

Analysis of Research and Development Investment

A DotEcon Report for BBC R&D

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Glossary

AMWA	Advanced Media Workflow Association
AR	Augmented Reality
AS-11	A specification for file-based delivery of air-ready programming
BAU	Business as Usual
BFI	British Film Institute
BIDI	BBC Internet Distribution Infrastructure
BoB	Box of Broadcast
CDN	Content Distribution Network
DPP	Digital Production Partnership.
DTT	Digital Terrestrial Television
DVB-T2	Digital Video Broadcasting – Second Generation Terrestrial
FTA	Free-to-air
HD	High Definition
HLS	HTTP Live Streaming traffic
IRFS	Internet Research and Future Service
ISP	Internet Service Provider
MOTD	Match of the Day
NABA	North American Broadcasters Association
NFB	National Federation of the Blind
NIST	National Institute of Standards and Technology
NPV	Net Present Value
OTG	BBC Online Technology Group
QC	Quality Control
R&D	BBC Research and Development department
UHD	Ultra High Definition
WCAG	Web Content Accessibility Guidelines
WHP	White Paper

Executive Summary

We have been asked to conduct a cost benefit analysis of the work of the BBC R&D department over the previous Charter Period

DotEcon has been commissioned by the BBC Research and Development department (R&D) to prepare an independent evaluation of its activity over the previous Charter Period.¹ We have been asked to evaluate the costs and benefits of R&D's work.

The assessment presented in this report is based on interviews with staff in the R&D department, the wider BBC and in the broadcasting sector, and our independent analysis of data provided by BBC finance and R&D. The views expressed in this report are our own, formed as a result of this research and data gathering, and do not necessarily represent the views of the BBC or R&D.

As part of our assessment, we have identified all the projects conducted by the department over the last Charter Period. Within this project portfolio we focus on selected case studies, using bottom-up microeconomic techniques to estimate their potential benefits. We assess potential benefits from R&D's activities in terms of direct benefits to viewers and listeners, as well as other measures such as time spent with BBC services, cost savings for the BBC and licensing income to the BBC. We also consider broader spill-over benefits to the broadcast and audiovisual sectors. The findings of these case studies are then used to estimate the overall net benefit of the work of the department as a whole, taking account of the likely probabilities of successful outcomes across the project portfolio.

We demonstrate that the R&D department has generated significant value for the BBC, its audiences and the industry as a whole that exceeds its cost by a large multiple. **We conservatively estimate an overall net benefit of between £5 and £9 for every pound spent by the department.**

¹ The Charter Period runs from 1 January 2007 to 31 December 2016. See "Copy of Royal Charter for the continuance of the British Broadcasting Corporation", October 2006. Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/charter.pdf

The role of BBC R&D

The department has an essential role in ensuring continued advancement of technology in the broadcast industry, guided by BBC strategic priorities.

BBC R&D undertakes a wide variety of applied research and development for the benefit of the BBC, the public and the wider industry as well as working in Joint Ventures on specific projects in which the BBC has an interest. Through its work R&D seeks to identify new operational infrastructures and distribution methods, new production tools, new BBC services and improved features for existing services. These may provide efficiencies and cost savings for the BBC, as well as audience benefits. R&D's research also plays an essential role in standards development, fostering interoperability across the industry. Therefore, whilst much of the work of R&D brings direct benefits to the BBC and its audiences, it also generates wider societal benefits.

The project portfolio is actively managed...

Innovation is, by its very nature, a highly uncertain activity and even in applied research success is not guaranteed. Some preparatory activities will typically be required to evaluate the potential of a new idea or technique. To this end, R&D maintains a portfolio of projects in different stages of development. Typically, projects start small and are allocated additional resources if they show promise, or are curtailed if they do not.

We find higher rates of success among larger projects (those with larger associated expenditure). This provides evidence that resources are indeed being selectively channelled to expand projects as they show promise.

... but there are inevitably costs of unsuccessful projects and overhead costs...

Whilst much of the expenditure on a terminated project cannot be recovered (as typically much of this is labour costs), we have found that such projects may provide insights that can be used elsewhere in other projects. Nevertheless, there will be some expenditure associated with unpromising projects, even where these have been weeded out of the project portfolio at the earliest opportunity. There is also a broad need to maintain and develop skills and capabilities within R&D, so some projects are undertaken to ensure continued development and to expand the knowledge base.

... which need to be covered by the benefits from successful projects

In this study, we focus on a selected number of case studies that provide examples of well-developed projects that have delivered, or are likely to deliver, benefits. Whilst there will of course be R&D projects that have delivered substantial benefits, it would be unreasonable to assume that all of the expenditure of the department brings direct and substantial benefits. For example, there are other expenditures within R&D, both overheads (which do not directly yield attributable benefits, but are a cost of maintaining the R&D function) and spending on smaller, 'seed projects'. These seed projects may have not yielded benefits to the same degree as more developed projects yet, but are a necessary precursor for future benefits. Therefore, successful projects need to yield sufficient benefits to cover not just the direct costs of those projects, but also overhead costs and costs of any unsuccessful projects. We take this into account for our overall cost benefits assessment.

A cost benefit assessment

The benefits of R&D's work need to be clearly identifiable.

This evaluation considers the costs and benefits associated with technical innovation but not programming innovation. Nevertheless, we do consider innovation in content origination leading to new or improved services. Before counting a benefit, we require that there is a clearly identifiable mechanism by which that benefit arises directly from the involvement of R&D.

We consider both direct benefits to the BBC and its audiences and wider benefits to other parties

For a number of case studies, we have identified:

- incremental costs incurred by R&D (labour costs and other expenditure directly attributable to the project, excluding any attribution of overhead costs);
- benefits for the BBC in terms of cost avoidance or direct financial revenues (e.g. licensing revenue);
- benefits for viewers and listeners arising from access to new services and quality improvements to existing services; and
- spill-over benefits to broader society (e.g. through development of standards, patents or knowledge transfer).

There may also be strategic benefits for the BBC, but these are difficult to quantify and typically long-term in nature. Therefore, whilst we include a qualitative assessment of the value and importance of such strategic benefits, we do not account for them in our quantitative results.

Bottom-up estimation of benefits

For each case study, we estimate a lower and upper bound of the ratio of benefits to the incremental cost of the project (i.e. the costs directly caused by the project, excluding any allocation of overhead costs). These benefit-cost ratios are summarised in the table below.

Table 1: Benefit-cost ratios for each case study project

Case study	Position in value chain	Costs (£m)	Benefits estimate		Benefit-cost ratio	
			Lower Bound (£m)	Upper bound (£m)	Lower Bound	Upper bound
Piero	Content	1.08	46.00	77.00	42.60	71.30
Redux/Snippets	Data, Content Analysis & Storage	1.39	53.20	58.70	38.30	42.20
FTA connected platforms	Distribution	3.40	32.50	49.50	9.56	14.60
DVB-T2	Distribution	2.82	76.70	152.00	27.20	53.80
AS-11	Production	0.467	12.00	12.00	25.70	25.70
Subtitles	Production	1.18	25.00	>25.00	21.20	>21.20
BIDI	Distribution	0.348	NOT QUANTIFIED			

Source: DotEcon based on case study cost and benefits estimates (figures displayed to 3.s.f.)

In order to estimate the overall benefits of R&D's entire work over the most recent Charter Period, we assume that other *successful* R&D projects would create benefits at a similar rate as our case studies. This rate is based on a weighted average of benefit-cost ratios across five of our seven case studies (weighted by project cost). We only use five of our seven case studies, as it was not possible to quantify the benefits of the BIDI and subtitling case studies robustly given the lack of data available and the substantial uncertainty around their estimation.^{2 3} However, the five case studies that are included in the weighted average provide sufficient coverage of the range of projects carried out by R&D and the type of benefits we would expect from successful projects.

The weighted average of benefit-cost ratios (weighted by project cost) gives a range of **24** to **38** for the ratio of benefits to

² We exclude subtitles from weighted average calculations as a result of the uncertainty in estimating both the true social value of subtitles and the value of the quality improvements achieved.

³ We exclude BIDI as a result of the substantial uncertainty in estimating the cost saving benefits to date given the lack of information surrounding the actual costs the BBC currently faces for use of third party CDN's which are subject to non-disclosure agreements.

incremental costs (i.e. excluding overhead costs) for successful projects.

We cannot assume that *all* of R&D's activity will be equally successful in generating benefits as our case study projects; our case studies are not a representative sample drawn at random, but rather examples of successful projects. The overall project portfolio will contain other, possibly less successful or less mature projects. For instance, some projects will be curtailed and not progress to realise benefits, whereas other projects may only be at a germinal stage and have yet to realise benefits.

To avoid applying our benefits ratio to all project spend and risk grossly overstating the benefits, we have considered (based on feedback and evidence provided by R&D) how the probability that a project yields benefits changes according to the relative size of the project within R&D's overall project portfolio. Larger projects will tend to have grown because of additional resources being allocated following promising earlier results, and so are more likely to yield benefits; in contrast smaller projects will tend to consist of seed projects that might or might not ultimately succeed and projects that have been curtailed.

R&D generates significant benefits

We find that BBC R&D brings significant value and generates benefits at a multiple of the costs, even taking a very conservative estimate

We estimate the overall benefits from R&D's activities in the following way:

- We rank the portfolio of projects by size (on the basis of each project's directly attributable cost excluding any share of overheads);
- We set a cut-off point within the distribution of project sizes. We assume that projects larger than this cut-off point generate benefits of magnitude commensurate to the weighted average benefit-to-cost ratios calculated above from the case studies;
- We assume that projects smaller than the cut-off point are not successful and generate no benefits (a conservative assumption, as in practice some of these smaller projects do yield benefits).

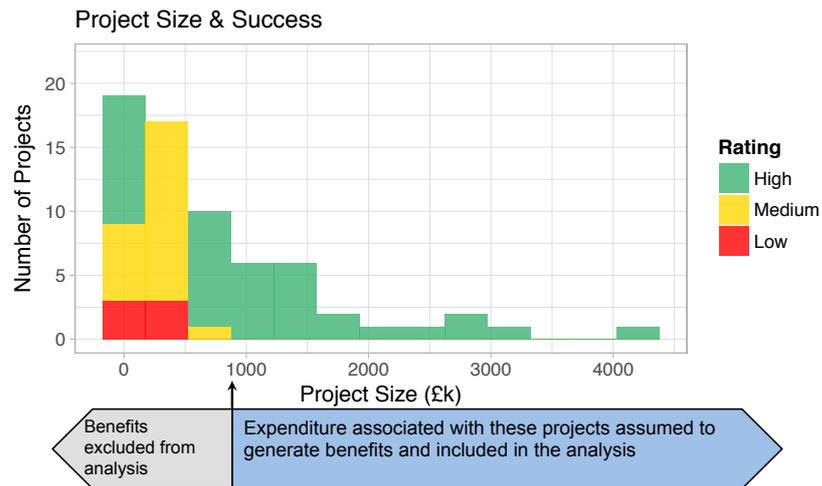
In order to determine where in our list of projects we should set this cut-off point, we used feedback from R&D on the likely success rates of projects. We asked R&D to classify each of the projects over the past Charter Period into three groups based on whether the project could be considered as:

- unsuccessful, projects that have been shut down or were expected to be shut down (indicated in red);
- moderately successful, generating benefits *at least* covering the cost of investment (indicated in yellow); or

- clearly successful, generating benefits many times greater than costs (indicated in green).

Figure 1 below, which shows the findings from the sample of projects that were given a ranking. It plots projects by size and colour-coded in line with R&D's classification.⁴

Figure 1: Finding the 'productive spend' cut-off point



Source: DotEcon figure from BBC data.

This evidence verified our hypothesis that larger projects tend to be more successful as they have shown sufficient promise to attract additional resources. This is not to say that smaller projects cannot be successful or that larger projects will not fail, but shows that the resource allocation procedures in place typically lead to higher rates of successful projects as their associated expenditure increases.

We set the cut-off point at the lowest value such that all larger projects are clearly successful (the case shown in the figure above, with all projects above the cut-off being green) and then assuming that all projects smaller than or equal to the largest 'not very successful' (i.e. classified as yellow or red) project generate no benefits whatsoever. This is the most conservative application of this approach as all projects above this 'cut-off' point are classified as green. Projects below the cut of point are a mixture of green, yellow, red and unclassified but we conservatively assume that no benefits have been generated by any of these projects.

⁴ Note that not all projects in our list were classified by R&D. As we describe in the report, and in line with our conservative approach, we assume that any 'unclassified' projects are 'red' and thus will not yield any benefits.

On this basis, we calculate net benefits over the past Charter Period to be in the range of around **£827 million to £1.40 billion**. Based on a total expenditure for R&D of £160.8 million for the same period, including overhead costs, this relates to **a net benefit of between £5 and £9 for every pound spent by the department**.⁵

These results demonstrate that R&D generates significant net benefits from its work and that even our most conservative estimates show that the value created per £1 invested are, at least with an order of magnitude, in line with findings from other studies on the value of research and development:

⁵ Rounded to one significant figure

For example, research by Breshanan (1986) on computer innovations in the 1970s, that include social gains (in addition to private benefits) finds a cost benefit ratio of around 1:5.⁶

Perhaps more relevant to the type of research and development activity undertaken by BBC R&D, there have been several value-for-money evaluations of research and science funding schemes. For example, a cost benefit analysis of Innovate UK's 'Smart' R&D financing programme⁷ determines the cost benefit ratio to be from 1:4 to 1:5. Although this report identifies potential spill-over and social returns, it does not seek to quantify them. One should also note that the 'Smart' ratio includes future unrealised benefits, in contrast to our approach.

An evaluation⁸ of the Collaborative Research and Development Programmes⁹ estimated the benefits of the programmes by conducting surveys on the total turnover generated for businesses from their participation. It found that for every £1 spent, the programme generated £6.71 (or £5.75 in constant 2010 prices) in gross value added (GVA).¹⁰

In a recently published report assessing the current status of the EU Horizon 2020 programme (the EU Framework Programme for Research and Innovation 2014-2020)¹¹ and its progress towards its objectives estimates that for every €1 invested, there will be benefits (in the form of increased GDP) of the order of €6-8.5.¹²

⁶ Breshanan (1986) estimates the value of price-reducing innovations for computers used in financial services. The value of the price-reducing innovation is proxied by willingness to pay by the financial sector for the computers and their downstream customers, and estimates that "[in] 1958 and 1972 the spillover from the adoption of mainframe computers in the financial services sector of the U.S. was at least five times the size of the expenditure for it in 1972" (emphasis added) See Bresnahan, T. (1986), Measuring spillovers from 'technical advance', American Economic Review, 76,741-755. (Subscription only).

⁷ The Smart scheme provides funding to small- and medium- sized enterprises working on innovative R&D projects. For the evaluation report see: SQW, 'Evaluation of Smart, Impact and Process Evaluation', October 2015. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467204/Smart_Evaluation_-_Final_Final_Report_7_October.pdf

⁸ Public and Corporate Economic Consultants, 'Technology Strategy Board – Evaluation of the Collaborative Research and Development Programmes – Final Report', September 2011. Available at: http://webarchive.nationalarchives.gov.uk/20130221185318/http://www.innovateuk.org/assets/pacec_evaluation_of_crandd_report_final260911%20%282%29.pdf

⁹ A knowledge transfer and innovation support system that brings together partners from Higher Education and businesses to support R&D projects

¹⁰ We note that this research differs from ours in several ways: it forecasts benefits substantially, does not attempt to quantify wider social returns and includes the economic impact arising from increased employment. The study estimates that the GVA of *project costs alone* was £1.97 forecasted and £0.31 in realised returns (£1.74/£0.28 in 2010 prices).

¹¹ Horizon 2020 is designed "...to drive economic growth and create jobs by coupling research and innovation (R&I), with an emphasis on excellent science, industrial leadership and tackling societal challenges." See European Commission Staff Working Document, 'In-depth interim evaluation of Horizon 2020', 16 June 2017. Available at: [https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd\(2017\)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagedmode=none](https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd(2017)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagedmode=none)

Extending our conservative assessment given above, we show that the benefits could plausibly be even larger given that there are some projects identified by R&D as generating significant benefits that fall below the size cut-off point we have applied.

We present results for a range of cut-off points, where any smaller projects with a cost falling below the cut-off are excluded from our grossing up exercise (as above). However, as we lower the cut-off point this will by construction include a mixture of successful and unsuccessful projects. We presume that there will be benefit created only by those successful (i.e. 'green') projects that are larger than the cut-off. To be clear we continue to apply our conservative assumption that any projects classified as yellow or red, or which are unclassified will yield no benefits at all.

Following this approach, we calculate that net benefits from R&D's activities over the past Charter Period could be as high as £1.73 billion. This relates to a net benefit of up to £11 for every pound spent by the department.¹³

Returns to R&D expenditure of this magnitude are not surprising given the potentially large audience benefits and social value associated with many of these innovations. It is entirely possible that the true value of all of the benefits arising from R&D activity are even higher, given that our results are based only on the benefits that we have been able to quantify in our bottom-up assessment.

There is a range of benefits that arise from R&D activity that are difficult to quantify and therefore are not included in the figures above. Furthermore, there are potentially significant additional benefits arising from the work of R&D in terms of time and effort spent by the department and its engineers to ensure that they remain at the forefront of their field and are well versed in new technologies that may become more relevant in future, allowing the BBC to take advantage of new technologies offering industry leading services for licence fee payers. This significantly reduces the risks facing the BBC from technical change.

For these reasons, the quantitative results presented in this report should not be considered as providing an estimate of the maximum conceivable value created by the department. However, the approach we have adopted is well-suited to the question of

¹² European Commission Staff Working Document, 'In-depth interim evaluation of Horizon 2020', 16 June 2017. Available at: [https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd\(2017\)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none](https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd(2017)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none)

¹³ Rounded to one significant figure.

whether the work of R&D generated benefits in excess of its costs.

The figures presented should be considered conservative estimates of the value of the work conducted by BBC R&D over the past Charter Period and as such demonstrate clearly that the benefits achieved outweigh the costs of the department.

Given that we can conclude that benefits exceed costs even when making conservative assumptions about benefits, this conclusion is robust.¹⁴

¹⁴ Indeed, even just the identified benefits found in our case studies alone are sufficient to exceed the total spend of the R&D department over the previous Charter Period.

1 Introduction and background

1.1 Terms of Reference

Background

During its recent charter renewal negotiation with the Government, the BBC agreed to review its research and development activity and spending for the Department for Culture, Media and Sport.¹⁵ This review would look at value for money achieved from research and development and the role of partnering in delivering benefits. Under the agreement, the BBC would undertake:

- a cost benefit analysis (including an analysis of the value delivered for the public, the creative sector and wider economy);
- a qualitative assessment of the success achieved from investment in research and development, taking into consideration at least the previous Charter Period, and up to the date of the review; and
- a review of objectives for the future, and potential ways in which the BBC may be able to improve collaboration with others.

Requirements

To help inform the BBC's assessment, DotEcon has been commissioned by the BBC Research and Development department (R&D) to prepare an independent evaluation of the activity of the department. Specifically, we have been asked to undertake an impartial and objective study to help address the first of the questions posed by the DCMS: a cost benefit analysis of the work of R&D over the previous Charter Period.¹⁶ Whilst we include some quantitative assessment of the successes achieved from investment into research and development, we also provide a qualitative cost benefit assessment. We stress that we limit our attention to expenditures made by the R&D department itself, rather than innovative activity occurring more widely across the BBC.

As a specialist economics consultancy with broad experience in providing policy, economic and strategic analysis and advice to a

¹⁵ The department has since been renamed as "The Department of Digital Media Culture and Sport".

¹⁶ The Charter Period runs from 1 January 2007 to 31 December 2016. See "Copy of Royal Charter for the continuance of the British Broadcasting Corporation", October 2006. Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/charter.pdf

wide range of both public and private sector clients around the world, DotEcon is able to provide an independent review. We have a track record of delivering high-quality economic analysis and demonstrate the expertise and skills necessary for such a review including, but not limited to:

- data gathering and stakeholder engagement;
- analysing the economic impact of policy proposals, including quantitative modelling;
- undertaking cost-benefit analyses and regulatory impact assessments; and
- understanding the implications of current economic thinking on business strategy.

We have undertaken a number of challenging cost benefit analyses for major clients, including in cases where data was scarce and there was a need to value innovation benefits. We have applied similar techniques in this assessment where necessary.

1.2 Overview of our approach

Scope of R&D activities

BBC R&D undertakes a wide variety of applied research and development for the benefit of the BBC, the public and the broader industry, as well as working together in Joint Ventures on specific projects that the BBC has interest in. The work of R&D spans a range of activities running from original (applied) research, where there may be considerable uncertainty about the nature of practical application of the results, through to creating, testing and trialling a proof of concept, on to implementing new tools and techniques and bringing them into everyday usage. BBC R&D also undertakes a significant amount of work related to standard setting throughout the broadcasting and wider media value chain.

In this report we are mainly concerned with quantifying the benefits from embodying the output of R&D in specific new services, quality improvements or cost reductions, rather than seeking to value research aimed at creating the underlying concepts in the first place. We focus on technical innovations arising from the activities of BBC R&D (e.g. the Digital Video Broadcasting – Second Generation Terrestrial standard), rather than programming innovation across the BBC at large (e.g. creating new formats such as Bake Off). Nevertheless, we do consider technical innovations that help content to be presented in new ways (such as Piero, a tool for sports analysis on TV using 3D graphics and real-time image processing) and so may have immediate benefits for programming.

We consider a selection of R&D projects in detail, estimating the benefits using microeconomic techniques...

For the purposes of this cost benefit analysis, we have taken a selection of key projects whose benefits have been estimated in a bottom-up manner using microeconomic techniques (e.g. estimation of additional consumer surplus created). For each of our chosen projects we consider:

- the incremental costs incurred by R&D (in terms of labour costs and other expenditure directly associated with the project);
- the benefits in terms of cost avoidance or direct financial revenues, benefiting the BBC;
- consumer benefits arising from access to new services and quality improvements; and
- a wide range of spill-over benefits to broader society (e.g. through development of standards, patents, knowledge transfer etc. and others using technology developed by R&D).

Rather than taking a narrow perspective and considering only benefits accrued to the BBC, we have sought to quantify broad benefits to society (such as reduced costs, new services or quality improvements for viewers). Whilst there are often significant uncertainties in quantifying these benefits, in such cases we have erred on the side of caution and sought to be conservative in our benefits estimates. We have only sought to quantify benefits where there are clear and uncontroversial mechanisms for generating those benefits.

