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A Practical Guide: Assessment of Socio-Economic Impacts of Research Infrastructures

Danube Transnational Programme
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A PRACTICAL GUIDE: ASSESSMENT OF SOCIO-ECONOMIC IMPACTS OF RESEARCH INFRASTRUCTURES

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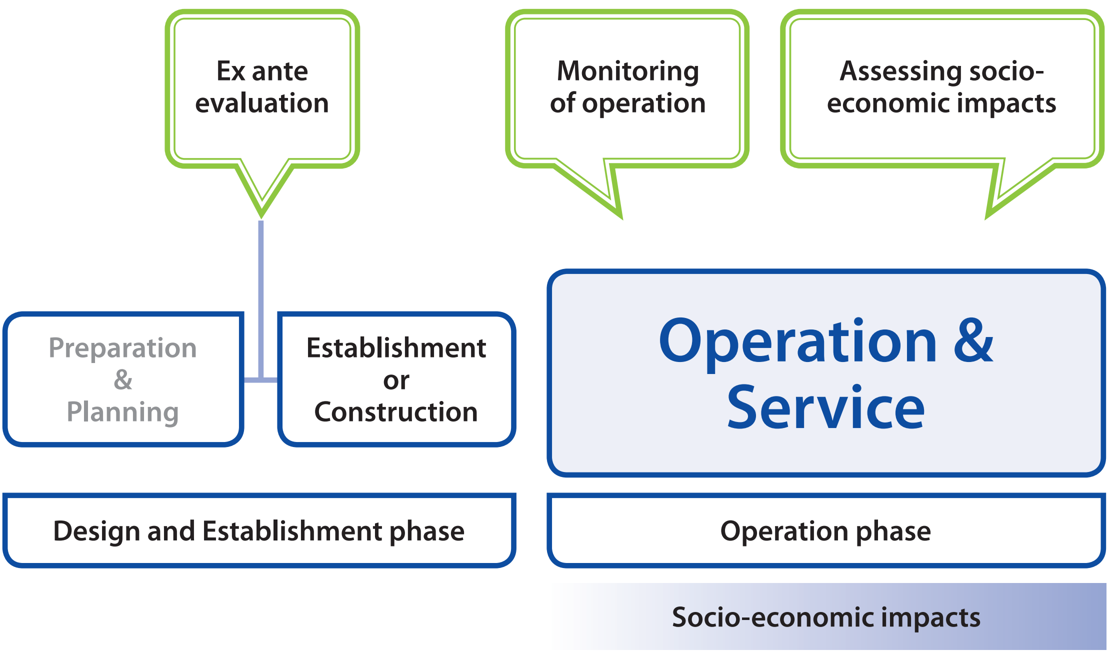
EXECUTIVE SUMMARY

The ResInfra@DR project has aimed at upgrading the knowledge of policy-makers and policy delivery organisations involved in the funding of research infrastructures (RIs), and RI managers. Thus, it has facilitated a dialogue process for RI stakeholders in the Danube macro-region; organised training workshops for RI policy-makers, managers and reviewers; compiled a registry of competent reviewers for RI evaluations; and arranged pilot peer learning activities to help existing RIs improve their operations and planned RIs to fine tune their investment plan and business model.

> For a more detailed account of these activities and their results, please consult: http://www.interreg-danube.eu/approved-projects/resinfra-dr

The project has produced three guidance documents for RI policy-makers, managers and reviewers on ex ante evaluation, monitoring and assessment of the socio-economic impact of RIs, thus covering the life cycle of RIs.

Life cycle of RIs, the relevance of ex ante evaluation, monitoring and socio-impact assessment at different stages of the life cycle



Source: ResInfra@DR, 2019

These guides, including this one, have been developed by the ResInfra@DR consortium with input from RI policy-makers, managers and reviewers at several workshops and a concluding consultation meeting. Together, these three documents aim to provide an overview of the relevant processes and methods to improve the management of RIs leading to better utilisation of their precious and unique capacities, enhance performance, and pronounced socio-economic impacts.

This document, intended for RI policy-makers, funding agencies, RI managers, and other relevant actors, considers the major aspects of assessing the socio-economic impacts of RIs. Social and economic impacts are often assessed separately and with different methods, but in fact they are complementary and sometimes overlap, which explains the importance of following an integrated approach, which can produce comprehensive information on these aspects in a cost-effective way.

The main purpose of socio-economic impact assessment is to prove to society that RIs bring benefit to the entire society and that their relevance goes far beyond pure science. It also helps RI managers in setting strategic directions; thus it is recommended an assessment to be conducted every 4-5 years. RI managers and policy-makers, however, face several challenges when organising or commissioning an assessment. First, there is no 'blueprint' or 'easy-to-follow' manual for assessing RIs: there is no set of methods or indicators that would be automatically appropriate for every RI; each RI needs to be understood first, and then assessed in its own context. Second, ex ante evaluation, monitoring and the assessment of socio-economic impacts are closely interlinked. There are at least two preconditions for a useful assessment exercise. The intervention logic of a given RI – why investment is needed, what impact can be expected and through what mechanisms – needs to be clarified as part of an ex ante evaluation. Further, an appropriate monitoring system should be in place not only for the purpose of monitoring, but also to systematically collect relevant data for socio-economic impact assessment. Third, timing is crucial: to measure certain impacts, one might need to wait. Fourth, some RI managers and/or researchers may be reluctant to engage in assessment exercises. However, assessment is a must, as RIs are funded by public money. Fifth, the evaluation culture in general is weak in quite a few countries, including several in the Danube macro-region, hence the required methodological skills are missing or not yet sufficiently developed. Assessing the socio-economic impacts of RIs is a necessity even in these countries, for the above reason. Learning by doing can contribute to developing missing capacities and skills.

1 INTRODUCTION

This guide is one of five documents intended to enhance the utilisation of research infrastructures (RIs) in Danube macro-region countries. The documents include three practical guides (on ex ante evaluation, monitoring and assessment of the socio-economic impacts of RIs) and two sets of recommendations (one for RI policy-makers and one for managers).

The current document proposes some practical guidelines for assessing the socio-economic impacts of RIs. It presents different types of impacts and some relevant questions to evaluate them, lists the typical indicators used to assess different impacts, and proposes ways to collect data for these indicators. The guide also discusses how to organise and manage the process of assessing the socio-economic impacts of RIs.

