JASPERS Smart Development Division

Staff Working Papers

Economic Analysis of Research Infrastructure Projects in the Programming Period 2014-2020

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JASPERS Staff Working Papers are prepared by JASPERS experts with the aim of facilitating the discussions with counterparts in the context of their different assignments, mostly in terms of project scoping and applicable criteria and methodology. These papers normally originate as part of the assessment of a specific project, in which case the version published here is edited to be made non-project and non-country specific and therefore easily applicable to other projects in the sector. This particular paper provides methodological guidance for the quantification of economic benefits of infrastructure projects in the RDI sector.

(*) This document benefited also from the comments provided by Massimo Florio (University of Milano), Silvia Vignetti (Csil Milano) and Witold Willak (European Commission) as well as by other members of the smart development team and the Networking and Competence Centre in JASPERS.

Table of Contents

1 Introduction

The European Commission's (EC's) 2014-2020 Guide to Cost Benefit Analysis (CBA) includes a chapter on CBA for major[1] Research Development and Innovation (RDI) Infrastructure (university research facilities, translational medicine facilities, single experiment facilities), a sector not previously covered in past versions of the publication.

While the use of CBA for the appraisal of infrastructure such as transport networks and public utilities is well grounded, the application of the technique in the RDI sector is yet to be well established. As a consequence, in certain instances the guidance provided for RDI in the current version of the Commission's 2014-2020 CBA Guide – hereafter referred to as the CBA Guide – requires further development and clarification.

The objective of this paper is to present a practical methodology for the quantification of economic benefits of infrastructure projects in the RDI sector that is in line with the new Council regulations for the 2014-2020 perspective[2], and that builds on the guidance provided in the CBA Guide. Some general recommendations for the risk assessment and the integration of climate change into the CBA are also provided.

The paper does not address the quantification of economic costs, nor does it cover the project context, project objectives, options analysis, demand analysis or the financial analysis. The CBA Guide and JASPERS previous RDI-related papers[3] may be consulted for further information on these topics.

The methodology presented here has been tested on a selection of JASPERS supported projects from the current and the 2007-2013 financing perspective. As new projects are tested and new insights gained, the paper may be updated.

The paper also makes reference to the results of the EIB commissioned EIBURS project "Cost/Benefit Analysis in the Research, Development and Innovation Sector" at the University of Milan, summarised in Florio et al. (2016)[4].

2 JASPERS Approach to the Quantification of Economic Benefits of RDI Projects

The fundamental CBA methodology that all major projects must adhere to is laid down in Commission Implementing Regulation (EU) 2015/207. The Regulation describes the main economic benefits per sector to be considered in the economic analysis. These are further elaborated in the CBA Guide. The main benefits for Research and Innovation Infrastructure projects are as follows:

(i) benefits to businesses:
  a. establishment of spin-offs and start-ups
  b. development of new/improved products and processes
  c. knowledge spill-overs

(ii) benefit to researchers and students:
  a. "new research"
  b. human capital formation
  c. social capital development

[1] See definitions in Regulation (EU) No 1303/2013 of the European Parliament and of the Council. For RDI infrastructure, major projects include those with total eligible costs (total eligible project expenditures minus net revenues) exceeding EUR 50 million.
[2] Regulation (EU) No 1303/2013 of the European Parliament and of the Council, Commission Delegated Regulation (EU) No 480/2014 as well as Commission Implementing Regulations (EU) No 1011/2014 and No 2015/207
[3] See http://www.jaspersnetwork.org/plugins/servlet/documentRepository for other JASPERS papers.
[4] Florio, Forte, Pancotti, Sirtori & Vignetti (2016), *Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework*, Working Paper N. 01/2016, http://www.csilmilano.com/docs/WP2016_01.pdf

(iii) benefits to the general public:

a. reduction of environmental risks
b. reduction of health risks
c. cultural effects for visitors

For each of these benefits, this document describes the methodology laid down in the CBA Guide, and the approach proposed by JASPERS to implement this methodology. Additional economic benefits (namely learning-by-doing benefits and open access to research infrastructure) and the quantification of the economic residual value are also presented.

2.1 Identification and Quantification of Economic Benefits according to the Implementing Regulation

2.1.1 Benefits to Businesses

The CBA Guide identifies two main benefits related to businesses: the establishment of spin-offs and start-ups, and the development of new products and processes.

Establishment of spin-offs and start-ups

a) The approach in the CBA Guide

The CBA Guide measures the economic value of spin-offs and start-ups by the expected shadow profit generated by the business during its lifetime, as compared to the counterfactual situation. In order to make this estimate, the following data are required:

- the annual and total number of spin-offs/start-ups expected to be generated by the RDI infrastructure;
- the expected value of annual profits earned by spin-offs/start-ups in the relevant country and sector; and
- the average lifetime of spin-offs/start-ups in the relevant country and sector.

