first half of 2011, which were not able to be resolved (see Section 3 para 3.17).

1.11. Comparing the fault rates for MPF and WLR+SMPF, the MPF rate was slightly lower (2%) in 2011/12 and slightly higher (2%) in 2012/13. The two line types therefore have similar overall fault rates.

1.12. Having determined overall 2011/12 and 2012/13 fault rates, CSMG calculated the In-Life Fault (ILF) and Early-Life Fault (ELF) rates of these products. These rates are shown below:

Figure 2: Fault Rates by Product 2011/12 and 2012/13 (ILF and ELF)

Line Type	IL Fault Rate (Faults per active line per annum)	
	2011/12	2012/13
MPF	8.5%	9.1%
WLR Only	7.4%	7.9%
WLR + SMPF	9.1%	9.6%

Line Type	EL Fault Rate (Faults per provisioning activity)	
	2011/12	2012/13
MPF	4.2%	4.8%
WLR Only	3.1%	2.7%
WLR + SMPF	2.4%	2.8%

1.13. Analysing the ILF rates, MPF fault rates were found to be consistently lower than WLR+SMPF by between 5% and 7%.

1.14. For ELF, the trend was reversed with MPF ELF rates significantly higher than WLR+SMPF ELF rates (70% higher in 2012/13).

1.15. Note that CSMG has calculated two measures of ELF rates: the first, used by Ofcom and Openreach in previous publications, measures total faults in a defined period compared to the working system size of ELF lines; the second (shown in the table above), measures the fault rate relative to the total number of provisioning activities in the period.

Understanding Differences in Rates

1.16. CSMG developed a series of hypotheses to explain these differences in rates. These hypotheses were:

- The lower MPF ILF rate was the result of MPF lines having a shorter line length on average than WLR+SMPF lines;
- The lower MPF ILF rate was the result of MPF lines generally being in more urban, densely populated areas with less overhead cabling;
- The higher MPF ELF rate was the result of higher segment specific fault rates (e.g. higher Frame ELF rate resulting from lower visibility of the line during a MPF provision between the TAM and the DSLAM).

1.17. CSMG conducted a series of regression analyses to test the first two hypotheses.

1.18. Although WLR+SMPF lines were found to be slightly (1.7%) longer on average, there was little correlation between line length and fault rate (R^2 of 0.0185).

1.19. A mapping of fault rates by population density demonstrated some clustering of high fault rates in rural locations, however a linear regression analysis showed the actual correlation to be weak (R^2 of 0.0014).

1.20. Finally, calculating the network segment ELF for MPF and WLR+SMPF demonstrated that there was no particular network segment that was driving the difference in ELF (the difference in Frames, E-Side and D-Side ELFs were similarly driving the difference). These network segment fault rates are presented below.

Figure 3: Fault Rates by Network Segment 2012/13 – ILF

Line Type	Network Segment ILF Rates, 2012/2013 (Faults by Network Segment as % of Avg. Annual IL WSS per Product)								
	D-Side	E-Side	Frames (MDF)	Drop Wire	Monopoly Wiring	Line Testing Equipment	FNF Local Line	All Network Segments	All Faults (inc. FNF)
MPF	3.3%	2.5%	1.1%	1.0%	0.8%	0.0%	0.4%	8.7%	9.1%
WLR Only	2.6%	2.5%	0.7%	1.1%	0.6%	0.0%	0.4%	7.5%	7.9%
WLR+SMPF	3.3%	2.7%	1.1%	1.3%	0.7%	0.0%	0.5%	9.2%	9.6%

Figure 4: Fault Rates by Network Segment 2012/13 - ELF

Line Type	Network Segment ELF Rates, 2012/2013 (Faults by Network Segment as % of Annual Provisioning Activities per Product)								
	D-Side	E-Side	Frames (MDF)	Drop Wire	Monopoly Wiring	Line Testing Equipment	FNF Local Line	All Network Segments	All Faults (inc. FNF)
MPF	1.3%	1.5%	0.9%	0.4%	0.6%	0.0%	0.2%	4.6%	4.8%
WLR Only	0.7%	0.9%	0.5%	0.2%	0.3%	0.0%	0.1%	2.6%	2.7%
WLR+SMPF	0.7%	0.8%	0.6%	0.2%	0.3%	0.0%	0.1%	2.7%	2.8%

2016/2017 Forecast

1.21. In order to forecast the 2016/17 fault rates of MPF, WLR Only and WLR+SMPF, CSMG assessed whether there was evidence that ELF and ILF fault rates were changing over time. If a trend over time was observed which could credibly be projected forward, then this trend could be extrapolated to forecast those rates in the future. If there was insufficient evidence to support a forward-looking change in ELF and ILF rates, the future rates would be assumed to be not materially different to those rates in 2011/12 and 2012/13.[1]

1.22. Assessing evidence of an on-going change in rates was challenging due to the relatively short-run dataset (approximately two years). In light of this CSMG examined the data through a series of analytical approaches.

1.23. The first approach involved a historical trend analysis using simple linear regression (ordinary least squares) to establish any pattern of increasing or decreasing fault rates, for individual products, across the most recent 24 month period. The predictive strength of the resulting trend – if one was observed – was evaluated based on the coefficient of determination (the R^2 value) of the regression line. Low R^2 values are an indicator that the regression analysis is not an accurate predictive tool for future fault rates. A high R^2 value would suggest the trend observed in the regression line is reliable and the historical trend is likely to continue in the future.

1.24. The regression analysis was performed on MPF, WLR Only, and WLR+SMPF products for both ELF and ILF rates. Some products (e.g., MPF) demonstrated an upward trend in fault rates with this approach, but the data showed there to be low coefficients of determination for all three line types (R^2 of between 0.0011 and 0.2517) and therefore the evidence to support the predictive strength of any potential trends was insufficient in this regard.

1.25. In an effort to adjust for any seasonal variations in the data, CSMG also conducted an interval-based analysis of fault rates in the most recent 24 months. This assessment was designed to mitigate any seasonal or external factors that may not have been apparent from the linear regression.

1.26. The interval assessment concluded that there was an increase in ELF rates for MPF lines across nearly all intervals from the first year to the second year of the analysis. However, the limitations of the range of available data did not provide sufficient evidence that the increase in MPF ELF rates that was observed from the first year of the interval assessment to the second would continue throughout the charge control period.

1.27. Having determined that a regression analysis of the historical fault rates, as well as an interval assessment comparing similar timeframes for changes in fault rates, did not provide sufficient evidence to conclude the existence – or lack thereof – of a long-term trend, CSMG evaluated whether there were additional factors within the dataset provided by Openreach which might provide further insight into the drivers of change in fault rates.

[1] As discussed above, there were issues with the integrity of the 2011/12 data set which impacted the fault rate calculation for this year.

1.28. The Openreach data enabled CSMG to identify the last transition activity on the line before an ELF. A hypothesis was developed that linked the type of these transition activities to the fault rate.

1.29. As the proportion of each transition activity type was likely to change over the charge control period (e.g. increase in simultaneous provides, increase in MPF migrations) this could therefore be a driver of change in fault rates over time.

1.30. CSMG conducted a regression analysis on the proportion of each transition type vs. the ELF rate. This analysis showed low correlation for each of the transition types, demonstrating that the transition type was not a significant driver of overall ELFs.

1.31. Another hypothesis was that the level of NGA activity at an exchange may be a driver of faults at that exchange. However, CSMG's analysis found that exchanges which had NGA lines actually had a lower fault rate than those that did not have NGA lines.

1.32. In summary, CSMG did not find evidence in the historical data over the past two years and did not find any underlying reason (either due to transition types or NGA activity) to suggest that fault rates would be higher or lower in 2016/17.

Results

There is no evidence to suggest an underlying trend in fault rates which could imply a material difference in 2016/17 fault rates compared to those in 2011/12 and 2012/13.

2. Scope and Objectives

2.1. In July 2013, Ofcom engaged CSMG to conduct an independent assessment of fault rates for Wholesale Line Rental (WLR) and Local Loop Unbundling (LLU) products.

2.2. The assessment was required as an input to the proposed 2014-17 charge controls for these products. Specifically, the objectives of the engagement were to determine:

- The appropriate level of faults for 2011/12 and 2012/2013, segmented into in-life fault rates and early-life rates.
- The appropriate level of likely faults for the end year (2016/17), with justifications for any differences.

2.3. The scope of the assessment was limited to faults occurring within BT Openreach's operational domain. The relevant products were WLR, Shared Metallic Path Facility (SMPF) and Metallic Path Facility (MPF).

2.4. CSMG was tasked with: specifying and requesting the necessary input data from BT Openreach; analysing the data to determine current and historic fault rates; and, forecasting the level of faults at the start and end of the charge control period.

2.5. This report describes CSMG's approach, the source data, the analysis undertaken and the conclusions of the assessment.

3. Methodology

Overview

3.1. At a high-level, CSMG's approach followed five steps:

i. Develop hypotheses regarding fault rates and strategies to test these
ii. Specify data requirements and request data from BT Openreach
iii. Analyse data to test hypotheses
iv. Draw conclusions from analysis
v. Document findings in final report

3.2. At the outset, CSMG was provided with an existing BT Openreach dataset of fault volumes. However the level of detail in this data proved unsatisfactory for the required analysis. To overcome the shortcomings, CSMG proposed an alternative methodology which required BT Openreach to supply additional data regarding fault rates and line volumes.

3.3. CSMG ultimately received two datasets from BT Openreach:

- Reported Fault database; and,
- Working System Size (WSS) database.

3.4. The fault rate analysis required the two databases to be used in conjunction. As the databases had slightly different timeframes, only the overlapping records were of use. These spanned 127 weeks, starting the week ending 6 April 2011 and continuing through 30 August 2013.

3.5. The analysis in this report is based on the records contained in these two BT Openreach databases. The contents of the databases are described below.

Fault Database

3.6. The Fault database contained approximately 11.8 million fault records, with each record containing field identifiers enabling aggregation and analysis of the data into a selection of categories. Fields included in the dataset are listed in the table below.

Figure 5: Fault Database Fields

Field	Description
Record Identifiers	Unique Fault Reference ("Journey ID"), ID to link previous faults database, Telephone Number / MPF ID
Exchange Code	MDF Site identifies relevant Exchange
Asset Category	Product on which fault occurred (e.g., MPF, WLR-Only, WLR+SMPF
Line Age	Age of the line date fault was recorded (Chapter Start Date - Fault Recorded Date); categorised as Very Early Life (VEL),Early-Life (EL) or In-Life (IL)
Chapter Start Date	Date of most recent Transition Activity on the line
Fault Recorded Date	Initial Date & Time when Fault Recorded
Fault Cleared Date	Fault Cleared Date & Time
CSS Week End Date	End date of week for grouping with BT CSS calendar

Field	Description
Transition Activity	Last Line Event processed on the line to start the current chapter - also referred to in this report as the provisioning activity (new provide, modify, cease, etc.)
Fault Clear Code	Engineer-provided Clear Code when fault is resolved
Exclude from WSS	Y or N field; Y denotes Internal BT Service Lines not relevant to analysis
Broadband Boost	Field denotes whether faults are related to BB Boost service
Special Fault Investigation	Field denotes whether faults are related to a Special Fault Investigation (SFI)
CP Group	CUPID lookup to Customer Owning CP group based on the Primary Line; only Major CP Groups included
Product Faulted	Specific type of product fault was raised against (SMPF, NGA, WLR, MPF, etc.)
Main Fault Location	Initially identified location of the fault when reported
CDTA FLAG	Denotes Conscious Decision to Appoint
CDTnA FLAG	Denotes Conscious Decision to Not Appoint
Customer Care Level	Care Level associated with Line (Either 1,2,3 or 4)
MBORC	Matters Beyond Our Responsible Control (Y or N field)

3.7. The raw data required pre-processing before it could be used in the fault analysis. This involved filtering out irrelevant records, aggregating categories that were more granular than required, and truncating the time series to exclude anomalous data at the beginning of the series.