It needs to be noted that this guidance document was written with the intention to be accessible and useful for a very diverse audience, from RI policy-makers to managers to researchers in a broad spectrum of science domains. Hence, it cannot provide specific and tailor-made recommendations on how to evaluate particular socio-economic impacts related to each type of research infrastructure. Nevertheless, it is intended to present assessment indicators, methods and processes that can be applicable and relevant in numerous different contexts.

What do we understand as research infrastructures?

Research infrastructures need to be understood broadly, including **all elements, which are indispensable for conducting scientific research and disseminating results**: equipment, biobanks and other banks of various materials, databanks, information systems, as well as human resources operating and using RIs. The variety of RIs is huge, and because they serve different research communities with complex research needs and objectives, each RI has its own specific characteristics.

Research infrastructures include:

- Major equipment or sets of instruments used for research purposes;
- Knowledge resources such as collections, archives, structured information or systems related to data management and used in scientific research;
- Enabling information and communication technology-based infrastructure or 'e-infrastructure' such as grid, computing, and software communications;
- Any other entity of a unique nature that is used to achieve excellence in research.

According to **the level of maturity (life cycle),** research infrastructures can be classified as:

- Proposals for the establishment of research infrastructures ("concept development");
- RIs in the design phase;
- RIs in the preparation phase;
- RIs in the construction phase ("implementation phase");
- RIs in the operation phase;
- RIs in the process of decommissioning ("termination phase").

According to their **geographical scope/relevance**, RIs are:

- Regional;
- National;
- Macro-regional;
- Pan-European.

TABLE 1: TYPOLOGY OF RESEARCH INFRASTRUCTURES ACCORDING TO THEIR STRUCTURE/DISTRIBUTION

Type of research infrastructure	**Description**	**Examples**
Single-site facility	Unified body of equipment at one physical location	High-performance laser system; clean room; coastal observatory; centre of competence; e.g. Multi-purpose Hybrid Research Reactor for High-tech Applications (MYRRHA); European Solar Telescope (EST)
Distributed facility	Network of distributed instrumentation or collections, archives and scientific libraries	European Light Infrastructure (ELI); Council of European Social Science Data Archives; Central European Research Infrastructure Consortium (CERIC); International Centre for Advanced Studies on River-Sea Systems (DANUBIUS RI); European Plate Observing System (EPOS)
Mobile facility	Mobile vehicles specially designed for scientific research	Research vessels, satellite and aircraft observation facilities
Virtual facility (e-infrastructures)	ICT-based system for scientific research, including high-capacity communication networks and computing facilities	European Grid Computing Infrastructure; Digital Research Infrastructure for the Arts and Humanities (DARIAH); Partnership for Advanced Computing in Europe (PRACE)

Source: Griniece E., A. Reid, J. Angelis, 2015, p. 5.

Why conduct an assessment of socio-economic impacts

Research infrastructures are primarily intended to facilitate research activities, but **their societal relevance goes beyond the realm of pure research**. The development of technologies, generation of knowledge and other activities of skilled researchers stimulate innovation, attract internal and external investment, and boost economic growth. This affects the economic, social and cultural life of a host region.

> *"An impact evaluation provides information about the impacts produced by an intervention - positive and negative, intended and unintended, direct and indirect. This means that an impact evaluation must establish what has been the cause of observed changes (in this case 'impacts')."*
> ESFRI – Long-Term Sustainability Working Group, 2017

Socio-economic impact assessment is a tool that aids in understanding a potential range of impacts by research infrastructures. The knowledge obtained through this assessment can contribute to the preparation of strategies to minimise the negative and maximise the positive impacts of RI's activities. Assessment of socio-economic impacts is also **necessary to obtain and justify the public**

funding that RIs receive. For **policy-makers**, such assessment is **very valuable in improving policies and programmes for planning, establishing and financing RIs**.

As stated by ESFRI, national authorities and funding bodies *"should be explicit about the role that socio-economic benefits play in their strategy and funding decisions, so that RI operators are aware of their significance and take appropriate action when developing strategy and operating models to enhance them in the future.* ***Periodic monitoring of societal impact should be part of the regular assessment of RIs"*** (ESFRI – Long-Term Sustainability Working Group, 2017).

Further, RIs "*should dedicate sufficient resources both to evaluate their value to the economy and society at large and to communicate this to targeted audiences, from the general public to policy- makers as part of local, national and European science-policy-society dialogues to gain acceptance and support at all levels*" (ESFRI – Long-Term Sustainability Working Group, 2017).

The potential benefits of assessing the socio-economic impacts of RIs

TABLE 2: WHO BENEFITS FROM ASSESSMENT OF THE SOCIO-ECONOMIC IMPACTS OF RIS AND HOW?

Policy-makers and RI funders	Assessment of the socio-economic impacts of RIs: ▪ will aid them understand the full variety of ways in which the outcomes of publicly funded research can benefit national economies, affect the lives of citizens, and address important societal challenges ▪ is essential to justify the investment of public funds for RIs and can help them decide how to allocate – the often insufficient – funds earmarked for R&D ▪ should be introduced as an obligatory element of the decision-making process. If decisions on funding new RIs or upgrading existing ones are based solely on scientific criteria, they might be influenced by different scientific or business lobbies, as opposed to a systematic and transparent decision-making process
RI managers	Assessment of the socio-economic impacts of RIs: ▪ provides a practical tool to **measure progress toward objectives**, identify problems and design necessary corrective actions ▪ can be applied as an argument to convince decision-makers **to obtain public funding for the operation, maintenance and upgrading of RIs** ▪ offers a broader view on the potential direct and indirect benefits of an RI ▪ helps look beyond cost-effectiveness concerns and optimise organisational structures, procedures and internal policies; this **maximises socio-economic impacts without eroding primary research objectives**
RI staff members	Assessment of the socio-economic impacts of RIs: ▪ provides possibilities to **obtain new knowledge and skills** ▪ helps them realise how important **their contribution is to generating long-term societal benefits** ▪ can additionally motivate them to reach the pre-established objectives of an RI ▪ may open new career advancement options
Other actors	Assessment of the socio-economic impacts of RIs: ▪ helps identify possible **collaborative or contracted research projects with businesses** ▪ can **raise awareness** among policy-makers, media, public and private entities, and the general public about the importance/necessity of investing and supporting the set-up of RIs ▪ can flag possibilities for **national and international research collaborations**, knowledge exchange and networking

2 ORGANISING AND MANAGING A SOCIO-ECONOMIC IMPACT ASSESSMENT OF RIS

Socio-economic impact assessments can be performed both **internally and externally**. An internal assessment may be performed in a shorter timeframe than an external assessment. Internal assessments can also be conducted as part of the preparation for external assessments, as they can provide crucial input. In this case, a major task for external evaluators is to assess whether the data and conclusions presented in an internal assessment report are credible and comprehensive.