The reader is directed to use data from official statistics.

b) JASPERS guidance

Where the data above are unavailable, the following simplified approach may be applied (see Table 1):

Table 1: Summary: Benefits related to the creation of spin-offs and start-ups

Benefit	Quantification method	Value calculation
Incremental shadow profits generated by spin-offs and start-ups	Number of jobs created * present value of shadow profit per employee	[Number of newly established entities] * [average number of employees per entity] * [shadow profit per employee]

The first piece of information needed to apply the approach proposed is the number of spin-offs and start-ups expected to be created by the relevant project. This should be project specific, based if possible on the historical track record of the project promoter or of similar RDI infrastructure operating in a comparable environment. The same goes for the expected number of employees associated with companies spun off and started up by the relevant RDI infrastructure.

The second item needed to estimate the flow of economic benefits associated with spin-offs and start-ups, is the expected value of annual shadow profits[5] earned by these companies. Here, JASPERS proposes to estimate total profits based on the estimated number of staff employed by spin-offs and start-ups and the shadow profit associated with one such employee.

Beneficiaries are free to use their own sources of data in the estimation of benefits; however, it is expected that in the majority of cases sourcing appropriate data will be a challenge. Where that is the case, it may be appropriate to look at national accounts. Data are available here to quantify the shadow profit that can be expected to be associated with one employee in the scientific R&D sector (NACE sector M72)[6]. As the best available measure of shadow profit, the gross operating surplus may be used, which is equivalent to gross value added minus compensation of employees.[7][8]

The third piece of data needed is the average lifetime of spin-offs and start-ups. This is normally the most challenging area for quantification, since little appears to be available by way of either official statistics or relevant academic literature. If appropriate data can be found related to survival and growth rates, it should be used. In the absence of a clear empirical basis, however, JASPERS proposes the following simplified approach:

> assume that growth in the number of employees in companies that survive broadly speaking cancels out the loss of employees in companies that do not survive i.e. the number of employees stays constant.

This means that the expected annual shadow profit from spin-offs and start-ups can be estimated as the product of: the number of such companies spun off from the RDI projects in any given year, the average number of employees in such a start-up/spin-off company (immediately following its establishment), and the shadow profit per employee.

Where the project incorporates an incubator or provides incubator services to its spinoffs and start-ups, a more optimistic scenario regarding company growth and survival may be applied, if properly justified.

Development of new/improved products and processes

a) The approach in the CBA Guide

The CBA Guide proposes estimating the benefits of new and improved products and processes by calculating the changes in the shadow profit expected from the sale of marketable goods and/or processes associated with the relevant research and development activity. When patents are expected to be produced as a project output, the value of patents should be estimated. As regards the determination of the economic value of patents, the CBA Guide makes reference to the following publications and provides the values as presented in Table 2.

[5] The shadow profit differs from the financial profit in the way that market distortions are considered, meaning that shadow prices for inputs and outputs are considered, when necessary. For example, if targeted businesses are located in areas with high unemployment, the shadow profit will be higher than the gross financial profit because the shadow wage will be lower than the market wage (see p. 282 of the CBA Guide, 2014).

[6] Other relevant sectors can be used depending on the concrete projects, as for example NACE sector 61 Telecommunications, 28 Manufacture of machinery and equipment n.e.c. etc.

[7] For more information see e.g. http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Gross_operating_surplus_%28GOS%29_-_NA

[8] In countries or regions with a high unemployment rate the calculation of the shadow profit should explicitly include the shadow wages.

Table 2: Patent Values from the literature

Author, year and name of publication	Value of patent	Valuation Method
European Commission (2006), The value of patents for today's economy and society[9]	Median value of patent of EUR 300,000; Average value of patent EUR 3 million	"The value of a patent is not the value of the patented invention. It is the value of the invention when the inventor holds a patent net of the value of the invention when she has no patent on it. Thus for example, if the patent provides a monopoly on a new product, the value of the patent is the difference between selling the product under monopoly as opposed to selling it under competitive conditions. Arora et al. (2003) call this value the "patent premium". Moreover, the value of patent is the value of an asset. It is the difference between the discounted stream of profits since the grant of the patent when the inventor holds a patent and the equivalent discount stream of profits without the patent." (p. 4 of EC, 2006)
European Commission (2005), PatVal EU project[10]	Value of European patents between EUR 100,000 and EUR 300,000, with a small share of patents yielding economic returns that are higher than EUR 3 million, and an even smaller share that are valued at more than EUR 10 million.	In the PatVal-EU survey, the inventors were asked to estimate the minimum price at which the owner of the patent (whether the firm, other organisations, or the inventor himself) would have sold the patent rights on the very day in which the patent was granted. This is a measure of the present value of the patent for the applicant. The inventor was asked to assume that the applicant had all the information available at the moment at which he responded to the questionnaire. The answers to the questionnaires were given 6-7 years after the application year of the latest patents in the survey (1997). (page 44)
EIB (2013), The Economic Appraisal of Investment Projects at the EIB[11]	Average monetised value of marketable, individual patents at USD75,000 (EUR57,500) and at about USD115,000 (EUR85,000) for patents that are effectively used in industrial applications (the top 10%, industrially viable patents).	"The market value of patents reported by Patent brokers like Ocean Tomo" (p.149).

It is stated in the CBA Guide that only those patents granted by the National Patent Office, European Patent Office (EPO) or others, and not the patent applications, should be considered in the CBA.