3.8. To filter the provided Fault database to the relevant faults for additional analyses, a series of records were filtered out as shown in the following figure.

Figure 6: Fault Database Filtering & Truncating

	Starting Database	**11,842,085**
Filtered	BB Boost	717,542
Filtered	Exclude from WSS	324,173
Filtered	Excluded Clear Codes	4,528,756
Filtered	Special Faults Investigations (SFI)	45,042
Filtered	VOICE + NGA (GEA) Products	292,764
Filtered	MPF + NGA (GEA) Products	25,284
Filtered	UNKNOWN Products	211,774
Filtered	NOT APPLICABLE Products	58,391
Filtered	UNCLASSIFIED Products	24,563
Filtered	CDTA & CDTnA w/ FNF Clear Codes	16,015
Truncated	Last 2 Weeks of Fault Data	40,698
	Total Faults in Analysis	**5,558,128**

3.9. It was necessary to map some records from more granular categories to the aggregated categories in the terms of reference for the study. In the product categories, PSTN-Only lines (i.e., WLR Classic) were included in the WLR Voice Only category. The Very Early Life "Line Age" (within 28 days of transition activity) category in the BT Openreach dataset was categorised as "Early-Life" in CSMG's analysis. The Early-Life (between 29 and 90 days after transition activity) and In-Life (more than 90 days after transition activity) Line-age categories in the BT Openreach dataset were categorised as "In-Life" in our analysis.

3.10. Disaggregating the faults on WLR+SMPF lines into discrete fault rates for the individual WLR and SMPF services on these lines would have been desirable for the analysis. However it was found that this could not be achieved with accuracy. Both the Product Faulted and Transition Activity fields proved to be unreliable for this segmentation. The WLR+SMPF rates are therefore considered only in aggregate.

Working System Size Database

3.11. The Working System Size (WSS) database contained aggregate totals of the BT Openreach WSS for each week in the date range (127 total weeks). Within each week, the WSS was segmented as shown in the following figure.

Figure 7: WSS Database Fields

Field	Description
CSS Week End Date	End date of week for grouping with BT CSS calendar (WSS a snapshot at this date)
Asset Category	Product categories within WSS (e.g., MPF, WLR-Only, WLR+SMPF
Transition Activity	Lines grouped into most recent event that start current line chapter (e.g., modify, new provide, cease)
Exclude from WSS	Y or N field; Y denotes Internal BT Service Lines not relevant to analysis
CP Group	CUPID lookup to Customer Owning CP group based on the Primary Line; only Major CP Groups included
Exchange Code	MDF Site identifies relevant Exchange
Very Early Life (VEL) WSS	Number of Active Lines in the Very Early Life State (VEL = less than 28 days since activity)
Early-Life (EL) WSS	Number of Active Lines in the Early Life State (EL = between 29 and 90 Days since last activity)
In-Life (IL) WSS	Number of Active Lines in the In-Life State (In-Life = greater than 90 days from last activity)
Total WSS	Sum of all Active lines during the period (VEL + EL + IL)

3.12. The WSS database also required some pre-processing before it could be used in the analysis.

3.13. For consistency with the Faults database, PSTN-Only lines (i.e., WLR Classic) were again mapped to the WLR Voice Only category. The three BT Openreach Line Age categories were also mapped to the "Early-Life" vs. "In-Life" categorization of this study.

3.14. Some filtering of the WSS records was also required to remove extraneous data and map with the Faults database. Internal BT lines, Unclassified WSS lines, as well as NGA and GEA products were excluded from the fault rate calculations.

Data Quality and Sufficiency

3.15. Two observations on the source data pointed to potential data quality issues in the datasets received from Openreach.

3.16. The first was that a small number of fault records had incompatible field codes (for example, a broadband fault on a WLR-only line). This is likely a result of incorrect data entry by technical staff when updating and/or closing trouble tickets. The extent to which this quality issue was manifest in fault records with internally-consistent field codes is unknown.

3.17. Secondly, the first week of fault data in the time-series was incomplete, resulting in very low fault rates compared to the following weeks, for both ELF and ILF. In addition, the fault rate for the first 10 weeks of data was inconsistent with the remainder of the data provided, with ELF rates rising up from near zero for the first 10 weeks. There was concern that including these records would distort any longitudinal trend analyses. The records were therefore excluded and trends were analysed over the most recent complete 2 year period from September 2011 through August 2013 (24 months / 105 weeks).

3.18. Beyond these observations, no formal assessment was made of the source data quality.

3.19. Regarding the sufficiency of the data, the relatively short time period of the available data limited the confidence that could be placed on long-run trend analysis.

4. Recent Fault Rates

4.1. The first stage of the analysis was to calculate fault rates by asset category (MPF, WLR, WLR+SMPF) for 2011/12 and 2012/13.

Overall Fault Rates

4.2. The overall fault rates are calculated as the total faults of an asset category over a given time period (week or year) divided by the average working system size for that asset category over the same period. For example, the equation for the annual rate for MPF lines is as follows:

$$Annual\ MPF\ Fault\ Rate = \frac{Annual\ MPF\ Faults}{Average\ MPF\ WSS\ over\ the\ year}$$

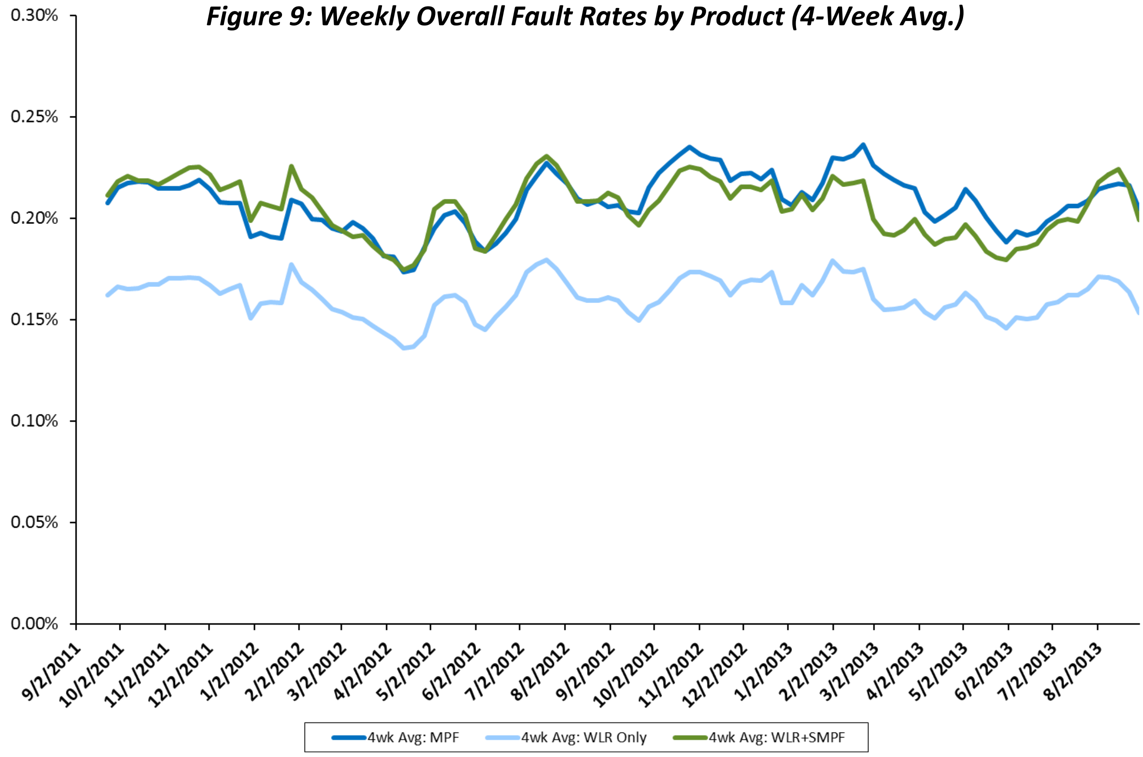
4.3. For the two complete years of the data, WLR+SMPF and MPF rates differ by only 0.2% and 0.3%, respectively. Annual overall fault rates are shows in the table below.

Figure 8: Annual Overall Fault Rates by Product

Overall Fault Rates (Annual Faults per Avg. Annual WSS)			
Line Type	**2011/12**	**2012/13**	**1H2013**
MPF	**10.3%**	**11.1%**	**4.5%**
WLR Only	**8.1%**	**8.4%**	**3.5%**
WLR + SMPF	**10.5%**	**10.8%**	**4.3%**

4.4. While, on aggregate, there is a slight disparity between the MPF and WLR+SMPF overall fault rates, a historical view of the data shows the two rates are very similar (average 0.002% weekly variation over the period). A view of historical data (shown as a 4-week rolling average of the weekly fault rate) is shown in the chart below.

Figure 9: Weekly Overall Fault Rates by Product (4-Week Avg.)



In-Life Fault Rates

4.5. The second level of detail for product fault rates was to separate the early-life from the in-life faults.

4.6. The ILF rate is calculated as the In-Life faults of an asset category over a specific time period divided by the average IL WSS of the MPF asset category over that same time period. For example, the equation for the annual rate for MPF lines is as follows:

$$Annual\ In\_Life\ MPF\ Fault\ Rate = \frac{Annual\ In\_Life\ MPF\ Faults}{Average\ In\_Life\ MPF\ WSS\ over\ the\ year}$$

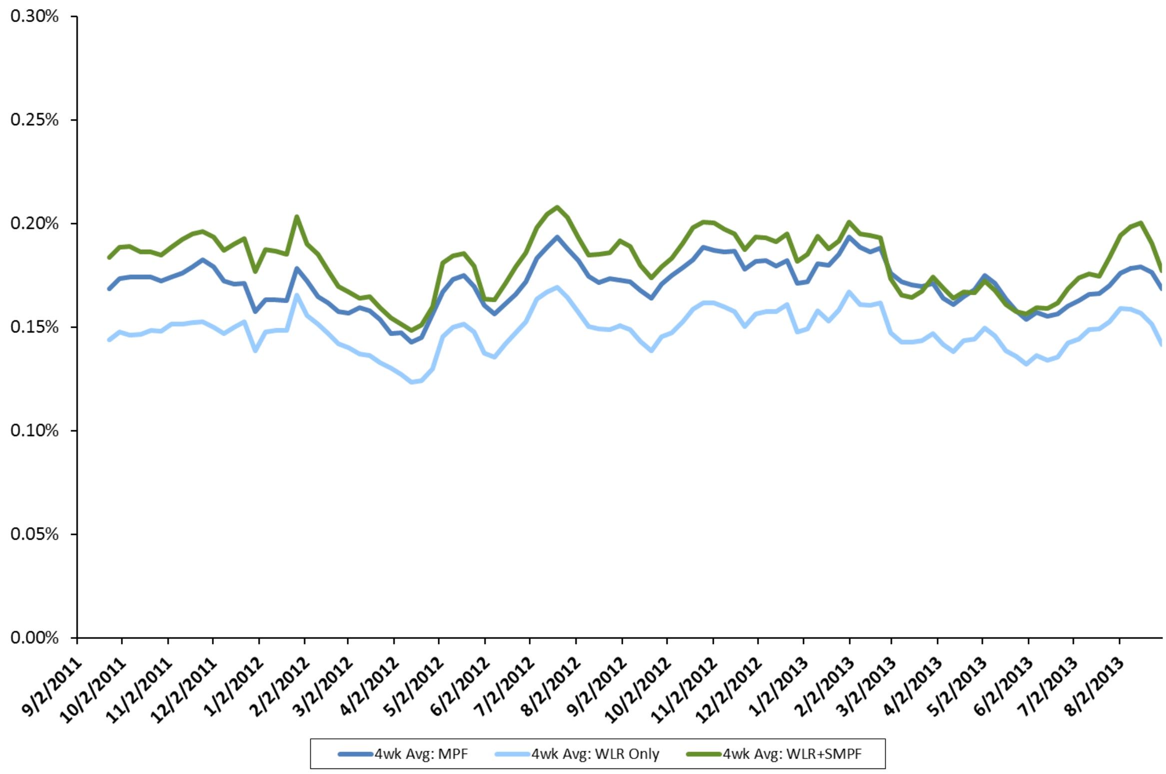
4.7. Annual totals are shown in the following figure, with only partial data for 2013/14.