External assessments can be performed by funding bodies if they have an in-house assessment unit that possesses the required skills and experience. Otherwise **independent national and international experts can be commissioned**.

Even in large countries, with an advanced evaluation culture, it might be **very useful to include foreign experts in an assessment process** mainly performed by national experts. In small(er) countries, especially those where evaluation traditions are weak, a leading role played by foreign experts is inevitable. National experts' contributions are also crucial, as a thorough understanding of a national (or regional) innovation system is key to a useful assessment.

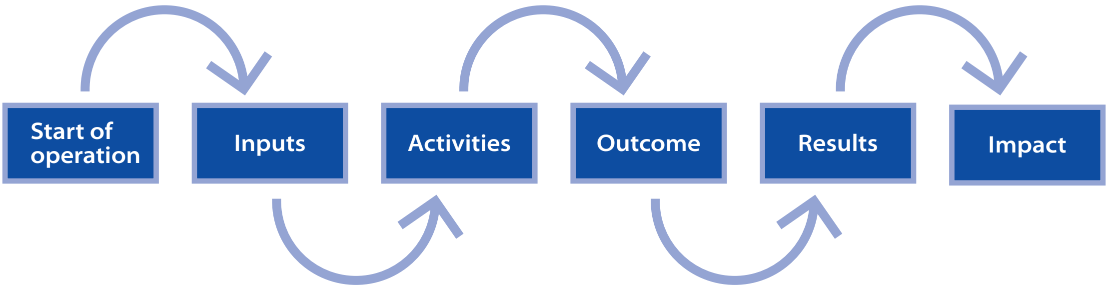
TABLE 3: THE PROS AND CONS OF INTERNAL VS. EXTERNAL EXPERTS

	Internal	External
Pros	Good knowledge and understanding of an RI and the context (institutional and organisational framework) in which the RI is active	Increased and more diverse experience and expertise; stronger credibility at the international level
	Higher availability to participate in meetings and activities when required; easier access to the RI and its personnel	Perceived objectivity and open-mindedness; this aspect weights even more in the case of public funding (accountability purposes, avoidance of conflict of interest)
	Good capacity to collect information, when an RI is less willing to give important information to external experts	Good capacity to collect information, as sometimes people find it easier to open up to a stranger rather than someone they work with
	Reduced costs (lower fees and travel costs)	Increased willingness to criticise and raise uncomfortable issues when necessary
	Utilisation of evaluation results; due to better knowledge of an RI's specificities, internal evaluators might be able to produce findings that are more likely to be implemented	Utilisation of evaluation results can be ensured through a participative approach (working closely with stakeholders)
Cons	Potential lack of expertise and experience in conducting evaluation; less diverse experience	Reduced understanding of RI's specificities; language barriers; weaker knowledge and understanding of the institutional and organisational framework of the country in which the RI is located
	Increased risk of subjectivity and reduced willingness to criticise, due to potential negative professional and social consequences and potential conflicts of interest	Potentially decreased availability to participate in meetings, activities and on-site visits (involves travelling back and forth from one country to another)
		Higher costs (fees, accommodation and transportation costs)

For Danube macro-region countries it is **strongly recommended to appoint external/international experts** to assess the socio-economic impacts of RIs. Of course, external experts need to work together with internal experts, but the leader of the assessment team should be an external expert with sufficient experience and expertise. This will raise the cost of an assessment, but the **benefits of a high-quality evaluation will be multiple and long-lasting**. An assessment of socio-economic impacts is conducted only once every four to five years, and hence **it pays off to ensure that it is conducted properly**.

3 TYPICAL CHALLENGES AND LIMITATIONS OF IMPACT ASSESSMENTS

FIGURE 1: THE LONG AND WINDING ROAD TO IMPACT



In recent years, several attempts have been made to propose a comprehensive and unified framework for assessing the socio-economic impacts of RIs, but most likely **it will never be possible to come up with a 'one-size-fits-all' solution for mapping all socio-economic impacts.**[1]

Assessment of the socio-economic impacts of research infrastructures is **a complex exercise** that involves numerous challenges and hides several pitfalls. To begin with, as demonstrated by Figure 1, the road to visible and measurable impacts is very long and full of twists and turns.

- **Impacts can** in most cases **be observed only after several years** of hard work and countless activities, and are **not always imminent,** even when the first (scientific) results and outcomes have already been achieved.
- Often it can be **very difficult to gather data** about the impacts and verify these data.
- An RI's socio-economic impacts can be **direct and indirect, intended and unintended, expected and unexpected, positive and negative**.
- **The socio-economic impact of different RIs should never be compared**, because each RI is unique. An assessment should, therefore, compare impacts only against the specific objectives of the given RI.
- Socio-economic **impacts are also heavily influenced by a large variety of external factors**, and hence an RI can never be considered fully responsible either for the positive or the negative impacts of its work. Indicators, which are used to establish that a certain impact has occurred, are rarely able to provide a comprehensive explanation as to why the impact actually happened.
- Some of the impacts may be produced by the indirect use of an RI, making it even more difficult to assess them.
- Certain types of impacts are more relevant for some RIs and less for others. **Each RI has to select the appropriate impacts, assessment methods and indicators** based on its own specific goals, while also taking into consideration the strategic visions and heterogeneous objectives of its stakeholders.

1 Several models to evaluate the socio-economic impact of RIs have been developed by projects supported by the European Framework Programmes (FP7, H2020), see, for example, EVARIO, http://cordis.europa.eu/project/rcn/97196_en.html; ERINA+, http://cordis.europa.eu/project/rcn/95676_en.html; and RIFI, http://cordis.europa.eu/project/rcn/91271_en.html

- Finally, it should never be forgotten that although they are very important, indicators for assessing the socio-economic impacts of RIs are **only part of an entire set of indicators necessary for managing an RI**.

All these challenges, however, should not discourage RI managers from engaging in assessing socio-economic impacts. Quite the contrary – such assessment is **absolutely necessary**. Most RIs are funded by public money and socio-economic impact assessment is **the best tool to prove** to policy-makers and the general public **that RIs bring numerous benefits to the society** and that their **relevance goes far beyond pure science**. Needless to say, an assessment also helps the RI managers plan the operation of their RI and secure its long-term financial sustainability.