[9] http://ec.europa.eu/internal_market/indprop/docs/patent/studies/final_report_lot2_en.pdf
[10] http://ec.europa.eu/invest-in-research/pdf/download_en/patval_mainreportandannexes.pdf
[11] http://www.eib.org/infocentre/publications/all/economic-appraisal-of-investment-projects.htm

b) JASPERS guidance

JASPERS overall follows the same approach proposed by the CBA Guide for the estimation of the economic benefits of patents: the market value of patents should be multiplied by the number of patents granted per year (see Table 3).

Table 3: Summary: Benefits related to patents

Benefit	Quantification method	Value calculation
Benefit attributed to patents granted	Market value as proxy for WTP	[Market value of patent] * [number of patents granted]

As regards the market value of patents, JASPERS advises the use of the values provided in EIB (2013), as these are actual market values. When data from EC (2006) is used, JASPERS advises using the more conservative estimates, i.e. the median values rather than the average values.

Knowledge spillovers

a) The approach in the CBA Guide

The CBA Guide values the benefit of knowledge spillovers as the shadow profit or avoided costs attributable to external users of knowledge in the public domain without any form of intellectual property protection (e.g. the RDI project promoter is a public entity that offers open access to research outcomes to academic researchers and business).

b) JASPERS guidance

Whilst this concept is clear, applying it in practice, especially in the absence of any empirical data, is likely to be challenging. For certain types of project, it may be possible to follow the suggestion in the CBA Guide and make a reasonable ex-ante case for what the benefits might be, based on the specific nature of the activity in question.

2.1.2 Benefits to Researchers and Students

"New research"

a) The approach in the CBA Guide

In the CBA Guide, the value of "new research" (terminology used in the Implementing Regulation) is interpreted as the value of new scientific publications of researchers who are users of the RDI project.

The CBA Guide bases the value of scientific publications on their marginal production costs, which is the gross salary of the author/researcher prorated by the time spent working on a publication. Other knowledge outputs, such as working papers, pre-prints and talks at conferences, can also be considered and valued according to the same marginal production cost approach.

The following project-specific assumptions are necessary:

- % of time researcher spends on research, speeches at conference etc.
- Number of publications per researcher per year
- Average gross salary of a scientist

A positive linear relationship between the value and the number of publications can be assumed.

It is also mentioned that, if justified in the project-specific case, the value of the scientific papers can be increased in proportion to the number of citations received by non-user academics who benefit from the new scientific literature created by the project users. The valuation approach is not further explained, though the use of scientometric techniques is mentioned.

JASPERS guidance

JASPERS recommends following the approach proposed in the CBA Guide for the valuation of new scientific publications, speeches at conferences and the like (see Table 4).

Table 4: Summary: Benefits related to "new research"

Benefit	Quantification method	Value calculation
Benefit to society of new scientific publications of researchers who are users of the facility	Marginal production costs (remuneration of authors)	([Average gross annual salary of scientist] / [Average % time researcher spends on 1 publication]) * overall number of publications by project per year

Data on the average gross salary of a scientist should be project specific and provided by the promoter. Country-specific data either from the OECD or national sources can also be used.

Where data on the average number of citations by scientific field is available and thought to be applicable and appropriate to the project and the institution, it may be valid to incorporate it into the analysis. While details of the method are not provided in the CBA Guide, they are explored further in Florio et al. (2016)[12].

Human capital formation

a) The approach in the CBA Guide

According to the CBA Guide, the incremental life-long salary to be earned by graduates and researchers who have been trained by the project and its staff should be interpreted as a "future premium" to the current salary (p.275). This "may require benefit transfer approaches from other contexts, interviews and expert opinion by specialists in the labour market of interest." (p.275). WTP estimates for junior researchers and students to attend a training/study period can also be used.

To estimate the total discounted benefit, the CBA Guide suggests using the present value of the total annual incremental gross salary gained by all students trained during the project time horizon and over their entire work career.

It is also noted that the benefits produced beyond the project's time horizon should be considered beyond the project's time horizon and included in the residual value[13] .

b) JASPERS guidance

Following the CBA Guide JASPERS recommends using the approach detailed in Table 5.

[12] Florio, Forte, Pancotti, Sirtori & Vignetti (2016), *Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework*, Working Paper N. 01/2016, http://www.csilmilano.com/docs/WP2016_01.pdf
13 See section 2.3of this paper and page 44 of the CBA Guide for more information on the residual value.

Table 5: Summary: Benefits related to human capital formation

Benefit	Quantification method	Value calculation
Benefit to society of an educated labour force	Market value as proxy for WTP	[Economic benefit in year t] = [Number of graduates in year t] * [Present value in year t of incremental gross salary over average number of years of working career ahead of graduates]

If no data from expert interviews, WTP studies etc. are available, JASPERS recommend measuring the incremental improvement on gross salary of master graduates and PhD students over the national average. Market values for the salaries of MA, MSc and PhD graduates can be taken from OECD (2012) statistics[14] for the specific country and compared against statistics on average salaries. If possible, sector-specific data should also be used.