Figure 10: Annual ILF Rate by Product

ILF Fault Rates (Annual ILF Faults per Avg. ILF WSS)			
Line Type	**2011/12**	**2012/13**	**1H2013**
MPF	**8.5%**	**9.1%**	**3.6%**
WLR Only	**7.4%**	**7.9%**	**3.2%**
WLR + SMPF	**9.1%**	**9.6%**	**3.8%**

4.8. With the exception of the final two weeks of March 2013 and the beginning of May 2013, the WLR+SMPF ILF rate was consistently higher (avg. of 0.01% on a weekly basis) than the MPF rate. The small changes due to bank holidays or seasonal events were consistent for all three of the asset categories (incl. WLR Only), and both WLR+SMPF and MPF had higher (4-week rolling average) ILF rates through the historical period. The chart below highlights these trends.

Figure 11: Weekly ILF Rates by Product (4-Week Avg.)



Early-Life Fault Rates

4.9. Previous reports on ELF rates (by Ofcom and Openreach) calculate the ELF rate as the number of faults relative to the working system size of active products in the early-life stage (i.e. lines within 28 days of a provisioning / modification activity). This calculation is similar to the Overall and ILF rate calculations, as the ELF rate will be equal to the total faults in a given period divided by the average WSS over the same period. The equation for annual ELF rate for a WSS size for MPF lines is as follows:

$$Annual\ Early\_Life\ MPF\ Fault\ Rate = \frac{Annual\ Early\_Life\ MPF\ Faults}{[Avg.Weekly\ Early\_Life\ MPF\ WSS]}$$

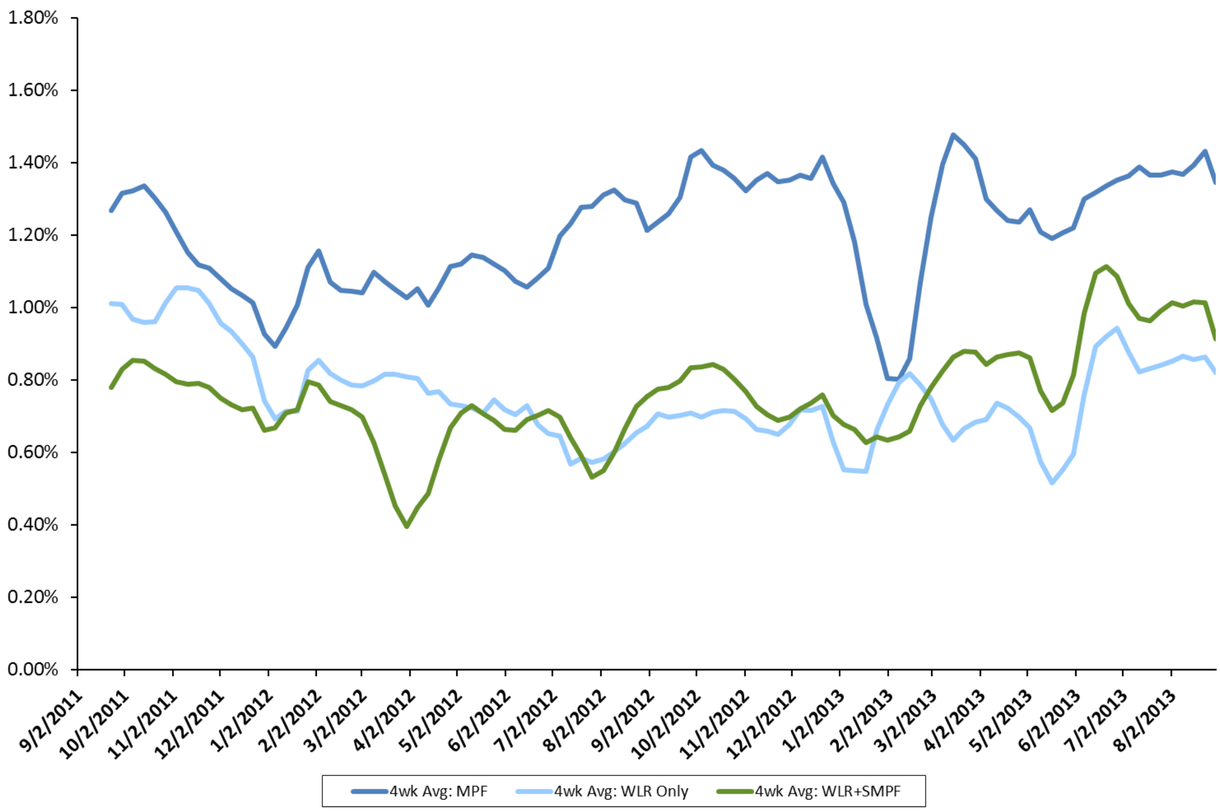
4.10. This calculation provides a measure for the likelihood of an ELF occurring given a particular ELF WSS and time period. The annual ELF rates based on the average weekly ELF WSS are shown below.

Figure 12: Annual ELF Rates for Avg. ELF WSS by Product

ELF Fault Rates by WSS (Annual ELF Faults per Avg. Weekly ELF WSS)			
Line Type	**2011/12**	**2012/13**	**1H2013**
MPF	**56%**	**63%**	**29%**
WLR Only	**42%**	**35%**	**16%**
WLR + SMPF	**32%**	**37%**	**20%**

4.11. Weekly ELF rates based on WSS, segmented by the three asset categories, are shown in the following chart.

Figure 13: Weekly ELF Rates for WSS by Product (4-Week Avg.)



4.12. The previous two charts can be compared directly with the ILF rates, and confirm that the likelihood of a fault occurring on a line in EL is higher than after the 28 day period - nearly 4 times more likely for WLR+SMPF (3.8x), and just under 7 times more likely for MPF (6.9x).

4.13. In an effort to understand the relationship between ELFs and provisioning activities, fault rates of early-life lines relative to the level of provisioning activities were also calculated. The Early-Life activity fault rates estimate the volume of faults given a projected number of provisioning activities. The Openreach-provided data did not include total provisioning activities in each CSS week, but provided figures for the total WSS of lines that were in "Early-Life status" during that week (indicating those lines had been provisioned in the previous 4 weeks). Given the lack of more detailed provisioning data, provisioning activities in a given week were estimated to be ¼ of the ELF WSS at the end of the week (shown below).

$$Weekly\ MPF\ Provisioning\ Activities = [Weekly\ Early\_Life\ MPF\ WSS]/4$$

4.14. The annual ELF rate is equal to the sum of the ELFs over the year, divided by the estimated total number of provisioning activities. Annual ELF rates using this calculation are shown in the table below. Using the estimation for weekly provisioning activities, the equation for the annual ELF rate for MPF lines is as follows:

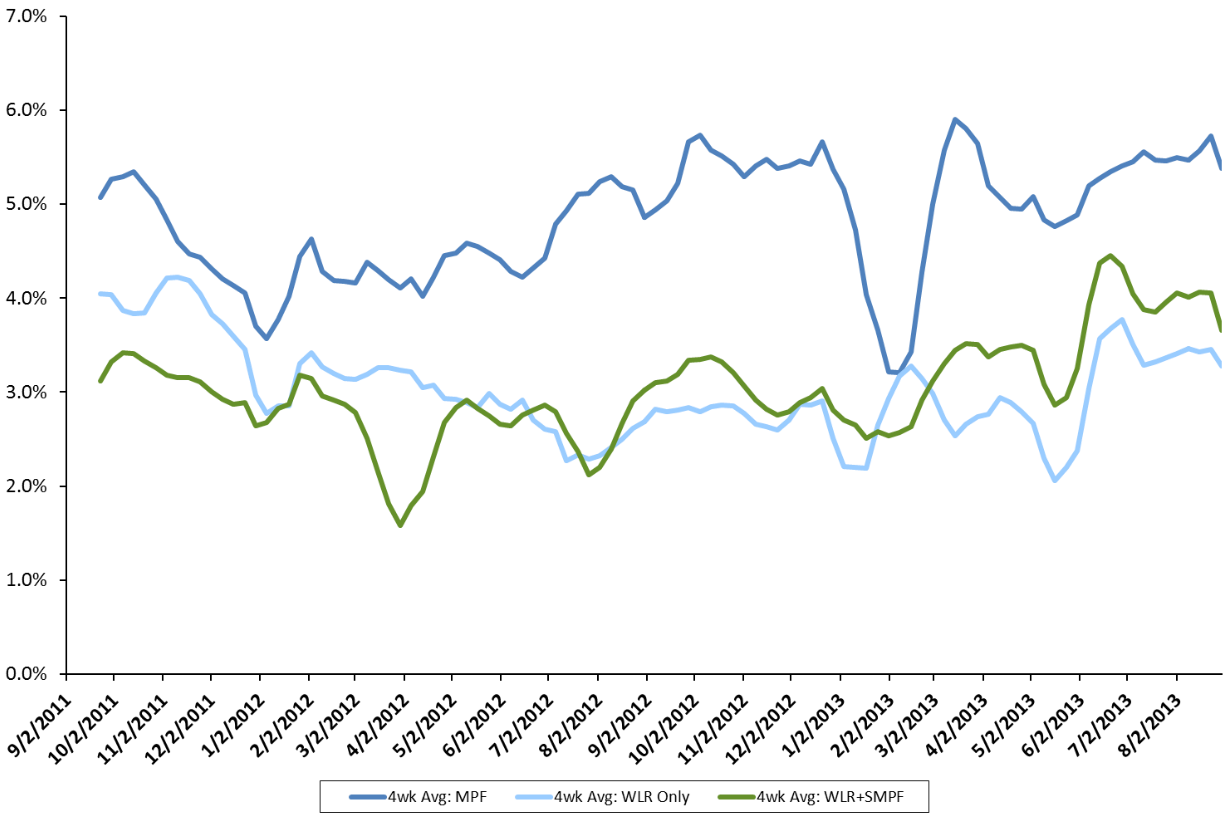
$$Annual\ Early\_Life\ MPF\ Fault\ Rate = \frac{Annual\ Early\_Life\ MPF\ Faults}{\text{SUM}[Weekly\ MPF\ Provisioning\ Activities]}$$

Figure 14: Annual ELF Rate by Product

ELF Fault Rates by WSS (Annual ELF Faults per Annual Provisioning Activities)			
Line Type	**2011/12**	**2012/13**	**1H2013**
MPF	**4.2%**	**4.8%**	**5.2%**
WLR Only	**3.1%**	**2.7%**	**2.9%**
WLR + SMPF	**2.4%**	**2.8%**	**3.6%**

4.15. The weekly ELF rate is calculated as the weekly ELFs of the product over the weekly provisioning activities (shown in the equations above), and charted for all three asset categories in the following figure.