3.1 Availability of relevant data and the relevance of available data

Challenge	All RIs collect and provide information regarding their scientific and technological activity, but collecting and analysing information about socio-economic impacts is usually given far less attention. Much of the data needed for socio-economic impact assessment (see Annex 1 for details) can only be obtained through dedicated, often costly methods (interviews, surveys, case studies). In addition, many RIs have a supranational impact, making the systematic collection of data much more difficult than in cases where RIs have a local and regional impact.

Possible solution	Determining the values of selected indicators requires the regular collection of a wide range of data. A significant part of the data needed to measure socio-economic impacts can – and indeed, should be – generated during day-to-day operations. These include: ▪ The database of users (academic researchers, businesses and other users; domestic and foreign, etc.) ▪ The database of students using the RI (the number of MA and PhD theses completed thanks to the use of a given RI, the number of PhD students and post-docs involved in projects conducted at the RI) ▪ The number of RI staff giving lectures/courses at universities ▪ The database of RI supplier contracts, including data on main characteristics of suppliers (local, regional, other domestic, foreign; size; type of product/service provided, etc.) ▪ The number of external users, who are likely to use travel, accommodation and other local services (these data are required for further calculations/estimations).

Example	The impact of RI on innovations – either for business purposes or solving societal challenges – is highly likely to be complex and obtained via multiple pathways. Therefore, it is necessary to carry out in-depth interviews with researchers, relevant business people and other users, and/or conduct surveys by sending carefully designed questionnaires to relevant partners, users, and analysts.

3.2 The impact is known – but who did it? (Attribution of impact)

Challenge	The operation of large RIs can cause a number of positive and negative externalities. For instance, RIs cause positive externality if the turnover of nearby hotels or catering establishments increases as a result of the increased number of visiting scientists or scientific conferences. RIs can also cause negative externalities: land loss, change in land value, congestion, greenhouse gas emissions etc. Such externalities should also be considered in assessing socio-economic impacts, but it is very challenging to establish to which extent the operation of an RI is responsible for the occurance of these externalities. Take for example one of the most important indicators – the number of new jobs created. Successful innovation activities undoubtedly lead to the creation of new jobs either at existing or newly established firms, but pieces of information about these developments are possessed by different actors, making it a demanding analytical task to identify and quantify the contribution of RIs to job creation.

Possible solution	When assessing the indicators listed in Annex 1, the role of multipliers must be considered, as they inevitably affect the impact of indicators. In order to achieve accurate assessment results, the application of quantitative methods should be supplemented with qualitative insights and validation. Another important aspect is time; the longer the time which elapses between the first appearance of a result achieved by an RI and its practical application (either for business or societal goals), the more likely it is that other factors will also enter the picture, making it more difficult to attribute a certain practical impact to the specific result of a given RI. Without considering these external influences, the socio-economic impacts might be underestimated.

Example	ELI-ALPS plans to pay special attention to the training of, and providing information to, secondary school teachers, as they influence students by passing on their knowledge. The course is open to active high school physics, biology and chemistry teachers. Clearly, the number of teachers who have participated in this special training is easy to obtain. However, the ultimate goal is to stimulate students to opt for STEM careers and information about the career paths of students is not easily accessible to ELI-ALPS and their evaluators. Establishing a causal link between courses offered to teachers and the impact of those on the career choices of their students would require further detailed, complex, time-consuming, and expensive analyses.

3.3 Smoke without fire – the problem of unfulfilled potential

Challenge	Research infrastructures are enablers. The knowledge, prototypes, discoveries, human capital, etc. which they produce represent an opportunity for their economic and social environment. However, if this environment does not have the capacity to use and further develop the opportunities delivered by the RIs, then the significant potential for their socio-economic impacts will remain partially or fully unfulfilled. In other words, the extent of socio-economic impact of a given RI depends on the quality of its immediate economic environment: the aspirations, strategies, skills and resources of those actors who can use the services and/or outcomes of RIs.

Possible solution	■ An assessment of the socio-economic impact of an RI must always take into consideration its limitations. It is never possible to fully explore the extent to which socio-economic benefits are influenced by external activities and factors. ■ A particular result/outcome of an RI's activities might not produce any visible impact in the short or even medium term. However, it could have a considerable impact in the long run. It is therefore necessary to collect and store data regularly and over long periods. ■ In order to accurately assess RI-induced impacts, other determinants – such as parallel initiatives in higher education, support measures for enterprises and national legal frameworks – should be also studied (as much as possible).

Example	Even a widespread and commonly used indicator such as patent citations suffers from some limitations. First, not all inventions are patented or even patentable. Moreover, even when patents are used to protect intellectual property rights, the propensity to patent differs considerably across sectors and technological fields, and hence relying merely on patent citations may seriously underestimate the contribution of an RI to innovation activities. To counter a widely shared misinterpretation, it should also be stressed here that innovations are new solutions applied in practice, and thus patents can provide important input to innovation, but are not innovations, per se.

3.4 From zero to hero – the long delay

Challenge	The amount of time that elapses between a scientific discovery and its practical use may be rather long. This makes it difficult to assess the economic impacts of relatively "young" RIs, but even in the case of established ones, the impacts have a long time-span, and proper assessment can require much more time and effort than is available. Another important challenge that needs to be considered is that scientific research in many cases leads to what appears to be a dead end. Researchers may reach a conclusion that their work is not heading in a promising direction and that it is better not to spend more time and effort to pursue a particular research line. However, later on, when new results from other projects, or even other disciplines become available, what seemed to be a dead end might turn out to be a new and promising starting point, leading to unexpected results and impacts.

Possible solution	All data is potentially relevant – even that from "dead ends" and discontinued scientific activities. Without this data, it might not be possible to properly evaluate impacts occurring after a long delay.

3.5 All different – all unique: Particularities and specific features

Challenge	With regard to their goals and way of operating, there are significant differences between research infrastructures. Furthermore, not only research infrastructures differ, but the conditions in countries where they operate can also be very different. This means that socio-economic impact assessments should never be used to compare the impact of different RIs, but only to evaluate the progress of individual RIs towards the realisation of planned goals and objectives. Does it mean that impact assessment is completely meaningless for policy-makers and research funders, who need to know which RIs contribute most to society and the economy and which therefore should be given a larger slice of the pie (public funding)?

Possible solution	When assessing socio-economic impacts, the specific features of RIs can be considered in (at least) two ways: ■ Careful selection of standard indicators or – if needed – definition of new indicators tailored to a given research infrastructure. As this approach does not produce comparable findings, which policy-makers might need for the effective and efficient allocation of funds, a second method can be added. ■ In order to include an element of comparability to the assessment, while still doing justice to the specific features of individual RIs, different weights can be assigned to standard indicators.