The value for increases in salaries of MA, MSc and PhD students needs to be multiplied by the number of students that graduate in a given year and by the length of an average career (a project-specific assumption of the length of their career needs to be made) and then discounted.

In the last year of operation, the value for the last generation of students graduating should be included. Benefits occurring beyond the reference period (e.g. the incremental salaries of the last generation of students forecast to graduate at the facility) should not be included in the residual value of the project (as stated in the CBA Guide) since they are already captured using the above approach.

Social capital development

a) The approach in the CBA Guide

The term social capital is a concept that describes the dimension and depth of the network of relations among individuals. The CBA guide suggests that the benefits related to this are expected to be evaluated in a qualitative way.

b) JASPERS guidance

The literature on the notion of social capital creation in the context of research infrastructure makes specific reference to the creation of networks between researchers, and the links between researchers and businesses. While the latter will be largely captured through the creation of spin-offs, contract research, the use of facilities by the private sector (see section 2.2.2 below) etc., the benefits related to the creation of research networks can be included where relevant.

While it is difficult to measure the full effect of network creation (that may occur beyond the scope of the project itself), parts of the benefits can be captured by estimating the WTP of researchers and business to attend networking events/specific conferences organised by the research infrastructure that lead to the creation and/or dispersion of knowledge.

The travel cost method can be applied to estimate the WTP. This implies that the travel cost as well as accommodation costs of researchers attending the event as well as the market value of the entrance fee[15] can be used as a proxy for WTP.

A detailed qualitative explanation about how the project intends to facilitate the creation of networks that will ultimately lead to broader economic benefits (whose direct measure is beyond the project scope) should also be provided.

[14] http://stats.oecd.org/index.aspx

[15] The costs of organising the conferences are in most cases already part of the operating costs of the project. If not, they need to be considered in the calculation.

Table 6: Summary: Benefits related to social capital development

Benefit	Quantification method	Value calculation
Benefit due to the creation of networks between researchers, and between researchers and private companies (through conferences, networking events etc.)	Market value as proxy for WTP	[Average travel costs + Average events/conference fee paid by participants] * [Average number of attendees] * [Events/conferences organised per year]

2.1.3 Benefits to the General Public

Reduction of environmental risks

a) The approach in the CBA Guide

For research infrastructure where the research carried out is specifically targeted at the reduction of environmental risk[16], it may be appropriate to calculate the benefits from this research. Examples of research in this area include; research into the reducing the impact of natural hazards or the impact of climate change risks, or research into technologies to reduce GHG emissions etc.

The CBA Guide proposes that the benefit of new knowledge in this area is calculated using the per capita avoided cost of the population potentially targeted or their willingness-to-pay for reduced environmental risk. Reference is made to literature that can help to quantify the relevant risks in individual cases.

The Guide further notes that as “ex ante, it is unknown as to whether the project will be successful in providing new solutions over its time horizon” (p. 277), a “carefully” optimistic scenario” should be defined. The evaluator should then consider the probability that the project is only partially successful and examine the risk affecting the Economic Net Present Value (ENPV) through a fully-fledged risk assessment, including the risk of failure to discover anything applicable.

b) JASPERS guidance

The inclusion of benefits in this area in the economic analysis is not a requirement for all projects. It is relevant only for specific infrastructures that conduct research in the field of environmental risk reduction.

It should also be noted that the calculation of this benefit is separate to the requirements of the Implementing Regulation to include the GHG emissions of the infrastructure, and the adaption measures employed in the structural and/or operating design of the infrastructure, in the CBA. These requirements are discussed in Section 2.1.4 below.

JASPERS recommendation is to pay attention to potential double-counting if the approaches described in the Guide for calculating the benefits of research on the reduction of environmental risks are used. If outputs such as publications, patents, etc. stemming from this research are also calculated, it is likely that the benefits will be captured twice - once through these outputs, and again through the per capita avoided cost of the population potentially targeted or their willingness-to-pay.

Reduction of health risks

a) The approach in the CBA Guide

[16] According to the CBA Guide section related to RDI, the ‘environment’ concept is understood here, in a broad sense, as the surroundings or conditions in which a person lives and operates.

According to the CBA Guide, research infrastructures that undertake research on health-related issues (for example, hospital research laboratories or other medical research facilities developing and administering a new type of treatment to their patients) should measure the marginal benefit of the results of this research.

The Guide makes a distinction between research that delivers results that are "internalized by businesses (e.g. in the pharmaceutical industry, or in the production of electro medical equipment), by means of patents" or other forms of IP; and research that affects, directly or indirectly, the target population through the reduction of mortality or morbidity rates or improved health conditions. The Guide suggests that the former, when fully internalized by businesses, should be captured through the methods described in "Benefits to businesses".

To capture the benefits associated with a reduction of mortality or morbidity rates or improved health conditions the following data is needed:

- a forecast of the number of patients over the time horizon of the project;
- an empirical estimation of the marginal benefit (value of a statistical life, quality adjusted life year, or other measures) for the target population that will be treated;
- a forecast of the success rate of the therapy.