The work conducted by R&D (and some of our sample projects in particular) also gives rise to significant strategic benefits to the BBC. It also provides the BBC with sway in standard setting processes, ensuring that the interests of public sector broadcasters are reflected. We discuss these benefits to the broader BBC in qualitative terms, but we have not included them in our quantitative assessment of benefits. Such benefits may be difficult to estimate and long-run in nature, but nevertheless substantial.

...we use these findings as a basis for estimating the overall benefits of R&D work in the last Charter Period

Our approach first constructs bottom-up estimates of benefits for a selection of projects. We then use these examples to estimate the productivity of R&D's overall expenditure over the most recent Charter Period, taking account of the fact that not all R&D projects are successful, with some falling by the wayside or being re-purposed for different ends due to the inherent uncertainties of the process of innovation.

Taking this approach, it is important that our selected case studies reflect the wide range of the R&D's activities and that we take into account any systematic difference between projects in terms of the scale of benefits they create. Therefore, as part of the selection process we undertook a taxonomic exercise, considering all the projects conducted by R&D over the most recent Charter Period and sought to classify these in light of their position within the overall

content creation, production and distribution value chain and the nature of its activities.

In agreement with R&D, we then chose our case studies to cover a selection of projects that cover the breadth of activities undertaken within R&D and demonstrate examples of successful projects. Therefore, whilst this is clearly not a random selection, in that we look at successful projects, it does provide good coverage of the activities that R&D undertakes.

Our selected projects were chosen to cover all areas of the value chain and a range of different project types, demonstrating the full scope of R&D work.

On this basis, we focus on seven projects for detailed assessment. We consider more projects in those areas where a greater proportion of R&D resources are committed (in particular, the 'production' and 'distribution' categories).

The projects chosen are:

- the Piero sports graphics system (Piero);
- Free-to-Air (FTA) connected TV platforms;
- Digital Video Broadcasting – Second Generation Terrestrial (DVB-T2);
- Development of a specification for file-based delivery of air-ready programming (AS-11);
- Subtitling;
- Redux/Snippets; and
- BIDI

We discuss the case study selection process and the selected projects in more detail in Section 3 of this report

Bottom up estimation of benefits

We draw on information from R&D and the BBC provided in the form of data sets and information collected from interviews with key R&D and BBC staff, as well as external data and information from interviews with external stakeholders as needed to develop our understanding of the projects and to inform our benefits estimates for each of the case studies. Where the BBC provided data to us, the analysis and interpretation of that data was conducted independently of the BBC and R&D. Where data is lacking, we make assumptions and seek proxies that allow us to find lower bound estimates of likely benefits. We are only seeking to estimate benefits to an order of magnitude.

For the large majority of our case studies, we are able to generate quantitative estimates of benefits to show that the benefits to the BBC, audiences and the wider industry far exceed the costs of investment. However, in some cases we present a qualitative assessment of the likely benefits achieved to date or expected to be achieved in the future, noting in particular that the internally developed content distribution project (BBC Internet Distribution Infrastructure – BIDI) has significant strategic benefits for the BBC in terms of strengthening its options for distribution of content in the future.

Having identified lower and upper bound benefit-to-cost ratios for each of our case studies, we take these as a proxy for the scale of benefits that may be achieved by other R&D projects. This assumption is used to estimate the overall benefits of all R&D work over the most recent Charter Period. However, given the unpredictable nature of research and development, it is unlikely that all the work of R&D will generate a similar level of benefits; indeed unpromising projects will have been closed down at an early stage.¹⁷

BBC R&D actively manage their portfolio of projects, curtailing projects that are unlikely to succeed and providing additional resources to projects that are likely to deliver relevant benefits. As a consequence, R&D's portfolio of projects at any point in time consists of a mix of relatively many small projects – which have yet to prove themselves – and a smaller number of larger projects, which have typically developed out of smaller seed projects. In turn this means that significant benefits and a greater return on investment are most likely from larger projects. Smaller, seed projects are nevertheless an unavoidable cost of the R&D function, as they are necessary to initiate successful projects and need to be progressed sufficiently before it can be determined whether or not they are likely to be successful.

Given that the portfolio of R&D projects has this structure, we hypothesise that projects with greater cumulative expenditure are more likely to generate substantial benefits, whereas projects with a smaller associated expenditure will be less likely to yield significant benefit. Data from R&D is consistent with this view.

Therefore, in estimating the overall benefits of R&D's activities, we have taken larger projects (i.e. those with a greater associated expenditure) which we consider to represent productive R&D expenditure that is likely to yield benefits (estimating the scale of the likely benefit by drawing on our case studies), as these projects have actively been allocated resources within R&D and been subject to review. We then treat smaller projects in the portfolio as being seed projects that could subsequently become larger projects that could generate benefits; however, to avoid double-counting benefits, and in line with our generally conservative approach, we suppose that these smaller projects do not yield benefits and that their costs amount to a fixed and common cost of undertaking exploratory work to seed new projects. We describe this 'grossing up' method in detail in Section 5.

¹⁷ Assuming all other projects achieve a similar scale of benefits might yield a gross overestimate. In particular, there is a natural risk that our case study selection includes only successful projects yielding significant benefits, and excludes unsuccessful R&D activities.

Our overall approach is microeconomic and ‘bottom-up’, considering the portfolio of R&D projects and identifying specific mechanisms by which benefits are likely to be generated. In contrast to this approach, previous assessments of the economic value-added created by the BBC at large have used macro-economic multipliers and could be considered ‘top-down’.

For example, a report on *‘The Economic Value of the BBC: 2011/12’*¹⁸ sought to establish the economic value the BBC’s spending delivers to the UK based on macro-economic multipliers. Under this approach, the BBC considered three types of ‘value-added’:

- Direct value added, defined as the value of total sales or revenue less expenditure on goods or services purchased from other organisations¹⁹;
- Wider indirect impacts through, for example, additional economic value to those further down the supply chain such as companies receiving income from BBC expenditure (e.g. equipment suppliers);
- Induced impacts when those companies spend that income on other goods and services (and the employees of those companies supported by BBC expenditure also go and spend some of their income on other goods and services).

In simple terms, the multiplier method tracks the initial BBC spending and assesses how this “ripples through” the economy creating further economic activity through what is referred to as the multiplier effect.²⁰ However, we consider that the multiplier approach is unsuitable for estimating the impact of R&D (and would probably lead to a gross underestimate of impact).

R&D activities yield innovations with some probability; some of this effort is productive and some unproductive, but it is not possible to tell in advance with certainty what are the most productive lines of enquiry. Where innovations are achieved, they may indeed yield very large benefits if they have mass-market effects. Therefore, there is the potential of benefits that may be significantly greater than those arising from macroeconomic multiplier effects, but to assess this we need to consider the specific impact of each

¹⁸ BBC, *The Economic Value of the BBC: 2011/12 – A report by the BBC*, January 2013. Available at: http://downloads.bbc.co.uk/aboutthebbc/insidethebbc/howwework/reports/pdf/bbc_economic_impact_2013.pdf

¹⁹ The BBC notes that this is roughly equivalent to the wage bill and operating surplus of the organisation.

²⁰ The report used figures from the Office for National Statistics that provide sector-specific estimates of multiplier values that measure the indirect and induced impacts, usually split by sector and region and were not BBC specific.

innovation rather than apply a generic macro-economic multiplier to total R&D spend.

The approach we have adopted is well-suited to the question of whether the work of R&D generated benefits in excess of its costs. In particular if we still find that benefits exceed costs despite making conservative assumptions about benefits where there is uncertainty, then this conclusion is robust. Furthermore, whilst it is impossible to eliminate uncertainty from our quantitative assessment, it is usually possible to estimate benefits to an order of magnitude.

1.3 Structure of this report

In Section 2, we provide an overview of the R&D department's activities, focus and approach. We consider the objectives of the department, its approach to investment in research and development and discuss the ways in which the work of the department can yield benefits both for the BBC and for wider society. We then outline how we categorise the projects conducted by the department over the last Charter Period.

In Section 3, we describe how our case studies were chosen and provide an overview of the methodology we used to generate estimates of the costs and benefits associated with each of these projects. The main results of our case study assessment are presented in Section 4,.

In Section 5 we outline our approach to estimating the overall benefits associated with BBC R&D's work over the Charter Period. This is based on applying benefit to cost ratios informed by the case studies to wider groups of projects likely to yield benefits. We then present the results of this grossing up exercise before summarising our conclusions in Section 6.

Some of the material relied on for our quantitative analysis is confidential or commercially sensitive and as such is not revealed in the public version of the report. Whilst the detailed calculations and data have been provided in confidential Annexes, these are available only to the DCMS. We have, however, tried to be as transparent as possible in the main body of the report in terms of methodology used and providing aggregated results.

The views expressed in this report are our own, formed as a result of the research and data gathering detailed within, and do not necessarily represent the views of the BBC or R&D.

2 The BBC R&D department

2.1 Overview of BBC R&D activities, focus and approach

R&D's mission

The BBC R&D's mission is to define the future BBC, drive UK competitiveness and benefit digital citizens by generating knowledge, assets and capabilities that advance the technological capabilities of the media and broadcasting industries²¹

The department's role in the broadcast industry for the last Charter Period was set out clearly in the BBC's Royal Charter and agreement with the UK government.²² Together with the Legal Agreement, these documents describe the need for the BBC to conduct research and development geared towards its public purpose. Specifically, "[t]he Executive Board must ensure that the BBC conducts research and development activities geared to the promotion of the BBC's Public Purposes and which aim to maintain the BBC's position as a centre of excellence for research and development in broadcasting and other means for the electronic distribution of audio, visual and audiovisual material, and in related technologies."²³

The BBC's publication 'British, Bold, Creative'²⁴ sets out a vision of the future BBC in which R&D would have a role in:

- delivering an internet-fit BBC driving creative partnerships and built on open platforms;

²¹ Statement based on conversations with BBC R&D management.

²² "Copy of Royal Charter for the continuance of the British Broadcasting Corporation", October 2006 (Referred to hereafter as "The Royal Charter"). Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/charter.pdf

²³ Article 87(1) of "An Agreement Between Her Majesty's Secretary of State for Culture, Media and Sport and the British Broadcasting Corporation", July 2006 (Referred to hereafter as "The Legal Agreement"). Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/agreement.pdf

²⁴ BBC, "British, Bold, Creative – The BBC's programmes and services in the next Charter", September 2015. Available at: <https://downloads.bbc.co.uk/aboutthebbc/reports/pdf/futureofthebbc2015.pdf>

- exploring new forms of delivery and options for syndicating content;
- looking at new forms of presentation and ways of reaching audiences; and
- giving viewers and listeners more control.

Strategic priorities

We understand that, in pursuing its mission to define the future for the BBC, R&D:²⁵

- drives innovation to support the delivery of the BBC's wider strategy and public purposes;
- strives to be at the forefront of technical change;
- provides knowledgeable and educated staff to solve problems or maximise opportunities;
- brings tangible value to the wider media industry; and
- maintains BBC partnerships and helps the BBC to maintain a primary position in the wider broadcasting ecosystem.

In line with this, R&D have told us that it seeks to deliver value by identifying new operational infrastructures and distribution methods, new production tools and new BBC products or features offering efficiency and cost savings for the BBC as well as through generating audience benefits from new and improved services. R&D considers that it must also develop new technologies to keep the BBC "relevant" by ensuring prominence of the BBC and deliver new experiences, addressing audience demands (such as streaming content over IP and accessing information 'on the go').

We also understand that R&D's internal experts offer advice and assistance throughout the BBC²⁶ drawing upon their specialist skills and experience in their respective fields. This is a core part of R&D's function.

Management of the project portfolio

Whilst guidance from the BBC on broad areas of focus can be helpful, research by its very nature requires freedom to explore new ideas and an environment where trial and error can ultimately foster new ideas. We understand that, within the guidance of meeting

²⁵ Based on conversations with BBC R&D management.

²⁶ We understand that R&D engineers spend approximately 10% of their time advising other areas of the BBC.

wider BBC business needs, the department allows staff some flexibility in determining where to focus their efforts. For example, we understand that the department typically allows staff to invest a few days to explore if a new idea has potential.

Providing such flexibility may allow R&D to identify possible beneficial changes even before the broader BBC has identified the opportunity or business need itself. For example, the idea and drive behind the BBC building its own content distribution network (CDN) – now known as 'BIDI' – originated from R&D before the BBC had identified any such opportunity.

Projects are defined at a sufficiently granular level such that if an idea shows promise, then more resources are assigned to that project. As project size increases, the justifications for use of resources come under greater scrutiny to determine whether it fits within the larger strategic objectives of the department and of the wider BBC. This implies that the more successful projects will typically have greater cumulative expenditure associated with them as they have justified their purpose and been allocated resources in competition with other projects. Therefore, a decision to continue/abandon a project is typically made at a relatively early stage (or for example as part of a periodic work plan review), which means that ideally 'unsuccessful' projects will be curtailed before they incur major costs. This is not to say that smaller projects cannot be successful or that larger projects will not fail; however, the procedures in place will tend to lead to higher rates of successful projects as their associated expenditure increases.

Benefits of R&D's activities

The work of R&D brings direct benefits to the BBC through cost saving and licence revenues, and to its audiences through new and improved services. Its work also brings wider benefits.

Some activities have strategic benefits for the BBC. For example, R&D's contribution appears particularly valuable in regard to distribution, where the BBC needs to continue to be able to meet changing viewer needs and to ensure prominence of BBC services on new distribution platforms.

Much of R&D's work (especially around standardisation) is intended to help advance the broadcasting and media industry as a whole. R&D often has an important role in collaborative projects and in projects leading to the generation of standards. By using its research to influence and set standards, R&D is able to foster a more collaborative approach and interoperability across the industry, as well as enabling efficient and low-cost transition to the new technology. By advocating these standards, R&D can drive industry-scale adoption bringing both direct benefits to the BBC and wider industry benefits.

The independence of the BBC allows R&D to co-ordinate multiple organisations in adopting mutually beneficial technical solutions where commercial self-interest may otherwise prevent such standardisation agreements. BBC R&D is widely regarded as being highly technologically competent given its established reputation and experienced staff (many of whom are experts in their field, regularly publish White Papers and speak at conferences). The department is well positioned to facilitate cooperation amongst other broadcasting organisations and external stakeholders when working towards a collective goal. As described in this report, this was a clear message from our discussions with industry, particularly for projects such as the development of a common standard for file-based delivery (the Advanced Media Workflow Association (AMWA) AS-11 standard) and the development of new platforms for delivery of free-to-air (FTA) connected services (such as Freeview Play).

This way of working is in line with the requirements of the BBC's Charter and Agreement. For example, R&D contributes significantly to *"supporting and engaging actively in national and international forums for the development of "open standards""*²⁷ and the requirement that *"[t]hese activities should be conducted both within the BBC and, as much as possible, in co-operation with suitable partners."*²⁸

An ever-expanding knowledge base

Not all projects started by R&D will necessarily lead directly to new tools, services or distribution methods, or even achieve their original objective. However, this is not to say that these projects entirely failed. Interviews we have held with R&D staff and project leads showed that in many cases the concepts and technologies developed may often find themselves being re-used in other ways. The experience gained through previous research, projects and collaborations, even if not directly successful, all contributes to the experience and knowledge base of the department, which in turn

²⁷ Article 87(2) of the July 2006 Legal Agreement and Article 65(2) of the December 2016 Legal Agreement: "An Agreement Between Her Majesty's Secretary of State for Culture, Media and Sport and the British Broadcasting Corporation". Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/agreement.pdf

²⁸ Article 87(3) of the July 2006 Legal Agreement and Article 65(3) of the December 2016 Legal Agreement: "An Agreement Between Her Majesty's Secretary of State for Culture, Media and Sport and the British Broadcasting Corporation". Available at: http://downloads.bbc.co.uk/bbctrust/assets/files/pdf/about/how_we_govern/agreement.pdf.

feeds into future work and might provide the catalyst for significant innovations.

For example, the technology that ultimately led to the development of the Piero Sports Broadcasting Platform was not developed with sport analytics in mind, but rather developed for a project that was aimed at developing methods to capture 3D images for delivering 3DTV content using image processing techniques.²⁹ Similarly, a project called Redux, which is now used to as a digital archive for recently broadcast television, was originally built as a proof of concept for a Flash-based iPlayer.

Furthermore, R&D may engage in research or activities that do not necessarily yield immediate benefits but are absolutely necessary to maintain a healthy diversity of skills and ideas within the department. These activities ensure that the engineers understand emerging technologies that may have a significant role to play in the future of broadcasting (for example, research and exploration in the field of virtual reality and 360 video).

2.2 R&D Projects over the most recent Charter Period

Over the last Charter Period (i.e. since 2007) R&D have conducted a large number of projects spanning a wide range of activities. As part of our assessment we have tried to form an understanding of these projects including the links between them, what they involved and how they were likely to benefit the BBC.

We identified a large number of distinct projects, varying in scale. It was clear that most of these projects could be categorised by their position within the overall content creation, production and distribution value chain and the nature of the R&D activities. We used the following categorisation:

- **Content origination** – projects that relate to the presentation of content for TV, radio and online and enable BBC editorial colleagues to assess and test how new forms of content might improve the BBC's ability to better “inform, educate and entertain” in future and improve the user experience. For example, projects associated with work in the areas of 360-degree video, virtual reality and binaural

²⁹ See: BBC R&D White Paper WHP 045, “Real-time production and delivery of 3D media”, September 2002. Available at: <http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP045.pdf>

audio as well as for the enhancement of content presentation such as Piero sports graphics tool;

- **Production** – tools and ideas that will improve the BBC's production process. For example, IP production tools that improve the capture of content and R&D's work in developing specifications that facilitated an industry-wide, coordinated approach to file-based delivery;
- **Distribution** – projects that contribute to the evolution of existing BBC distribution platforms through efficiency improvements (for example, its work in DVB-T2 and capacity optimisation to allow for the delivery of High Definition content and further develop the UK's free to air market); development of platforms (such as YouView and Freeview Play); and providing reliable operational infrastructures for the BBC's services delivery at present and in the future, for example building the foundation to deal with the increasing importance of IP distribution (such as BIDI).
- **Data, Content Analysis and Storage** – projects that allow the BBC to gather and interpret data about its processes and its users that will bring efficiency benefits and improved user experiences (for example its work on increasing the personalisation of BBC's online services), and work on improving the way in which archive content is physically stored and ensuring greater accessibility of large amounts of content and its metadata.

Defining the categories in this way allowed us to group all of the identified projects into one of these four distinct categories following discussion with, and advice from, the department and project leads. This taxonomic exercise helped to identify the distribution of R&D effort across different areas of the value chain, which was important for determining the number and type of projects we selected for our case studies. In particular, we have selected our case studies to ensure that we have coverage across these four groupings of projects, as described in the section below.

3 Case study methodology

The case studies have been chosen to cover the wide range of work conducted by the R&D department and demonstrate some particular examples of projects that have delivered a range of different benefits. We also considered that the focus of our case studies should reflect the distribution of resources within R&D. Therefore, within each of the 'value chain' categories identified (see Section 2.2 above), we sought to identify at least one project. For areas where there is proportionally more work undertaken we have included more than one case study. On this basis, we considered more cases in the 'distribution' and 'production' categories than the 'content origination' category. Our case studies cover about 13% of the department's project-related expenditure over the last Charter Period (i.e. direct costs of projects excluding department-wide overheads).

Clearly this approach means that our case study selection tends to include more of those projects yielding significant benefits, and excludes unsuccessful R&D activities. We account for this potential bias when grossing up our results to estimate the benefits generated by the department's overall activity. In particular, we are careful not to assume that R&D expenditure falling outside of our case studies is necessarily as productive as the expenditure falling within our case studies. Our approach to assessing overall benefits is described in more detail in Section 5 of this report.

In the sub-sections below we discuss the case studies selected and provide an overview of our approach to generating cost and benefit estimates.

3.1 Choice of case studies

We have chosen our case studies to cover a selection of projects that cover the wide range of activities undertaken within R&D and demonstrate examples of successful projects. We independently selected and subsequently agreed with R&D to focus on the following seven R&D projects:

- **Piero sports graphics system** (Piero) – Piero is a tool for sports analysis on TV using 3D graphics and real-time image processing. This project demonstrates R&D's work in developing innovative production tools that have been licenced to third parties all over the world. Benefits achieved include direct income to the BBC from licence revenues, royalty payments and cost avoidance, audience benefits through improved analysis of sports events and

spill-over benefits in the form of benefits to licensees of the system;

- **Free-to-Air connected TV platforms** – this includes the development of YouView and Freeview Play. These FTA connected television platforms seamlessly integrate digital terrestrial television (DTT) with catch-up services delivered over the Internet. These platforms allow the user to access subscription-free digital television and catch-up TV or on-demand services from all the major FTA broadcasters directly from their television through an intuitive interface or directly from the Electronic Programme Guide (EPG), using a set-top box or an enabled TV set with a broadband connection. These projects demonstrate R&D's work in developing new platforms that ensure continued prominence of the BBC (which has a potentially significant strategic benefit) whilst also generating benefits for audiences and the wider industry;
- **Digital Video Broadcasting – Second Generation Terrestrial (DVB-T2)** – DVB-T2 is a standard created for the transmission of digital terrestrial television, and allowed for an increase in capacity through improvements in spectral efficiency of digital transmission. This enabled HD TV to be transmitted on the terrestrial platform. This project demonstrates R&D's work in developing new standards that allow for increased efficiency and improvements in the distribution network. The BBC benefits from licensing income as well as being able to provide an improved quality of service to its audience bringing benefits for all viewers.
- **Development of a specification for file-based delivery of air-ready programming (AS-11)**– AS-11 is a file specification for distribution of air-ready programming that allowed the industry to move away from tape based delivery (a dying format) to a common file-based approach. R&D played a major role in developing the specification and worked on developing software, sample files and the Digital Production Partnership (DPP) Compliance Programme processes and on testing. This project demonstrates R&D's work in developing new standards and addressing the challenges faced by legacy technology (i.e. tape-based delivery) ensuring co-ordination between key stakeholders in the broadcasting industry to bring mutual benefits.
- **Subtitling** – Subtitles are an important add-on to television programmes and there is a large social value associated with improving accessibility. R&D's work on accessibility and subtitling, in particular on the timing of live subtitles and automated subtitle recovery for online clips, have led to increased quality and increased coverage of subtitled content bringing potentially significant benefits to those audiences reliant on subtitles to enjoy television programming;

- **Redux/Snippets** – Redux is a system that records and stores TV/radio content (including subtitles) from off-air sources into an archive and extracts meta-data that can be used at a later date to improve searching for specific material. Snippets is an advanced search and retrieval system and provides a frontend for making use of the material in the archives created through Redux. This project demonstrates R&D's work in developing new technologies to support the continued shift away from physical media as well as helping the BBC meet its requirements to make archived material accessible. The BBC benefits through more efficient use of staff time as well as a reduced reliance on physical media;
- **BBC Internet Distribution Infrastructure (BIDI)** – BIDI is the BBC's own content delivery network (CDN) used for the distribution of media streams to end users in the UK. This project demonstrates R&D's contribution to stimulating major changes in distribution methods and helping facilitate a shift to greater distribution of content over IP, which will become increasingly important for the future of broadcasting. There are potentially significant strategic benefits for the BBC of adopting its own CDN and having significant control over its IP distribution network.