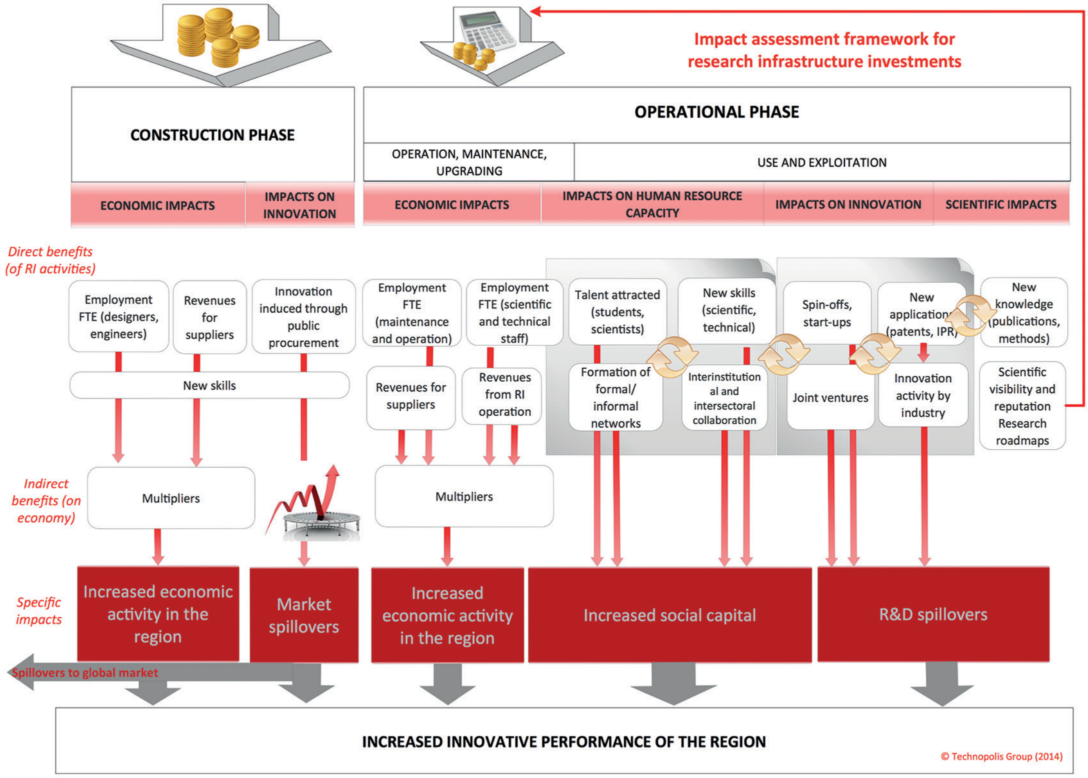
Example	For example, the ratio of foreign visiting researchers should be granted a specific weight for a medium-sized RI, which mainly serves domestic research needs, and a different weight for large international research infrastructures.

3.6 Alone in the desert – context and preconditions for successful RI operation

Challenge	issue of local, regional, and national capacity to exploit the potential of RIs has already been discussed. But there is another conditionality to relations between an RI and the environment. To start with, the quality of research depends on the availability of well-trained and experienced researchers and other staff members needed to operate an RI. This, in turn, depends on the quality of the education system. Thus, the main features of the sectoral, regional and national innovation systems, in which a given RI is embedded, as well as the way and degree of this embeddedness, needs to be considered when socio-economic impacts are assessed. Countries also differ in terms of having a strong or weak evaluation culture, and thus having a sufficient number of experts with the right qualifications and experience to assess the socio-economic impacts of RIs.

4 TYPES OF SOCIO-ECONOMIC IMPACTS OF RIS[2]

FIGURE 2: LOGICAL FRAMEWORK FOR SOCIO-ECONOMIC IMPACT ASSESSMENT



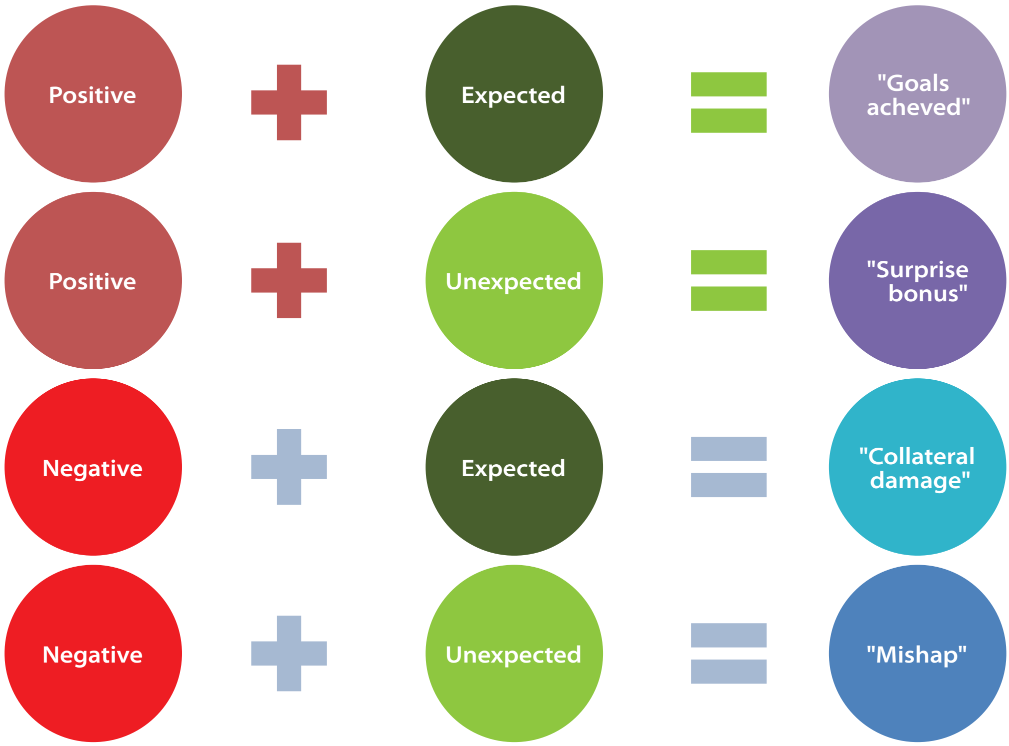
Source: Griniece E., A. Reid, J. Angelis, 2015.

