# FAMR: Review of Openreach's DES model

A REPORT PREPARED FOR BSKYB AND TALKTALK

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# Executive Summary

Openreach has developed a model (the DES model) which is intended to estimate the relationship between the level of resources available within Openreach's workforce and certain indicators of quality of service (QoS). This model has been submitted to Ofcom as evidence of the increased forward-looking costs needed for a higher QoS level in terms of the percentage of repaid and provisioning jobs being completed within service level agreements (SLAs); and the higher incremental costs required to meet higher QoS in terms of faster repair of faults, for certain services.

The model has not been shared with stakeholders other than Ofcom as it is subject to copyright. Therefore, we have had very limited opportunity to interrogate the modelling and assumptions. This report relies on a review of Sections 3-4 and Annexes 5-9 of the December Consultation.[1] We note that some information within the annexes has been redacted.

Our key conclusion is that the model developed by Openreach is fundamentally mis-specified and consequently the results of the model cannot be relied upon.

In summary:

- The model is fundamentally mis-specified, failing to reflect causality;
- One of the key assumptions in the model, the distribution of completion times, does not fit the observable data;
- The assumptions of how the distribution of completion times changes as QoS changes are not supported by any evidence;
- The assumptions made by Openreach of the changes in the distribution time with higher QoS seems counter-intuitive and appear to lead to increases in peak resource requirements above those which would be required to meet the increase in QoS efficiently; and
- The assumption that an increase in resources at peak times would translate into a proportionate increase in costs does not reflect the ability to deliver higher peak resources for certain types of job without hiring full time staff.

These conclusions are outlined below and described in more detail in the body of the report.

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1 Fixed Access Market Review: Openreach Quality of Service and approach to setting LLU and WLR charge controls dated 19 December 2013 (the "December Consultation")

### *Model mis-specification*

The fundamental issue is that the model treats the "completion time" between a job being booked and the corresponding task being completed as an exogenous variable. Clearly this does not reflect causality, as the waiting time before the task begins will be a function of a combination of the available resources, the jobs already in the queue and the relative priority of the jobs. This mis-specification will lead to unrealistic results as, for example, the model implicitly assumes that, even if resources are available, the job will not be started until the pre-defined waiting time is completed.

While models by their nature necessarily entail some degree of simplification to make calculations tractable, Openreach's approach is not a modelling simplification but reverses the causal relationship between resources and quality of service.

It is not clear why Openreach has chosen such a specification given that they had an existing model: the DES model[2] supplied by Openreach in 2011 during the administrative process leading up to the current charge control ("The 2011 Model"). The 2011 Model reflected the actual causal relationship with engineering resources as an input and the resulting distribution of completion times, and hence QoS, being an output[3].

### *Inappropriate input distribution of completion times*

Openreach's implementation of this fundamentally flawed approach introduces further issues (although it is unlikely that any implementation could adequately address the fundamental flaw in the model). Openreach has chosen a Gamma distribution to model completion times without any theoretical justification other than "Use of a gamma distribution is not a priori unreasonable (as such distributions do arise in queuing theory)". Given that the empirical evidence shows that the Gamma distribution is a poor fit to the actual distribution of completion times, there appears to be little justification for using such a distribution. The poor fit for provision tasks in particular suggests that the model as specified does not adequately reflect the efficient allocation of resources between tasks. The fact that Openreach has managed to calibrate the model baseline to output a similar level of resources to that actually available to

2 See details provided at http://stakeholders.ofcom.org.uk/binaries/consultations/wlr-cc-2011/annexes/Openreach_repair_cost_analy1.pdf

3 The level of resources can then be varied to achieve the desired QoS

Openreach provides no confidence in the output as this is a necessary, but not sufficient condition[4].

### *There is no empirical basis to model alternative QoS scenarios*

While the base line completion time distribution chosen has a (weak) link to empirical data, it is the changes to the distribution under different QoS scenarios that drives the results used by Ofcom to set the charge controls. With the Gamma distribution having two degrees of freedom, there are an infinite number of solutions which provide for a given QoS. Ofcom's own consultants recognise that the way Openreach has modified the baseline Gamma distributions in order to model alternative scenarios for QoS is not supported by evidence. With no supporting evidence the choice of distribution made by Openreach between the infinite number of solutions is essentially arbitrary, allowing Openreach to choose inputs which meet their commercial objectives.