Table 2 below provides a summary of where each of these projects falls within our 'value chain' categories:

Table 2: Categorising the selected case studies

Content origination	Production	Distribution	Data, Content Analysis and Storage
Piero	Subtitling AS-11	Free-to-air connected TV platforms BIDI DVB-T2	Redux/Snippets

3.2 Assessing costs and benefits

3.2.1 Costs

When assessing the costs associated with each of our selected projects, we need to identify the period over which resources were

committed to the development of the project and consider the amount spent by R&D on labour and non-labour expenditures.

We received data from BBC Finance showing full year costs for the BBC Research and Development department since it became a distinct department (from an accounting perspective) in 2007/08. However, we needed more granular data to estimate costs related to a specific project. To this end, we refer to two R&D datasets (provided to us by BBC R&D) one for labour costs and one for all other R&D expenditure:

- Labour costs from 'efforts data' from the 'YAMIS database', showing staff time logged against particular tasks that can in most cases be linked specifically to projects or work streams; and
- Other expenditure from R&D's 'Cost centre data', showing all other expenditures logged against particular activities that could be linked specifically to a project.

We describe each of these data sets and how we used them to calculate the costs of our selected case-study projects. However, in the small number of cases where this data was not available, or was incomplete, Project Leads³⁰ gave best estimates of the staff time and capital expenditure invested in the project.³¹

Labour costs based on the efforts data

Labour costs have been identified from data extracted from the YAMIS database where R&D staff are required to log time spent (in man-days) working on a project against specific codes known as 'Apollo Codes'. As well as the Apollo code, the data provides a brief description of the task, the 'area' of work or team the task was conducted by,³² the days when the task was started and finished and the 'owner' (in most cases, the Section Lead). YAMIS is an internal tool to allow the tracking of R&D's effort in collaborative research projects, chargeable projects, and EC funded projects. In addition, Project Leads use it to track efforts of teams.

In consultation with R&D and Project Leads we were able to match specific 'Apollo Codes' to particular projects or project areas,

³⁰ The Project Lead is the member of R&D staff in charge of the project.

³¹ For example, in some cases, not all staff time was logged in the YAMIS database, or only a proportion of 'efforts' logged in a broader area were specific to the particular project of interest. Therefore, we relied on cross checks with Project Leads to ensure that our cost estimates for the case studies were reasonable.

³² In some cases, this 'area' corresponds to the cost centres described in the subsection below.

allowing us to identify the total amount of time logged by R&D staff against a particular project (with guidance from Project Leads). Whilst some projects have just one of these codes, for others, many codes may relate to one project.

Each logged 'effort' equates to one working day. We converted logged efforts into equivalent man-years (on the assumption of around 230 working days per year³³). We then calculated the labour costs for each project by multiplying the number of man-years by the weighted average R&D staff salary (calculated using the average salaries against grade and the weight provided by BBC R&D). The fully-loaded, weighted average salary applied is £55,000.

Salaries are 'fully-loaded' in the sense that we use the salaries that include all employer contributions such as National Insurance and pension contributions. The fully loaded salaries are used throughout this assessment. We consider this to be appropriate given that we are assessing benefits delivered compared with the direct cost to the BBC. However, if we were instead considering a full social cost benefit analysis it would be appropriate to ignore costs to the BBC arising from employment taxes as they simply represent a transfer rather than a true resource cost (i.e. the government is the beneficiary of those taxes).

Non-labour costs based on cost centre data

In addition to labour costs, we need to consider all other expenditure on the project by R&D. We obtain this from 'cost centre' data provided to us by the BBC. This dataset includes all R&D expenditures logged against a particular 'cost centre'.

The cost centres against which expenditures are logged are mainly related to the research sections within BBC R&D, plus some additional cost centres³⁴ as well as some cost centres that relate to wider overhead and operations costs.³⁵

The date for when the expenditure was incurred, and other details of the expenditure such as a broad indication of what the cost entailed (e.g. 'Legal' or 'Hardware') is also provided. In addition,

³³ 260 week days less 8 public holidays less around 20 – 25 days of paid holiday.

³⁴ For example, cost centres included: Immersive and Interactive Content; Automated Production and Media Management; Distribution Core Technology; Broadcast & Connected Systems; Internet Research and Future Services; User Experience; Connected Studio; Chief Scientist; Controller / GM / Staff Retention.

³⁵ Note that wider overhead and operations costs are not included in our assessment of project-related spend. Such costs are considered as non-project-related or 'business as usual' costs.

where expenditures are logged against Apollo codes that correspond to the codes found in the 'efforts' data we were able to identify expenditures matched against specific projects. We understand that expenditures that do not have a partner Apollo code should also be considered as 'business as usual' (BAU) expenditure.

Total cost estimates

In order to obtain cost estimates for a particular project, we calculate labour and non-labour costs associated with that project separately using the efforts and cost centre data respectively. Expenditure is then aggregated and any additional cost estimates added. This gives us the project's incremental cost, as it does not include any allocation of fixed and common costs. For the purposes of our case study assessment, we are only interested in the project-specific incremental costs. We account for the fixed and common costs (the BAU costs) when estimating the total net benefit of R&D activities as a whole in Section 5.

3.2.2 Benefits

For each of the projects chosen for our case studies, we consider the estimation of benefits using microeconomic techniques, drawing on information provided by R&D and the BBC, as well as external data when needed. Where data is lacking, we try to find lower bounds for the benefits using appropriate proxies.

As discussed above, R&D projects can generate benefits in many different ways. For the purposes of our assessment we seek to establish the benefits arising from each of our selected projects in terms of:

- cost avoidance or direct financial revenues benefiting the BBC;
- consumer benefits from new services and quality improvements; and
- spill-over benefits to broader society (e.g. through development of standards, patents, knowledge transfer etc).

Therefore, we adopt a broad grouping of benefits that we apply in each of our case studies, notwithstanding that different R&D activities can have very different aims and yield benefits in a variety of ways. We consider the following categories of benefit:

- **Direct income**, (e.g income from technology licensing and patents) and **cost avoidance** (e.g. in the area of distribution costs, increasing efficiency through compression standards, production tools which increase efficiency) would typically

benefit in the form of lower prices for a commercial service, but in the case of the BBC, income and cost savings make more money available for investment in programming;

- **Quality improvements**, which increase the value of services to viewers and listeners and are typically reflected in a higher (potential) willingness to pay, greater audience shares and higher levels of appreciation;
- **Enabling fundamentally new or improved services**, which creates the largest benefits from meeting previously unmet needs of viewers and listeners; and
- **Spill-over benefits** where the project generates improvements for the wider industry.

Direct income

Direct income typically comes from licence revenues or royalty payments and patents and can be easily quantified with reference to R&D contracts and accounts. However, unlike commercial organisations who maximise private returns from successful innovation by limiting the extent to which new ideas can be exploited by competitors, the BBC is required (by Charter Agreement) to conduct R&D in cooperation with suitable partners, striking a balance between:

- monetising the R&D through licensing; and
- the value that might be made available to licence fee payers and the UK economy by making innovations widely and openly available.

Therefore, in many of these cases R&D and the BBC have collaborated with other organisations or may licence its technology to other organisations and may receive a royalty or licence payment in return. Where relevant, we outline the specific sources of income to the BBC and R&D for our selected projects.

Cost avoidance

Benefits from cost avoidance are normally easy to measure. Savings that manifest themselves in the form of reductions in variable costs (for example, reduction in labour costs due to time savings) typically translate into price reductions, and increase in output for end users. However, this volume effect is absent where services are provided for free at the point of use, as with the BBC. Nevertheless, any reduction in fixed or variable costs frees budget that can be deployed for other purposes (e.g. commissioning of programming), which may have additional value in a budget-constrained operating environment. Therefore, R&D work that brings cost savings to the BBC or allows for cost avoidance can be particularly valuable.

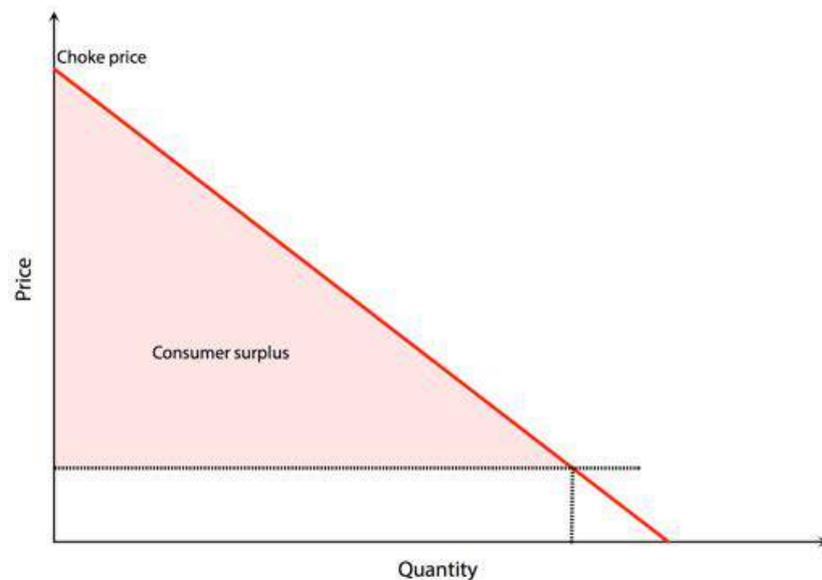
In order to assess cost savings for the BBC as a result of R&D's work, we consider direct cost savings (for example where there are demonstrable savings associated with staff time) compared against an appropriate counterfactual case where, for example, the BBC would have to rely on a third party to provide the same service.

Increased quality or entirely new services

Benefits from increased quality or entirely new services are typically large but difficult to estimate with any precision. In general terms, benefits are only partly reflected in increased revenues earned by the successful innovator; the majority of benefits arise from higher valuations of goods and services for users. However, the challenge of estimating benefits can be even greater where services are provided for free at the point of use, as in the BBC's case. In this case, comparable commercial services can be used to provide some indication of willingness to pay for similar services.

For example, consider the problem of estimating the benefits to the end user in terms of additional consumer surplus³⁶ arising from the provision of a fundamentally new service free at the point of use. In this case, benefits of a new service are represented by the entire area under the demand function (consumer surplus – see Figure 2). The additional consumer surplus created will depend on the shape of the demand curve and the price at which demand would be zero (known as the 'choke price'), which is the lowest price at which no-one would choose to buy the service.

Figure 2: Illustrative example of demand curve and consumer surplus



With adequate demand data, techniques can be used to estimate this choke price and the shape of the demand curve to produce benefit estimates. In the absence of adequate demand data, it is still possible to form an order of magnitude estimate of consumer

³⁶ Consumer surplus is the amount that a consumer would be willing to pay at most for a product or service, less the amount the consumer actually pays. Different consumers will be willing to pay different amounts, giving rise to a demand curve. Adding consumer surplus across those consumers purchasing a product or service gives a metric for the benefits enjoyed by consumers as a group.

surplus by making assumptions about the shape of the demand curve and using rough estimates of the choke price. In the case of BBC services, where services are free at the point of use, we need to find suitable proxies, but the principle of estimating new service benefits from choke price and the shape of the demand curve still applies.

For example, in the simplest case, we know that at a choke price of (X), demand is zero and we can refer to actual viewing or subscriber figures (Q) to determine the quantity at a zero price (i.e. free at the margin as is the case with BBC services provided to licence fee payers). Therefore, assuming a linear demand curve this would mean that the consumer surplus (which equates to the area under the demand curve) can simply be calculated as the area of the triangle with height X, and base Q, so consumer surplus = $X*Q/2$. This is not a particularly precise estimate, as the true consumer surplus will depend on the shape of the demand curve (and so the distribution of willingness to pay amongst the population of consumers); however, for forming rough estimates, this approach is adequate.

Spill-over benefits

Successful innovation not only benefits the innovator, but often also generates **spill-over benefits** for other firms within the industry or the economy more widely. In some cases, these benefits could greatly exceed the direct benefits to the innovator and its users. For example, the BBC has a commitment to open standards and a remit to make innovations available to others. Where possible we seek to estimate the value of this additional benefit and include it our calculations. For example, in the case where other users of R&D developed tools/technologies pay a licence fee this would indicate a lower bound estimate of the value to those users.

In some cases there may also be strategic benefits to the BBC

As discussed earlier in this report, the work conducted by R&D (and some of our representative projects in particular) brings strategic benefits to the BBC. However, as discussed above, these are very difficult to quantify and strategic benefits may not always be unambiguously welfare enhancing. Therefore, whilst we include a qualitative assessment of the value and importance of these strategic benefits, these do not form part of our quantitative results. However, we understand that R&D considers that creating strategic opportunities for the BBC is an important part of its role.

3.2.3 Comparing the costs and benefits

For each case study we identify:

- a) development costs incurred to date;
- b) benefits achieved to date (upper and lower bound); and
- c) potential future stream of benefits (where relevant/possible).

Strictly speaking, b) and c) should be calculated as Net Present Values (NPV), i.e. discounting net benefits over time and summing. An appropriate discount rate to use would be the Treasury Green Book³⁷ real discount rate of 3.5%, which relates to the Social Time Preference Rate, i.e. the value society attaches to present, as opposed to future, consumption. However, given that we are only seeking estimates of benefits to an order of magnitude and given the fairly short length of periods over which we are assessing costs incurred and benefits achieved (at most 10 years), the effect of discounting at a fairly low interest rate is minimal. Therefore, we can ignore discounting for the purposes of our evaluation of such costs and benefits given the other uncertainties involved.

In estimating future benefits, discounting could be very important if benefits were expected to continue in perpetuity (or at least for a long time). However, in our case studies we have focussed on identifiable future benefits accruing in the near term. Given that we are interested in order of magnitude benefits the impact of any discounting will be negligible.

Having estimated the costs and benefits, for each case study, we calculate a cost benefit ratio that is used as an input to our 'grossing up' methodology. As described in section 5.2, the ratio we use for our primary assessment is based on costs and benefits achieved to date (i.e. the ratio b/a) given that we are seeking to estimate the benefits that have arisen from R&D work in the most recent Charter Period.

Our approach is similar to the classic study undertaken by Zvi Griliches (1958),³⁸ which laid the groundwork for estimating the societal benefits of R&D investment. A summary can be found in the box below, which explains how we could also use components *a*), *b*) and *c*) above to calculate an implied social rate of return from R&D investment

³⁷ HM Treasury, 'The Green Book – Appraisal and Evaluation in Central Government',

³⁸ Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change", *Econometrica*, Vol. 25, No. 4 (Oct., 1957), pp. 501-522.

Using a detailed case study, Griliches estimates a perpetual rate of return by comparing all funds invested in hybrid corn research to net social returns over the period 1910-1955.

To estimate the value of hybrid corn to society, the author uses three components:

- Private and public research expenditures from 1910 to 1955;
- Cost of additional resources from 1933 to 1955; and
- Gross social returns from 1933 to 1955,

The research costs are expressed as a lump sum.

The cost of additional resources needed for the production of hybrid corn is calculated as the price difference in hybrid and non-hybrid seed, multiplied by the annual use of hybrid seeds.

Because the use of hybrid seed increases the corn yield, Griliches measures the benefit to society as the loss of production using non-hybrid seed compared to hybrid seed. This is equivalent to calculating the loss in consumer surplus.

Griliches arrives at an annual flow of net social returns by subtracting all additional resources spent on hybrid corn from the annual returns.

The rate of return is calculated by cumulating all past research expenditures and net social returns and bringing these forward to 1955.

$$r = 100 (PR * k + AFR) / RC$$

where **PR** is cumulated past returns, **k** is the external rate of interest used to cumulate/discount returns, **AFR** is annual future returns and **RC** are cumulated research costs

An external rate of interest of both 5% and 10% is used to cumulate past costs and discount future returns. The flow of net future returns is added to the flow of net past returns, giving a perpetual flow of net social returns. This flow is divided by the sum of research expenditures to reach the realised social rate of return.

Applying these formulas to the BBC R&D, **PR** and **RC** can be regarded as a Net Present Value (NPV) stock. As **PR** is a NPV of past returns, **PR * k** is the annuity associated with that "lump" of benefits (i.e. the benefit per year that gives the same NPV as the "lump" at the rate interest rate k). Then **PR * k + AFR** is an annualised flow of benefits per year. We can think about **RC** as an "investment" that returns **PR * k + AFR** each year, so this ratio is the rate of return to the research and development investment.

The cost-benefit ratio is closely related to the rate of return, which can be seen by looking at the calculation of the rate of return where:

$$B/C = (PR + AFR/k) / RC$$

Hence, the rate of return can be expressed using the benefit cost ratio:

$$r = 100k(B/C)$$

This equation is a ratio between the total NPV of benefits to total NPV of costs. If we get a benefit of **AFR** per year, then the NPV of that flow in perpetuity is **AFR/k**.

4 Case study findings

In this section, we present the key findings from each of our case studies. For each study, we give:

- a brief overview of the project;
- a headline quantification of costs;
- a brief description of benefits; and
- a headline quantification of benefits (including upper and lower bounds where relevant).

A more detailed description of the project, and further explanation of our quantitative assessment, assumptions and calculations can be found in Annexes to this document. However, given the extent of confidential and commercially sensitive information provided in those Annexes, they have been removed from the public version of this document and are included only for the benefit of the DCMS.

4.1 Piero sports graphics system

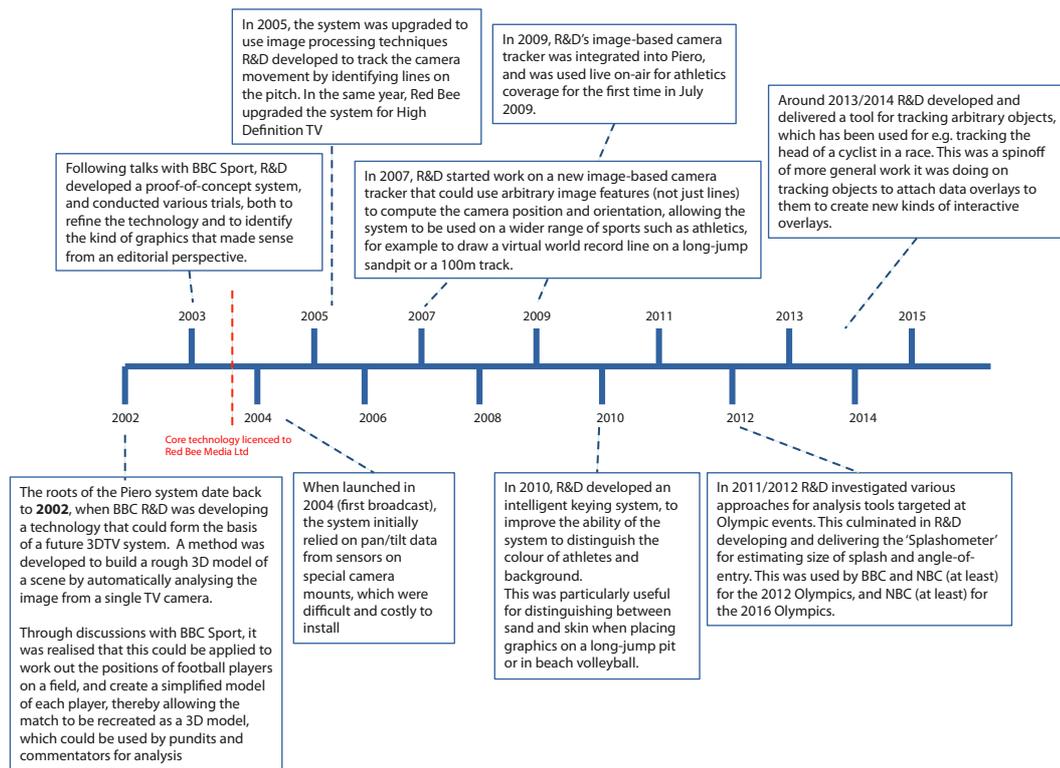
Project name:	Piero sports graphics system
Start and end dates:	2004 – present
Position in the value chain:	Content origination
Collaborators	Ericsson (formerly Red Bee Media), BBC Sport
Estimate of costs attributable to BBC R&D to date:	£1.08 million
Total estimated benefits to date:	£46 - £77 million
Potential future benefits:	£2.05 million per annum

Brief overview and history

The Piero sports graphics system (Piero) is a tool for sports analysis on TV using 3D graphics and real-time image processing. It is a computer-based system that generates 3D graphics from conventionally shot footage that can be used to analyse and explain sports events. The user-friendly production and analytical system provides visually engaging and informative effects and statistics that can be used by TV presenters and pundits on programmes such as BBC1's 'Match of the Day' (MOTD), for example, to *"highlight and track football players, draw off-side lines on the pitch, and generate a unique 'virtual view' of the action from a viewpoint where a real camera could never be placed"*.³⁹ Figure 3 below provides a summary of R&D's involvement and the key developments that have fed into the Piero product over its lifetime.

³⁹ BBC, Piero Queens Award Submission, 2010.

Figure 3: Piero development timeline



Costs assessment

For Piero, the main source of costs were labour costs, with around **£1.08 million** worth of staff time committed to the project since 2004.

Benefits assessment

Direct financial benefits – royalty revenues

The development of Piero creates direct financial benefits for the BBC in terms of licensing revenues received from Red Bee Media/Ericsson. Therefore, we include royalty income accrued to the BBC for the period 2009-2016 in our benefits assessment based on figures provided to us by the BBC and Red Bee Media/Ericsson. Extrapolating from existing royalty income in line with licensing agreements, we are also able to estimate the future stream of royalty income over the next 5 years.

*Direct financial
benefits – cost
savings*

In addition, since the upgrade to using image-processing techniques in 2005, Piero helps the BBC to save costs relative to deploying the earlier systems that required dedicated hardware fitted to cameras at the venue.^{40,41}

We considered the per-event cost of this earlier hardware-based implementation and estimate the cost saving for each sports programme following the introduction of the new Piero product in 2005 (which used advanced image-processing techniques rather than specialist hardware). On this basis we estimate the costs avoided per annum and use this as the basis for our estimate of the overall cost savings achieved to date.