4.1 Expected and unexpected impacts

Impacts can be divided into expected and unexpected varieties. This sub-section reiterates that when assessing the socio-economic impacts of a given RI, it is important to **keep in mind that it is not possible to foresee all (or even most of) the impacts.**

2 This chapter draws on the following sources: Griniece E., A. Reid, J. Angelis (2015): Guide to Evaluating and Monitoring Socio-Economic Impact of Investment in Research Infrastructures; OECD Global Science Forum (2018): Reference Framework for Assessing the Socio-Economic Impact of Research Infrastructures, and OECD: Socio-economic Impact of Research Infrastructures, https://www.innovationpolicyplatform.org/system/files/ALAGNA.pdf

FIGURE 3: TYPES OF IMPACTS: EXPECTED, UNEXPECTED AND POSITIVE, NEGATIVE



Traditionally, a large number of research facilities have been created for scientific purposes only. Yet, major economic and social impacts have inevitably occurred even in these cases, as unexpected by-products of scientific activities. Some examples are highlighted in the box below.

1

The development of the Large Hadron Collider (LHC) has contributed to a wide range of innovations: highly advanced superconducting magnets capable of producing a very strong field at extremely low temperatures; as well as advances in data communication, storage and analysis to deal with the annual production of about 15 petabytes of experimental data so they can be analysed by teams of collaborating scientists worldwide.

2

Some indirect socio-economic impacts related to RIs can be even more significant than direct ones. A prime example is the World Wide Web. Developed at CERN originally only for researchers, it eventually had huge implications for practically all economic sectors – including leading to the emergence of new sectors and new business models – as well as for a very large part of mankind (who have access to internet).

3

Another illustrative case is the surge in tourism in the Canary Islands due to the establishment of the Mount Teide Telescope, which has attracted the attention of tour operators cashing in on the appeal of the night sky and offering special star-gazing walks and astrophotography tours.

4.2 Scientific impact

The principal objective of each research infrastructure is to conduct excellent research. Production and accumulation of new knowledge and methods is primarily assessed through a set of purely scientific indicators, and those are of concern only to the research community. However, in addition to their scientific value, RI outcomes have a considerable impact on the wider society as well.

Scientific impact with added societal value can be observed and documented in areas of mutual learning and knowledge exchange (scientific papers and articles, books, scientific events, completed PhD dissertations), new services and opportunities with implications for society (new products, patents and discoveries that respond to grand societal challenges, etc.).

4.3 Technological impact and impact on innovation

Depending on the scientific field and focus of an RI and applicability of the knowledge developed, solutions might have a technological impact. A careful check covering all phases of an RI (from establishment to operation and probably decommissioning) can reveal relevant elements.

A further important objective of several RIs is to contribute to the innovation activities of businesses. The most common indicators in this area measure collaboration between firms and RIs, patents, licenses, co-patenting, patent citations, access to an RI, grants, proprietary use of an RI by businesses, prototypes, innovations, etc.

4.4 Direct and indirect economic impacts

During the design and construction phase, some direct economic impacts (revenues, new jobs, increased spending) arise from the participation of local suppliers, various service providers, and businesses involved in the construction and refurbishment of buildings. While a construction or upgrading phase is inevitably limited in time and therefore its direct effects are short-term in nature, it can have a further multiplier effect on the local economy, as the companies involved in building or supplying advanced equipment will gain valuable experience and enhance their reputation.

The impacts of RIs are typically longer-lasting during the operation phase. They include jobs for scientists, technicians, administrative and support personnel working for the RI, as well as opportunities for additional work in high school establishments. The operation of RIs generates consumption, as funds are spent to purchase goods and services. RIs also need to be regularly maintained and periodically upgraded. These direct impacts have further multiplier effects on the local economy and the relevant global supply chains.

4.5 Impact on human resources

Educational activities and responsibilities of RIs have already been mentioned among the wider social impacts, but the influence of RIs on the development of human capital deserves special attention. RIs can provide a variety of training and skill-development activities for different groups and levels of users and can play an important role in higher education activities at several levels (bachelor, master, and PhD). RIs can also serve as magnets to retain or attract talent as researchers, technicians and students gain access to the most recent scientific results, and learn how to use advanced scientific equipment. The local innovation system can additionally benefit from commercialisation skills acquired by management and scientists at an RI. However, if the RI is not successfully embedded into the local academic and business environment and no cooperation has been established, the accumulated human capital may not be absorbed and utilised.

4.6 Societal impacts

The broader impacts of RIs on society are often difficult to trace and measure. Some of the more important social impacts include the role RIs play in scientific communication and scientific education, and presenting narratives to strengthen the positive image of science. RIs can make a very significant contribution to raising public awareness and enhancing the popularity of science through information events like open days, exhibitions, lectures, and seminars. RIs can inspire more school students to learn STEM subjects and the social sciences can maintain their reputation by developing, maintaining and using major international databases, such as RIs.

Needless to say, many of the innovative products developed by drawing on research conducted at and by RIs directly benefit society (for example, new medical instruments, diagnostics, treatments), as they tackle important societal challenges (health, quality of life, food quality and safety, environment, socially and environmentally sustainable development, ethical concerns related to new technologies, etc.). Investment in RIs also has other direct positive impacts, such as improvements to local infrastructure, community services and the revitalisation of local areas.

TABLE 4: MEASUREMENT OF THE IMPACT OF RIS AND METHODS OF ANALYSIS

Type of impact	Measurement of	Methods of analysis
Scientific impact	▪ scientific outputs ▪ rate of utilisation of the resource ▪ training and capacity building	▪ peer review ▪ bibliometrics ▪ statistical reports ▪ administrative records held by research infrastructures ▪ surveys of users
Technological impact	▪ actual and potential spin-off products and services ▪ links to private sector ▪ national statistical information on inputs and outputs	▪ survey of spin off companies and activities ▪ in-depth interviews with scientific staff of research infrastructures ▪ innovation surveys ▪ factor productivity analysis
Economic impact	▪ contribution to GDP at regional and national levels ▪ employment and incomes created at local, regional, national and supranational levels	▪ national and regional accounting input output models ▪ autoregressive variance analysis models ▪ analysis of administrative data held by RIs
Social impact	▪ contribution to family and community wellbeing ▪ amenity value of the facility	▪ synthetic reviews of evidence from science based on use of RIs ▪ local population surveys
Political impact	▪ contribution to political stability, cohesion	▪ interviews with key informants ▪ analysis of media publications
Environmental impact	▪ impact on air, water quality ▪ energy balances ▪ CO2 footprint	▪ synthetic reviews of evidence from science based on research infrastructures ▪ analysis of energy use ▪ analysis of environmental measures

Source: ERA, 2010, p. 48.