As indicated in the CBA Guide, the latter is the most challenging aspect of the analysis, as, "by definition, in medical research it is unknown whether a new treatment will work or not on a certain pathology and for a certain sample of patients" (p. 279). It is therefore suggested that "the economic benefit to the target population shall be estimated under the (carefully) optimistic scenario, but the risk that the research is not fully or partially successful should be assessed through the risk analysis" (p. 279).

The CBA Guide also stipulates that the target area may be enlarged if one considers that the results of medical research will spread further through publications, conferences etc.

b) JASPERS guidance

The direct target area of the projects is the estimated number of patients to be treated at the facility in the future and it can be assumed that the project is successful in developing new treatment methods after a certain time span. Reasonable (and "carefully optimistic" as the CBA Guide puts it) and project-specific assumptions should be made (based if possible on the hospital's past research track record) and should be justified in detail.

When undertaking this analysis, one must be careful to assess how far and to what extent the research to be carried out triggers for example the following[17]:

- Quicker treatment/reduced stay in hospital
- Reduced year of disabled life
- Other reduced morbidity
- Reduced hospital costs (independently of duration of stay)

JASPERS proposes testing the main project-specific assumptions as part of the Monte Carlo Risk Analysis to be carried out for the overall CBA (see section 3 for more details.

Cultural effects for visitors

a) The approach in the CBA Guide

17 A distinction between the benefits due to increase in capacity of the hospital and the benefits that arise due to process innovation should be made.

Some RDI infrastructures include outreach activities for the general public. These can be guided tours, agreements between a research centre and schools and universities etc. The value created for visitors of large infrastructure projects can be estimated by the travel cost method or benefit transfer approach. The number of visitors each year and the appropriate willingness-to-pay needs to be estimated. The willingness-to-pay replaces the financial revenues from visitor fees if there are any.

It is also suggested to evaluate the economic value of educational books aimed at the general public as well as visits to websites or other virtual media. It is stated that this can be done qualitatively.

b) JASPERS guidance

JASPERS expects that the number of projects where cultural effects for visitors occur will be rather limited in number. For those projects that are big enough and of interest to the general public, it is recommended to use the travel cost method as outlined in more detail in the following JASPERS working paper:

JASPERS (2011), Best practice in the preparation of projects in the culture sector, http://www.jaspersnetwork.org/plugins/servlet/documentRepository/displayDocumentDetails?documentId=203

As regards the economic value of educational books, the market price may be a sufficient proxy for the economic value in most cases, as the book market is a well-functioning market.

JASPERS recommends describing the benefits related to websites etc. qualitatively.

2.1.4 Economic Costs and Benefits Related to Climate Change

The requirements for the inclusion of climate change in the CBA, as laid out in Section 2.3.3 of Annex III to the Implementing Regulation, can be broken down into two parts:

1) Climate change mitigation and GHG emissions

For the mitigation of GHG emissions, the regulation states that the CBA should take into account the costs and benefits related to GHGs emitted by the project. The methodology proposed by JASPERS for the calculation of these costs and benefits, is provided below.

2) Climate change adaptation

For adaptation, there are two basic requirements. Firstly, costs of measures aimed at enhancing the resilience of the project to climate change impacts that are justified in feasibility studies should be included in the economic analysis. Second, the benefits of those measures should be assessed and included in the economic analysis if they can be quantified; otherwise they should be properly described.

a) Climate Change Mitigation

In RDI infrastructure projects, GHG emissions are mainly due to the building's use of heat and electricity. If the project foresees the refurbishment of an existing building, GHG emission savings are usually achieved. In the case of the construction of a new building, the project usually leads to increased GHG emissions. These two cases are further described below.

i) Refurbishment of an existing building

Economic benefits can be derived from energy savings through energy efficiency tools and building design of projects where an existing building is refurbished. The quantification of greenhouse gas emissions savings due to these energy savings should, where possible, follow the EIB Carbon Footprint Methodology (EIB, 2014)[18].

The EIB Carbon Footprint Methodology suggests the use of the following formula for the calculation of CO_2 equivalents of Building Refurbishment projects (p. 34):

CO_{2e} per year (in g) = Electric Energy Use (kWh per year) * Country Electricity Grid Emissions Factor (*g CO_2 /kWh*) + Heat Energy Use (kWh per year)* project specific heat emission factor (gCO2/kWh)

The Country Electricity Grid Emission Factor can be taken from table A2.3 of the carbon footprint methodology. JASPERS recommends using the LV Grid for a research facility.

The heat emission factor should be project specific.

As regards the unit cost of carbon, the CBA Guide suggests using the central scenario of the EIB (2013), going from EUR 25 per tonne of CO_2e in 2010 and then assuming a gradual increase to EUR 45 per tonne of CO_2e until 2030 by applying an annual adder of 1 (see page 63 of the CBA Guide).

ii) Construction of a new building

In projects where a completely new building is constructed, economic costs due to increased CO_2 emissions may occur, if the emissions from the energy consumption of the new building are greater than the emissions expected in the reference scenario (which is often a no investment/no building scenario) and are not offset by renewable energy generation.

For the quantification of the economic costs related to GHG emissions, the same formula as above can be used.