When dedicated hardware fitted to cameras was required, broadcasters could cover around three in every eight weekly events of note for each of 30 sports programmes. The BBC estimates that the cost savings from replacing this with Piero amounts to £12,500 per year for each of these 30 programmes. Therefore, relative to the hardware solution, Piero brings total cost savings of around £375,000 per annum.

However, we cannot count this saving in each and every year since 2005. Despite pioneering the use of image-processing techniques for graphical analysis in sports, alternative solutions have emerged since Piero first came to the market. Specifically, Piero's current main contender, Viz Libero (formerly a LiberoVision product under the name of DiscoverEye), entered the market in spring 2007, offering similar functionalities to Piero.⁴² Taking a conservative approach, we should only consider the costs avoided for the period

⁴⁰ Initially, graphical analysis tools relied on expensive and complicated hardware used at the recording of the event, which meant that only a small proportion of cameras could be fitted with the required rigs and not all events could be covered in this way.

⁴¹ The reduction in costs has also resulted in an increase in the number of events that could be covered, but as the costs of Piero to broadcasters are practically flat once the licence has been acquired, we can ignore this volume effect.

⁴² In Spring 2007, LiberoVision (later acquired in full by VizRT in 2013) launched a product called DiscoverEye that "*produces high-quality virtual replays of sports events based solely on the camera images from the TV productions*" including the provision of capabilities for "*offside analysis, player speed, pass distances, player tracking, ball tracking, automatic distance calculations, and the ability to watch an incident from a number of virtual perspectives*". See LiberoVision Case Study, available at:

<https://bluefish444.com/component/casestudies/article/17/libero-vision-case-study.html?tmpl=component>

Details of the current VizRT product with equivalent functionality (Viz Libero) can be found at: http://www.vizrt.com/products/viz_libero/

predating Viz Libero⁴³ on the simplifying assumption that these costs would have otherwise been avoided by using the Viz Libero product following its launch.

Therefore, our lower bound estimate of costs avoided is based on an assumption that the BBC only achieved these cost savings in the years 2005, 2006 and the first quarter of 2007 when the Viz Libero product was launched.

It is possible that the R&D work on Piero provided the catalyst to development of competing products by demonstrating that there is clearly a market for a product of this nature and that the technology is viable. Therefore, we could speculate that in the absence of Piero the Viz Libero product might not have come to market quite so early or have included all the same features at the outset. On this basis we could extend the period of potential benefits on the assumption that without Piero, the Viz Product would have taken longer to come to market. Our upper bound estimate of cost savings is based on an assumption that it could have taken around four years for a suitable alternative product to reach the market in the absence of Piero.

Therefore, assuming the BBC only achieved these cost savings in the years 2005, 2006 and the first quarter of 2007, total costs savings to the BBC over this period amount to approximately **£850,000** (= £375,000 * 2.25). Extend the period of potential benefits to four years the cost savings to the BBC could be in excess of **£1.5 million**.

Strategic benefits to the BBC

Given that Piero was the first system to offer the 3D graphical analysis functionality, the BBC could have exploited this strategically to attract audiences for its own sports programmes, or to increase the chances of winning broadcasting rights⁴⁴. The product was instead made available to competitors, who have subsequently benefited not only from the ability to provide enhanced coverage but also from the cost savings attributable to Piero.

The BBC R&D's continued involvement in the development of Piero, both in improving the quality of provision for sports already covered and broadening the range of events to which graphical analysis can be applied, still serves to add to the BBC's prestige in

⁴³ However, this does not imply the entry of Viz Libero completely negates the benefits of Piero's existence; Piero still has the largest share in the market (based on Piero market data provided by Ericsson's Piero product manager), and the two products' shared space in the market spurs both cost and innovation based competition.

⁴⁴ Under the assumption that when bidding for sports broadcasting rights, broadcasters want to offer the highest possible quality of coverage and demonstrate the ability to add value to the basic content, Piero's unique abilities (at the time) to provide 3D analysis could have been used to strengthen a broadcaster's bid.

the sports broadcasting environment. Moreover, by extending coverage to more than just ‘the standard’ events such as football, and using the Piero tool to enhance understanding, BBC R&D helps the BBC to fulfil its public purpose of ensuring *‘enrichment for all audiences by covering a wide range of cultural activities.’*⁴⁵

More generally, both the knowledge gained in the development of Piero, and the links between BBC R&D, BBC Sports and Red Bee Media (now part of Ericsson) established in the process, have paved the way for further sports analysis tools to be developed. For example, extensions to Piero (such as object tracking software) have grown not only out of technical knowledge gained from developing Piero, but have benefited from the collaborative networks created by the original development process. These relationships will continue to be mutually beneficial for creating further progress in the range and quality of sports analysis tools and work beyond sports-focused applications, such as virtual and augmented reality in video applications more generally.

As discussed in Section 3, we do not consider strategic benefits to the BBC in our quantification of benefits.

Benefits to audience from new services or improved quality

Piero has substantially increased the scope for the use of graphical analysis in the presentation of sports programmes. Given the development of image-processing techniques, graphical analysis can now be used for all games, (and pre-recorded footage) without the need for specific hardware to be used at the time of recording.

The audience benefit in terms of ‘enjoyment’ is clearly a difficult concept to quantify. However, we seek to estimate the value that people put on similar experiences to proxy how much benefit they receive from Piero, and then aggregate this across the viewership.

Following an assessment of a range of proxies we could use for viewers’ willingness to pay for Piero, we estimated a value of £5 per annum for viewers (based on commercially available consumer services that give a proxy for the value of augmented reality services). As an estimate for viewership in the UK we conservatively use the average number of viewers for Match of the Day in 2016/2017 – around 3 million.⁴⁶ We acknowledge that this is a conservative assumption, as all viewers who watch any event where Piero is used to improve analysis and presentation will benefit to some degree. However, viewers of Match of the Day, a programme

⁴⁵BBC, ‘Public purposes: Stimulating creativity and cultural excellence’. See: <http://www.bbc.co.uk/aboutthebbc/insidethebbc/whoware/publicpurposes/creativity.html>

⁴⁶ Based on BARB viewing data, the average audience for Match of the Day in the 2015/16 Season was 3.2 million, and the average audience up to mid February in the 2016/17 season was 2.9 million (BARB data provided by the BBC).

that specialises in sports analysis, are perhaps those who gain the greatest benefit from the use of Piero (and may reasonably be assumed to be a subset of all viewers who might conceivably watch events enriched by the use of Piero). This gave us an estimated viewer benefit of **£15 million per annum**.

As with the cost savings, we can only consider the benefits to audiences for the time period before which an equivalent solution would have come to market. We generate a lower bound estimate of audience benefits on the assumption that the benefits were only achieved in the years 2005 to 2007, when the Viz Libero product was launched. Our upper bound estimate of audience benefits is based on this assumption that benefits would have been achieved over a four year period assuming that without Piero, the Viz Libero product might not have come to market quite so early or have included all the same features at the outset.

On this basis we estimate **the audience benefits to be in the range of £30 million – £60 million**. In any case, this remains a conservative estimate, not only because it is based on a limited audience size (only viewers of BBC MOTD) but also because it ignores benefits to international audiences.

Spill-over benefits:

Cost savings accrue not only to the BBC, but also to other broadcasters who use Piero instead of a hardware solution. Assuming that broadcasters are limited in their ability to extract the benefits that accrue to their viewers from improved analytics (given the widespread use of sport analytics tools across all major broadcasters), their willingness to pay for the software should largely reflect cost savings. Therefore, the licence revenues of Red Bee Media/Ericsson give a lower bound approximation of the value of using Piero for graphical sports analysis to broadcasters. We estimate a lower bound estimate of the value to broadcasters by taking the BBC royalty rate and the royalty revenues, to estimate the total licence fees and include this in our total benefits estimate.

Benefits summary

	Lower bound	Upper bound
Total benefits estimate:	£53.2m	£58.7m
Main strategic or un-quantified benefits	<p>Strategic benefits to the BBC from improving its prestige in sports broadcasting and for paving the way for further sports analysis tools to be developed by collaborators such as Ericsson (formerly Red Bee Media)</p> <p>The benefit to audiences enjoying Piero-enhanced content shown by broadcasters outside of the UK.</p>	

As direct financial benefit and spill-over benefit figures are calculated using confidential information, only aggregated figures are shown in this summary table.

4.2 Redux and Snippets

Project name:	Redux and Snippets
Start and end dates:	Redux: 2007 – 2016 ⁴⁷ Snippets: 2011 - present
Position in the value chain:	Data, Content Analysis and Storage
Collaborators	N/A
Estimate of costs attributable to BBC R&D to date:	£1.39 million
Total estimated benefit to date:	£53.2 million - £58.7 million

Brief overview and history

Redux is a system that records and stores TV/radio content (including subtitles) from off-air sources into an archive and extracts meta-data that can be used at a later date to improve searching for specific material. Whilst originally developed as part of a proof of concept for a Flash version of the iPlayer, the main development of the system has been to make the Redux archive an instantly accessible content store, providing BBC staff with easy access to all programmes broadcast since July 2007. The Redux digital archive store can be used for finding material to include in new productions, for research purposes and has also enabled other R&D projects such as projects related to automated subtitle recovery.

In operation since 2007, the BBC Redux video archive now contains over 3 million BBC TV and radio programmes available in a variety of formats. Users can access the archive via a basic system API at bbcredux.com to find material to include in new productions and or for research purposes.

R&D sought to improve search functionality and worked on a tool that would make use of innovative features such as search by word/phrase said in a programme and allowing users to make 'snips', which are short clips that can be shared or downloaded. This advanced search and retrieval system is known as "Snippets"

⁴⁷ The BBC PSS have been running the service from April 2016 (with some overlap with R&D since winter 2015). BBC R&D continue to provide the hardware platform and network

(launched in 2011) and provides an alternative frontend for accessing and making use of the material in the Redux archive.⁴⁸

Cost assessment

Together, the development of Redux and Snippets required around 9 man-years of effort, which equates to a cost of approximately £432,400.

A further £960,000 of R&D expenditure was spent on these projects, typically related to physical infrastructure, network architecture and storage.

This represents a total cost of around £1.39 million.

Benefits assessment

Direct financial benefits

We understand that the BBC does not receive any direct financial income from third parties through licensing of this material. Therefore, we consider direct financial benefits to the BBC in the form of cost savings only.

Cost savings associated with staff time

In the absence of the Redux/Snippets system, the method for reviewing archive footage (off physical media) would have involved requesting a physical tape/DVD and then watching through each of the requested videos to find the correct scene of a programme before making a 'Request to Archive' to create and transcode a 'rough cut'.

This process could be tedious and the request and review of video may not necessarily yield results first time, given that the programme chosen may not contain the clip(s) desired. Therefore, there are benefits from Redux/Snippets associated with staff time saved as a result of the much improved search functionality and the ability to review programmes digitally with near instant access.

Based on material gathered from the BBC we estimate the time saved by BBC staff since the introduction of Redux/Snippets using the following assumptions:

- The main case for use of Redux alone will be to find and view programmes directly from a desktop, forgoing the need to request viewing copies, and saving time in the review process. However, the process for making of 'clips'

⁴⁸ BBC R&D, Snippets project description. Available at: <http://www.bbc.co.uk/rd/projects/snippets>

remains unchanged.⁴⁹ Therefore, based on information obtained from results of the BBC's qualitative reviews of the system, we conservatively estimate that (on average) this would save a Redux user one hour per week.

- Given the advantages of Snippets over Redux (i.e. no need to download the entire programme, and the ability to do keyword searches and jump directly to the relevant scene/clip, and then make 'snips' directly within the software) there will have been further (and perhaps more significant) time savings achieved following the introduction of Snippets in 2011.
- In particular, we consider the incremental benefit of Snippets over and above Redux use alone by considering the time savings associated with being able to jump directly to a particular moment in a programme and make a 'snip' directly in the software rather than searching through a programme and requiring creation of a rough-cut as would be the case with physical archive access. Again using figures obtained from results of BBC qualitative reviews of Snippets and Redux, we conservatively estimate that (on average) there is a time saving of 2 hours for each 'clip' made.⁵⁰
- We quantify the cost saving using an average of BBC Staff hourly rates of approximately £24 per hour.⁵¹

Using data on the number of users and the number of 'clips' made, we estimate cost savings associated with staff time to date to be in the region of £32 million for Redux⁵² and an additional £11 million

⁴⁹ With Redux alone, a 'rough cut' of a particular scene/clip would still need to be requested from the Archive department.

⁵⁰ Relative to the alternative of using Infax tape, Snippets can save time from not needing to watch a programme to find a specific moment and the time taken to create and transcode a rough cut. Both of these tasks become almost instant with the use of Snippets.

⁵¹ Figure provided to us by the BBC and used as a proxy for BBC staff costs for previous internal reviews and impact case studies. Note that this is an estimate for BBC staff costs so is different to the weighted average, fully-loaded R&D staff salary used to estimate the resource costs for each R&D project considered in this assessment.

⁵² As a conservative assumption, we consider only the impact on production staff time (approximately 3,750 users who will be most likely to have experienced the biggest change in their day-to-day routine by no longer having to rely on physical media) and assume a time saving of (on average) about 1 hour a week. Therefore an estimated cost saving per annum (based on 46 working weeks) of £4 million. Taking this as a lower bound and working on our assumption that time savings benefits (associated with Redux alone) were achieved from 2009 we estimate savings to the BBC in terms of staff costs of approximately £32 million over the Charter Period.

Cost savings associated with reduced shipping of physical media

for the incremental value of Snippets⁵³. This gives a total estimated cost saving of **£44 million**.

Furthermore, through the introduction of Redux/Snippets there are cost savings associated with the reduced need to ship viewing copies of physical tapes/DVDs throughout the organisation. BBC staff have described how they have become less reliant on tapes and/or their use of tapes has become much more efficient since the launch of Redux/Snippets, namely through only ordering tapes once they know exactly what programme/tape they are looking for (rather than having to order a large number of tapes that *might* have been helpful).

We estimate the cost savings associated with the reduced need to ship physical viewing copies⁵⁴ assessing the change in the number of requests over time since the Redux Archive was made accessible.

Based on figures from BBC Archive showing the total number of requested viewing copies for a number of years (12 month periods between 1 July – 30 June) and a breakdown of the number of this total by original transmission date, we calculate a lower bound estimate equal to the potential cost savings that have been achieved from the reduced need to ship such physical viewing copies.

We take a conservative estimate that the cost of shipping a physical DVD viewing copy is approximately **£5**, but could be as high as **£10**⁵⁵, and consider cost savings over a relatively small window over which the counterfactual to Redux/Snippets usage would have involved shipping of physical DVDs - Redux usage is (primarily) relevant for material broadcast since 2007 and the use of the platform was not encouraged until around 2009 onwards.⁵⁶

⁵³ Using data on the number of 'clips' taken each year since launch (2011 – 2016 inclusive) and an estimated (lower-bound) time saving per clip of 2 hours we calculate the cost savings associated with Snippets to be £11 million over the period.

⁵⁴ Since 1996, BBC Archives has created and shared DVD viewing copies of many programmes to provide access to content for research purposes.

⁵⁵ This £5 figure was an estimate provided by BBC archive. However, the BBC mail team also advised that the "same day delivery" of material throughout the BBC would typically use an external courier which could cost as much as £10.

⁵⁶ Furthermore, in more recent years, there are other ways in which digitised footage can be accessed. For example, any programmes delivered since late 2014/early 2015 would have been delivered as files and stored in digital format anyway meaning preview copies for those programmes can be viewed digitally through other archive sources, For example, from October 2014, all UK broadcasters began receiving programme deliverables in file-based format, which amongst other things meant that they could be included in the archive in digital rather than physical format. See: <https://www.digitalproductionpartnership.co.uk/file-delivery-day-test-page/>

We assess the change in the proportion of requests for 'near-term' footage (taking requests for programmes broadcast in the past 5-years as a proxy for the type of content people will use Redux/Snippets for⁵⁷) relative to a counterfactual base level of viewing requests⁵⁸ to estimate the costs saved.

Comparing the actual number of viewing library discs requested for 'near-term' footage in each year since 2010 to 2014/15, relative to a counterfactual of 19,500 requests per annum, we estimate that in total around 66,000 fewer viewing library discs have been requested. At £5 per disc, this represents a cost saving of around £330,000. However, this is likely to be an upper bound estimate for the saving that can be attributed to increased use of Redux/Snippets and it is likely that only some proportion of this can fall can be attributed to the emergence of other digital archive resources. As a conservative lower bound estimate, assuming that only 50%⁵⁹ of this reduction in DVD viewing copy requests is directly associated with Redux/Snippets, this still represent a costs saving of over **£165,000**.

At £10 per disc, this represents a cost saving of up to £660,000 and assuming that only 50% of this reduction in DVD viewing copy requests is directly associated with Redux/Snippets, a cost saving of **£330,000**.

Benefits to audiences from improved quality of programming

One of the primary benefits of the Redux archive and the Snippets tool is making the archive more accessible, and there is clear evidence to suggest that the number of clips being accessed has increased significantly since launch. Based on this, it is possible that the greater accessibility of a digital archive facilitated by Redux/Snippets has led to an increased usage of archive footage. Increased breadth and depth of use of archive footage in programming could be considered as a 'quality improvement' in programming. However, data does not exist within the BBC on the use of archive footage in programming to the level of granularity

⁵⁷ Considering the change in the number of requests for broadcast footage since 2007 would be imperfect as there is no way of controlling for the offsetting impacts of the increased number of programmes available and any reduction in number of requests due to alternative access

⁵⁸ Prior to 2010, (the point at which the proportion of near-term requests begins to fall), the number of requests for 'near-term' term footage as a proportion of total requests was fairly constant at around 65% suggesting an average number of requests of around 19,500 per annum. We take this as our base for the counterfactual

⁵⁹ We assume only some proportion of the reduction in requests and the associated savings can be directly attributed to Redux/Snippets usage, given other forms of digital archive access.

that would be required to make a robust quantitative assessment of the true impact of increased use of archive footage in programming.⁶⁰ In line with a conservative approach, we do not seek to quantify this potential benefit.

*Benefits to
Snippets/Redux users
of new service*

Nevertheless, one fundamentally new service arising from the Redux/Snippets work is the searchable functionality of an extensive video and radio archive. Given that this service is provided free to BBC staff, and that there are no licence revenues from third party users, there is no obvious metric for calculating the value of this service to users, which are primarily BBC staff. However, it must be true that by choosing to use the system over alternatives, the value to users is at least equal to the value of the time savings achieved (which we have calculated above). Therefore we assume that the benefits to users of the Redux/Snippets system are worth in the region of **£2 - 3 million**⁶¹ per annum. Taking a conservative approach and only counting these benefits from 2011, when use across both Redux and Snippets was prevalent, this equates to a benefit of around **£10 - 15 million** to date. However, we do consider that this is likely to be a conservative estimate, as it does not include any direct benefits to other users of the system including third party users (such as BFI researchers).

⁶⁰ Furthermore, given the large number of other ways in which people can access the entire 90 year archive (including through other digital search methods introduced in recent years such as Auto-rot, Jupiter and Rewind Portal) it would be extremely difficult to attribute any of this to Redux/Snippets directly.

⁶¹ We use as a lower bound proxy, the estimated time/cost savings per annum for active Snippets users in recent years.

Benefits summary

	Lower bound	Upper bound
Direct financial benefits	£32 million in cost savings associated with staff time (Redux only 2009-2016)	£32 million in cost savings associated with staff time (Redux only 2009-2016)
	£11 million in cost savings associated with staff time (Snippets 2011 - 2016)	£11 million in cost savings associated with staff time (Snippets 2011 - 2016)
	£165,000 in cost savings associated with reduced shipping of physical media	£660,000 in cost savings associated with reduced shipping of physical media
Benefits to users from new services or improved quality	£10 -15 million to date in terms of benefits to Redux/Snippets users.	
Total benefits estimate:	£53.2m	£58.7m
Main strategic or un-quantified benefits	<p>We have not quantified the value to BBC audiences who might see more archival in the programmes as a result of programme-makers having easier access to this material</p> <p>The benefits to users is also conservative estimate as it does not include benefits to third party users such as BFI.</p>	

4.3 Free-to-Air connected platforms

Project name:	Free-to-Air connected TV platforms
Start and end dates:	<p>Project Canvas: 2008</p> <p>YouView: launched July 2012</p> <p>Freeview Play: launched October 2015</p>
Position in value chain:	Distribution
Collaborators:	<p>YouView: BT, ITV, Channel 4, Channel 5, BT, TalkTalk, Arqiva</p> <p>Freeview Play: Freeview (a brand launched by DTV Services Ltd – a company owned and run by BBC, Sky, Channel 4, ITV and Arqiva) and Digital UK.⁶²</p>
Estimate of costs attributable to BBC R&D to date:	£3.4 million
Total estimated benefits to date:	£32.5 – 49.5m to date

Brief overview and history

YouView and Freeview Play are both free-to-air (FTA) connected television platforms that seamlessly integrate digital terrestrial television (DTT) with catch-up services delivered over the Internet. These platforms allow the user to access subscription-free digital television and catch-up TV or on-demand services from all the major FTA broadcasters directly from their television through an intuitive interface or directly from the Electronic Programme Guide (EPG), using a set-top box or an enabled TV set with a broadband connection.

The development of these platforms began with 'Project Canvas', which was developed as part of a joint venture with ITV, Channel 4, Channel Five, BT, TalkTalk and Arqiva. The aim was to develop and promote "a common standard for internet-connected digital terrestrial

⁶² Digital UK provides operational support for Freeview platform, "including management of the Freeview electronic programme guide, and leads on developing DTT strategy, working with its broadcast partners and industry. We also work in conjunction with Freeview to provide viewers with information and advice about terrestrial TV channels, services and reception" Digital UK is owned by the BBC, ITV, Channel 4 and Arqiva, which owns and operates the transmitter network. See: http://www.digitaluk.co.uk/about_digital_uk

television devices".⁶³ The BBC's participation in Project Canvas was approved by the BBC Trust in June 2010,⁶⁴ later becoming known as 'YouView', with the first YouView set-top boxes launched in July 2012.

Since July 2012, integrated digital TV sets had begun to replace standalone DTT set-top boxes that were common around the time of digital switchover (DSO). Although YouView provided a product that had not existed before and met the requirements of being FTA and PSB-friendly, that product was offered primarily (and effectively subsidised) through ISP-bundled propositions (and initially as a set-top box only solution) the BBC considered that it needed a mass-market retail solution that would also give it greater presence on connected television sets. BBC R&D, which had a long history of collaborating with Freeview and Digital UK, was enlisted to help in bringing the idea to fruition

In response to this strategic decision, development of "Freeview Play" started in 2013. Freeview Play was to be based mainly on existing standards to keep the platform 'open' and in line with the direction global TV manufacturers had already agreed in terms of connected TV standards. This meant that adding Freeview Play functionality could be done with relatively little additional complexity for consumer electronics (CE) manufacturers that are adopting increasingly global, standardised product strategies. This should ensure that more manufacturers would include Freeview Play in their devices, helping to drive take-up.⁶⁵ The Freeview Play platform was launched in October 2015, and since coming to the market, over one million Freeview Play devices have been sold.⁶⁶

⁶³ BBC Trust Review, "YouView Summary of Findings", 22 May 2014.