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ANNEX I: INDICATORS FOR ASSESSMENT OF THE SOCIO-ECONOMIC IMPACTS OF RIS

When interpreting – making sense – of the actual value of indicators, one must keep in mind that the socio-economic impacts of RIs may depend on actions – either orchestrated or independently taken – by other players. This is certainly the case when R&D results are used as knowledge input for business innovations or new solutions addressing societal challenges. That is, the **socio-economic impacts of an RI are influenced to a significant extent by its surrounding environment and its embeddedness in prevailing socio-economic structures**. Hence, **indicators need to be assessed with a great deal of prudence**. Further, the socio-economic impacts of RIs are multifaceted, and thus **a carefully selected set of indicators must be considered when assessing impacts**.

TABLE 5: INDICATORS FOR ASSESSING SCIENTIFIC IMPACTS

Indicator	Data needed	Phase
Bibliometrics	Number of scientific papers and articles in International Scientific Indexing (ISI) journals published as a direct result of research using a given RI Number of publication citations that include authors from or hosted by the RI Number of books published	Operation
Scientific Productivity	Number of research methods/designs developed Number of international patents granted and published patent applications	Operation
Generation of knowledge	Number of completed PhD dissertations predominantly or partly based on use of a given RI (per year of completion and per scientific field)	Operation
Mutual learning and knowledge exchange	Number of scientific events organised on research topics directly related to services provided by the RI Frequency and types of scientific events Data on participants (affiliation, scientific field, country of residence, gender) National and international collaboration by RI researchers National and international collaboration by RI users Repetition of experiments or experimental apparatus in other, similar RIs	Operation
Networking and collaboration	Number of joint projects elaborated (by type of collaborator) Number of joint projects implemented (by type of collaborator)	Operation
Recognition and awards	Scientific prizes (to the RI as an organisation, its personnel and users as researchers)	Operation

TABLE 6: INDICATORS FOR ASSESSING TECHNOLOGICAL IMPACTS AND IMPACTS ON INNOVATION

Indicator	Data needed	Phase
Novel technical solutions for construction of the RI	Joint development activities with suppliers	Construction and design
Impact on learning and skill development amongst suppliers	Number of contracts concluded for services that require development or calibration of new designs/equipment to meet specific requirements	Construction and design

Indicator	Data needed	Phase
Patents	Number of patents granted Number of international patents granted Number of co-patents with companies	Operation
Innovations co-developed with businesses	Number of innovations by business partners to which the RI has contributed	Operation
Joint technology development projects between the RI and businesses	Number of joint technology development projects between the RI and businesses Prototypes of new products and services developed jointly with businesses	Operation
Collaborative projects with business partners	Number of collaborative projects in which businesses are directly involved	Operation
Students working for businesses	Number of students working for businesses and using the RI	Operation
R&D projects commissioned by companies	Number of projects funded by companies Size and type of "client base"	Operation
Scaling up and commercial development of prototypes	Number of technology prototypes and industrial designs co-developed by the RI and sent to the production stage by business partners	Operation
Long-term sustainability of start-ups and spin-offs	Number of start-ups and spin-offs created with support from RI services that remained operational/continued to grow for at least 5-10 years	Operation
Commercialisation of research results	Number of feasibility or market studies for private investment and application of technologies Actual investment in the application of new technologies by business (tracked over time; 5-10 years)	Operation
Procurement contracts signed for the development and upgrading of research equipment	Number and type of procurement contracts for the development of new instruments	Operation

TABLE 7: INDICATORS FOR ASSESSING ECONOMIC IMPACTS

Indicator	Data needed	Phase
Commercial suppliers for RI design and construction	Total number of suppliers Suppliers mapped per sector, field of activity, size, level of technological advancement, ownership (domestic, foreign) Increase in supplier turnover due to the RI increase in supplier employment due to the RI (temporary and permanent jobs)	Construction and design
Overall economic impact covering a wider area	Total amount of purchases from suppliers Value of contracts with suppliers and other involved businesses Taxes and social contributions paid by the RI and its employees	All phases

Indicator	Data needed	Phase
Overall economic impact in the local area	Purchases from local suppliers Contracts with local suppliers and other involved businesses	All phases
Public procurement and contracts	Number and types of procurement operations and contracts signed	All phases
Employment in the RI	Number of FTE (full-time-equivalent) employees by age, gender and citizenship	All phases
Directly created jobs	Number of new jobs by type (scientific/technical/administrative staff) and wage level Average hourly labour costs for scientists, technicians, administrative staff	All phases
Expenditure for personnel, operations and maintenance	Total cost for personnel, operations and maintenance	All phases
Students and researchers using the RI	Number of researchers and students with access to the RI by type of activity (research, test, etc.)	Operation
Companies using the RI	Companies by sector, field of activity, size, level of technological advancement, ownership (domestic, foreign) Total number of companies	Operation
Collaboration with businesses	Number of medium- and long-term collaborative R&D contracts with business partners Contribution of firms to development of the RI Patents and licenses created in cooperation with the RI and firms Patents sold to businesses by the RI	Operation
Sales and profits by firms as result of cooperation with the RI	Increase in sales and profits of firms stemming from new products, services, production processes developed and other types of innovations generated using research results of the RI	Operation
Spin-offs	Number and type of spin-off companies created as the result of the RI's operation	Operation
Spin-out jobs	Number and type of spin-out jobs created due to the presence of the RI	Operation
Start-ups	Number and type of start-ups using the RI	Operation
Boost to economic development	New sectors created and/or new markets opened as a consequence of the research results of the RI	Operation
Economic impact related to local tourism	Total number of visitors and users of the RI Increase in the number of visitors using local tourist company services (hotels, conference venues, catering)	Operation

TABLE 8: INDICATORS FOR ASSESSING IMPACTS ON HUMAN RESOURCES CAPACITY

Indicator	Data needed	Phase
Educational and outreach activities	Number of RI staff members engaged in educational & outreach activities Total number of participants Number of educational and outreach projects and events	Operation

Indicator	Data needed	Phase
Career of students trained within the RI	Number of former students employed by another RI Number of former students employed by firms Number of former students employed by universities Number of former students employed in the public sector	Operation
Grants for trainees	Grants awarded to trainees to attend RI training events	Operation
Students trained	Number of students (national and international) trained within the RI Number of defended MA and PhD thesis based on knowledge and skills gained at the RI	Operation
Inflow of new human capital	Number of new jobs for research and technical staff attracted from abroad	Operation