### *Openreach's assumptions when modelling changes in QoS appear counter-intuitive*

Openreach's choice of parameters appears to be counter-intuitive. In particular by assuming that the mode of the Gamma distribution is constant as QoS varies, Openreach assumes waiting times for some customers would increase as resources and hence quality of service improves. This would appear to lead to a greater increase in the peak resources required for a given increase in QoS than other assumptions which appear more intuitively reasonable.

In the absence of any empirical evidence, a conservative approach would be to set the distribution in such a way as to minimise the required increment in resources for an increase in QoS. This would be consistent with the higher quality of service being delivered in the most efficient manner.

### *The assumption that costs are directly related to peak resource requirements is unfounded*

Even if the estimates of the increase in peak resources required for individual types of job were correct, these would not necessarily translate into proportionate increases in costs as the overall number of jobs will remain constant. To a certain extent peaks in demand for some tasks with narrow SLA windows, such as fault repair, can be met by diverting resources from tasks with wider SLA windows, such as provisioning, or from tasks not subject to SLAs such as preventative maintenance. Short term peaks could also potentially be met by flexible working

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4 Calibration is straightforward as the Gamma distribution has two parameters and there are separate distributions for repair and provisioning giving four degrees of freedom with which to achieve calibration.

practices, for example through overtime or the use of contractors rather than recruiting additional full time staff.

### *Use of the model results to input to the charge control*

There is general agreement that there is a relationship between the resources available and the quality of service for tasks undertaken by Openreach's workforce. However, given the nature of the tasks to be undertaken, this relationship is complex. With the large information asymmetry between Openreach and Ofcom (and the even greater asymmetry between Openreach and stakeholders as evidenced by the lack of access to the model), the burden of proof should be on Openreach to demonstrate the degree to which meeting higher levels of QoS would lead to increased costs. In the light of the multiple shortcomings in the model provided by Openreach, and the lack of supporting empirical evidence, Ofcom should not place significant weight on the results.

### *This report*

In the remainder of this report we briefly summarise the operation of the model. We then comment below on:

- the key assumptions made by Openreach;
- how the model is used to estimate the increased resources required with an overall increase in QoS; and
- how the model is used to estimate the incremental resources required to deliver services with high levels of QoS.

# 1 Construction and operation of the model

## 1.1 Overview of the model

The discrete event simulation (DES) model constructed by Openreach attempts to reproduce the relationship between QoS and the resources required to provision jobs and repair jobs within each Openreach management area.

The approach taken by Openreach does not attempt to simulate the actual process through which jobs are accepted, prioritised, assigned to engineers and completed by engineers, and then estimating how quickly these jobs can be dispatched by an input number of engineers. In such a model the distribution of the time to complete jobs, and hence the achieved QoS, is an output of the model based on inputs for the level of demand and resources available.

Instead the inputs to the model are:

- The flow of provisions and repair jobs to be completed based on actual data;
- A task time[5]; and
- A probability distribution of the time elapsed between the job being booked (i.e. the fault notified or the request for a new service to be provisioned) and the job being completed (i.e. time to compete).

Based on these inputs, the model calculates the number of jobs to be carried out in each shift and the resources (expressed as the number of staff required at each grade) required to complete the jobs estimated to be completed on each day/shift.

The demand for staff at each grade in a year is the demand for staff on the peak days. However, as higher grade staff can perform lower grade tasks, the model does not simply sum the peak demand for each grade during the year. For lower grades peak demand in each day is net of any surplus staff from higher grades.

The design of the model is unusual in that it treats an exogenous variable (the resources allocated to certain tasks) as an output and an apparently endogenous variable (the distribution of the time elapsed between booking and completion) as an input. This would appear to reverse causality as the distribution of task times would be expected to be a function of:

- The flow of provision and repair jobs to be completed based on actual data;

5 This appears to be based on average task times but it is not clear whether this is modelled as a single task time for all jobs of a given type or a probability distribution.