⁶⁴ BBC Trust, "Canvas Public Value Assessment"

⁶⁵ At the same time this approach means that new features cannot be introduced as quickly and consistently across the entire base of devices as in the case of YouView. As YouView covers the entire software stack, upgrades that introduce additional features can be deployed across all of the devices fairly rapidly. By contrast, Freeview Play permits more variety by allowing equipment manufacturers to innovate around a base specification/set of standards. Thus, whilst Freeview Play is capable of being deployed much more widely across a greater range of devices, there is also likely to be more variation in the progressive versions of the platform when compared to YouView.

⁶⁶ Freeview press release, "Thanks a million" says Freeview boss as Freeview Play sales surpass one million", 1 March 2017. See: <https://www.freeview.co.uk/news-and-blog/press-releases/thanks-a-million-says-freeview-boss-as-freeview-play-sales-surpass-one-million.html>

Cost assessment

The development of YouView required the equivalent of around 50 person-years of effort and Freeview Play required the equivalent of around 6 person-years of effort. The time spent on Freeview Play is much smaller given the experience gained from the YouView work and the fact that it was based on open standards. Together, this equates to a total labour cost of approximately £3.08 million.

In addition there were additional (non-labour) costs of around £320,000, which relate to the YouView project.

This represents a total cost of around £3.4 million.

Benefits assessment

In this case study we consider only the incremental benefits of free-to-air (FTA) *connected* platforms over and above the general benefits of DTT services. However, we recognise that whilst the two propositions are serving two very different purposes (YouView now primarily as a bundled IPTV offer and Freeview Play as a retail IPTV offer), the BBC's investments in both ventures have served to create significant public value.

Direct financial benefits

We understand that the BBC has received direct income in the form of:

- An initial fee for assigning some of the IP to YouView in 2010/11;
- Reimbursement for R&D development efforts in YouView; and
- Royalties from licensing IP to YouView.

Using commercially sensitive financial data provided to us by BBC R&D we calculate the total income received since 2010 and include this in our total benefits estimate.

In contrast to the YouView platform, we understand that the BBC does not receive any direct financial income from the Freeview Play platform (for example through licensing the specification) or royalties from the sale of Freeview Play devices.

Strategic benefits to the BBC

Both YouView and Freeview Play have been developed with a view to ensuring continued prominence of FTA offerings in a competitive marketplace, which is of clear strategic benefit to the BBC. Because BBC is a shareholder in both the YouView and Freeview Play ventures it has some influence over prominence of BBC content and the user interface in general.

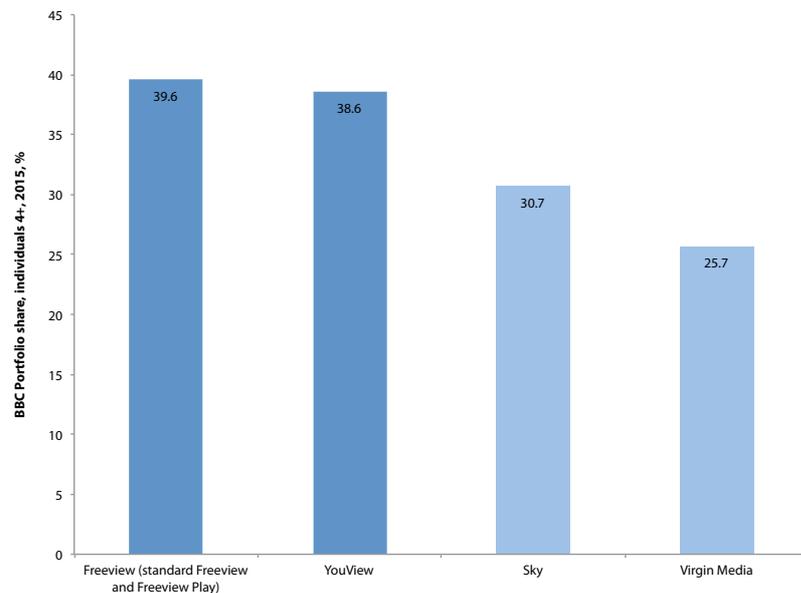
The exact value of this strategic benefit is very difficult to quantify in any meaningful way; however, we consider the benefits to be potentially large for the BBC. This is particularly true for the development of the Freeview Play platform and the integration into

TV sets. The development of the Freeview Play platform in such a way that manufacturers could add the functionality to TV sets at little additional cost will have led to increased coverage. The highly competitive market for TVs (together with the relatively low incremental cost of implementation) means that TVs integrated with Freeview Play can be sold without any major premium.⁶⁷ As integration of Freeview Play becomes more commonplace, a larger number of customers will get access to Freeview Play services, which promote the prominence of BBC and other free-to-air broadcasters. Furthermore, the Freeview Play development has also provided the Freeview platform with its next 'innovation story' in the context of a rapidly developing competitive market (and in the same way the Freeview Plus PVR and Freeview HD initiatives had acted in previous years) retaining FTA as a 'relevant' option for audiences.

Strategic benefits might be reflected in the extent to which BBC services attract greater audiences and are being used more extensively on free-to-air connected platforms than on alternative platforms (such as Sky or Virgin Media). We demonstrate that the development of YouView and later Freeview Play has likely enabled much greater coverage of PSB services and is a major strategic benefit to the BBC in terms of ensuring prominence (and thus reach and consumption) of its services. Figure 4 below demonstrates that by introducing YouView, the BBC's share of linear broadcast viewing is higher than it might otherwise have been. For example, the BBC share of linear broadcast viewing is higher on the YouView platform used in the provision of pay TV services by BT and TalkTalk than on other pay TV platforms such as Sky and Virgin Media and indeed nearly as high as on the Freeview category (which includes both Freeview Play and standard Freeview). We would expect the BBC portfolio share of linear viewing on just Freeview Play devices to be similarly high.

⁶⁷ To test the hypothesis that there is no significant difference in price between a FVP enabled TV and a non-Freeview enabled TV, we collected data on a large number of TV's scraping data from a well known electrical retailer's website. Using the data collected we ran a regression with Freeview Play as a dummy variable whilst controlling for a number of other key variable such as screen size and display type. We found that whilst television price could be explained by screen size, whether the television was Bluetooth enabled, length of guarantee and OLED display technology, there was no statistically significant relationship between Freeview Play and price. Thus we rejected the hypothesis that there was a difference between the price of a Freeview Play enabled television and a non-Freeview Play television.

Figure 4: Linear broadcast viewing share data for BBC on a platform-by-platform basis



Source: based on BARB data and analysis carried out by BBC Audiences research team.

Ultimately, having a good connected TV proposition could allow the BBC more control over the types of services and the way it provides content over IP, which may be of further benefit in the future.

Benefits to audiences In broad terms, both YouView and Freeview Play provide users with new or improved viewing experiences by augmenting FTA offers with functionality that previously was available only through a series of separate applications accessed through a connected TV, laptop or other connected device for each FTA on-demand/catch-up service. At the time of YouView and Freeview Play launch (and even today) many smart/connected TVs often included a limited number of on-demand apps built-in, and inclusion of ITV, Channel 4 and Channel 5 on demand services was often incomplete. In contrast, YouView and Freeview Play ensure ubiquity of all PSB on-demand/catch-up services in one place; indeed, 19 out of the top 20 TV brands now have Freeview Play functionality, and with it all the PSB player applications integrated into much of their range.

Providing access to all FTA on-demand and catch-up services in one place directly through the TV and through an intuitive interface with direct integration in the EPG (offering pan-platform functionalities like search, recommendations and other innovative content discovery features) simplifies the process of using such

services and the time spent finding content to watch. This can be considered as the primary benefit for audiences.

We focus on the benefits of the Freeview Play platform, given that YouView devices are predominantly used by subscribers to BT's and TalkTalk's pay-TV and broadband services,⁶⁸ and a conservative assumption is that BT and TalkTalk would have used an alternative platform for the provision of their services, or that viewers using the YouView platform would have subscribed to another pay-TV service to obtain (at least some) of these benefits.

We consider two methods for estimating audience benefits arising from Freeview Play. Following the first approach, we consider a choke price (i.e. the price at which no one would be willing to pay to access the services) set at a price just over the most expensive standalone box providing Freeview Play functionality, and the number of existing, active Freeview play users.⁶⁹ Using these two figures, we can estimate the consumer surplus associated with Freeview Play. This gives an estimated audience benefit that we include for our lower bound estimate.

We also consider an alternative approach where we value the time saved with having all PSB catch-up services in a single place on a single device (relative to the counterfactual of spending more time searching across platforms and devices). Based on assumptions about the average daily viewing time of an individual (about 3.5 hours per day⁷⁰) and assumptions about the number of viewing choices per annum (one viewing choice per hour of viewing and assume one in three requires search time for which Freeview Play saves time), we calculate audience benefits in terms of the value of time saved (350 minute time saving per annum at an average hourly wage of £14⁷¹) for the stock of Freeview Play users at present. This figure provides us with an upper bound estimate of audience value and we include in the total benefits assessment.

⁶⁸ Reviewing the offers of TalkTalk and BT, we understand that YouView boxes are offered/provided to consumers subscribing to any package with 'TV' included. Whilst consumers will not be provided a YouView box if they subscribe to an internet only package, any deals with TV alone, or bundles including TV will typically include a YouView box.

⁶⁹ Using GfK figures provided to DotEcon by Freeview, we know that the number of Freeview Play TVs have been sold since launch in October 2015, and the proportion of these which are connected and in use.

⁷⁰ Ofcom's 2016 communication report reported that daily viewing time for TV was 3 hours and 26 minutes in 2015

⁷¹ According to the Office for National Statistics, in April 2016 median gross weekly earnings for full-time employees were £539, and the average actual weekly hours of work for full-time workers (seasonally adjusted) in 2016 was 37.5 hours. See: ONS, 'Annual Survey of Hours and Earnings: 2016: provisional results' and 'Average actual weekly hours of full-time workers (seasonally adjusted).

In each of these cases, we consider there to be additional benefits for some users in terms of the cost savings relative to the counterfactual. Supposing that a proportion (20%⁷²) of those customers who are now connected to Freeview Play would have sought an (imperfect) alternative to trying to access all PSB on-demand services through the TV (such as a Now TV box or a Google Chromecast) we calculate the costs avoided by these customers. Based on an average cost of a basic non-subscription Now TV box (£15)⁷³ or a Google Chromecast (£25)⁷⁴, this amounts to cost savings for these consumers of approximately **£2 million**. This is in addition to the audience benefits estimated above.

Spill-over benefits

The benefits of the YouView and Freeview Play platforms are likely to extend beyond just the BBC and audiences. Not least, the other PSBs supported by the platform will achieve similar benefits to the BBC in terms of increased prominence of their offerings. With Freeview Play in particular, all PSBs benefit from retaining share and strategic control over the distribution and discovery of content on a platform that they all own. This helps retain the scale of reach and consumption of PSB content.

Whilst difficult to quantify in a meaningful way, we also consider further potential spill-over benefits arising from other PSBs (such as ITV, Channel 4 and Channel 5) only needing to support one set of technical specifications for their on-demand/catch-up service for connected TVs. Without a standardised platform, content equipment (TV) manufacturers might decide to implement their own on-demand/catch-up services, using proprietary solutions. PSBs would then have to negotiate a 'place' on each connected TV interface and potentially support a wider variety of clients/technical standards, each with associated development costs and support costs.

Furthermore, by developing Freeview Play in line with existing global standards it is easier for manufacturers to incorporate the FVP offering into their TV sets, which removes the need for UK-specific offerings and potentially bring further benefits from additional economies of scale in production. This may result in a

⁷² This 20% figure is broadly in line with BARB figures that suggest that 20% of households have a terrestrial only "OTT connected TV". That is defined as "households claiming an internet connection for their TV via a direct connection to the internet, a dedicated set-top-box, a games console or a PC/tablet". See BARB, "The UK Television Landscape Report", 26 July 2016. Available at: <http://www.barb.co.uk/tv-landscape-reports/think-youre-connected/>

⁷³ For example, see: <http://www.nowtv.com/tv-box> (accessed 25 May 2017)

⁷⁴ For example, see: <http://www.currys.co.uk/gbuk/tv-and-home-entertainment/digital-and-smart-tv/smart-tv/google-chromecast-10137566-pdt.html#srcid=11026> (accessed 25 May 2017)

greater number of manufacturers offering devices with the functionality built-in, and potentially greater availability of the platform functionality in the future, thus strengthening the strategic and audience benefits described above. Furthermore, any cost savings should be competed away in the competitive TV set market.

Benefits summary

	Benefits to date (lower bound)	Benefits to date (upper bound)
Total benefits estimate:	£32.5 million	£49.5 million
Main strategic or un-quantified benefits	<p>Strategic benefits to the BBC in terms of ensuring continued prominence of FTA channels, keeping the Freeview brand relevant despite competition from other TV platforms, and a strong connected TV proposition allows the BBC to maintain control of how it delivers content over IP.</p> <p>Strategic benefits to other public service broadcasters.</p>	

As direct financial benefit figures are confidential, only aggregated figures are shown in this summary table.

4.4 DVB-T2

Project name:	DVB-T2
Start and end dates:	2006 - 2011
Position in value chain:	Distribution
Collaborators:	BBC Distribution, Harmonic, Atos.
Estimate of costs attributable to BBC R&D to date:	£2.82 million
Estimate of benefits arising from R&D contribution to date:	£76.7 million - £151.7 million

Brief overview and history

DVB-T2 (Digital Video Broadcasting – Second Generation Terrestrial) is a standard created for the transmission of digital terrestrial television, which allowed for an increase in capacity through improvements in spectral efficiency of digital transmission. This enabled more channels to be made available including for the transmission of High Definition (HD) TV on the terrestrial platform. The project was initiated by the BBC in 2006 and BBC R&D was instrumental in proposing and specifying the new standard.

DVB-T2 improves on the quality and performance of its predecessor (DVB-T) which was first published in 1997. The higher bitrate means DVB-T2 can provide a much higher data rate than DVB-T, a more robust signal, or a combination of the two.⁷⁵ DVB-T2 offers “*more robustness, flexibility and 50% more efficiency than any other DTT system*” and “*supports SD, HD, UHD, mobile, TV, radio or any combination thereof.*”⁷⁶ A clear benefit to the public has been that advancements in efficiency coming from DVB-T2. The switch from DVB-T to DVB-T2 allowed for three more HD channels, without a reduction in the number of SD channels. This enabled the launch of the Freeview HD service in December 2009, the first TV service to use the new standard. Since then, further work on capacity optimisation and improving the efficiency of coding standards has resulted in the launch of three more HD channels and one more SD channel. Therefore, the introduction of BBC HD services, together with ITV HD and Channel 4 HD to all Freeview homes across the UK

⁷⁵ https://www.dvb.org/resources/public/factsheets/dvb-t2_factsheet.pdf

⁷⁶ DVB, ‘DVB Fact Sheet, August 2016. Available at: https://www.dvb.org/resources/public/factsheets/dvb-t2_factsheet.pdf

should be seen as the core benefit of BBC's work in developing the DVB-T2 standard and its capacity optimisation work.

The success of the standard is demonstrated by the fact that DVB-T2 has now been embraced globally, adopted in 29 countries and already deployed in a further 84 (total 113) as of October 2016⁷⁷.

Cost assessment

Restricting our calculations to hours worked starting from 2007, approximately 6,361 man-days were spent on DVB-T2 work.⁷⁸ In addition, some of the benefits included in our analysis arise from R&D's work around capacity optimisation – 2,610 man-days were logged to this project between 30/03/13 and 31/03/2017⁷⁹. This amounts to a total of 8971 man-days for both DVB-T2 and capacity optimisation work. Using an average of around 230 working days per year⁸⁰, the total corresponds to around 39 man-years.

Taking the weighted average from BBC R&D salary grades, we take an annual salary of around £55k per annum which would therefore suggest a total labour cost of around £2.15 million.

In addition to labour costs, there was additional expenditure of around £673,000.

Therefore, total costs are approximately £2.82 million.

Benefits assessment

Direct financial benefits

We understand that the BBC has received direct income in the form of Royalties from DVB-T2 patents and royalties from T2 Demodulator licences. We have included the total of these revenues within our total benefits estimate for this case study.

Strategic benefits

The primary strategic benefit to the BBC of DVB-T2 is maintaining the capability of the terrestrial free-to-air platform and providing an

⁷⁷ https://www.dvb.org/resources/public/documents_site/dvb-t2_deployment_2016.xls

⁷⁸ 190 man-days were logged against 'DVB-T2' between 01/04/06 – 29/06/07 (a period of approximately 15 months). Therefore we assume an average of 12.7 days per month and estimate approximately 89 days worked on this job from January 2007. We add to this the 6272.25 hours logged against DVB-T2 related jobs between 31/03/2008-30/03/2012.

⁷⁹ This includes man-days logged under 'DTV Design and Assurance' in the efforts data. The BBC has advised us that this is relevant to the 'capacity optimisation/platforms' work.

⁸⁰ 260 week days less 8 public holidays less around 20 – 25 days of paid holiday.

innovation pathway for the Freeview platform. The simultaneous upgrade of the transmission standard and the compression technology resulted in an uplift of the free-to-air terrestrial platform, allowing the BBC to broadcast significantly more channels in higher quality including the launch of HD channels. This has allowed the BBC to maintain a universal and subscription-free offering of both standard and high definition services over the Freeview platform, maintaining the scale of the DTT platform and help the BBC retain control in a way that best promotes access to PSB content and services.

Audience benefits

The core public service benefit is the general uplift in the quality of free-to-air platform enabling more channels and higher quality. For example, the most tangible improvements relate to the delivery of all the BBC's HD services together with ITV HD and Channel 4 HD to all Freeview homes across the UK (so enabling fundamentally new services). Therefore, in broad terms, through its facilitation of the launch of Freeview HD, the work in developing the DVB-T2 standard (and the subsequent capacity optimisation work that helped the introduction of even more HD channels) provides users with new or improved viewing experiences by augmenting FTA offers with a 'high-definition services' offer considered to be similar to that available through other broadcast methods (satellite and cable) offered by pay TV platforms.

We estimate the consumer surplus benefits of being able to access Freeview HD functionality by considering the number of active Freeview HD customers and an estimate for the 'choke price' at which no user would be interested in obtaining access to the Freeview HD functionality. Given that Freeview HD is now available on a large number of TVs as standard (i.e. TV's are sold with integrated DTT receivers and have HD capabilities), for little additional cost premium, we consider that the cost of a standalone Freeview HD set-top box providing this functionality would represent the maximum willingness to pay for the service.⁸¹ Whilst we consider some alternative valuations for willingness to pay for HD capabilities, we take a conservative approach and perform our calculation on the basis of a choke price of the most expensive Freeview HD box of around £200, noting that a calculation of consumer surplus on this basis will provide an estimate for the value to consumers of the Freeview HD platform.

We also assume that the demand curve is unlikely to be linear. It is more likely to take the form of a curve convex to the origin (rather than a linear demand curve given that it is likely that there will be a

⁸¹ We note that this choke price represents the highest value and acknowledge that this might also include a value for a set of (non-HD) channels they would access via the box.

small number of people that put significant value on HD content, with a much larger majority placing little value (in terms of willingness to pay) on accessing HD content. Therefore, we take this into account when calculating our consumer surplus estimate, with a convex demand curve resulting in a consumer surplus (measured by the area under the demand curve) smaller than would be the case with a linear demand curve.

On this basis we estimate the additional consumer surplus per annum.

In line with a conservative approach, when we calculate a lower bound estimate of the audience benefits, we assume that DVB-T2 would have come to market in any case and delivered benefits to PSB audiences in terms of the provision of an improved service, but the work by R&D helped to bring the benefit forward much earlier. On the basis that the work may otherwise have taken up to five years without R&D's involvement rather than three, our lower bound estimates are based on an assumption of benefits being achieved two years earlier than they may otherwise have done. Therefore, to estimate the benefit to users as a result of the accelerated introduction we take the per annum estimate and multiply it by two, to reflect that audiences had access to services two years earlier than in the counterfactual. We take this as our upper bound-estimate of audience benefits.

We acknowledge that not all of this benefit might be attributable to R&D alone; BBC Distribution and other BBC bodies and external partners played a significant role in launching Freeview HD. If we only attributed some proportion of the benefit to R&D directly (with some proportion of the benefits attributed to the work of other BBC bodies and external partners) then this would lower our estimate. However, even if we adopted a conservative approach and only attributed 50% of the benefit to R&D's contributions then this would still represent a significant benefit of over that two-year period. We apply this assumption and take 50% of our total audience benefit estimated above and present this as our lower bound estimate for audience benefits.

Spill-over benefits

In considering the benefits to wider industry we estimate the value of DVB-T2 by calculating the market value of spectrum that is saved by moving from DVB-T to DVB-T2. The total value of spectrum saved can be estimated by estimating a per MHz market value for the spectrum and then multiplying this figure by the amount of MHz freed up.

We estimate the market value of this spectrum by considering the opportunity cost – the value of the next best use of the spectrum. This is defined by the value of (and willingness to pay for) the spectrum to potential users other than those licenced to use the spectrum.

As Ofcom and the UK government, and regulators and governments across Europe, are clearing the 700 MHz band of DTT

spectrum for mobile use, then the spectrum freed by DVB-T2 could be valued at the price that mobile phone operators would be prepared to pay for that spectrum. Therefore, we estimate the opportunity cost of spectrum by using historic auction “benchmarks” for mobile telecoms bands that are similar to this spectrum. Frequency bands that are technically and commercially most comparable to the 700 MHz frequencies would serve as the most appropriate benchmarks.

Looking at auction benchmarks, we estimate a market value of 700 MHz spectrum of £0.40 per MHz per capita. Assuming that this value is uniform nationwide and this additional spectrum is split in the same ratio between PSB and commercial as the DVB-T2 multiplexes with the same coverage rates then the value of the 16 MHz of additional spectrum hypothetically freed up by DVB-T2 is £353 million.

Assuming that the value of the additional services exceeds the value of the spectrum in other uses, this is a theoretical *maximum upper bound* for our benefits estimate (i.e. to get to the same bitrate broadcasters could buy more spectrum, or alternatively they could use DVB-T2).