Table 7: Summary: Benefits and costs related to variations in GHG emissions

Benefit	Quantification method	Value calculation
Change GHG emission (if reduction then benefit, if increase then cost)	Incremental change in associated GHG emissions valued per tonne of CO_2 equivalent	[GHG savings in MtCO2e] * [Value for each MtCO2e following CBA Guide]

b) Climate change adaptation

All projects are required to consider their vulnerability to potential climate hazards as part of a project specific climate risk assessment.

Where the assessment identifies that a project is at risk due to current climate variability and/or future climate change, the project should implement adaptation measures in the design and/or operation of the project to reduce the risks to an acceptable level.. The project promoter is required to include the cost of these measures in the economic analysis and assess the benefits.

If adaptation measures have been put in place, their cost will inherently be part of the total cost of the project, as presented in the economic analysis. The inclusion of this cost, as required by the Implementing Regulation, is therefore unproblematic.

What may be difficult in practice, will be identifying and separating out the exact costs attributable to these adaptation measures and quantifying the benefits (this may be particularly true if climate considerations were taken into account early on the projects development). Where this is the case, JASPERS suggests describing the measures taken, rather than trying to assign specific costs, and qualitatively describe the associated benefits.

[18] http://www.eib.org/attachments/strategies/eib_project_carbon_footprint_methodologies_en.pdf

2.2 Additional Economic Benefits

In addition to the economic benefits listed in the Implementing Regulation, JASPERS advises including learning-by-doing benefits and benefits related to open access to research infrastructure, where relevant.

2.2.1 Learning-by-doing Benefits

As suggested in Florio et al. (2016), economic benefits may be created for high-tech suppliers of non-off-the-shelf equipment that are involved in the design, construction or operation of the RDI infrastructure. These benefits are not considered in the Implementing Regulation, but are mentioned in the CBA Guide (2014, p.287). The approach suggested by Florio et al. (2016) to estimate the incremental shadow profit of suppliers is the following:

Table 8: Summary: Benefits related to learning-by-doing

Benefit	Quantification method	Value calculation
Learning-by-doing benefits for the supply chain	Incremental shadow profit	Volume of high-tech procurement*sales multiplier*average profit margin

The volume of high tech procurement is project-specific data that should be made available by the project promoter. For example, one can estimate the % of the overall investment costs that is spent on non-off-the-shelf equipment.

As regards the value to be used for the sales multiplier, Florio et. al. (2016) provides an example where the multiplier has a uniform probability distribution ranging from 1 to 3 (the baseline value is 2) (p. 30). The average profit margin is estimated by the authors based on a triangular probability distribution ranging from 1% to 10% with a modal value of 7%.

2.2.2 Open Access to Research Infrastructure

Another additional economic benefit that is not considered but is of potential relevance, is open access of research facilities for visiting research fellows free of charge and the use of facilities by the private sector.

Open access for research

Open access to the research infrastructure is the distribution of access time of the facility and its equipment to research teams based on scientific merit, judged on the quality of their experiment proposals, along with the track record of the applicants, without consideration of the nationality of the applicants.

The justification is that by allowing users to access the facility free of charge or at a fairly low fee, research infrastructures promote the mobility of researchers in the EU.

In order to quantify the economic benefits that arise from the access granted to visiting researchers, the use value of the research infrastructure needs to be quantified.

The starting point for JASPERS’ approach is to estimate the proportion of the facility that will be used by “home” researchers i.e. academics employed by the project promoter, versus external researchers on an annual basis. If for instance the given facility is expected to be one third utilised by the project promoter, with the remaining two thirds of its capacity made available to research teams from across Europe under the open access principle, and the economic benefits expected to be generated by the project promoter's team are X, then assuming the same productivity of external researchers, the total economic benefits of the facility can be expected to be 3X[19].

Use of facilities by the private sector

Where the use of facilities by an external party (usually the private sector) generates revenue, JASPERS advises using the fees applied for access as a proxy for willingness to pay.

To calculate the economic value of this use two pieces of information are needed, the proportion of the facilities capacity devoted to use by the private sector, and the revenue generated.

If fees are used as direct proxy for benefits, there are a number of risks that need to be mitigated and kept in mind by the expert appraising the project. In particular, if fees are not properly estimated and justified there is a risk that fees will be increased solely in order to improve the apparent benefit.

Table 9: Summary: Benefits related to open access to research infrastructure

Benefit	Quantification method	Value calculation
The value of research carried out by visiting researchers with open access to the RDI facility	Same assumed productivity for open access as for project promoter	[Economic benefits per unit of capacity used by project promoter] * [Units of capacity to be utilised by visiting researchers under open access policy]
Value of research carried out by paying users with access to the facility	Market value as a proxy for benefit	Fees paid by private sector for access to the facility; alternatively, a willingness to pay approach

2.2.3 Benefits arising from contract research and academic consulting

It is increasingly common for universities to engage in business orientated research activities such as academic consulting and contract research.

JASPERS proposes that one way to capture some of the benefits arising from academic consulting and contract research is to evaluate the financial revenues from these contracts with the private or public sector[20].