- A task time; and
- The available resources for jobs (taking into account issues such as geographic availability).

This reversal of causality would need to be supported by a robust evidence base showing that it adequately modelled the relationship between QoS and resources for it to be considered a reasonable modelling simplification. Openreach does not appear to have gathered or supplied this evidence.

### 1.1.1 Comparison with previous models

In the administrative process leading up to the current charge control, Openreach submitted details of a far more complex DES model, named the Workforce Dynamic Simulator (WDS). The results were used by Openreach to argue for a higher proportion of repair costs to be allocated to 'care level 2' (CL2) services, including MPF. While only limited details of the 2011 Model are publically available it appears to be considerably more complex than the current DES model, and to reflect cost causality in that resources were an input to the model with completion times/QoS being an output.

The results of the 2011 Model were not accepted by Ofcom, in part because Openreach chose to model scenarios with very high QoS (on-time repair at 98.3%) which did not reflect Openreach's actual performance.

In its conclusions on the 2011 Model Ofcom note that:

*"We would encourage Openreach to consider for future reviews how they might provide evidence to validate the results of their operational model."*[6]

Rather than developing the 2011 Model, which appears to have been a reasonable approximation of reality, changing the assumptions to closer reflect actual performance and providing further supporting evidence, Openreach has chosen to develop a novel, and counter-intuitive, model. It is not clear why Openreach has taken this approach.

Openreach also does not appear to have provided evidence that validates the results of the current model, which was identified by Ofcom as a shortcoming of the 2011 Model.

6 Charge control review for LLU and WLR services Annexes Statement Publication date: 7 March 2012 Paragraph A4.302

# 2 The approximation of the time to complete distribution

For the approach adopted by Openreach to provide an accurate estimate of resource requirements under different QoS, it would seem to be a necessary[7] condition for the assumed probability distribution of completion time to match closely the actual distribution of actual completion time (ideally for an efficient operator).

## 2.1 Use of Gamma distribution

Each job that is modelled is randomly assigned a "time to complete", drawn randomly from a Gamma probability distribution. The distribution varies over time on a week by week basis to reflect changes in the QoS achieved over the year. Openreach has assumed that the time to complete approximately follows a Gamma distribution and (implicitly) that the distribution of the time to complete is constant within each week. We do not have information to test this latter assumption, but it would seem reasonable to assume the time to complete distribution may vary depending on the day of the week, with the waiting list of fault repair jobs to complete being higher on Mondays, due to faults reported over the weekend.

The December Consultation annexes provide information on the fit of the Gamma distribution to the actual data, which we examine below.

## 2.2 Fit of the Gamma distribution

The base line distributions of time to complete are based on the actual performance in 2011/12. A "Gamma Distribution" function is fitted to the actual 2011/12 performance. The methodology used to fit the Gamma distributions is not disclosed. Charts shown by Analysys Mason compare the "fitted" Gamma distributions to the actual distributions.

### 2.2.1 Provisioning jobs

For provisioning the fit is very poor. This can be seen in **Figure 1** below which shows the distribution of provision jobs.

The actual distribution is broadly bi-modal, with peaks around 1 day and 12 days. The peak at 1 day presumably reflects provision jobs being completed rapidly (for example jobs which do not require a customer appointment), when there are

[7] Although not a sufficient condition.

free resources available, in order to prevent a back log building up. The peak at around 12 days presumably reflects provision jobs being given increased priority when they near the time limit defined under the SLA.

This distribution is intuitively reasonable when considering that a common workforce is used to deliver both provisioning jobs and repair jobs. In general repair jobs will be given priority, with provisioning jobs being carried out when repair jobs do not require all the available resources. However, when provisioning jobs are close to the timescales set out in the SLA they will be given greater priority.