Figure 15: Weekly ELF Rate by Provisioning Activity, by Product (4-Week Avg.)



4.16. As can be seen in the chart, MPF ELF rates are consistently higher than both WLR+SMPF and WLR Only ELF rates.

4.17. In summary, we have calculated two different fault rates for ELFs. The first is a measurement of fault rates given an average EL WSS, while the second is a measurement of faults per provisioning activity. The latter measure (per Provisioning Activity) is used throughout the rest of the report (with the exception of Section 6 for the interval analysis).

5. Understanding Differences in Rates

5.1. CSMG developed a series of hypotheses to explain the differences in MPF and WLR+SMPF rates. These hypotheses were:

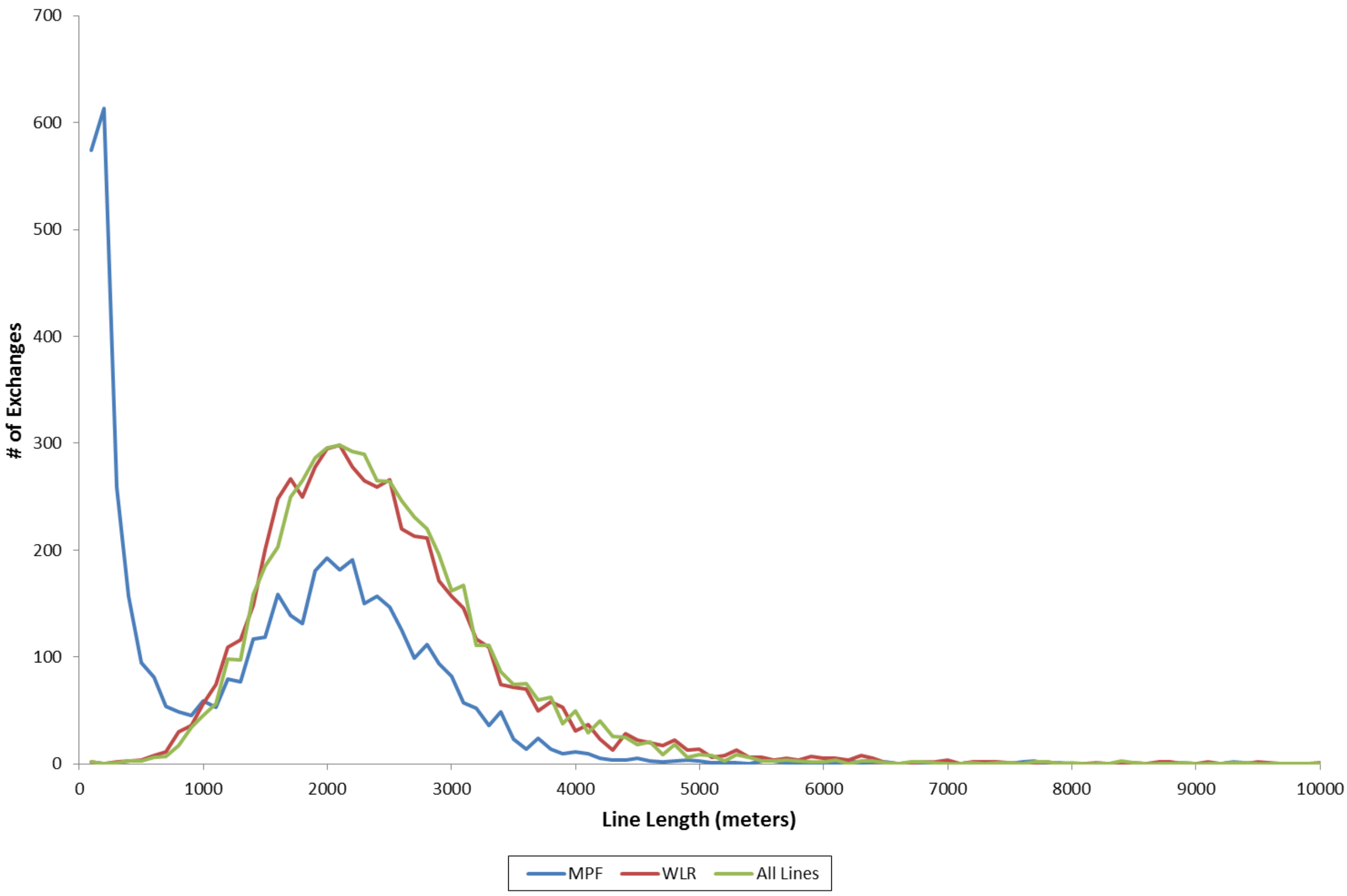
- The lower MPF ILF rate was the result of MPF lines having a shorter line length on average than WLR+SMPF lines;
- The lower MPF ILF rate was the result of MPF lines generally being in more urban, densely populated areas with less overhead cabling;
- The higher MPF ELF rate was the result of higher segment specific fault rates (e.g. higher Frame ELF rate resulting from lower visibility of the line during a MPF provision between the TAM and the DSLAM).

5.2. CSMG conducted a series of regression analyses to test the first two hypotheses.

Line Length Analysis

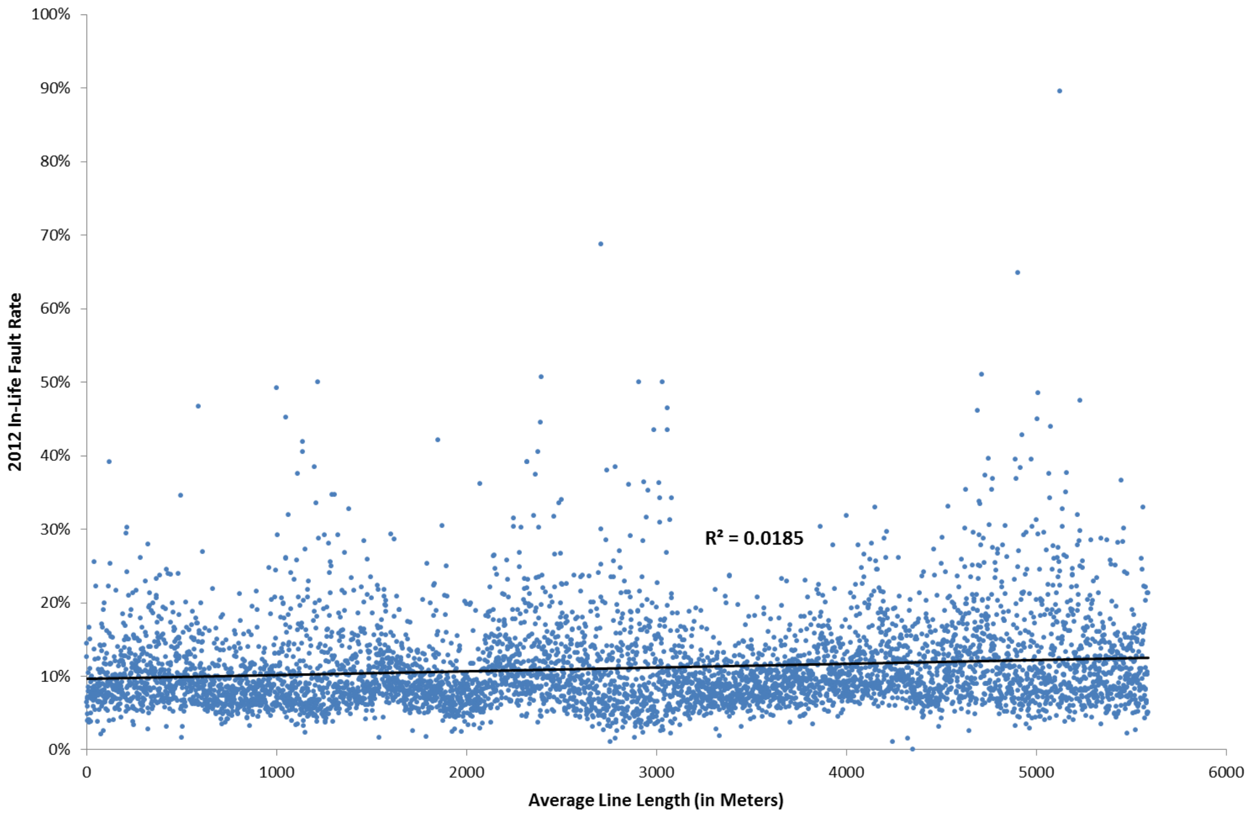
5.3. To test the hypothesis that higher WLR+SMPF ILF rates were driven by MPF line lengths being (on average) shorter, the correlation between line length and ILF rates was explored. An assessment of exchanges throughout the UK found that, on average exchanges do have shorter MPF lines than WLR lines, so the pattern of longer line lengths for WLR+SMPF over MPF was confirmed (see figure below).

Figure 16: Average Line Length by Exchange



5.4. However, the data did not show a strong correlation between line length and ILF rate (R^2 of 0.0185 in chart below). Given the lack of demonstrable impact of line lengths on the ILF rates, this difference was not sufficient to explain the higher WLR+SMPF ILF rates.

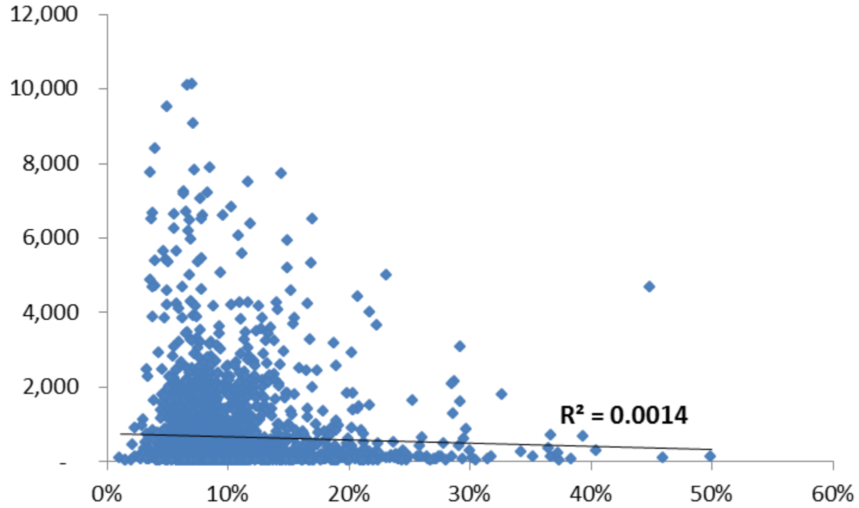
Figure 17: In-Life Fault Rates compared to Average Line Length



Population Density

5.5. An additional analysis was conducted which compared population density with the geographical locations of faults. An analysis of the fault rates by location indicated that higher fault rates were more likely to occur in lower population density areas (e.g. Wales and Scotland). Further analysis demonstrated that a weak inverse relationship exists between fault rate and population density. As a higher percentage of exchanges with MPF are located in urban areas compared to WLR+SMPF, this could explain some of the difference in fault rates between MPF and SMPF. However the correlation was weak (see chart below).

Figure 18: Population Density (DPs per km²) by ILF Rates 2012



Network Segments

5.6. Fault rates at the network segment level were compared across products and ILF/ELF distribution. While there were differences in fault rates across network segments, no network segment in particular was overly responsible for the disparity; fault rates at the Frames, E-Side, and D-Side all impact the disparities in the ELF network segment rates.

5.7. ELF rates in the table below are calculated as the ELF rate per provisioning activity, and therefore appear lower than the ILF rates. The ILF rates by network segment are based on the average ILF WSS, while the ELF rates are based on the total number of provisioning activities.