However, we note that this calculation is based on the value of the alternative use for this spectrum (i.e. the opportunity cost), and in this counterfactual the Freeview HD benefits would not have been realised. For these reasons, the spectrum efficiency benefits calculation cannot be counted in addition to those accrued by customers using the service (as this would be double counting). Spectrum savings represent a maximum theoretical upper bound and we consider that this grossly overestimates the actual benefits likely to have been achieved. In line with taking a conservative approach, when considering the total benefits estimate, we account for the direct financial benefits and benefits to audiences only.

Benefits summary

	Benefits to date (lower bound)	Benefits to date (upper bound)
Total benefits estimate:	£76.7 million	£151.7 million
Main strategic or un-quantified benefits	The primary strategic benefit to the BBC is maintaining the capability of the terrestrial FTA platform and providing an innovation pathway for the Freeview platform by providing a universal and subscription free standard and high definition offering.	

As direct financial benefit figures are confidential, only aggregated figures are shown in this summary table.

4.5 Subtitles

Project name:	Subtitling
Start and end dates:	2012 – present
Position in the value chain:	Production
Collaborators:	Ericsson
Estimate of costs attributable to BBC R&D to date:	£1.18 million
Total estimated benefit to date:	Uncertain, but >£25 million

Brief overview and history

In fulfilling the BBC's remit to best serve all of its audience - including those with accessibility needs - R&D has undertaken a range of projects related to subtitling and improving accessibility more broadly. Over the previous Charter Period, R&D has continued to support the improvement of subtitling at the BBC. The work helps improve the quality of subtitles, keep them on air and fix issues identified. Some major developments in this area also arise from the work of R&D over the previous Charter Period, including:

- improving live subtitles; and
- automating subtitle recovery.

Live subtitles

R&D developed and implemented a solution for reducing the latency of live subtitles without unnecessary delay in the transmission of live programmes. This exploited the discrepancy between the length of time it takes to encode a video for transmission (about five seconds for HD) and the shorter time it takes to encode subtitles. A White Paper setting out the details was published in April 2016.⁸² Implementation of the technique across the BBC's broadcast channels began in September 2016.

Automated subtitle recovery

BBC R&D has developed a system that automatically retrieves subtitles for web clips from their broadcast counterparts. This approach of using metadata recovery and archived content requires

⁸²BBC R&D, 'White Paper WHP 318 – Live subtitles re-timing proof of concept', April 2016. Available at: <http://www.bbc.co.uk/rd/publications/whitepaper318>

almost no adjustments to current production workflows or installed systems and services, keeping costs low.⁸³

Cost assessment

In total, around 20 man-years of effort can be attributed to all of R&D's work related to subtitles over the past Charter Period. This equates to a cost of approximately £1.1 million. Further £72,800 of non-labour costs were incurred. **This implies a total cost of around £1.18 million** and represents the cost of all subtitle work over the entire Charter Period. The benefits assessment focuses on the clearly identifiable benefits arising from this work, in particular in relation to automated subtitle recovery and quality improvements.

Benefits assessment

Direct financial benefits

We understand that at present the BBC receives no revenues directly related to R&D's work on subtitles.⁸⁴ Therefore, financial benefits to the BBC only comprise of the cost savings achieved as a result of this work.

Automated subtitle recovery saves the BBC approximately £20-£30 per 2-minute clip. However, this cost saving should only be applied where automated recovery has *replaced* manual subtitling that would otherwise have occurred. Where automated subtitle recovery has resulted in newly subtitled programming (such as Bitesize) it would be appropriate to ignore such benefits as these cannot be considered as cost savings.

Nevertheless, we understand that around 3,187 clips recently uploaded to the BBC website have benefited from automated subtitle recovery. Similarly, about 850 clips for BBC Worldwide have also benefited from this process. On the assumption that each of these 4,037 clips is around 2 minutes long and would have cost £20 to be manually subtitled, this represent a cost saving of approximately **£80,000**.

⁸³ Mike Armstrong, "Automatic recovery and verification of subtitles for large collections of video clips", September 2016, <http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP323.pdf>

⁸⁴ However, we understand that the part of the automated subtitle recovery process that uses audio matching is now in the process of being patented, and if the patent were granted this could generate direct revenues in terms of licensing income in the future (see <http://www.bbc.co.uk/rd/publications/whitepaper293>).

This cost saving will be on-going as new clips are added that would otherwise have to have been subtitled manually. To get an indicative estimate of the potential future cost savings, suppose that around 1000 clips added to the website annually would benefit from automated subtitle recovery the NPV⁸⁵ of costs savings over the next 5 years would be approximately **£90,300**. This benefit can be expected to increase as the number of clips added to the website continues to grow (noting that the cost saving relate only to those clips that are lifted from previously broadcast material).

*Benefits to audiences
– improved quality*

In order to estimate the size of benefits from improved quality of subtitling, we start by establishing the *total* value that users place on subtitling as a starting point. However, there are several approaches we could use to estimating the total value of subtitles and, as we demonstrate below, there is significant uncertainty as to the likely magnitude of the benefits depending on which approach we take.

In each case, we base our estimates on a figure of 2.5 million viewers who claim to use subtitles for most of their viewing⁸⁶; this is a conservative basis, as we are ignoring occasional users of subtitles.

One approach to estimating the total value of subtitles starts by considering a counterfactual in which, in the absence of subtitles, users would have to pay to obtain a similar service. Such an alternative (albeit not for live programming) would be to enlist the services of a transcriber. At a price of around £10 per hour,⁸⁷ this represents the maximum value that anyone would place on obtaining subtitles, i.e. the choke price. That is, at a price of £10 per hour or higher, no-one would be willing to pay for this service as it would be cheaper to get a transcriber.

Whilst this may appear to place a high value on subtitles, we note that alternative services for adding subtitles to video or transcription of audio can be much more expensive. For example, a service called “Rev” allows people to upload videos or insert a URL

⁸⁵ Using the 3.5% discount rate suggested by the Green Book available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/20541/green_book_complete.pdf

⁸⁶ Mike Armstrong, Andy Brown, Michael Crabb, Chris Hughes, Rhianne Jones, and James Sandford. ‘Understanding The Diverse Needs Of Subtitle Users In A Rapidly Evolving Media Landscape’, International Broadcast Conference 2015 (see <http://www.bbc.co.uk/rd/publications/whitepaper307>); the reference to the proportion of people with hearing difficulties using subtitles is to the annual RNID survey of 2008.

⁸⁷ This is the typical rate for the hourly wage of freelance transcription work (such as: ‘Phonetics assistant to transcribe and annotate speech for Amazon’ or ‘Note-taker to support deaf students at a College’) based on information gathered from recruiting websites

(for example, to a YouTube video) and receive captions at a cost of \$1 per minute. Similarly, the company offers transcription of audio at a rate of \$1 per minute.⁸⁸ By way of indirect comparison, the call-out fee for a freelance British Sign Language interpreter in the UK can be between £60 - £250.⁸⁹

We use this £10 per hour figure together with our conservative assumption that, when free, 2.5 million viewers use subtitles to estimate the consumer surplus. On an assumption of 350 hours viewing of subtitled content per annum,⁹⁰ the total value of subtitling to TV audiences in the UK is well in excess of **£4.4 billion per annum**⁹¹. This represents an upper bound on the *total value* to users created by subtitling.

An alternative approach for determining the total value would be to take the licence fee as the lower-bound estimate of the value to viewers of accessing BBC services and consider the value of services “unlocked” for deaf people by the introduction of subtitles:

- Value of the BBC to users can be assumed to be at least the licence fee income, which is around £3.7 billion per annum (based on 2016 figures)⁹²
- The 2.5 million people who use subtitles most or all of the time represents around 6% of the BBC audience according to the BBC audience research⁹³
- On this basis, subtitling “unlocks” benefits to users of at least **£222 million per annum**.

⁸⁸ See Rev caption and subtitle videos: <https://www.rev.com/>

⁸⁹ For example, see the National Union of British Sign Language Interpreters, ‘Freelance Fees for interpreting engagements for BSL/English interpreters’ 1 January 2017 – 31 March 2018. Available at: <http://www.nubsl.com/guidance/interpreter-fees/>

⁹⁰ On average, viewers in 2015/16 spent around 13.5 hours per week watching BBC services across the BBC One, Two, Three and Four (BBC Annual Report and Accounts 2015/16), or around 700 hours per annum. Conservatively assuming that viewers who use subtitling for most of their viewing watch at least 50% of programmes with subtitles, this would suggest the use of subtitles for around 350 hours per annum

⁹¹ $0.5 * 350 * 10 * 2.5$ million. This calculation ignores use of subtitles by viewers who only use subtitles occasionally i.e. not for most of their viewing.

⁹² See BBC Full Financial Statements 2015/16. Available at: <http://downloads.bbc.co.uk/aboutthebbc/insidethebbc/reports/pdf/BBC-FS-2016.pdf>

⁹³ Mike Armstrong, Andy Brown, Michael Crabb, Chris Hughes, Rianne Jones, and James Sandford. ‘Understanding The Diverse Needs Of Subtitle Users In A Rapidly Evolving Media Landscape’, International Broadcast Conference 2015 (see <http://www.bbc.co.uk/rd/publications/whitepaper307>); the reference to the proportion of people with hearing difficulties using subtitles is to the annual RNID survey of 2008.

We would expect the willingness to pay for services to be greater than the cost of a licence fee (otherwise viewers would not get a licence); therefore, this £222 million is likely to be a significant underestimate of the total benefit of subtitling to users.

A third approach would be to try and obtain a better estimate of the value of the services unlocked by subtitling, as we know using the licence fee will underestimate this. We use the cost of a Pay-TV package as a proxy for the willingness to pay to access content. For example, taking a Sky TV Variety package including Sky Sports would cost around £60 per month (£720 per year).⁹⁴ For the 2.5 million people using subtitles, this equates to a total value of around **£1.8 billion per annum**.

Therefore, we have a range of estimates for the total private value associated with having access to subtitles. In any case, each of these are based on private value to viewers alone, and ignoring broader social benefits, for example assisting the participation of the deaf in democratic debate.

Given this range of estimates, there is significant uncertainty in the magnitude of the value associated with availability of subtitles. Therefore, the benefits of improvements to subtitles (which would lead to increased value) vary significantly depending on what we assume about the overall value of subtitles to viewers.

For illustrative purposes, we proceed on the basis that the total value of subtitles is estimated to fall somewhere in the range of our lower bound estimate (based on the licence fee) and our estimate based on using the cost of a Pay-TV package as a proxy for the willingness to pay to access content (£1.8 billion). For example, consider a total value of subtitles of **(at least) £500 million per annum**. This is a substantial amount, but reflects the large number of heavy users of subtitles, each of whom is likely to place considerable value on the service. Taking this as our base, we then consider the value of R&D work in improved subtitling.

There is clear evidence to demonstrate reductions in latency and increases in accuracy in recent years, both of which lead to an increase in the perceived quality of subtitling. However, it is difficult to translate these improvements into an estimate of the increased value of the service to its users. However, given the high *total* value of subtitles to their users, even small *incremental* improvements in quality will yield significant benefits. For example, even a 1% increase in the value of subtitles could plausibly be worth over £5 million in benefits per annum, or **£25 million** over the last 5 years of

⁹⁴ Sky Variety bundle = £32 a month with Sky Sports an extra £27.50 per month. See: <http://www.sky.com/shop/sky-bundles/> (accessed on 6 July 2017)

work R&D has done on subtitling. However, given our range of estimates the benefits could easily be much larger.

The scale of these benefits is considerable, but not implausible when considered on a 'per user basis' (given we assume 2.5 million users). If, hypothetically, subtitle users were asked whether they wanted to pay, say £2 per annum, for an improved subtitling service, this amount is modest in comparison to typical personal budgets for services related to deafness. For example, a study conducted in 2015 on the additional costs of living for people who are deaf concluded that the minimum weekly budget of a single, working age adult who is deaf was approximately £160 higher than the standard minimum budget⁹⁵.

The benefits of these quality improvements in subtitles are likely to be enjoyed fairly widely by all users of subtitles, rather than concentrated on narrow subgroups, such as the profoundly deaf. For instance, reduced lag in live subtitling may be particularly valuable for those who watch TV with sound as well as subtitles. Research conducted by R&D shows a clear difference in the impact of timing and accuracy of subtitles depending on whether viewers are watching with the sound turned on or off. For those watching with sound, timing is the most important factor affecting perceived quality of the subtitles.⁹⁶

*Benefits to audiences
– improved coverage*

In addition to increases in quality of existing subtitles, users will benefit from increased coverage if subtitles are added where they might otherwise have been absent. However, where clips would have been subtitled anyway (for example, as we assumed for the 4,000 web clips recently uploaded to the BBC website and BBC Worldwide, and all live programming), there would be no direct audience benefit.

One example of increased coverage of subtitles is subtitling of video clips in the BBC's revision tool Bitesize. Over 3,000 video clips on the Bitesize website have been subtitled using the automated subtitle recovery process. Using figures on the number of visitors to BBC

⁹⁵ This difference is largely due to the estimated costs of hiring an interpreter (estimated at 'a modest baseline' of 10 hours per month, costing £127 a week) and extra budget needed for travel and social activities (for example, needing to travel further to cinemas or theatres providing subtitles if local provision is limited). See: Centre for Research in Social Policy, 'Additional costs of living for people who are Deaf', Research Findings, January 2015. Available at: <http://www.lboro.ac.uk/media/www/lboroacuk/content/crsp/downloads/reports/Findings%20-%20Additional%20costs%20of%20living%20for%20people%20who%20are%20Deaf.pdf>

⁹⁶ Mike Armstrong, 'The Development of a Methodology to Evaluate the Perceived Quality of Live TV Subtitles', September 2013. Available at: <http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP259.pdf>

bitesize and the number using videos on the service, we can estimate the number of videos being watched. Assuming that 35%⁹⁷ of these children are using subtitles and assuming each clip is about 4 minutes long,⁹⁸ we estimate the value of increased subtitle coverage on Bitesize to be around **£145,000** per annum. Given that the automated subtitle recovery for Bitesize clips started in September 2016, this suggests benefits over the Charter Period to be around **£100,000**.

An interesting question arising from the BBC's automated subtitle recovery work is whether being able to subtitle clips automatically might have increased the number of clips available on all BBC platforms. We have not been able to investigate this possibility, but it could be a source of significant further benefits.

Spill-over benefits

The BBC R&D's work in this area has made significant contributions to the way in which the user experience of subtitles are measured. In some cases, improved measurement techniques have changed the conventional wisdom around the appropriate standards for subtitle latency.

The research in the areas of subtitle quality, speed and subtitle retrieval undertaken by R&D has resulted in a large number of White Papers and conference presentations and helped to improve subtitling throughout the broadcasting industry. As can be demonstrated by the large number of whitepapers published by R&D on this subject,⁹⁹ BBC R&D contributes to the academic field, which will benefit wider industry by disseminating the results of the research, bringing improvements to other audiences and encouraging a collaborative approach to improving end user experiences. It is, however, difficult to quantify these benefits. Nevertheless, it is possible that this work could lead to further substantial cost savings and improvements in viewing experience of a large number of viewers of other broadcasters.

⁹⁷ A BBC audience survey, subtitle usage for BBC children's services is around 30 percent, and for content classified as 'Learning' as high as 35 percent. Based on iPlayer usage figures (see Mike Armstrong, "Automatic recovery and verification of subtitles for large collections of video clips", September 2016, <http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP323.pdf>)

⁹⁸ Based on the assumptions made in the "Automatic recovery and verification of subtitles for large collections of video clips" white paper that the 7509 videos in the Bitesize corpus amounted to around 500 hours of video.

⁹⁹ For example, see BBC R&D publications, Whitepapers 295, 305, 317, 316, 306, 293, 323.

Benefits summary

	Lower bound	Upper bound
Direct financial benefits	£80,000 in cost savings	£80,000 in cost savings
Benefits to audiences from new services or improved quality	<p>Improvements in quality: worth over £5 million per annum or £25 million over the past 5 years (even if we assume only a very small increase in quality the benefits could be substantial given the large value viewers place on subtitling.</p> <p>Improvements in coverage: £100,000 to date just for BBC Bitesize, with potentially larger benefits in future</p>	
Total benefits estimate:	£25m	Potentially much larger
Main strategic or un-quantified benefits	<p>The influence of BBC subtitling research on the broader broadcasting industry;</p> <p>Value to viewers who watch television with sound as well as subtitles;</p> <p>Value for audience of more online subtitled content being made available on other platforms beyond Bitesize that would not otherwise have been subtitled;</p> <p>Wider social benefits such as enabling the deaf to participate in democratic debate</p>	

4.6 BBC Internet Distribution Infrastructure (BIDI)

Project name:	BIDI
Start and end dates:	2012 – 2015
Position in the value chain:	Distribution
Collaborators	BBC Online Technology Group
Estimate of costs attributable to BBC R&D to date:	£347,500
Total estimated benefit to date:	Limited quantifiable benefits to date, but further benefits expected to be realised in the future

Brief overview

BIDI is the BBC’s own Content Distribution Network (CDN) used for the distribution of media streams to end users in the UK. By building its own CDN, the BBC will be able to reduce its reliance on third-party commercial CDNs as the main means of distributing content. Although currently only about 5% of viewing of the BBC’s television content is online, this is expected to grow rapidly in the future, so having greater control over distribution is of strategic importance to the BBC.

We understand that a “mixed distribution strategy” was put forward to the BBC’s Financial Board in 2012, proposing that a BBC controlled IP distribution structure (built by the BBC or by a third-party on behalf of the BBC) could be used to support distribution of the BBC’s content and that the proportion of traffic passed over to third party CDNs would gradually be reduced and transferred to the BBC network.¹⁰⁰ This ultimately led to the creation of BIDI.

R&D spearheaded the initial work. It suggested the project, and began with the proof-of-concept implementation (building caches, integrating them into the network and establishing the mechanisms for controlling the infrastructure), building on previous

¹⁰⁰ We understand that the volume of traffic handled by third party CDNs has continued to increase despite the presence of BIDI because the demand has continued to rise. Whilst the *proportion* of traffic going to third parties has shrunk, the total volume of traffic is still growing.

research on IP distribution it had undertaken in the 90s. Then, when the BBC undertook a complete revamp of its distribution in 2015, it used the technology that R&D had developed for the design of BIDI.

R&D was very much the catalyst for the project. The department made the case for building BIDI, convinced stakeholders of the advantages and built the prototype (working with the BBC Online Technology Group). The BIDI project was handed over from R&D to the BBC Online Technology Group (OTG) in 2015, with OTG responsible for developing BIDI into an infrastructure that could be used at scale and for the running, maintenance and upgrading of BIDI (though R&D retains an advisory role).

Cost assessment

Total labour costs to date for R&D work committed to work on BIDI amounts to approximately £227,500.

A further £120,000 of R&D expenditure was spent on BIDI prototyping projects, primarily related to purchasing new equipment such as servers, switches and small form-factor pluggable transceivers. Some equipment, such as servers, was recycled from previous projects.¹⁰¹

Together this represents a total cost of around **£347,500**.

Benefits assessment

The BBC Internet Distribution Infrastructure (BIDI) is a key part of the BBC's future distribution strategy and therefore a lot of data and information regarding the project is highly confidential and commercially sensitive. Whilst we are able to undertake a qualitative assessment, we have been unable to develop robust quantitative estimates of the benefits of the system to date owing to lack of data. As we discuss below, there are good reasons to believe that R&D work on BIDI will lead to significant benefits for the BBC (and many other large IP media companies are also investing in their own CDNs suggesting that there are benefits from doing so). However, as we have not been able to generate reliable quantitative estimates, we do not use the results of this study for the grossing up exercise.

¹⁰¹ R&D did have some outlay on building the BIDI development and integration environments here at Centre House. Some of this was recycled equipment from previous projects (e.g. Quanta servers for vmhost1, vmhost2) while other kit was new (e.g. Dell servers for c1b1chint, c2b1chint), access switch, DAC SFPs, etc. Information provided by Lead Technologist, BBC R&D.

Strategic benefits We consider that the main strategic benefit of BIDI is that it gives the BBC a greater level of control and flexibility over its distribution network; it also improves relationships with UK Internet Service Providers (ISPs). Furthermore, the BBC has a strong incentive to take control to the extent it can save costs on the growing distribution of its content over IP. Whilst commercial companies are able to recover costs and to monetise additional IP streams and IP users, thus funding the additional costs of provision, for the BBC only costs increase with additional consumption.

Cost savings We consider whether there have been any potential cost savings achieved to date associated with providing the base-load traffic over BIDI rather than a third party CDN. Using actual volume of traffic distributed over BIDI in each month in 2016, we could compare the total cost of distribution based on the reported BIDI per GB with the costs of distributing that traffic over a third party CDN pricing. Ideally, we would do this using the costs the BBC actually face(d) for using third party CDNs, however this information is commercially sensitive and was not available to us.

We could use prices of third party CDNs using rate cards available in the public domain (for example, what Microsoft charges for delivering content over its 'Azure' CDN¹⁰²) as a proxy for what the BBC may otherwise have to pay for third party CDN services to generate a rough estimate the cost savings in each month of 2016. However, these results should be considered with caution as the third party rates obtained by BBC may be very different from those publicly available, as they will likely be negotiated based on volume of traffic and particular use cases. Due to this uncertainty, we do not include an estimate of cost savings on this basis as it would likely be a significant overestimate.

Benefit to audiences from new services or improved quality Greater control over the distribution network could allow the BBC to improve viewer experience by optimising the IP infrastructure specifically to its needs. The main benefit to audiences would be in the form of better quality of streaming over IP, for example, reduced buffering times or increased picture and/or sound quality. This could lead to greater consumption of BBC content for viewers, as poor quality or long buffering times can lead users to choose not to watch content over IP, or to consume content from a different provider offering better quality.

For example, a study conducted by Limelight found that buffering was cited as the primary frustration of viewing video online. It found that more than 78% of respondents would stop watching an online video that buffered three times. More than 46% will stop watching

¹⁰² Microsoft charges £0.0187 per GB for content distribution 500TB-4200TB/month. <https://azure.microsoft.com/en-gb/pricing/details/cdn/>

after only the second time the video buffers.¹⁰³ Likewise, Krishnan and Sitarman study the impact of video streaming quality on viewer behaviour using data from Akamai's network. They find that viewers start to abandon watching a video if it takes more than two seconds to start, with each incremental delay of one second increasing the abandonment rate by 5.8%. Furthermore a viewer who experiences a failed visit is 2.32% less likely to return within a week than a viewer who experiences a normal visit¹⁰⁴. However, we have been unable to quantify any quality improvements relative to third party solutions to date.