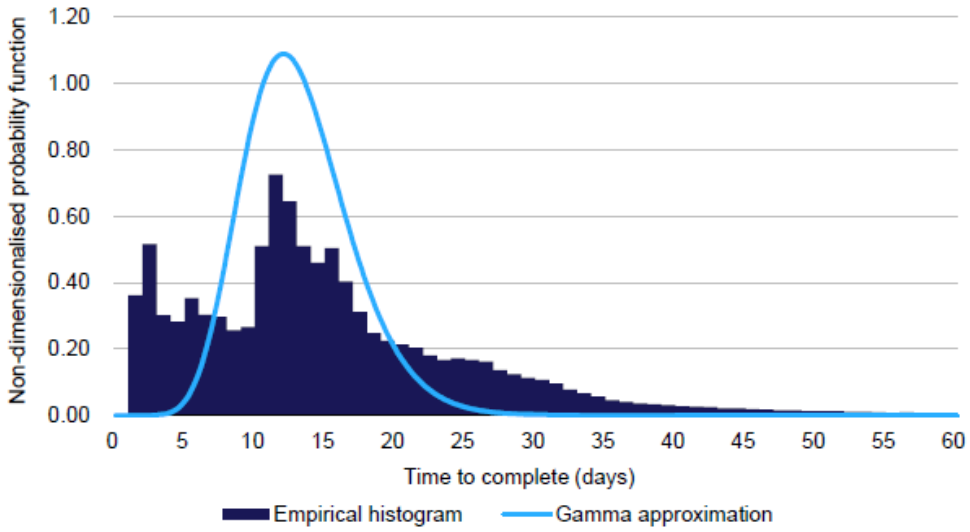
For example Ofcom notes that planned provisioning is diverted when peaks are reached. "*We observe in Table A5.2 that Openreach chose to divert resources from provision to repair in 2012/13. This was consistent with priority given to repair by Openreach and its customers and reflected the increase in repair demand. There was a small overall resource increase in 2012/13 compared with 2011/12 of [*[8]*%.*"[8]

A fixed Gamma distribution does not capture the interplay between repair jobs and provisioning jobs. As a result the distribution implies that very few jobs are completed in the first five days after the job is booked (even if there are idle resources in these days).

8 December Consultation paragraph A5.32.

## The approximation of the time to complete distribution

**Figure 1.** Example of actual distribution of provision job completion with fitted distribution

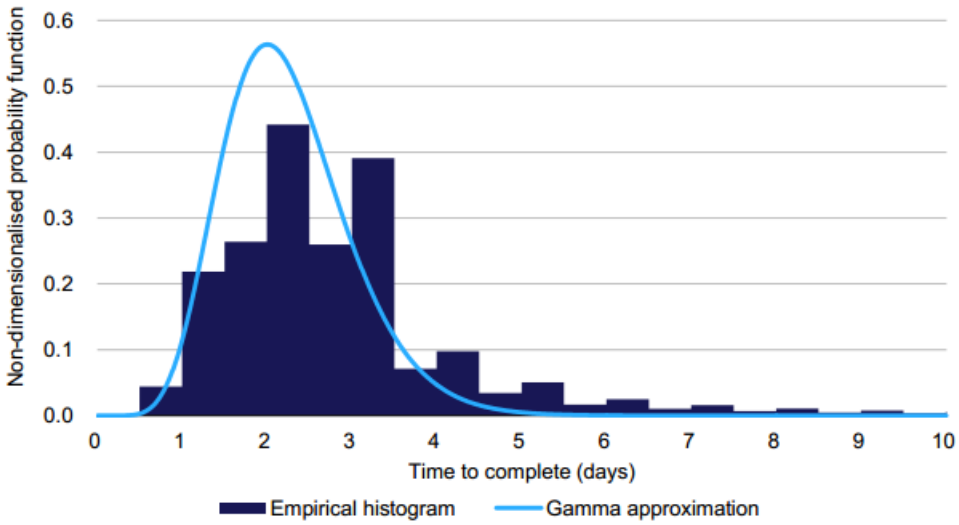



Source: AM report Figure 3.2

### 2.2.2 Repair jobs

The fit for repair jobs is better, reflecting the fact that repair jobs need to be completed in a short period of time and will generally have higher priority than other tasks. However, there are systematic differences between the two distributions, with the actual distribution showing peaks at regular one day intervals, which may reflect deadlines for SLA targets, or the resources available within a day (reflecting shift patterns).