5.8. The network segment classifications are based on the Clear Code associated with the fault. The fault rate for each network segment is calculated as the total faults attributed to the network segment in the given period over the total WSS of the product, thus aggregating the individual network segment fault rates nearly equals the overall product fault rate. However, a number of fault clear codes indicated that there was no fault found (FNF) in any network segment, therefore the total product fault rate is slightly higher (0.4 – 0.5% for ILF, 0.1 – 0.2% for ELF) than the sum of the network segment fault rates.

Figure 19: 2012/13 ILF Rates by Network Segment

ILF Product		2012 / 2013 In-Life Faults [Faults by Network Segment as % of Avg. Annual WSS]								
		D-Side	E-Side	Frames (MDF)	Drop Wire	Monopoly Wiring	Line Testing Equipment	FNF Local Line	All Network Segments	All Faults (Incl. FNF)
ILF Rates	***MPF Rentals***	3.3%	2.5%	1.1%	1.0%	0.8%	0.0%	0.4%	8.7%	9.1%
	WLR-Only Rentals	2.6%	2.5%	0.7%	1.1%	0.6%	0.0%	0.4%	7.5%	7.9%
	WLR+SMPF Rentals	3.3%	2.7%	1.1%	1.3%	0.7%	0.0%	0.5%	9.2%	9.6%

Figure 20: 2012/13 ELF Rates by Network Segment

ELF Product		2012 / 2013 Early-Life Faults [Faults by Network Segment as % of Annual Provisioning Activities]								
		D-Side	E-Side	Frames (MDF)	Drop Wire	Monopoly Wiring	Line Testing Equipment	FNF Local Line	All Network Segments	All Faults (Incl. FNF)
ELF Rates	MPF Products	1.3%	1.5%	0.9%	0.4%	0.6%	0.0%	0.2%	4.6%	4.8%
	WLR-Only Products	0.7%	0.9%	0.5%	0.2%	0.3%	0.0%	0.1%	2.6%	2.7%
	WLR+SMPF Products	0.7%	0.8%	0.6%	0.2%	0.3%	0.0%	0.1%	2.7%	2.8%

6. 2016/2017 Forecast

Trend Analysis

6.1. In order to forecast the 2016/17 fault rates of MPF, WLR Only and WLR+SMPF, CSMG assessed whether there was evidence that ELF and ILF fault rates were changing over time. If a trend over time was observed which could credibly be projected forward, then this trend could be extrapolated to forecast those rates in the future. If there was insufficient evidence to support a forward-looking change in ELF and ILF rates, the future rates would be assumed to be not materially different from those rates in 2011/12 and 2012/13.

6.2. Assessing evidence of an on-going change in rates was challenging due to the relatively short-run dataset (approximately two years). In light of this CSMG examined the data through a series of analytical approaches.

6.3. The first approach involved a historical trend analysis using simple linear regression (ordinary least squares) to establish any pattern of increasing or decreasing fault rates, for individual products, across the most recent 24 month period. The predictive strength of the resulting trend – if one was observed – was evaluated based on the coefficient of determination (the R^2 value) of the regression line. Low R^2 values are an indicator that the regression analysis is not an accurate predictive tool for future fault rates. A high R^2 value would suggest the trend observed in the regression line is reliable and the historical trend is likely to continue in the future.

6.4. The regression analysis was performed on MPF, WLR Only, and WLR+SMPF products for both ELF and ILF rates. Some products (e.g., MPF) demonstrated an upward trend in fault rates with this approach, but the data showed there to be low coefficients of determination for all three line types (R^2 of between 0.0011 and 0.2517) and therefore the evidence to support the predictive strength of any potential trends was insufficient in this regard.

Figure 21: ILF Rate Trends by Product

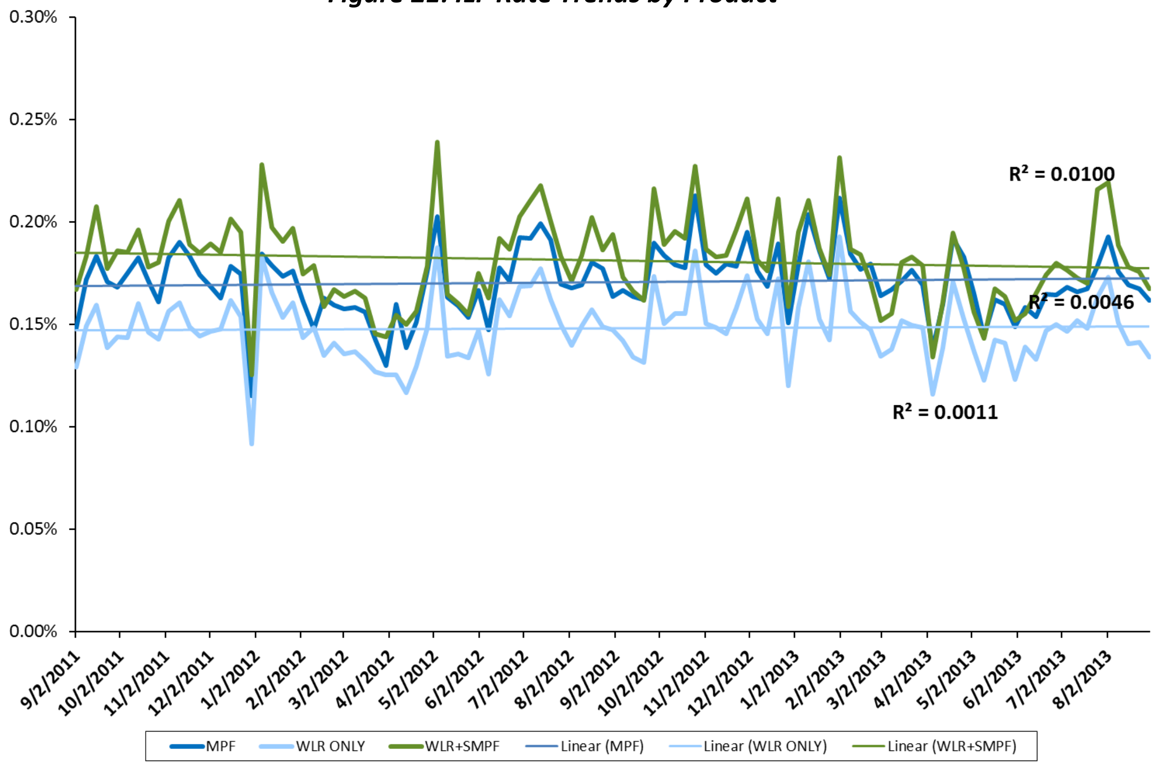
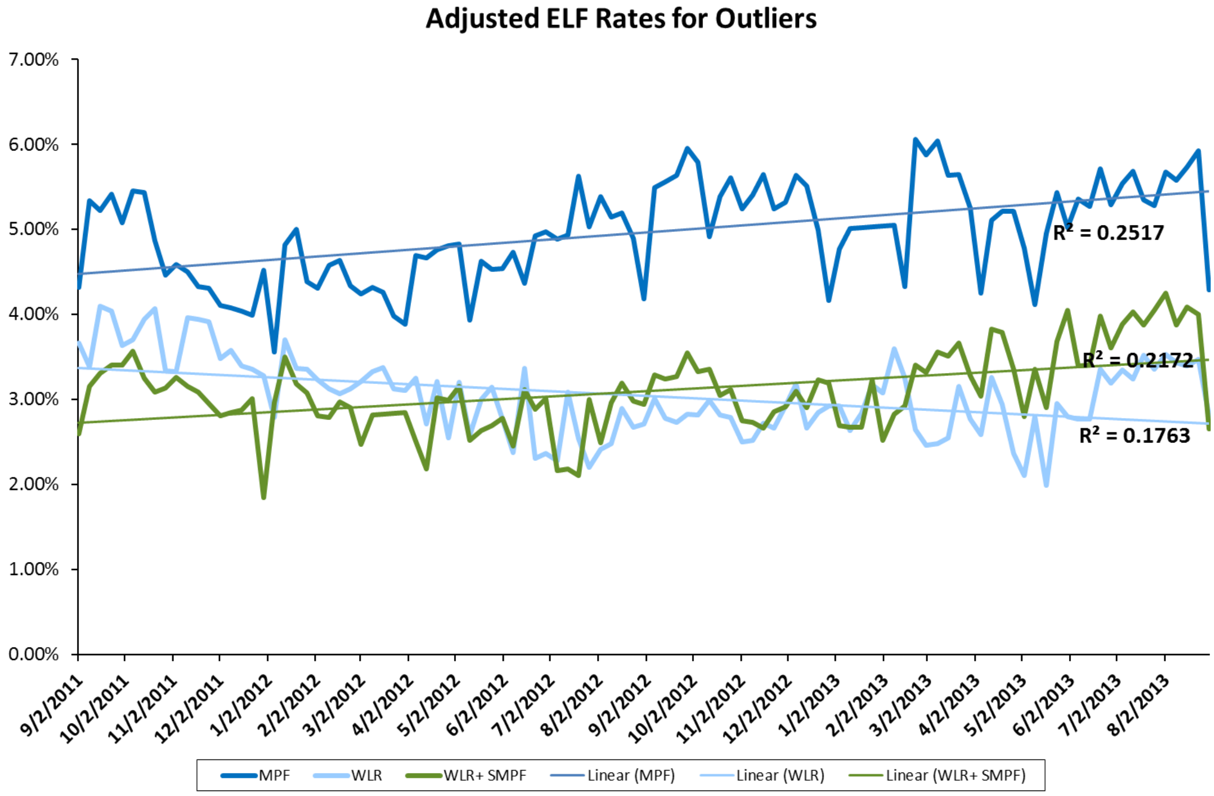


Figure 22: ELF Rate Trends by Product



6.5. The above chart shows that even when outliers in the ELF data were excluded, none of the rates exhibited strong linear correlation. The result is perhaps not surprising given the short-run volatility of the data, for example fluctuations around bank holidays.

6.6. In light of the limitations of applying linear regression to this data set, CSMG also investigated whether there was evidence of consistent year-on-year changes within the data. This analysis compared the average weekly fault rate across similar intervals over the most recent 24 months of data. The available data was separated into two 52-week years, referenced hereafter as 'Year 1' and 'Year 2'.

6.7. Each 52-week period, spanning approximately September to August, was divided into 12 comparable intervals, labelled 1 through 12. The intervals were chosen to limit the impact of bank holidays in the trend analysis, as well as allow comparisons of any changes in one interval to the same interval a year later. The intervals do not correspond directly with calendar months, however interval 1 roughly corresponds with September, and interval 5 with January. Not using calendar months avoided issues arising from months having additional weekends or a different number of working days, which would have impacted the comparison.