Summary

At this moment in time, we understand that the main functionality being provided by BIDI could be met by third party CDN solutions. Furthermore, due to the limited availability of data on key metrics, we have no evidence to support the hypothesis that significant cost savings and/or quality improvements have been achieved to date as a direct result of the R&D work associated with BIDI.

Although limited quantifiable benefits have been achieved to date, this is not to say that the R&D's work in developing the solution and the subsequent adoption by BBC OTG has not generated benefits and/or will not result in any benefits in future, particularly in light of BBC's future strategy in regard to IP distribution. Of course, the potential for cost savings and the strategic benefits obtained from controlling one's own distribution infrastructure would need to be sufficiently large to justify the decision of a commercial entity to build/buy its own CDN. The project would need to generate a return above the hurdle rate. The fact that companies such as Netflix, Facebook, Apple and Sky have invested in their own CDN's suggests that this must be the case for these parties¹⁰⁵ and that

¹⁰³ Limelight, The State of Online Video, December 2016. Available at: http://img03.en25.com/Web/LLNW/%7Bc02f1632-f615-471f-a79e-354d5cc0244f%7D_2016StateofOnlineVideo.pdf

¹⁰⁴ Krishnan, S. Shunmuga, and Ramesh K. Sitarman. "Video stream quality impacts viewer behavior: inferring causality using quasi-experimental designs." *IEEE/ACM Transactions on Networking* 21, no. 6 (2013): 2001-2014.

¹⁰⁵ Whilst it is difficult to obtain the hurdle rates faced by these private companies, insight from Analysts reports can provide some insights. For example, we can consider measures such as Return on Capital Invested (ROIC) and weighted average cost of capital (WACC). One analyst site has reported Netflix Inc's annualised ROIC for the quarter ending Dec 2016 as 11.57%. Furthermore it reports that currently (April 2017), Netflix Inc's WACC is 8.53% and ROIC is 8.68% such that returns on investment exceed what it costs the company to raise the capital needed for that investment. See: <http://www.gurufocus.com/term/ROIC/NFLX/ROIC-/Netflix-Inc>

there are genuine benefits to large media companies investing in their own CDNs.

Furthermore, the initial R&D effort was as much about influencing the future of distribution as it was about developing the technology. As demonstrated, the cost of the R&D effort was minimal and provided a relatively cheap initial solution for the entry into the CDN market. This cost should be considered relative to the potentially significant benefits that may arise in future in terms of opening up potential future options for IP distribution. This demonstrates the value of R&D's involvement in generating ideas and providing proof of concept solutions for new distribution methods, which could lead to widespread changes in the way the BBC operates.

Once the BIDI network is fully established, it is likely that the BBC will arrive at a point where the marginal cost of building more nodes/caches is just the expense of the additional physical equipment. This will be cheaper and more predictable than third party business models, based on a 'do more, pay more' approach (which involve charges above marginal cost to recover common and fixed costs). Therefore, there may be greater, tangible cost saving benefits to the BBC in future if it only faces the marginal cost of expanding CDN capacity.

Through the continued development of BIDI and in line with the BBC's goal of creating stronger direct relationships with ISPs, the BBC may benefit from deeper technical insights allowing it to optimise its distribution architecture further. Furthermore, wider benefits may be achieved if the BBC's relationships with ISPs can be used to help shape the UK Internet industry to the benefit of public service broadcasters and UK citizens more generally. For example, the BBC's direct participation with ISPs could help ensure that new or improved streaming technologies (such as multicasting for example) are based around open, rather than proprietary, standards and technology for the benefit of all broadcasters as more content is distributed over IP. If the BBC also achieves its goal of making the UK's internet infrastructure less London-centric this will have wider implications for systems resilience and disaster recovery.

The most significant strategic benefit of BIDI is likely to be realised from its role in helping the BBC respond to the increasing importance of IP distribution. We understand that the ambition of the BBC is to deliver all TV over IP in the future and to do so at at least the same quality as DTV today, and at even higher quality in future.¹⁰⁶ Therefore, the BBC needs to be in a position to be able to

¹⁰⁶ For example, if UHD distribution of content is to become the standard in future, the BBC believes that this will probably happen over IP. DotEcon meeting with Controller of Digital Distribution.

fully distribute content by IP by then and a fully operational and high capacity CDN will likely be required to meet this need. By developing BIDI rather than continuing to rely on third party CDNs, the BBC will have full control of the CDN and be able to ensure that it is developed in a way that protects its ability to distribute content at an equivalent or higher quality in future.

In summary, we consider that the benefits of BIDI are largely strategic in nature and may only be achieved in the longer term.

4.7 AS-11 specification for file-based delivery of air ready programming

Project name:	AS-11
Start and end dates:	2011 – 2016
Position in the value chain:	Production
Collaborators	Digital Production Partnership (UK broadcasters)
Estimate of costs attributable to BBC R&D to date:	£467,000
Total estimated benefit to date:	Difficult to quantify, but in the range of £12 million. This is a lower bound estimate as it does not include the potentially large strategic benefits

Brief overview

Until recently, UK broadcasters have relied on physical videotape for the delivery of television programmes.¹⁰⁷ However, in 2011, a group of UK broadcasters came together to form the UK Digital Production Partnership (DPP)¹⁰⁸ and agreed a move from tape-based to file-based delivery with the aim of receiving all programme deliveries in this form by 2014.¹⁰⁹ This eventually led to the development of the

¹⁰⁷ Prior to 2011, the BBC exclusively used tapes, although broadcasters who provide less linear programming (such as Sky and Channel 4) had already started using some file-based delivery methods (at least for promotional material and commercials, not long form which remained tape based.) Interview with Head of Technology BBC HD and UHD, BBC Design and Engineering.

¹⁰⁸ The Digital Production Partnership was formed in 2011 as a membership-based, not-for-profit group by the UK public service broadcasters (BBC, Channel 4 and ITV), with active participation from commercial broadcasters. See Digital Production Partnership News, 'UK Broadcasters Announce Partnership'. Available at: <https://www.digitalproductionpartnership.co.uk/news/uk-broadcasters-announce-partnership/>

¹⁰⁹ Digital Production Partnership News, 'DPP Initiatives Accelerate Digital Production'. Available at: <https://www.digitalproductionpartnership.co.uk/news/dpp-initiatives-accelerate-digital-production/>

“AS-11” specification, which “define[s] the file formats for the delivery of finished media to broadcasters or publishers”.¹¹⁰

Working closely with the US-based trade body AMWA, the DPP and BBC R&D guided the transition from tape to a file-based delivery solution in the UK. Together they facilitated agreement on a common specification to which all companies should adhere so that any work commissioned by any broadcaster could be delivered in a common file format.¹¹¹ This goal was achieved when, on 1st October 2014, all UK broadcasters began receiving programme deliverables as files in a common format known as the AMWA AS-11¹¹², with some files having been delivered to several broadcasters even before this date.¹¹³ Though some tape delivery still remains for now (for example, of programmes originally commissioned on tape, or where programmes are being delivered close to transmission), from 1st October 2017 the major UK broadcasters will no longer accept delivery on videotapes¹¹⁴.

The role of BBC R&D

The role of BBC R&D in the overall process of moving to file-based delivery was to provide technical expertise to the DPP¹¹⁵ and to develop the AMWA AS-11 specification. Therefore, R&D led the development of the technical specification, its reference implementation in software and the development of product testing procedures for the specification.¹¹⁶

¹¹⁰ BBC R&D Blog, ‘Advancing file-based delivery: UHD, North America & Beyond’, 24 June 2016. Available at: <http://www.bbc.co.uk/rd/blog/2016-05-advancing-file-based-delivery-uhd-north-america-and-beyond>

¹¹¹ Interview with Principal Engineer at BBC R&D.

¹¹² Digital Production Partnership News, ‘Why 1st October Delivered More Than Just Files’. See: <https://www.digitalproductionpartnership.co.uk/news/why-1st-october-delivered-more-than-just-files/>

¹¹³ BBC, ITV and Channel 4 began to take delivery of programmes using the AMWA DPP specification on a selective basis in 2012, with file delivery becoming the preferred delivery format on 1st October 2014

¹¹⁴ Digital Production Partnership News, ‘DPP Halts Delivery Of New Programmes on Tape’. See: <https://www.digitalproductionpartnership.co.uk/news/dpp-halts-delivery-of-new-programmes-on-tape/>

¹¹⁵ BBC R&D Blog, ‘Delivering File-based Delivery’. See: <http://www.bbc.co.uk/rd/blog/2014-10-delivering-file-based-delivery>

¹¹⁶ We understand that development of the AS-11 specification built on R&D’s earlier work to encourage the move of file-based production away from proprietary standards and towards a common one (such as the MXF standard), ensuring interoperability across the broadcasting industry.

Cost assessment

Total labour costs for R&D work committed to work on AS-11 amounts to approximately £407,000. A further £60,000 of R&D spend was spent on the AS-11 project. **Together this represents a total cost of around £467,000.**

Benefits assessment

Given that tape is a format reaching the end of its life, we can reasonably assume that there would have been a shift to file-based delivery in any case.¹¹⁷ Therefore, what is important for our assessment is the incremental benefit delivered by adopting AS-11 as a coordinated specification relative to the counterfactual of individual broadcasters adopting their own individual file-based solutions.

Specifically, we focus on the introduction of the AS-11 file specification for distribution of air-ready programming and the transfer of files from a post-production house to a broadcaster or from broadcaster to a playout service.

We understand that the BBC has not earned any revenues as a result of the R&D work on the development of the AS-11 specification. Therefore, we consider other sources of benefit to the BBC and wider industry.

Relative to the counterfactual of many different file specifications and lack of interoperability, there are a large number of potential benefits to the co-ordinated approach. These could include, for example: cost savings associated with not having to procure multiple playout systems (or having one system supporting multiple formats at higher cost); duplication of equipment or time and money transcoding from one format to the other (with associated quality losses). There are both direct cost savings and indirect savings from allowing better workflows and reducing the complexity of playout and all post-playout services that would otherwise be needed to support multiple formats.

¹¹⁷ It could be argued that the work by R&D and the DPP accelerated the move away from tape to a file-based solution. However, we understand that the UK was already quite late in considering this change (for example, relative the US) and that there was a fairly immediate need to shift away from physical media to ensure the continued delivery of content (especially in light of the Tsunami in Japan that highlighted the potential for a single point of failure). Therefore, we conservatively assume that the introduction of the AS-11 specification did not cause a significant re-timing of the introduction of file-based delivery and focus on the primary benefit of a common specification and the associated interoperability benefits.

We consider that the main benefits of this coordinated and standardised approach are through cost savings and quality improvements or strategic advantages. We assessed the potential benefits in detail and consider that:

- There are benefits from easier procurement of external services, including playout, due to all suppliers using a common specification;
- There would be benefits through avoidance of transcoding, which avoids some costs (software licensing and server farms and the need to test any format to any format conversion);
- There would also be a significant quality benefit from avoiding decompression/recompression, which benefits viewers;
- There is higher reliability through AS-11, as 'failed' files (for example, the need to 'debug' files as a result of variation in bitstream rates) are very rare due to the work conducted by R&D in developing the DPP Compliance Programme processes and testing and the AMWA Certification programme, which reduces incompatibilities in playout;
- There are benefits for the BBC through easier supplier relationships. No vendor lock-in as standards are open and potentially more competition for supply of services such as playout;
- AS-11 facilitates the supply of air-ready content into global markets with potential cost savings for BBC worldwide and for purchasers of BBC content.

Whilst it is difficult to determine the true value to the industry of a co-ordinated approach and the benefits of interoperability throughout the entire supply chain without extensive data on all the individual elements of cost savings, we consider the general benefits of interoperability in the industry to indicate the potential order of magnitude benefits that may occur. To the extent that the AS-11 specification (specifically designed for air-ready content) has led to the development of a wider family of specifications that bring coordination benefits in other areas of the broadcasting industry, we consider the potentially very significant wider benefits of improved interoperability more generally.

We can at least get an indication of the magnitude of the overall benefits with reference to the academic literature and studies that have considered the costs of interoperability of files/data shared along the supply chain in other industries. Applying a value of 0.3% of total industry revenue (as found in the literature in other studies

of interoperability benefits¹¹⁸) to the revenue associated with the Film, Video and TV Programme Distribution market in the UK¹¹⁹ (to which the AS-11 related standard is arguably most relevant), this gives us a total value of around **£12 million**.

Benefits summary

Whilst we consider that AS-11 will have brought significant benefits to the BBC and to the UK broadcasting market as a whole, we have been unable to quantify the full extent of these benefits owing to a lack of data and/or tangible evidence. However, based on studies that have considered the benefits of interoperability we consider that an order of magnitude indication of the potential benefits to be of the order of at least **£12 million**.

A large majority of our assessment of this case study is mainly qualitative in nature, but demonstrates the potential for significant benefits from R&D's work in the area of standardisation. This case in particular highlights that the independent nature of the BBC and R&D alongside its significant technical expertise and reputation allows it to facilitate co-ordinating between a large number of organisations to come to mutually beneficial technical solutions where commercial self-interest may otherwise prevent such standardisation agreements.

Of course, there are also other potentially large strategic benefits to the BBC. By taking the lead on the technical development of the specification, the BBC had the opportunity to ensure that its own requirements on quality, metadata and future-compatibility were incorporated into the specification, or at the very least, by ensuring that everyone is using common specifications the BBC would benefit through easier supplier relationships and improved workflows. A common approach across the industry might also benefit the BBC through greater competition for supply of services such as playout.

¹¹⁸ For example, Smita B. Brunnermeier, and Sheila A. Martin, "Interoperability Cost Analysis of the U.S. Automotive Supply Chain", March 1999. Available at: http://www.rti.org/sites/default/files/resources/US_Automotive.pdf and Michael P. Gallaher, Alan C. O'Connor, John L. Dettbarn, Jr., and Linda T. Gilday, "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry", August 2004, National Institute of Standards and Technology NIST GCR 04-867. Available at: <http://fire.nist.gov/bfrlpubs/build04/PDF/b04022.pdf>

¹¹⁹ IBS World, "Film, Video & TV Programme Distribution in the UK: Market Research Report", Jun 2017. Available at: <https://www.ibisworld.co.uk/market-research/film-video-tv-programme-distribution.html>

Furthermore, the DPP's '*phenomenal achievement*'¹²⁰ in implementing a common format in the UK "*has attracted considerable attention from other territories.*"¹²¹ As a major contributor to the DPP, the success of the initiative could also strengthen the BBC's position in the global broadcasting environment. In turn, the greater ability to influence the direction of future progress in technology and cooperation may be of value to the BBC.

Given the UK's small internal market, the export market is of major importance to the BBC¹²². A format that can be used internationally will facilitate the distribution of BBC content worldwide and facilitate the supply of air-ready content into global markets. For example, BBC worldwide can offer fewer 'options' for playout formats and could lead to further cost savings for BBC Worldwide and the broadcaster purchasing BBC content if there is a reduced need to convert files on input/output.

The network effects of having a common specification across a large number of countries could bring even larger benefits to the entire industry. Interoperability across all these regions could open up greater possibilities for cross-border collaboration and allow production workflows to become more efficient. For example, production houses could easily supply to broadcasters around the world without having to accommodate a unique file specification for each, allowing them to extend their reach, from which broadcasters may benefit by being able to get access to a larger range of content.

¹²⁰ Q&A with Mr Clyde Smith (member of the NABA/DPP Steering Group and Chair of The Joint Task Force on File Formats and Media Interoperability). See: <http://www.tvtechnology.com/news/0002/clyde-smith-parses-dpp-developments/278430>

¹²¹ North American Broadcasters Association Press Release, 'DPP and NABA for Strategic Partnership'. Available at: http://www.nabanet.com/nabaweb/news/articles/59_files/DPP-NABA%20Partnership%20PressRelease%202015-04-07.pdf

¹²² Interview with Head of Technology BBC HD and UHD, BBC Design and Engineering

5 Calculating overall benefits of R&D work

Having identified benefit estimates for our selected case study projects, we now use these results to conduct a grossing up exercise to estimate the overall benefits of the R&D department's overall activities during the last Charter Period.

An important consideration to our analysis is that by definition, our chosen case studies are likely to represent a subset of the most successful R&D projects. Therefore, in calculating the overall benefits of R&D work, we must not assume that *all* project-related expenditure will yield benefits of a similar magnitude when scaling up our findings to estimate the benefits from all R&D expenditure.

In this section, we first describe how we use the results from our case studies to determine an average benefit to cost ratio that we will apply to other expenditures (falling outside our case studies). We then describe how we use this to reach an estimate for the overall benefits of BBC R&D work over the last Charter Period, making adjustments for selection bias.

5.1 Benefit to cost ratios

We present a summary of the costs, benefits, and benefit-to-cost ratios for each of our case studies in Table 3 below. In this table, all costs are measured on an incremental basis to the project, i.e. they are costs directly caused by the project and do not include any allocation of overhead costs.

Table 3: Costs benefit ratios for each case study project.

Case study	Costs (£m)	Benefits estimate		Benefit to cost ratio	
		Lower Bound (£m)	Upper bound (£m)	Lower Bound	Upper bound
Piero	1.08	46.00	77.00	42.60	71.30
Redux/Snippets	1.39	53.20	58.70	38.30	42.20
FTA connected platforms	3.40	32.50	49.50	9.56	14.60
DBV-T2	2.82	76.70	152.00	27.20	53.80
AS-11	0.467	12.00	12.00	25.70	25.70
Subtitles	1.18	25.00	>25.00	21.20	>21.20
BIDI	0.348	NOT QUANTIFIED			

Source: DotEcon based on case study cost and benefits estimates (figures displayed to 3 s.f.)

We use a weighted average of the cost benefit ratios from our selected case studies to determine an overall cost benefit ratio to be applied to productive R&D spend. Weights are determined by the expenditure on the respective projects. This takes into account that costs can vary considerably from project to project, and ensures that those case studies that represent a larger proportion of R&D's spend are given greater significance in our calculations.

Using a weighted average across the estimates is appropriate given the types of benefits across the case studies and some of the uncertainties associate with individual benefits. We have not sought to create separate estimates of benefit ratios for each value chain category given that there are a small number of case studies and no evidence of systematic variation in the rate of benefit generation according to our categorisation of projects.

Given the particular uncertainties about the magnitude of benefits from subtitles and BIDI, we do not include these case studies when calculating an overall average:

- We exclude subtitles from the weighted average calculations as a result of the uncertainty in estimating both the true social value of subtitles and the value of the quality improvements achieved.

- We exclude BIDI from the weighted average calculations as a result of the substantial uncertainty in estimating benefits to date given the lack of data and information available.¹²³ The results presented in the case study are only qualitative and indicative and cannot be used to put a quantitative estimate on the value of benefits achieved to date.

Using the costs and benefit-to-cost ratios as outlined in Table 3 gives an average benefit-to-cost ratio of between **1:24 at the lower bound** and **1:38 at the upper bound**.¹²⁴

For the avoidance of doubt this implies that, on average for these projects, the department generates between £24 and £38 of benefit for every £1 spent on BBC R&D. However, as has been previously emphasised not all R&D projects will necessarily yield benefits at a rate similar to our case studies. We turn to the question of how to correct for this bias below.

5.2 Grossing up

The basic premise of the grossing up exercise is to use total project-related spend (incremental costs of each project) and the estimated weighted average benefit-to-cost ratio to generate an estimate for the overall net benefits of the entirety of R&D's work over the Charter Period. The total spend for the period is just over **£160 million**.¹²⁵ Whilst this is instructive to determine the overall spend of the R&D department over the last Charter Period, we need to consider expenditure data at a more granular level so we can determine which of these costs are project-related expenditure.

Identifying project-related expenditure

In order to determine project-related expenditure, we follow the approach as described in Section 3.2.1. That is, we refer to two R&D datasets (provided to us by BBC R&D): one for labour costs (from the YAMIS database), and one for all other R&D expenditure (known as

¹²³ The BBC Internet Distribution Infrastructure (BIDI) is a key part of the BBC's future distribution strategy and therefore a lot of data and information regarding the project is highly confidential and commercially sensitive.

¹²⁴ Figures presented have been rounded to the nearest whole number. The numbers used for our calculations are: lower bound ratio = 1:24.07; upper bound ratio = 1:38.10.

¹²⁵ As part of our assessment of the overall costs of the department we received data from BBC Finance showing full year costs for R&D since it became a financially distinct department in 2007/08.

'cost centre data'). These datasets show costs logged against specific Apollo codes, which relate to specific projects. We were able to use this data to compile a list of all R&D projects conducted over the previous Charter Period and their associated costs. Those logs that do not have an associated Apollo code, or are tagged as wider overhead and operations costs, are not considered project-related expenditure for the purpose of this exercise, but rather as fixed costs common across all projects ('business as usual costs').

Estimating the benefits arising from project-related expenditure

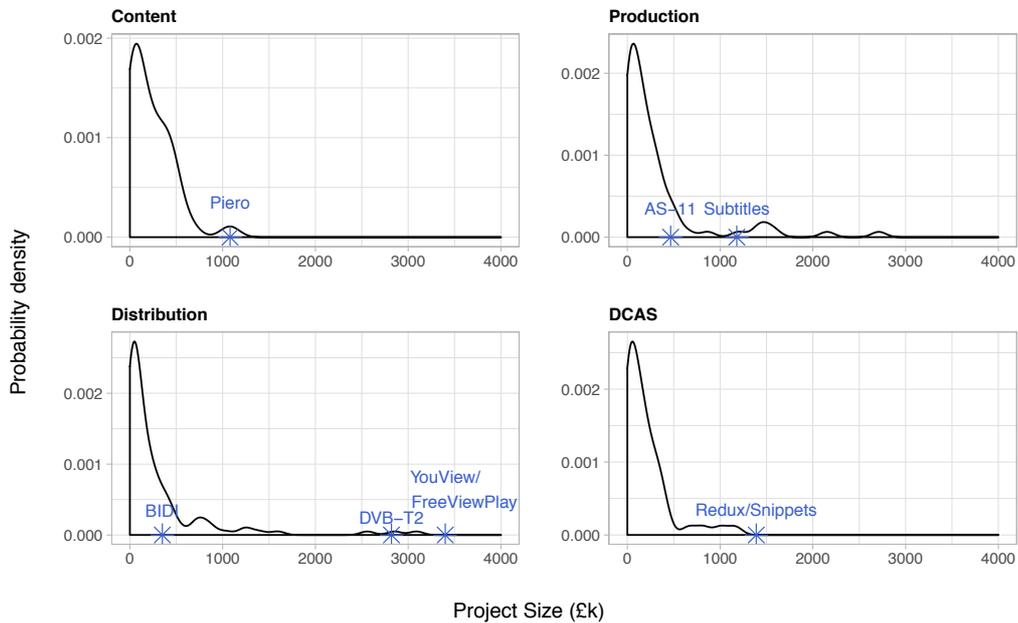
Once we have identified incremental project-related costs, the simplest approach to estimating the benefits would be to apply the estimated weighted average benefit-to-cost ratio to all incremental project-related spend to find a gross benefit estimate, and then deduct the entire R&D spend for the Charter Period (i.e. all incremental project costs plus 'business as usual' costs) to give a total net-benefit figure. However, as described earlier in this report we know that some projects are curtailed at an early stage or are germinal and have yet to generate direct benefits. Significant resources are only committed once the potential for success of the project is established. Therefore assuming that all project expenditure is equally productive would overstate benefits.