Table 10: Summary: Benefits related to academic consultancy and contract research

Benefit	Quantification method	Value calculation
Benefits arising from academic consultancy or contract research	Market value as proxy for Willingness to Pay (WTP)	(Average financial value per contract) * (number of research or consultancy contracts)

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[19] As an alternative approach, Florio et al. (2016) suggests to either using the long-run marginal cost of the services as a proxy for the economic benefits or the WTP for the services. The WTP should be evaluated based on contingent valuation methods. The long-run marginal cost can be estimated based on the costs incurred by the infrastructure to make the services available by using, for example, the following formula:
((Total hours of activity * Share used for free access) * (Economic production cost of service)) * Discounting = Total Discounted Benefit. JASPERS proposes estimating the economic production cost of service based on the average incremental economic cost, which is the reference value for the cost of one hour of use of the facility.

[20] Note that it is stated in the CBA Guide (p. 279) that "research contracts or contributions granted from the public sector, either through competitive or non-competitive arrangements, should be considered operating revenues (…) in line with Article 61 of Regulation 1303/2013) but only if they are payments against a service directly rendered by the project promoter. This condition is often verified when the ownership of the expected research output is transferred to the contracting public entity and does not remain with the research institution."

Provided that the commercial price of the contract includes depreciation and return of capital and respects the relevant state aid rules, the financial value of academic consultancy and research contracts can be seen as an appropriate proxy for their economic value. The resulting calculation is then straightforward, as shown in table 10**Error! Reference source not found.**.

2.3 Quantification of Economic Residual Value

As regards the calculation of the residual value (in financial and economic analysis), Article 18 (1) of the Delegated Regulation stipulates the following:

"*Where the assets of an operation have design lifetimes in excess of the reference period […], their residual value shall be determined by computing the net present value of cash flows in the remaining life years of the operation. Other methods of calculating residual value may be used in duly justified circumstances*."

This is relevant for a large number of RDI projects. As the reference period for RDI infrastructure is set to 15-25 years by the Delegated Regulation, there is indeed the need to extend the period beyond these 25 years in justified cases, in particular projects with a higher share of long-lifetime assets such as buildings and other civil works[21].

The CBA Guide makes it clear that in particular for non-revenue-generating projects other methods can be applied such as "*computing the value of all assets and liabilities based on a standard accounting depreciation formula or considering the residual market value of the fixed asset as if it were to be sold at the end of the time horizon*" (p. 45).

This may be justifiable for projects with a high share of technology or other shorter life assets, and a low share of long-lifetime assets such as buildings and other civil works[22].

In the case of non-revenue generating projects where the net present value of future cash flows method is applied to estimate the economic residual value, the financial residual value should be put to zero.

2.4 Overview of benefits and quantification methods

The table below provides a summary of the benefits and their respective quantification methods presented in the present paper.

This list of economic benefits is by no means prescriptive but rather a proposal based on JASPERS-supported projects along with values from other sources which may be used to approximate market values.

Also additional benefits may be added depending on the objectives of specific projects.

Table 11: Summary table: RDI project benefits, quantification methods and valuation calculations

	Benefit	Quantification method	Value calculation

[21] Potential reinvestment costs should be carefully considered. Reinvestment costs may become necessary during the extended period of analysis in order to keep the infrastructure operational. The estimation of these reinvestment costs should be based on expert estimate and is project-specific. It is also important to ensure that, where relevant, decommissioning costs are included in the analysis.
[22] It may be appropriate to determine the reference period based on the (shorter) lifetime of the dominant asset and deal with the residual value of the civil works using the net book value (depreciation) approach, or where appropriate the residual market value of the asset.

Benefits to businesses			
Establishment of spin-offs and start-ups	Incremental shadow profits generated by spin-offs and start-ups	Number of jobs created * present value of shadow profit per employee	[Number of newly established entities] * [average number of employees per entity] * [shadow profit per employee]
Development of new/improved products and processes	Benefit attributed to patents granted	Market value as proxy for WTP	[Market value of patent] * [number of patents granted]
Knowledge spillovers	-	-	-
Benefits to researchers and students			
"New research"	Benefit to society of new scientific publications of researchers that are users of the facility	Marginal production costs (remuneration of authors)	([Average gross annual salary of scientist] / [Average % time researcher spends on 1 publication]) * overall number of publications by project per year
Human capital formation	Benefit to society of educated labour force	Market value as proxy for WTP	[Economic benefit in year t] = [Number of graduates in year t] * [Present value in year t of incremental gross salary over average number of years of working career ahead of graduates]
Social capital development	Benefit due to creation of networks between researchers and between researchers and private companies (through conferences, networking events etc.)	Market value as proxy for WTP	[Average travel costs + Average events/conference fee paid by participants] * [Average number of attendants] * [Events/conferences organised per year]
Benefits to the general public			
Reduction of environmental risks	Benefits to general public of research that leads to a reduction of environmental risks	Expected avoided costs as a preferred method (WTP only when duly justified on the basis of sound assumptions)	Appropriate methodologies based on the risk directly tackled by the research, where relevant (see chapter 4.3 of the CBA Guide)
Reduction of health risks	Benefits to general public of research that leads to a reduction of health risks	Value of statistical life	No generalised approach
Cultural effects for visitors	Benefits due to outreach activities to the general public (i.e. visitors, tourists)	Travel Cost Method	Approach according to JASERS Working Paper on Cultural Projects
Other economic benefits			
Climate change benefits (or costs)	Change in carbon footprint (if reduction then benefit, if increase then cost)	Incremental change in associated GHG emissions valued per tonne of CO_2 equivalent	[GHG savings in MtCO2e] * [Value for each MtCO2e following CBA Guide]
Learning-by-doing-benefit	Economic benefit to firms producing equipment for a RDI infrastructure	Incremental shadow profit	Volume of high-tech procurement*sales multiplier*average profit margin