6.8. Details of the intervals used are presented in the following table.

Figure 23: Interval Analysis Groupings

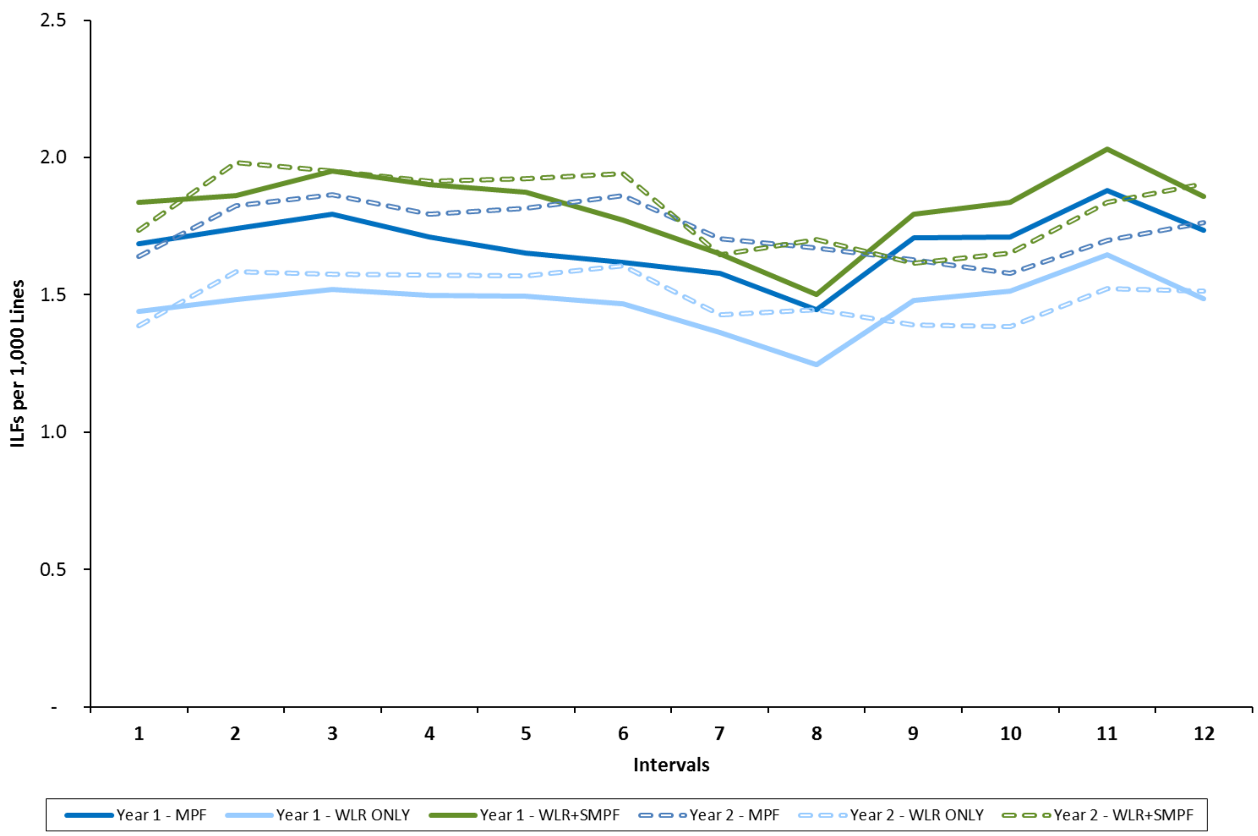
Interval	1	2	3	4	5	6	7	8	9	10	11	12
Weeks	4	4	4	4	5	4	4	5	5	5	4	4
Year 1 bank holidays	1	-	-	-	3	-	-	2	1	2	-	-
Year 2 bank holidays	1	-	-	-	3	-	-	2	1	1	-	-

6.9. Fault rates for both ILFs and ELFs were calculated as the fault rate per 1,000 lines. ILF and ELF rates for each interval were calculated as the average weekly fault rate of each product according to the following formula:

$$Avg. Weekly\ Interval\ Fault\ Rate = \frac{Avg. Weekly\ Faults\ in\ Interval}{[Avg. Interval\ WSS]}$$

6.10. For ILF rates, there was no clear trend of higher fault rates in Year 2 of the interval comparisons relative to Year 1, as shown in the figure below. For some intervals the Year 1 ILF rate was higher, for others Year 2 was higher

Figure 24: Interval Comparison of ILF Rates per 1,000 lines



6.11. Comparison of ELF rates across intervals resulted in more obvious differences across the two periods. These trends are highlighted in the figure below.

6.12. MPF lines in Year 2 of demonstrated consistently higher fault rates (per 1,000 lines), with the exception of Interval 6 in which the trend was reversed (13% avg. increase over Year 1)[2].

6.13. There was no consistent trend for WLR+SMPF and WLR Only lines.

- WLR+SMPF ELF rates were slightly lower or equivalent in Year 2 compared to Year 1 for the first six Intervals (avg. of 5% lower than Year 1)[3], though for the remaining intervals the ELF rates of Year 2 were considerably higher (avg. nearly 60% over Year 1)[4,5].
- ELF rates for WLR Only lines were lower in the second year for the first nine intervals (avg. 28% lower than Year 1), then increased substantially with the final three intervals of Year 2 being higher (39% higher than Year 1)[6].

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[2] The decrease in the MPF rate in Year 2 relative to Year 1 in Interval 6 was due to a temporary increase in the early-life WSS of MPF lines spanning 5 weeks from mid-January through February 2013. A flurry of "Modify Primary Line" transition activities nearly doubled the overall early-life MPF WSS over that period (~210K weekly WSS in the 5 weeks leading up to the change, and ~430K WSS during the following 5 weeks) and, without a corresponding increase in faults (increased from avg. of 2,500 to 3,600 over the same periods), the fault rate temporarily lowered

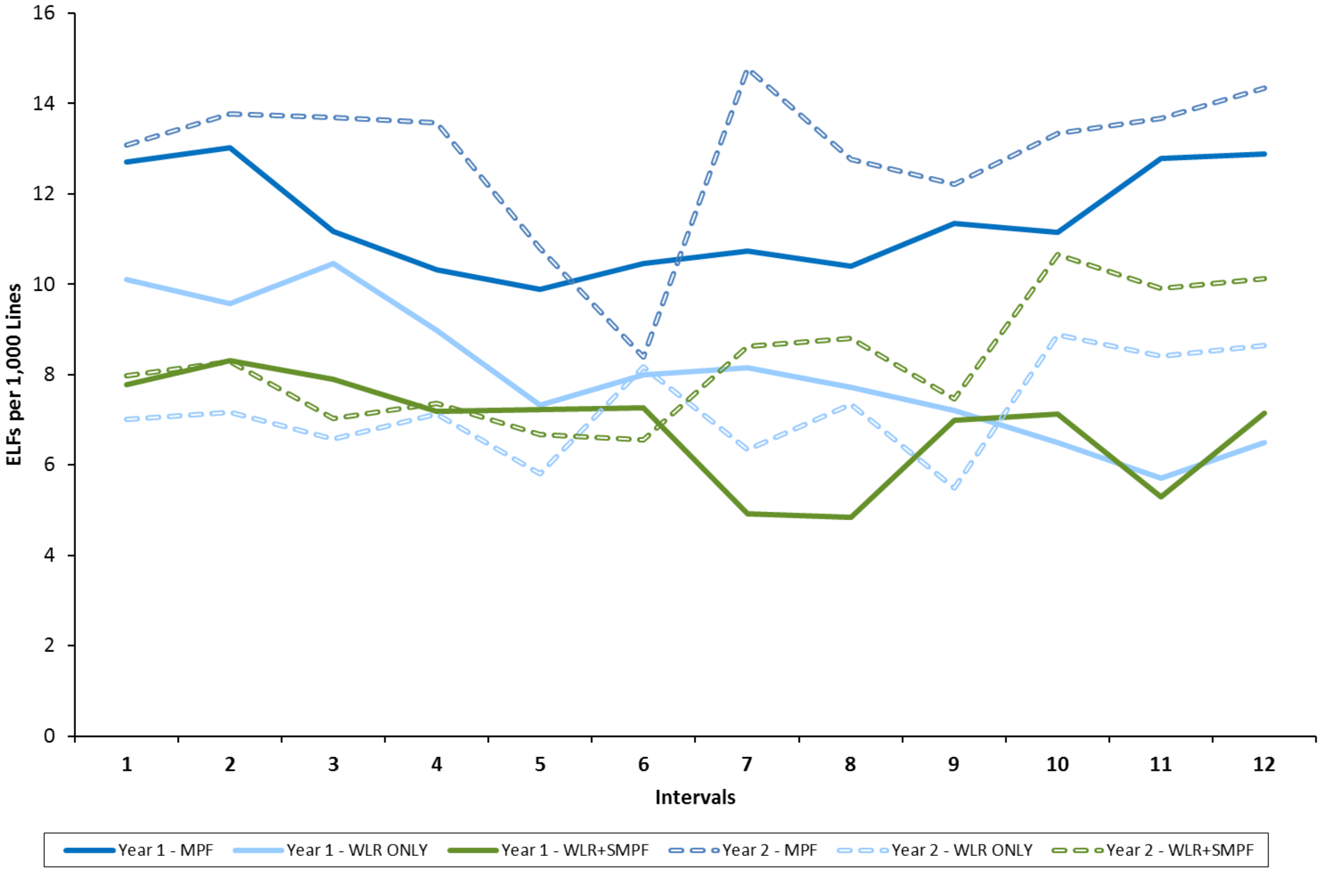
[3] For WLR+SMPF, the overall trend in the latter half of the intervals for higher Year 2 rates over Year 1 was the result of a general decrease in the early-life WSS without a corresponding decrease in the absolute number of faults. This shift can be attributed to the decrease in modification activities with no change of CP over the period, which accounted for an average of ~230K lines in the WLR+SMPF early-life WSS for the first 70+ weeks of the interval analysis (incl. all of Year 1). During the final 30 weeks of the data in the interval analysis – which is included in Intervals 7-12 of Year 2 – averaged only 70K weekly early-life WSS for lines following a modification to WLR+SMPF service with no change of CP

[4] The spikes in the Year 2 ELF rate for WLR+SMPF relative to the Year 1 rate were the result of temporary drops in fault rates in the Year 1 data, rather than any increases in Year 2 fault rates. The first incident, spanning Intervals 7 and 8, was the result of a temporary increase in the WLR+SMPF early-life WSS due to Modification transition activities with no change of CP. This change occurred in March 2012 (included in Year 1), and resulted in the weekly WSS size for WLR+SMPF doubling from 600K to 1.2M for four weeks. An increase in modification transition activities (with no change of CP) again occurred in Interval 11, leading to another increase in the WLR+SMPF WSS and a corresponding decrease in the Year 1 fault rate. In this instance, the WSS temporarily increased from 425K to over 700K, lowering the average Interval 11 weekly fault rate

[5] Sudden and temporary changes in the WLR+SMPF WSS that drove down the average weekly fault rate for specific Intervals during Year 1 help explain the peaks in the figures above. However, even adjusting for those incidents, the overall WLR+SMPF rate for Year 2 is higher for Intervals 6-12 due to the steady decrease in the modification transition activities