In scaling up benefits, cost-benefit ratios should only be applied to a proportion of total R&D expenditure.

We instead assume that only a proportion of projects actually yield benefits at a similar rate to our case study projects and conservatively assume that all other projects generate no (quantifiable) benefits.

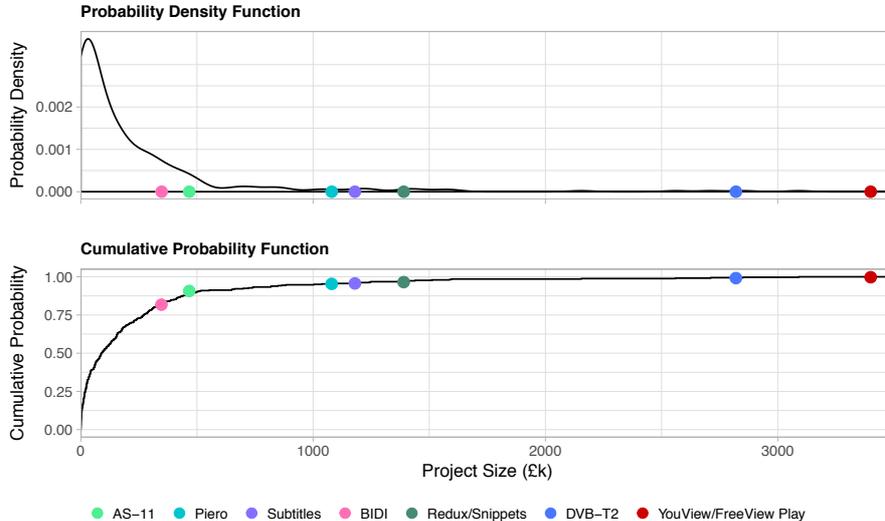
Plotting the distribution of project sizes (with size measured by each project's incremental cost) confirms that there are many small projects and a long tail comprising a small number of larger projects. Figure 5 shows the project size distribution for each value chain category and Figure 6 on an overall, pooled basis. We indicate the position of the case study projects within the size distribution.

Figure 5: The plotted probability density functions of project sizes (costs) for each 'value chain' category.



Source: DotEcon analysis of BBC data. Note that these figures represent a 'snapshot' showing the costs of a project at the point of time up to the end of the previous Charter Period.

Figure 6: Project size cumulative distribution function for all projects.



Source: DotEcon figure from BBC data.

The R&D department works on many small and a few large projects.

This mix of a relatively large number of small projects – which have yet to prove themselves – and fewer large projects that have typically developed out of smaller seed projects is as expected given the description of the R&D department resource allocation process outlined in Section 2. This implies that significant benefits are most likely to be realised from larger projects, which will tend to be more mature projects that have been subject to scrutiny and

earned additional resources. Smaller, seed projects are nevertheless an unavoidable cost, as they are necessary to initiate successful projects. Figure 5 and Figure 6 also clearly demonstrate that our 'successful' case studies are generally in the top end of the distribution for their respective 'value chain' category, as would be expected for mature projects.¹²⁶

Evidence on project success likelihoods

Furthermore, to test the hypothesis that higher cost projects are more likely to be successful we sought to gather more evidence by asking R&D to indicate of the varying levels of success of projects.

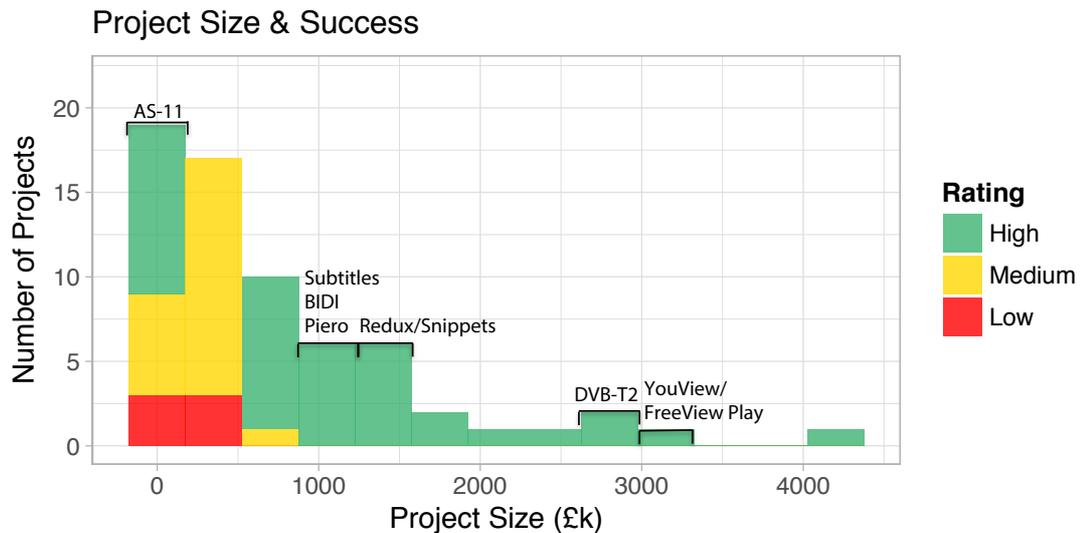
We asked R&D to classify each of the projects over the past Charter Period into three groups based on whether:

- they had been shut down or were expected to be shutdown (low success, indicated in red);
- were expected to be moderately successful, generating likely benefits that would have *at least* covered the cost of investment (medium success, indicated in yellow); or
- were expected to generate benefits many times greater than costs (high success, indicated in green).

Although not all projects were given one of these classifications, of those projects that were classified by R&D (together, comprising about 67% of total project expenditure) we provide a visual representation of the data in the histogram in Figure 7 below. This shows that the larger the project, the more likely it is to be successful.

¹²⁶ Ranging from the top 13% (AS-11) to top 1% (DVB-T2), and generally around the top 5%. Note that the costs of BIDI are much lower, but this is because many of the R&D costs were hardware related and much of the hardware for the initial trials was recycled from other uses.

Figure 7: Project size versus success



Source: DotEcon figure based on information from R&D

There is evidently a positive relationship between project size and success.

The result of the project rating exercise is consistent with the description of the resource vetting process, and again suggests a strong relationship between project size and success. Although some small projects can be successful and some larger projects can be unsuccessful, it demonstrates the likelihood of success increases with cumulative expenditure on projects.

Identifying projects that yield benefits

Based on our findings, to estimate overall benefits from all of R&D's activities, we only apply the average benefit-to-cost ratio from the case studies to projects at the higher end of the size distribution. We conservatively assume all smaller projects do not generate benefits.

Therefore, we must choose a 'cut-off point' for which we assume only projects above this critical size generate any benefits. To identify this 'cut-off point' we review the success ratings of the projects as indicated by R&D (summarised in Figure 7).

We assume that only projects that are strictly larger than the *most expensive* project that was *not* considered wholly successful (and therefore identified in red or yellow) generate benefits. By definition, this presents the cut-off point at which all larger projects are unambiguously considered to demonstrate significant benefits. Indeed, all projects above this cut-off point have been checked and classified as being 'green'

This approach benefits from minimising the probability of including large 'unsuccessful' projects in our scaling up exercise. It is also consistent with our conservative approach, as it does not include

even moderately successful projects (yellow). Furthermore, and for the avoidance of doubt any uncategorised projects in our list are conservatively assumed to be red or yellow and thus will not be included in the benefits estimate.

Following this method, we identify a “cut-off” point (p) at £700,300. At this point all projects with a strictly greater incremental cost are classified as ‘green’ and successful, with the marginal project (rated as yellow) being a project called ‘DIRAC’.¹²⁷

We apply our weighted average benefit-to-cost ratio to the sum of expenditures on all projects that were more expensive than this cut-off point.

5.3 Results

The sum of project-related expenditure for all projects above this cut-off point is £41.0 million, which together represents around 49% of R&D’s total project-related expenditure.

We calculate the benefits by applying our weighted cost-benefit ratio from the case studies (1:24 at lower bound and 1:38 at upper bound) to this £41.0 million figure, and then determine the net benefit by deducting the total spend of R&D (£160.8m).

The results are summarised in Table 4.

Table 4: Total value of R&D estimates based on most expensive ‘unsuccessful’ project approach.

	Gross benefit of project-related expenditure (£m)	Net of total R&D spend £160m (£m)
Lower bound	988	827
Upper bound	1,560	1,400

Source: DotEcon Calculations – figures subject to rounding and displayed to 3 significant figures.

Therefore, these results show that:

- Based on our lower-bound benefits estimates, BBC R&D generated net benefits of approximately **£827 million** in

¹²⁷ DIRAC is a “new general purpose video compression system, suitable for resolutions from internet streaming to HDTV, that has been developed by the BBC.” See BBC R&D White Paper 124, “Dirac Video Compression”, January 2005. Available at: <http://www.bbc.co.uk/rd/publications/whitepaper124>

the previous Charter Period (taking account of all costs of the department including business as usual fixed and common costs). This corresponds to a total cost benefit ratio of **1:5.14**. That is, for every one pound spent on BBC R&D, the department generated approximately **£5** in net benefits.¹²⁸

- Based on our upper-bound benefits estimates, BBC R&D generated net benefits of around **£1.40 billion** in the previous Charter Period. This corresponds to a total cost benefit ratio of **1:8.73**. That is, for every one pound spent on BBC R&D, the department generated approximately **£9** in net benefits.¹²⁹

In line with our conservative approach we take these as the 'headline' benefits estimates for this report. As described above, this should be considered a **conservative estimate**, as it ignores any projects identified as successful (green) that fall below our cut-off point, with benefits assumed only for projects that larger than the cut-off point i.e. the top 49% of R&D project-related expenditure for which all projects were classified as successful (green).

Given that there are projects outside of this range that will most likely have also generated benefits, we present some sensitivities where we lower the cut-off point and apply our benefits ratio to additional project-related expenditure associated with those projects classified as successful (green).

In the tables below we present results for a range of cut-off points p , where p is the point at which all green projects with expenditure greater than p are included in our benefits assessment, and all projects with an expenditure equal to or less than p are excluded, and assumed to generate no benefits.

To be clear, as we lower the cut off point we *only* apply the benefit ratio to project expenditure *above* the cut-off point that is associated with successful (i.e. 'green') projects. We continue to apply our conservative assumption that any projects above the cut-off classified as yellow, red or that were unclassified will yield no benefits at all.

We present the results from three cases:

- the base case - as described in the main text above. The project with cost £700,300 is the most expensive 'non-green' project. We apply our benefit ratio to all project expenditure above this level (which in this case, is all classified as 'green') and represents around 49% of total

¹²⁸ Rounded to one significant figure.

¹²⁹ Rounded to one significant figure.

project-related expenditure. We exclude all projects with a cost less than or equal to £700,300;

- Case 2 – this is an intermediate case between our base case and case 3. In this case we start by considering projects larger than £193,800.¹³⁰ We then apply the benefit ratio to the cumulative expenditure associated with those projects above this level that have been classified as ‘green’ by R&D and exclude those that were red, yellow or were uncategorised. We also exclude all projects with a cost less than or equal to £193,800.
- Case 3 – in this case we start by looking at all projects i.e. those with a cost greater than £0.¹³¹ We then apply the benefits ratio to the cumulative expenditure associated with all projects that have been classified as ‘green’ by R&D and exclude all those that were classified red, yellow or were uncategorised.

We summarise the results below, based on both upper- and lower-bound estimates of benefit-to-cost ratios and for each of these cases.

¹³⁰ Which together make up around 84% of total project-related project-related expenditure.

¹³¹ Which together make up 100% of total project-related expenditure.

Table 5: Total benefit of R&D activity (lower bound estimate)

	'Cut-off point' (p) (£)	Cumulative expenditure associated with 'successful' (green) projects with expenditure strictly greater than p (£m)	Proportion of total expenditure above this cut-off point that is associated with successful ('green') projects	Total benefits net of total R&D spend (£m)	Implied overall benefit ratio of BBC R&D (displayed to 2.s.f.) ¹³²
Base case:	700,300 ¹³³	41.0	100%	872	5.1
Case 2:	193,800 ¹³⁴	48.1	68.2%	996	6.2
Case 3:	0	49.6	59.2%	1030	6.4

Table 6: Total benefit of R&D activity (upper bound estimate)

	'Cut-off point' (p) (£)	Cumulative expenditure associated with 'successful' (green) projects with expenditure strictly greater than p (£m)	Proportion of total expenditure above this cut-off point that is associated with successful ('green') projects	Total benefits net of total R&D spend (£m)	Implied overall benefit ratio of BBC R&D (displayed to 2s.f.) ¹³⁵
Base case:	700,300 ¹³⁶	41.0	100%	1400	8.7
Case 2:	193,800 ¹³⁷	48.1	68.2%	1670	10
Case 3:	0	49.6	59.2%	1730	11

Source: DotEcon calculations based on estimated cost benefit ratios and BBC R&D cost data (figures rounded to 3.s.f. unless stated otherwise)

¹³² Net benefit divided by total spend of BBC R&D over the Charter Period (£160.8m).

¹³³ Strictly speaking the exact cut-off point is set at £700,304.40.

¹³⁴ Strictly speaking the exact cut-off point is set at £193,827.50.

¹³⁵ Net benefit divided by total spend of BBC R&D over the Charter Period (£160.8m).

¹³⁶ Strictly speaking the exact cut-off point is set at £700,304.40.

¹³⁷ Strictly speaking the exact cut-off point is set at £193,827.50.

This demonstrates that applying our *upper bound* weighted average benefit-to-cost ratio to all projects that were classified as being successful ('green') we would find that R&D would have generated a £1.73 billion of net benefit from a £160.8 million investment over 10 years (see Table 5), i.e. for every £1 invested by R&D, around £11 worth of net benefits are generated.¹³⁸ This represent the maximum upper bound estimate arising from the methodology presented.

¹³⁸ Rounded to one significant figure.

6 Conclusions

Conducting an assessment of the benefits generated by R&D expenditure over the last Charter Period, we find that even the subset of projects we considered in case studies are sufficient by themselves to create benefits in excess of the entire expenditure of the R&D department (including both incremental project costs and business as usual costs). Therefore, the work of R&D creates net benefit, even before we consider benefits arising over and above those quantified for the seven R&D projects we considered in detail in our case studies.

We recognise that our case studies are successful projects and so we cannot simply assume that other project expenditure by R&D is equally productive in terms of generating benefits. However, we can correct for this by considering the chances of projects being successful. There are good reasons to expect that larger projects are more likely to mature and yield benefits than smaller projects, which will more likely be in their germinal stages.

This picture of R&D's resource allocation process was borne out when we asked R&D to classify projects into groups according to whether projects have been shut down or were expected to be shut down (red), generated benefits that would have – in R&D's view – covered at least the costs of investment and considered moderately successful (yellow), or generated benefits many times greater than costs (green). Larger projects tended to be more likely to be successful.

On the basis of this data, we have taken the conservative assumption that only the largest projects (which together account for 49% of all project-related expenditure) yield benefits and ignored any benefits from smaller projects. On the assumption that these larger projects yield benefits at a similar rate to our case studies, we estimate overall net benefits over the past Charter Period to be in the range of around **£872 million - £1.40 billion**. Based on a total spend of £160.8 million for the same period, this relates to a net benefit of between **£5 and £9** for every pound spent by the department.¹³⁹

Returns to R&D investment of this magnitude show that the BBC R&D department is performing well and that the benefits of the department are significant. However, the magnitude of these benefits should not be surprising given the potentially very large

¹³⁹ Rounded to one significant figure.

audience benefits and social value associated with many of these innovations.

Furthermore, there is evidence in the literature to provide some context to the cost benefit ratios described above. Although the methodology used to assess costs and benefits varies substantially across the literature, we find that the results of our analysis are broadly in line with the findings of a number of other studies that compare the costs and benefits of research projects and innovations.

For example, research by Breshanan (1986) on computer innovations in the 1970s, that include social gains (in addition to private benefits) finds a cost benefit ratio of around 1:5.¹⁴⁰

Perhaps more relevant to the type of research and development activity undertaken by BBC R&D, there have been several value-for-money evaluations of research and science funding schemes. For example, a cost benefit analysis of Innovate UK's 'Smart' R&D financing programme¹⁴¹ determines the cost benefit ratio to be from 1:4 to 1:5. Although this report identifies potential spill-over and social returns, it does not seek to quantify them. One should also note that the 'Smart' ratio includes future unrealised benefits, in contrast to our approach.

An evaluation¹⁴² of the Collaborative Research and Development Programmes¹⁴³ estimated the benefits of the programmes by conducting surveys on the total turnover generated for businesses from their participation. It found that for every £1 spent, the programme generated £6.71 (or £5.75 in constant 2010 prices) in gross value added (GVA).¹⁴⁴

¹⁴⁰ Breshanan (1986) estimates the value of price-reducing innovations for computers used in financial services. The value of the price-reducing innovation is proxied by willingness to pay by the financial sector for the computers and their downstream customers, and estimates that "1958 and 1972 the spillover from the adoption of mainframe computers in the financial services sector of the U.S. was at least **five times** the size of the expenditure for it in 1972"¹⁴⁰ (emphasis added). See Bresnahan, T. (1986), Measuring spillovers from 'technical advance', American Economic Review, 76,741-755. (Subscription only).

¹⁴¹ The Smart scheme provides funding to small- and medium- sized enterprises working on innovative R&D projects. For the evaluation report see: SQW, 'Evaluation of Smart, Impact and Process Evaluation', October 2015. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467204/Smart_Evaluation_-_Final_Final_Report_7_October.pdf

¹⁴² Public and Corporate Economic Consultants, 'Technology Strategy Board – Evaluation of the Collaborative Research and Development Programmes – Final Report', September 2011. Available at: http://webarchive.nationalarchives.gov.uk/20130221185318/http://www.innovateuk.org/assets/pacec_evaluation_of_crandd_report_final260911%20%282%29.pdf

¹⁴³ A knowledge transfer and innovation support system that brings together partners from Higher Education and businesses to support R&D projects

¹⁴⁴ We note that this research differs from ours in several ways: it forecasts benefits substantially, does not attempt to quantify wider social returns and includes the economic impact arising from increased employment. The study estimates that the GVA of project costs alone was £1.97 forecasted and £0.31 in realised returns (£1.74/£0.28 in 2010 prices).

In a recently published report assessing the current status of the EU Horizon 2020 programme (the EU Framework Programme for Research and Innovation 2014-2020)¹⁴⁵ and its progress towards its objectives estimates that for every €1 invested, there will be benefits (in the form of increased GDP) of the order of €6-8.5.¹⁴⁶

Therefore, the results of our study demonstrate that R&D generates significant net benefits from its work and that even our most conservative estimates show that the value created per £1 invested is of similar order of magnitude to other successful research projects.

It is entirely possible that the true value of all of the benefits arising from R&D activity are even higher than those presented here. These results presented are based only on the benefits that we have been able to quantify as part of our detailed assessment. As described in the qualitative assessment in each case study, there are a wide range of benefits that arise from R&D activity that are difficult to quantify and, in line with our conservative approach, these are excluded from the figures above. For example, in the case studies we exclude:

- for Piero, the strategic benefits to BBC from improving its prestige in sports broadcasting and for paving the way for further sports analysis tools to be developed by collaborators such as Ericsson (formerly Red Bee Media);
- for Redux and Snippets, the value to BBC audiences who might see more archival footage in the programmes as a result of programme-makers having easier access to this material, and the spill-over benefits to the BFI and other third party users of the system;
- the strategic benefits to the BBC and other PSBs of FTA connected platforms and of DVB-T2 and the strategic benefits for the BBC in developing its own CDN;
- the added value to all broadcasters and society of the BBC's research into the quality of subtitling;
- the wider global benefits of DVB-T2 and Piero where these standards and technologies are used outside the UK;

¹⁴⁵ Horizon 2020 is designed "...to drive economic growth and create jobs by coupling research and innovation (R&I), with an emphasis on excellent science, industrial leadership and tackling societal challenges." See European Commission Staff Working Document, 'In-depth interim evaluation of Horizon 2020', 16 June 2017. Available at:

[https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd\(2017\)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none](https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd(2017)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none)

¹⁴⁶ European Commission Staff Working Document, 'In-depth interim evaluation of Horizon 2020', 16 June 2017. Available at:

[https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd\(2017\)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none](https://ec.europa.eu/research/evaluations/pdf/archive/h2020_evaluations/swd(2017)220-in-depth-interim_evaluation-h2020.pdf#view=fit&pagemode=none)

- the true costs avoided from not having a large number of fragmented file specifications for delivery of air-ready programming as a result of the development of the AS-11 file specification.

Although difficult to quantify, such benefits could be significant and should be considered over and above the estimates of net benefit presented above. There are also general project-related expenditures that may have yielded benefits but were not specific to any one such project, and were thus not included in our benefits calculations applied to 'successful' project-related expenditure.¹⁴⁷

Furthermore, there are potentially significant additional benefits arising from the work of R&D in terms of time and effort spent by the department, its engineers and subject matter experts to ensure that they remain at the forefront of their field and are well versed in new technologies that may become more relevant in future, amplifying the value of R&D staff and allowing the BBC to take advantage of new technologies offering industry leading services for licence fee payers.

This significantly reduces the risks facing the BBC from technical change. Moreover, the experience gained through such research, as well as through previous projects and collaborations all contributes to the experience and knowledge base of the department that feeds into all future work and might provide the catalyst for significant innovations.

For these reasons the quantitative results presented in this report should not be considered to indicate the maximum possible value of the department. **Therefore, benefits of £5 - £9 for every pound spent by the department should be considered conservative estimates of the value of the work conducted by BBC R&D over the past Charter Period, and demonstrate clearly that the benefits achieved outweigh the costs of the department.**

¹⁴⁷ Such expenditures relate to those logged under categories such as 'IFRS General Project Spend' and 'General Prototyping'. At least some proportion of these expenditures will likely have brought benefits, but in the line with our conservative approach we did not seek to estimate that proportion and instead assumed that these general expenditures can be treated as a general overhead and are not allocated any benefits in our assessment.