**Figure 2**. Comparison of actual distribution of repair job completion with fitted distribution




Source: AM report Figure 3.1

### 2.2.3 Conclusion

The Gamma distribution is a poor fit to the actual data, in particular for provisioning jobs. This reflects the fact that the time to complete distribution for provisioning will be dependent on the level of faults, an interaction not captured in Openreach's model. This provides further evidence that the approach adopted by Openreach will not provide robust estimates of the relationship between the resources available and QoS.

The approximation of the time to complete distribution

# 3 Modelling overall increases in QoS

In the past two years Openreach's performance against the targets set out in SLAs has deteriorated, with the percentage of jobs completed within the defined time decreasing. Ofcom is proposing to introduce a new SMP Condition governing QoS requirements (in terms of percentage completion of existing SLA performance targets) within the regulation (and reflect this QoS in the charge control), to incentivise Openreach to improve its performance against these targets. Openreach argues that setting QoS at these levels will require additional resources (compared to the current QoS level), with the DES model being used to estimate the required level of additional resources.

The model attempts to model the resource implications of increasing QoS in a multi-stage process:

1. An increase in performance across the year is modelled by increasing the number of jobs completed by the SLA target, from the base line level;
2. The increase in jobs completed within the SLA target is distributed evenly across the year, subject to the performance being below a "glass ceiling" maximum level of performance defined by Openreach. Jobs which would require performance to exceed this glass ceiling are re-allocated to those weeks with the poorest performance;
3. For each week, for both the base line level and the improved level of performance, a Gamma distribution of completion times, that replicates the estimated percentage of jobs completed within the SLA target, is applied to the jobs within that week;
4. For each shift, the number of jobs completed is estimated based on a combination of jobs booked in previous periods and the assumed distribution of time to complete;
5. The mix of staff required to meet the jobs completed in each shift/day is estimated; and
6. The overall workforce required to meet the peak requirements resource requirements in the year is estimated.

## 3.1 Modelling an increase in performance

The assumption that an increase in QoS will be broadly spread over the year may be reasonable, in that an improvement in average performance over a year, due to an increasing level of resources, would be expected to lead to a general improvement in performance throughout the year.

In weeks where there is already very high performance, indicating that there may already be surplus resources, an increase in resources may not further increase

performance measured by the SLA target. Thus the application of some "ceiling" may be appropriate[9]. However, it is not clear that simply re-assigning the increase in jobs that need to be completed within the SLA to those weeks where performance is worst, is an efficient method of increasing performance. The fact that performance in these weeks is lower suggests that demand is at its highest and so increased performance in these weeks may require a disproportionate increase in resources compared to other weeks. Openreach's approach leads to some counterintuitive results, with much greater increases in QoS required for some weeks than others[10].

## 3.2 Use of the Gamma function

As we have seen above, the Gamma distribution does not provide a good fit for the base line time for completion. This in itself suggests that estimates based on varying the time to complete between the base line distribution and another gamma distribution is unlikely to be a robust methodology. However, accepting these limitations, there will be methods of modelling changes in QoS which may be more realistic than others.

It is straightforward to link the Gamma distribution with the QoS input. For a given Gamma distribution, the number of jobs completed within the SLA is the cumulative distribution function (CDF) at this point in time. As the Gamma distribution has two parameters, there are an infinite number of combinations of parameters with the same CDF at a given point.

For the baseline, the pair of parameters could be chosen by fitting the distribution to the actual distribution, for example through a least squares fit (although it is not clear if Openreach has fitted the distribution based on some objective criteria or solely by inspection). For the hypothetical improved level of QoS, there is no empirical evidence to choose between the infinite combinations of pairs of parameters.

In order to choose between the infinite number of combinations for the improved QoS, Openreach has added a constraint that the mode (i.e average) of the distribution of the time to complete is fixed, both for the baseline over time (i.e. across different weeks) and for the hypothetical case where performance is improved.