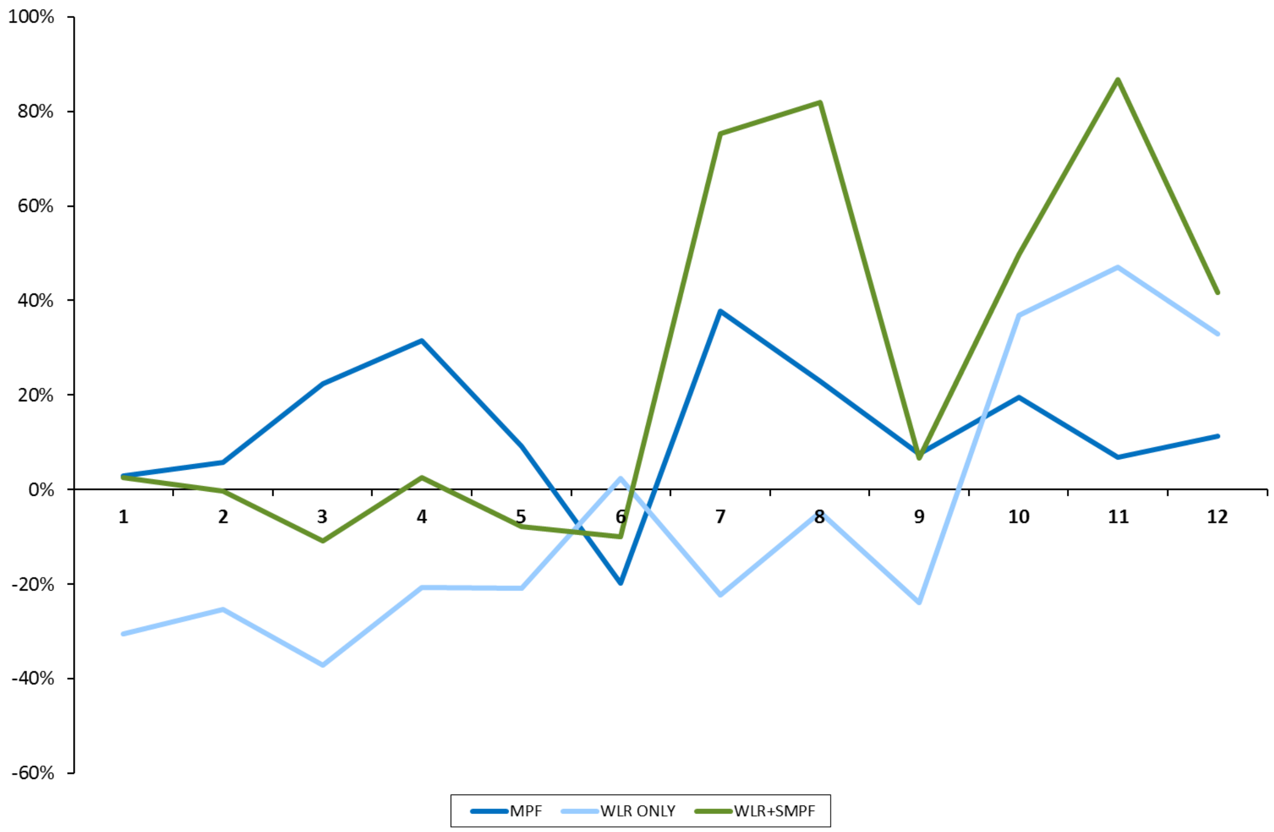
[6] Increases in the Year 2 ELF rates for WLR Only lines for Intervals 10-12 were driven by the reduction in Activation activities, and resulting early-life WSS, for WLR Only service during the period (last 12 weeks of Year 2 experienced a 40% decrease in Activate Primary Line activities compared to the average of the preceding 92 weeks of the Interval comparison). The average weekly WLR Only early-life WSS in final 3 intervals was the lowest of any intervals across Year 1 and 2

Figure 25: Interval Comparison of ELF Rates per 1,000 Lines



6.14. To highlight the differences between Year 1 and Year 2 ELF rates by interval, the figure below charts the change in fault rate from Year 1 to Year 2, as a percentage of the fault rate in Year 1. Please note that the ELF rates in the interval comparison is calculated as the WSS fault rate, rather than the Provisioning Activity fault rates also shown in this report.

Figure 26: Change in Avg. Weekly Interval ELF Rate in Year 2 as % of Year 1 ELF Rate



6.15. While MPF ELF rates in Year 2 of the Interval analysis were consistently higher than Year 1, this does not necessarily indicate the MPF ELF rates will continue to increase throughout the charge control period. The interval analysis was only able to compare the change across two similar periods, with effectively two isolated data points, and therefore cannot be extrapolated to conclude the ELF rates for MPF lines will continue to increase.

Transition Activity Analysis

6.16. Having determined that a regression analysis of the historical fault rates, as well as an interval assessment comparing similar timeframes for changes in fault rates, did not provide sufficient evidence to conclude the existence – or lack thereof – of a long-term trend, CSMG evaluated whether there were additional factors within the dataset provided by Openreach which might provide further insight into the drivers of change in fault rates.

6.17. The Openreach data enabled CSMG to identify the last transition activity on the line before an ELF. A hypothesis was developed that linked the type of these transition activities to the fault rate.

6.18. As the proportion of each transition activity type was likely to change over the charge control period (e.g. increase in simultaneous provides, increase in MPF migrations) this could therefore be a driver of change in fault rates over time.

6.19. CSMG conducted a regression analysis on the proportion of each transition type vs. the ELF rate. This analysis showed low correlation for each of the transition type, demonstrating that transition type was not a significant driver of overall ELFs (the correlation coefficients are presented in the table below). .

Figure 27: Correlation of Transition Activities and Overall Fault rates and Trend Analysis of Transition Activities

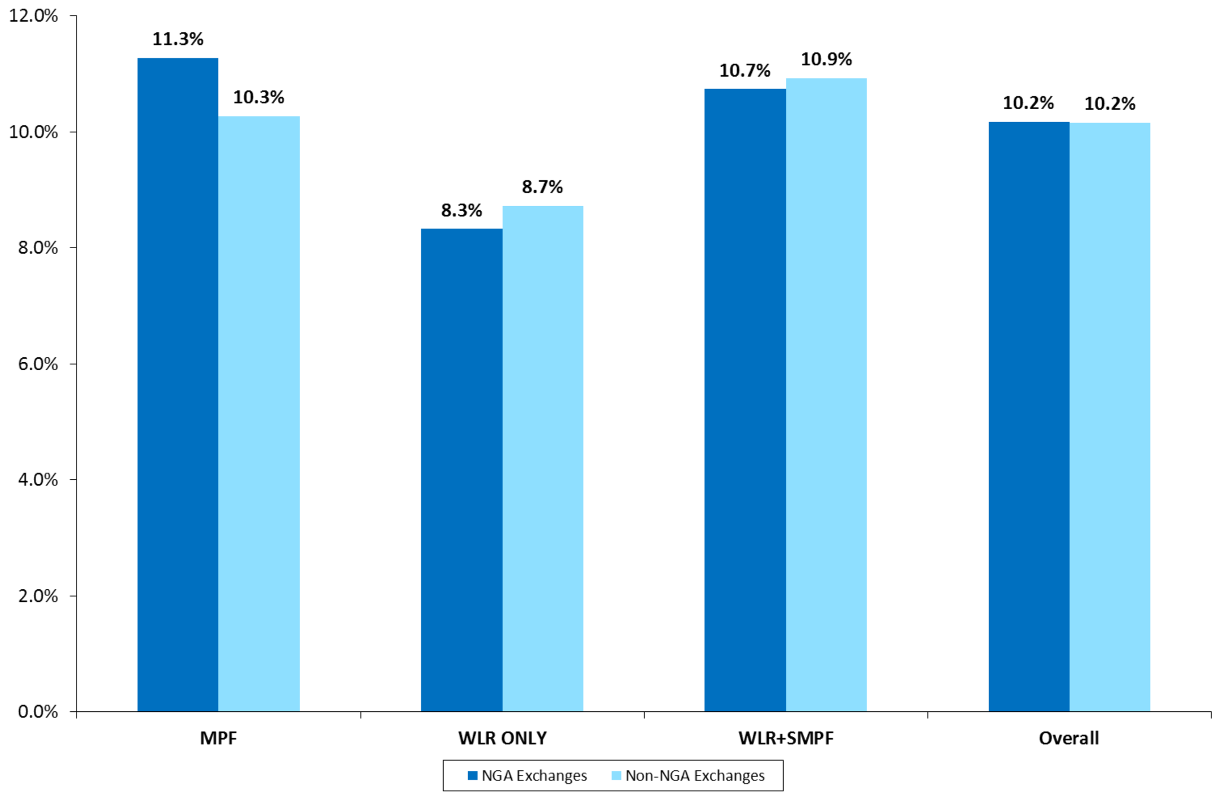
Product & Transition Activities	Corr. Coefficient w/ % of Transitions & Product ELF Rate
MPF	
ACTIVATE_PRIMARY_LINE	-0.1994
CEASE_BROADBAND	*N/A*
MODIFY_PRIMARY_LINE	0.1984
WLR Only	
ACTIVATE_PRIMARY_LINE	-0.1283
CEASE_BROADBAND	0.0650
MODIFY_PRIMARY_LINE	0.0426
UNCLASSIFIED	0.1850
WLR+SMPF	
ACTIVATE_BROADBAND	-0.2809
ACTIVATE_PRIMARY_LINE	0.1397
CEASE_PRIMARY_LINE	0.0677
MODIFY_BROADBAND_CUPID_CHANGE	0.2865
MODIFY_BROADBAND_NO_CUPID_CHANGE	-0.2187
MODIFY_PRIMARY_LINE	0.0941
SIM_PROVIDE	0.1214
UNCLASSIFIED	0.2523

<u>NGA Assessment</u>

6.20. Another potential hypothesis was that the level of NGA activity at an exchange may be a driver of faults at that exchange. However, CSMG's analysis found that exchanges which had NGA lines actually had a lower fault rate than those that did not have NGA lines.

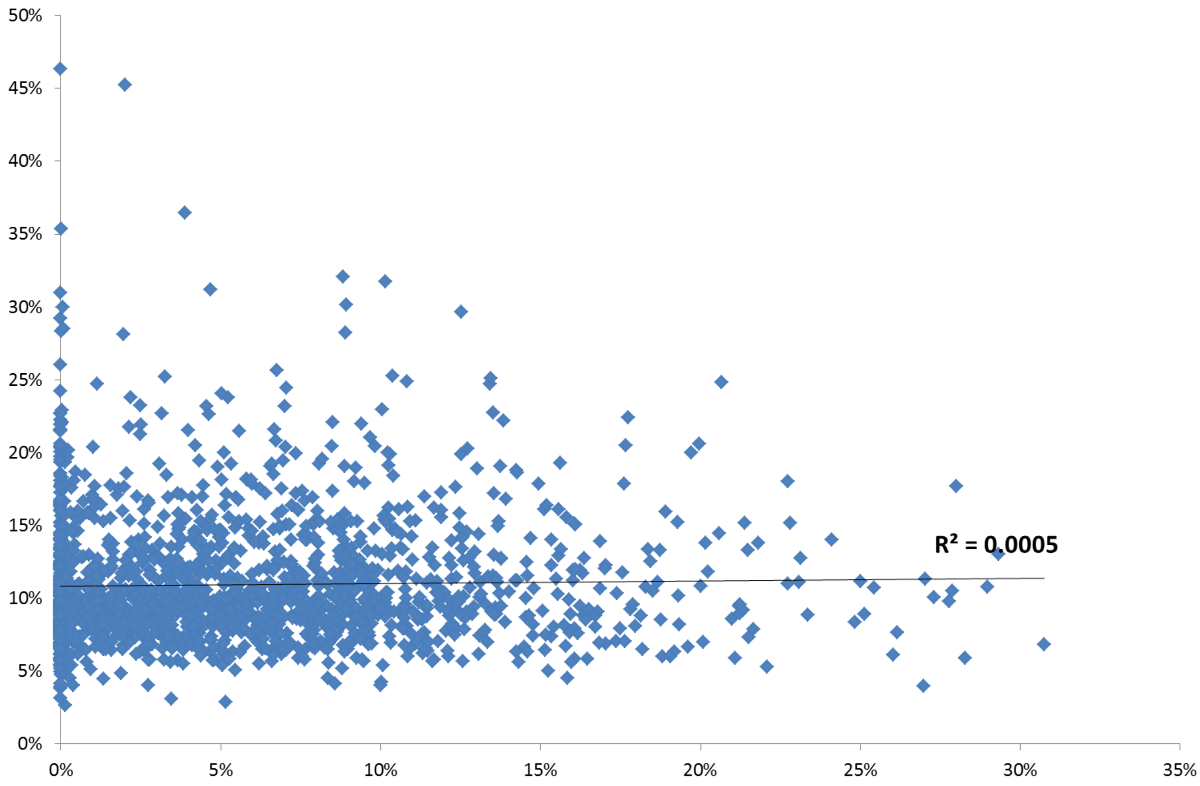
6.21. The initial portion of the NGA analysis reviewed overall fault rates (of all three products) at exchanges with and without NGA lines. Using 2012 annual data it was determined that exchanges with NGA lines did not have a difference in fault rates relative to those exchanges without NGA lines, as shown in the chart below.