Open Access to research infrastructure	The value of research carried out by visiting researchers with open access to the RDI facility	Same assumed productivity for open access as for project promoter	[Economic benefits per unit of capacity used by project promoter] * [Units of capacity to be utilised by visiting researchers under open access policy]
	Value of research carried out by paying users with access to the facility	Market value as a proxy for benefit	Fees paid by private sector for access to the facility; alternatively a WTP approach
Benefits arising from academic consultancy or contract research	Value of research carried out for public or private sector on the basis of contract research or consultancy contract	Market value as proxy for Willingness to Pay (WTP)	(Average financial revenues from contracts) * (number of research contracts)
Residual value of infrastructure	Benefit to society of residual value of investment	NPV of future costs and benefits or Net book value (depreciation method)	

3 Risk Assessment

1) New requirements as set out in the Implementing Regulation

According to Section 2.4 of Annex III of the Implementing Regulation, a risk analysis should comprise a sensitivity analysis and a qualitative risk analysis. The requirements as regards the sensitivity analysis have not changed compared to the previous period, whereas the qualitative risk analysis needs to be somewhat more detailed than what was acceptable in the previous perspective. Detailed information is provided in Section 2.4 of Annex III of the Implementing Regulation (note also the rather long list with the main risks for the RDI sector to be covered in the analysis provided in table 2) and in chapter 2.9 of the CBA Guide. The methodology is easily applicable to RDI projects. Therefore, no further guidance is provided here.

In addition, it is stipulated in Section 2.4 of Annex III of the Implementing Regulation that a probabilistic risk analysis is necessary in those cases “where the residual risk exposure is still significant”. This is arguably the case in RDI projects, where in particular the assumptions used for the calculation of economic benefits are subject to a significant amount of uncertainty.

The probabilistic risk analysis should include the following two steps:

i) Probability distributions for critical variables[23] informing about the likelihood a given percentage change in the critical variables will occur.
ii) Quantitative risk analysis based on Monte Carlo simulation, providing probability distributions and statistical indicators for expected result, standard deviation, etc. of project financial and economic performance indicators.

2) Probabilistic Risk Analysis - Methodology presented in the CBA Guide

The CBA Guide is very specific about the fact that the uncertainties in the CBA for RDI projects are so significant that a probabilistic risk analysis should be carried out. The CBA Guide provides some examples of different probability distributions for the critical variables to be tested, which are a normal distribution, a triangular distribution and a rectangular distribution (all continuous probability distributions).

[23] The critical variables are to be determined by the sensitivity analysis.

3) JASPERS guidance

Step 1: Probability distribution of critical variables

The most important assumptions to be made for a probabilistic risk analysis concern the probability distributions of the values the critical variables can take. In line with common practice and the CBA Guide, a continuous probability distribution should be chosen as these are more complete than discrete distributions[24]

Triangular distribution may in general be more suited for the analysis of financial variables such as investment costs, operating costs, revenues etc., whereas for the economic variables (like value of spin-offs, publications etc.) a rectangular probability distribution may be more appropriate.

The main difference between the two types of distributions is that in the case of triangular distributions it is assumed that the estimated value of the base-case variable used in the CBA is the most likely one and that other values within a given range between an assumed maximum and minimum value are also possible (the likelihood depends on the exact probabilities in a specific case). In rectangular distributions only one probability of a range of outcomes between a maximum and minimum value (not of a specific outcome) is given. This means that for a given variable any other value within a given range is as likely as the one that was chosen as a base-case in the CBA.

Step 2: Quantitative risk analysis based on Monte Carlo simulation

Once the probability distributions of the critical variables have been defined, a Monte Carlo simulation can be run by Excel. The Excel sheet to be developed can be based, to a large extent, on the Excel Sheets presented as part of the following two JASPERS papers:

Economic Analysis of Gas Pipeline projects (Francesco Angelini),
http://www.jaspersnetwork.org/plugins/servlet/documentRepository/displayDocumentDetails?documentId=183

Monte Carlo simulation of Cost Benefit Analysis results (Francesco Angelini and Marko Kristl),
http://www.jaspersnetwork.org/plugins/servlet/documentRepository/displayDocumentDetails?documentId=223

[24] One could think of a distribution of probabilities of different scenarios to take place. For example, a scenario where the project is not successful at all, i.e. achieves no positive outcomes (“very pessimistic scenario”), one where it is 25% successful (“pessimistic scenario”) and another one where it achieves 50% of the proposed outcomes (“rather pessimistic scenario”) successful.

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