There is no theoretical or empirical justification for assuming that the mode should fixed in this way. For example, Analysys Mason note in its review of the model:

9 We have not assessed whether the glass ceiling assumed by Openreach is reasonable.

10 As shown in figure 10 of the EY document.

> *"More fundamentally, the way in which the gamma distribution is manipulated to try to test scenarios with different performance, SLAs or job mixes from those observed historically is not based on any testable rationale"*[11]

And

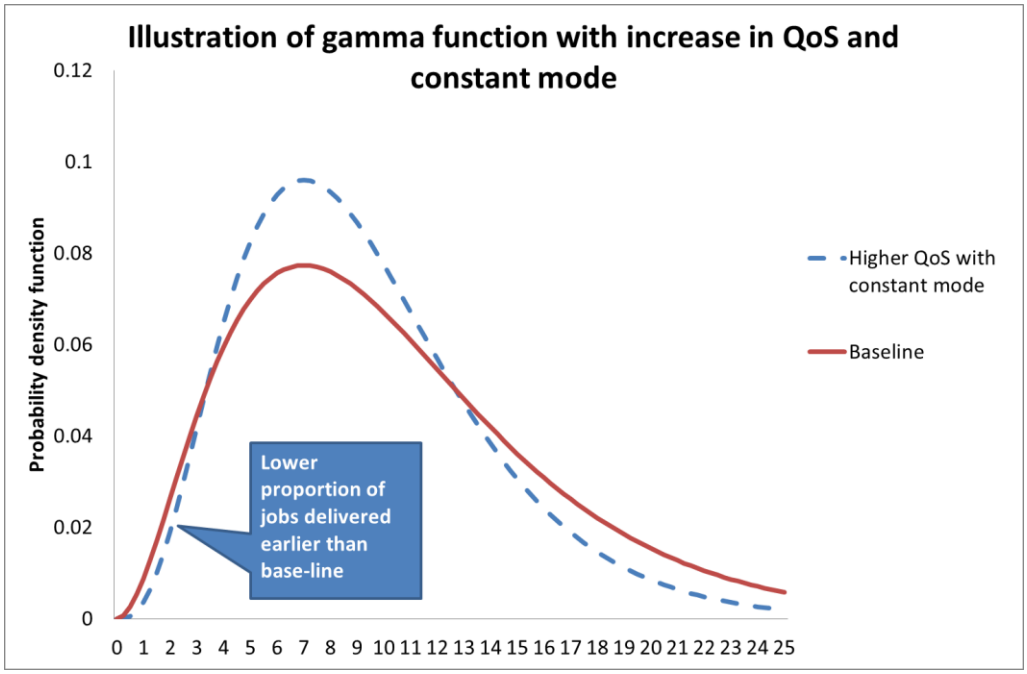
> *"this methodology relies heavily on the assumption that the mode of the distribution remains at a fixed point. While that may have been an accurate observation from the empirical data (although we have not seen direct evidence of this), there is nothing a priori to suggest that this should continue to be the case when the performance is adjusted.* […] *Importantly the magnitude of the effect of fixing the mode of the gamma distribution on the calculated resource requirements is unclear. This is an important point because, even though we do not consider that the decision to fix the mode is necessarily unreasonable, an alternative choice could have been considered equally reasonable and could have yielded very different outputs across the range of scenarios we consider in later sections."*

To the extent that any constraint should be placed on the distribution, an appropriate constraint could be to choose the distribution that minimises the required resources. This would be consistent with an assumption of efficient operations at both the base line and improved performance case. In other words, the distribution of completion times for a hypothetical efficient operator would result in the distribution (and hence mode) at the most efficient (cost minimising) level, not at a level which is constrained to a fixed mode.

Intuitively it does not seem reasonable to assume that the mode of a Gamma distribution would be fixed as QoS increases. Doing so essentially concentrates the distribution of job completions in the time around the mode, reducing the number of jobs in the 'tails' on both sides of the distribution as shown below. This means that with an improvement in QoS, the cumulative number of jobs completed within relative short times is reduced. This appears counter-intuitive, as with increased resources there are more likely to be unused resources when jobs are booked which could complete jobs rapidly. This concentration effect is illustrated in **Figure 3** below.