Figure 28: Fault Rates in Exchanges with NGA vs. Exchanges without NGA



6.22. A further analysis of the potential relationship between NGA and fault rates was conducted by comparing the proportion of NGA activity in an exchange (i.e., estimated NGA provisioning activity relative to the total provisioning activity in the exchange), with the overall fault rates of MPF, WLR, and WLR+SMPF. This analysis also found that there was no meaningful correlation with NGA activities and an increase in fault rates, highlighted in the figure below.

Figure 29: NGA Activity (as % of Total Activity) vs. Overall Fault Rate by Exchange



7. RESULTS

7.1. The objectives of the project included determining the fault rates for 2011/12 and 2012/13 and forecasting fault rates for the year 2016/17. This section summarises the preceding analysis, the conclusions drawn from the results, and presents the final outputs.

7.2. CSMG determined the IL and EL fault rates for MPF, WLR Only and WLR+SMPF products in 2011/12 and 2012/13 through analysing BT Openreach fault and WSS data for this period.

7.3. To forecast these IL and EL fault rates for 2016/17, CSMG assessed whether there was evidence that faults rates would differ from the 2011/12 and 2012/13 rates. This was approached from two angles: firstly, is there evidence that headline fault rates were changing over time; and secondly, is there evidence of root causes which may change fault rates as the volume of specific types of activity change.

7.4. The investigation into whether headline fault rates were changing over time was inconclusive. Linear regression revealed weak correlation between the EL and IL fault data and a linear trend over time. An interval-based analysis revealed that EL faults for MPF had increased over the assessed period, however there was insufficient evidence to predict with confidence that these rates would continue to grow over time.

7.5. The relatively short time period of the available data limited the confidence that could be placed on long-run trend analysis.

7.6. The root cause investigation focussed on types of transition activity and the volume of NGA activity in the BT Openreach network. Neither analysis provided a clear correlation with fault rates. It was therefore not possible to forecast how fault rates may evolve as the volumes of specific activities change over time.

7.7. There was therefore no evidence to suggest an underlying trend in fault rates which could imply a material difference in 2016/17 fault rates compared to those in 2011/12 and 2012/13 .

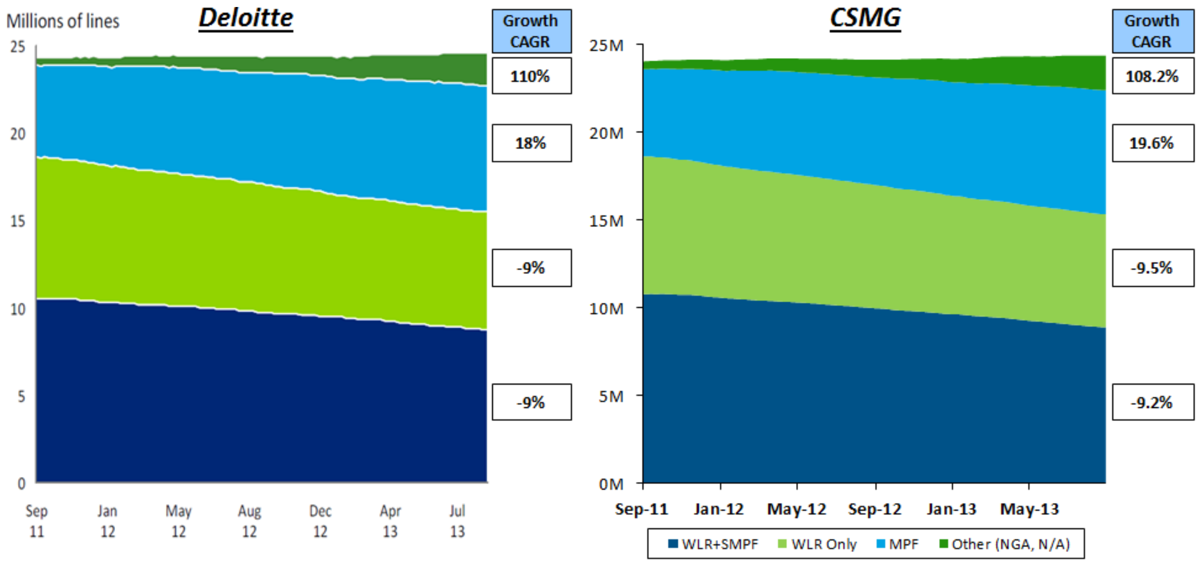
8. Annex 1 – Deloitte Report

8.1. Deloitte was commissioned by Openreach to investigate fault rates for MPF, WLR and WLR+SMPF lines. This brief Annex provides a comparison of Deloitte's report and CSMG's findings.

Data Sources

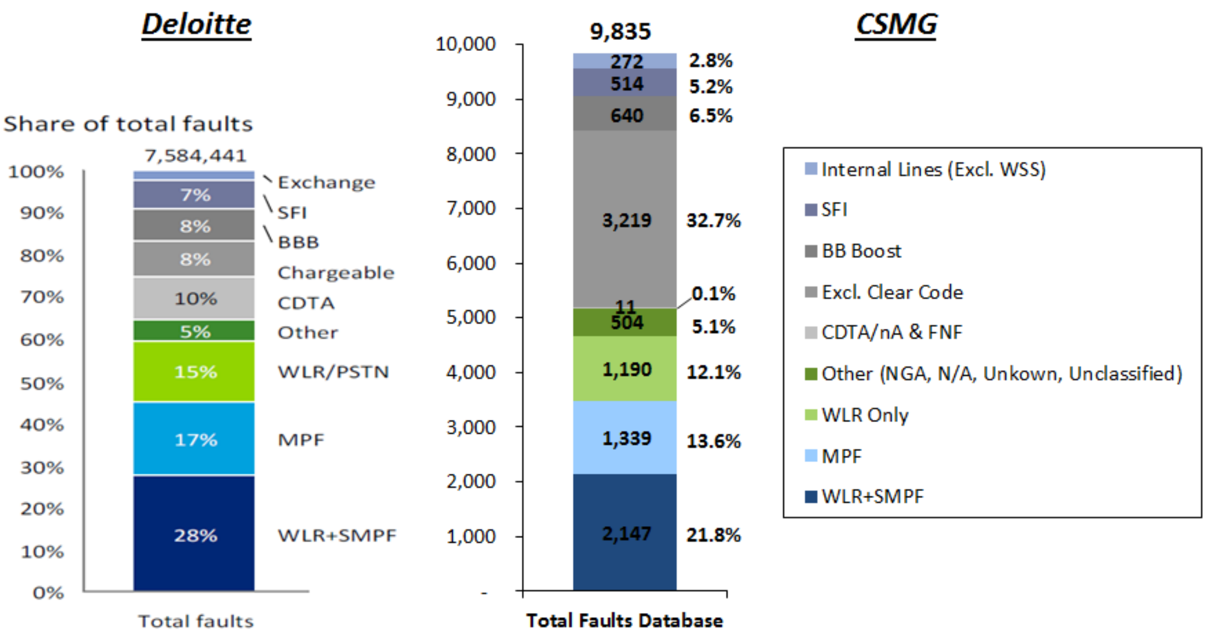
8.2. Deloitte used a working system size which was consistent with that used by CSMG (see chart below).

Figure 30: Deloitte WSS (Left) vs. CSMG WSS (Right)



8.3. However, there were inconsistencies in the fault database used in Deloitte's analysis and that used in CSMG's analysis (see chart below). CSMG's fault database was larger (9.5m records) than that used by Deloitte (7.5m records). CSMG was unable to reconcile the difference.

Figure 31: Deloitte (Left) vs. CSMG (Right) Faults Database Breakdown



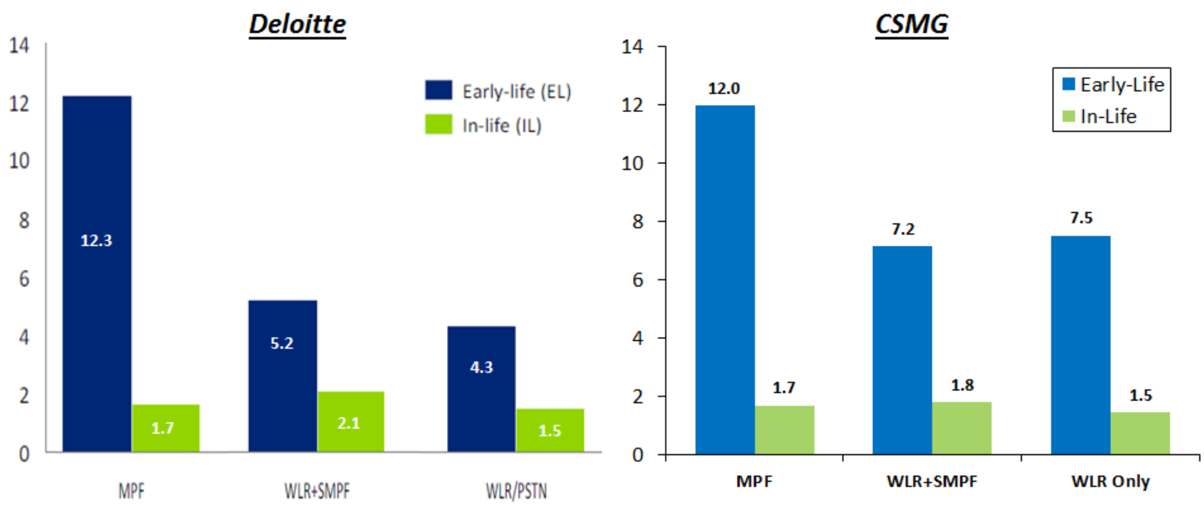
Comparison of Results

8.4. CSMG attempted to replicate Deloitte's analysis and produced the following results for comparison.

8.5. For ILF rates, CSMG's analysis produced similar results to Deloitte, though the ILF rate for WLR+SMPF was slightly lower than Deloitte.

8.6. However for ELF rates, CSMG's WLR+SMPF and WLR Only fault rates were significantly higher than Deloitte's analysis (see figure below).

Figure 32: Deloitte vs. CSMG ELF & ILF Rates (per 1,000 lines)



8.7. The differences between the underlying data sources are the likely reason for these variations.

9. Annex 2 – Glossary

Figure 33: Glossary of Terms

Term	Description
BB Boost / BBB	Broadband Boost
CDTA / CDTnA	Conscious Decision to Appoint / Conscious Decision to Not Appoint
CP	Communications Provider
CSS Week / Year	Openreach-defined Calendar; 52 or 53 weeks per year running April - March
DP	Distribution Point
EL	Early-Life
ELF	Early-Life Fault
FNF	Fault Not Found
IL	In-Life
ILF	In-Life Fault
LLU	Local Loop Unbundling (product category for MPF / SMPF)
MBORC	Matters Beyond Our Responsible Control
MDF	Main Distribution Frame
MPF	Metallic Path Facility
NGA	Next Generation Access
SFI	Special Fault Investigation
SMPF	Shared Metallic Path Facility
WLR	Wholesale Line Rental
WLR+SMPF	Combination of WLR and SMPF products on the same line
WSS	Working System Size