11 December Consultation Annex 9 Analysis Mason Report page 50.

**Figure 3.** Openreach assumption for increased QoS

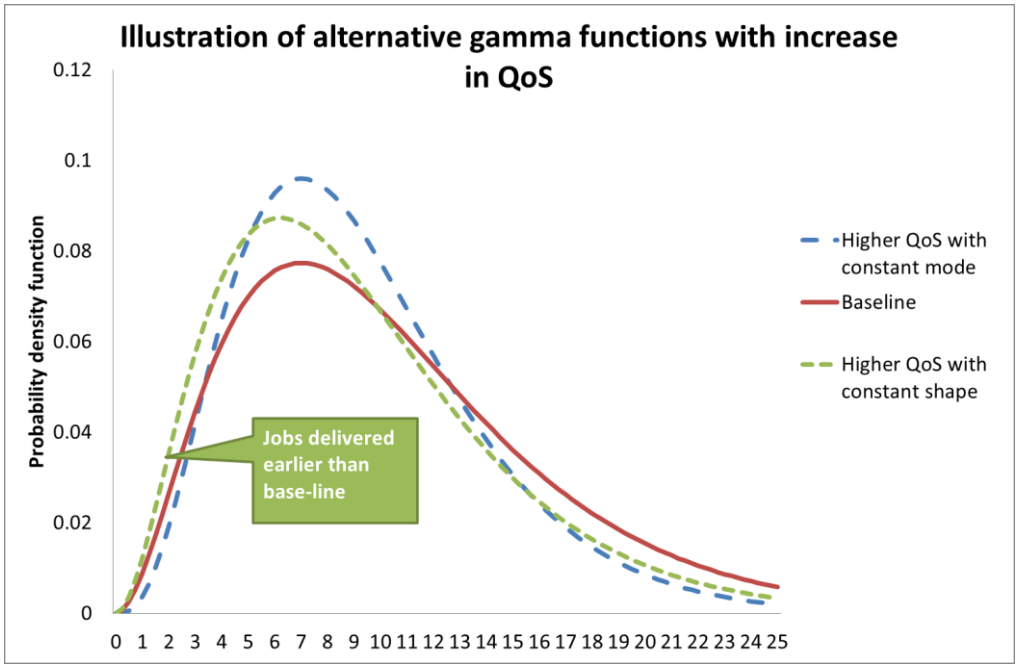



Source: Frontier

A more intuitively reasonable assumption would be that the increased resources, consistent with improved QoS, leads to jobs being completed more rapidly in general rather than the proportion of jobs being concentrated around a fixed mode. One way of applying such an assumption would be to keep the alpha "shape" parameter of the gamma distribution constant while varying the beta "rate" parameter. This results in a lower peak rate of jobs being delivered than when keeping the mode constant, which is likely to require fewer peak resources. This is illustrated in **Figure 4** below.

## Modelling overall increases in QoS

**Figure 4.** Alternative distributions for higher QoS




Source: Frontier

While the availability of an alternative distribution which achieves a similar QoS with lower peak resource requirements is not in itself proof that the approach adopted by Openreach is incorrect, it does suggest that Openreach needs to provide further justification of the modelling choices it has made. This could take the form of empirical data that the mode of the time to complete distribution is constant as QoS varies, or independent evidence that the model closely reflects the correlation between QoS and resource inputs.

## 3.3 Converting jobs into resource requirements

The methodology used to convert estimates of the number of completed jobs in each shift into total resource requirements appears broadly reasonable, subject to the fundamental issue noted above that jobs are assigned a start time independent of the available resources. For example, Openreach has two overlapping shifts[12] and when operating efficiently the number of jobs completed in the overlap between the two shifts would be approximately double that of

12 EY report figure 7.

other times when only one shift is working. This is not reflected within Openreach's model.

## 3.4 Cost implication

The cost model calculates peak resource requirements in a year, rather than total resource requirements. As the number of jobs is fixed as QoS varies, overall the same volume of work is carried out. Thus the resources required to carry out a task will be the same, independently of the QoS (although travel time between jobs may vary depending on the order in which jobs are carried out).

Openreach has assumed a linear relationship between peak resources and costs. However, this is likely to overstate the cost impact of increasing QoS for a number of reasons:

1. There will likely be scope to re-engineer the business to deliver greater resources for fault repair at peak times, without increasing overall resources through the year;
2. Increased peak demand could be met by other, less expensive, sources compared to recruiting additional full time staff, for example using contractors or overtime; and
3. To the extent that additional full time staff are required to deliver additional resources at peak times, the additional labour available at off-peak times can be used for other tasks, such as preventative maintenance, the benefits of which will offset the increased cost, by reducing overall fault levels.

# 4 Modelling differences in CL1 and CL2

## 4.1 Overall approach

A similar overall modelling approach is adopted to modelling differences in resource requirements between care level 1 (CL1) and care level 2 (CL2) and as a result the same fundamental issues apply.

## 4.2 Scenarios modelled

For each year Openreach model three scenarios:

- A baseline scenario, reflecting the current mix of CL1 and CL2 services;
- A scenario based on all services being delivered at CL1; and
- A scenario based on all services being delivered at CL2.

## 4.3 Changes to the distribution

For the three scenarios, Openreach uses different Gamma distributions with fixed modes:

- For CL1, where the SLA requires the repair to be completed by the end of the second working day after the fault is reported, the mode is set to two days after the call is logged;
- For CL2, where the SLA requires the repair to completed before the end of the next working day, the mode is set to one day after the call is logged; and
- For the baseline scenario, a gamma distribution with a mode between the two is used which appears to differ from the base line distribution used above[13].

There appears to be no empirical justification for the Gamma distributions selected for the different mixes of care level. Clearly as the distribution of job completion times under the hypothetical scenario where all jobs are completed under a single care level cannot be observed, there can be no empirical support for the job completion distributions chosen for the extremes. However, even for the base-line scenario Openreach appears to have used a distribution which differs from the empirical evidence or a simple mix of the two extreme distributions.

13 EY report page 16

## 4.4 Interpretation of the results

In order to estimate the difference in the incremental cost between CL1 and CL2 a regression line is fitted to the three scenarios, with the independent variable being the proportion of CL1 (or CL2) services. The resulting estimates are thus heavily influenced by the extreme scenarios where all services are assumed to be delivered under CL1 or CL2.

Ofcom rejected the results of the 2011 Model in part because it was based on similar extreme assumptions:

*"We are cautious about accepting that the results of Openreach's modelling can be taken as representative of the current delivery of repair services, for two reasons:*

- *The modelling exercise demonstrates the effect of moving all services from Care Level 1 to Care Level 2. We are considering the case where there is a mix of services delivered at the two care levels.*
- *[…]*

*We think that the modelling data presents an extreme case of the impact on resources because of these two points and therefore it would not be appropriate to make the adjustment suggested by Openreach."*[14]

In the currently proposed charge control modelling Ofcom has moved to explicitly model the incremental cost differences of services such as MPF and WLR. To reflect this change Ofcom should be attempting to estimate the incremental cost of additional CL1 or CL2 customers, given the existing customer base. The extreme assumptions modelled are likely to be inappropriate for this estimation as moving to delivering all services at one care level or another would presumably require extensive re-engineering of Openreach's operations. Instead, estimating the impact of relatively small perturbations around the current service mix would appear to be more appropriate.

Ofcom's model auditors point out that "*it is clear that the absolute level of resource is overestimated but the effect of this on the resource delta* [i.e. the difference between resources required for CL1 and CL2] *is not known.*"[15]

## 4.5 Conclusion

Openreach's approach to estimating the additional cost of CL1 is based on scenarios which Ofcom previously rejected as being too extreme. In addition, Openreach's choice of the distribution of completion times, which drives the

14 Charge control review for LLU and WLR services Annexes Statement Publication date: 7 March 2012 paragraph A4.291

15 Analysys Mason Quality of Service model assessment page 21

results, appears not to be based on any empirical evidence at all. As such, Ofcom can have little confidence in the results.

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