TABLE 9: INDICATORS FOR ASSESSING SOCIAL IMPACTS

Indicator	Data needed	Phase
Number of employees	Number of engineers Number of scientists Number of administrative workers Number of technicians Distribution of employees (by age, gender and nationality)	All phases
Contribution to public policies	Number and type of reports, recommendations and other information resources in support of public policies, drawing on the results of the RI Databases/ biobanks/IT resources useful for evidence-based policy-making Number of contracts with public bodies for consulting services Expert reports and expert advice Contributions to regulatory or legal texts, conferences, etc. Number of meetings with policy-makers	Operation
Open days for the wider public	Number of events for the public Number of open visits to the RI Number of visitors (divided per target group)	Operation
Educational and outreach activities of the RI	Number of training events for secondary and university students Number of student visits to the RI and use of its facilities "On-the-job" training for students and their participation in research projects conducted at the RI Use of RI facilities to teach graduate and post-graduate students as part of their curricula Opportunities for post-docs and other researchers to improve their methodological skills and deepen their knowledge by working as visiting researchers at the RI	Operation
Educational activities of RI staff	Number of RI staff members providing lectures or teaching a full course at a university	Operation
Use of open data	Information on accessible and downloadable open data Use of open data	Operation

Indicator	Data needed	Phase
Public awareness	Number of visitors to the RI-related website, social media and other online sources Number of visitors on open days, public lectures, seminars	Operation
Public visibility of the RI	Appearance of the RI in print, electronic and online media (local, regional, national, and international) Articles in print media and online content regarding the RI	Operation
Public approval of the RI	Data from satisfaction and feedback surveys of participants to the RI's public events	Operation
New products, services and solutions	Number of new or improved products, services, or solutions stemming from the RI's results	Operation
Contribution to local infrastructure	Improved local infrastructure, or community services; increase in local cultural and recreational activities due to the RI	Operation

TABLE 10: INDICATORS FOR ASSESSING IMPACTS ON THE ENVIRONMENT AND HUMAN HEALTH

Indicator	Data needed	Phase
Scarce resources	Food waste reduction (%) due to the RI	All phases
Pollution	Reduction in GHG emissions (%) due to the RI	All phases
Food safety and quality	Reduction of chemical contaminants in food (%) due to the RI	Operation
Well-being	Reduction in food-related diseases (%) due to the RI Reduction in hospitalisation costs (%) due to the RI	Operation

ANNEX II: ASSESSMENT METHODS[3]

To take into account the complexity and variety of socio-economic impacts, many assessment methods are used. These methods are designed to fit specific objectives and focus on specific impacts. Thus, it is up to those who commission and design such an exercise to select a specific set of methods fitting the objectives of a particular assessment.

The RI-PATHS project has compiled a comprehensive review of different methods and approaches for assessing the socio-economic impact of research infrastructures. It identified six main groups:

1) socio-economic assessment based on impact multipliers;
2) methods applying the knowledge production function;
3) cost-benefit analysis;
4) approaches based on multi-method, multiple partial indicators;
5) theory-based approaches;
6) case studies.

1) Socio-economic assessment based on impact multipliers

- Impact multipliers measure the effect of an investment project on a particular sector or economic activity (direct impact) or on the whole economy (indirect and induced impacts). An RI pays suppliers, suppliers buy goods and services from other firms and pay their workers. Workers and firms, in turn, buy further goods and services.
- Impact multipliers can be established in two different ways: i) by making use of multipliers from already existing sectoral, regional or national statistical tables or those embodied in input-output software and applying them to an RI's internal data; ii) by making an independent calculation of impact multipliers and estimating indirect and induced impacts.
- The first option is less demanding and usually used by evaluators, since input-output software and tables already exist. The second option requires significantly more time and effort, as well as a broad consideration of all potential effects (market, financial, technological, etc.).

Strengths:

- Highly reliable, as it is based on a well-defined and accepted theoretical foundation.
- Standardised and consistent input-output tables and software based on real data are readily available in many – although not all – cases.
- Effective for assessing the economic impacts of RI investments. Effects, being direct, indirect or induced, are clearly defined by the theoretical framework. This informative power is, however, somewhat threatened by the concept of the multiplier itself, as well as data availability.
- An RI needs to collect a relatively limited amount of data (e.g. the amount of investment, the total value of supplier contracts).

3 This section is adapted from Giffoni, F. et al (2018): RI-PATHS project Task 3.2: State of play – literature.

Shortcomings:

- This method focuses on economic and financial aspects, leaving aside non-monetary impacts (scientific performance, human capital accumulation, education outreach, environmental and production externalities).
- Multipliers show average effects and are not accurate enough to precisely explain factors leading to a given impact.
- Input-output tables and impacts multipliers are not always available or updated, because large amounts of statistical data are needed to maintain them, which can make the application of this method costly and time-consuming.

Relevance:

- Exceptionally relevant for policy-makers: assessment based on impact multipliers is a macroeconomic approach, and very useful for estimating the socio-economic effects of RIs on GDP, gross value added (GVA), or employment.
- Less informative for RI managers: it does not offer information about the performance of an RI.

2) Knowledge production function approach

- The production function approach (PFA) is the basis of the modern growth theory and of growth accounting, and tries to answer a basic question: what factors account for observed growth in the economy and to what extent?
- The method can be used to evaluate the transformation process leading from input (public R&D funding) to new knowledge (mainly in the form of patents).
- The method is best suited to estimating macroeconomic effects at the country and regional levels, but can be also applied to analyse the economic impacts of R&D and research activities connected to RIs.

Strengths:

- Rigorous theoretical foundation leading to consistent and generalisable results.
- The models are able to estimate both private and social returns from investment in research and development, recognising that such returns could broaden from individual organisations implementing an investment to society as a whole.
- The approach produces clear and easily understandable numerical information about the impact of investment in R&D (e.g. in terms of GDP, value added, or firm performance gains).

Shortcomings:

- Relies on simplified assumptions about the properties of technology (technological domains, durability, etc.).
- The PFA approach addresses only a small share of the expected socio-economic impacts of an RI.
- It is very difficult to measure scientific knowledge and its contribution to economic or social welfare by using econometric approaches that simplify the complex nature of R&D and

innovation activities. For instance, new knowledge exists in many different forms, not only as patents. Further, the propensity to patent varies significantly by technological domain and economic sector.

- The approach demands considerable resources in terms of time, expertise and data.
- The results do not include any detailed information on how impacts are generated.

Relevance:

- Very important for policy-makers, who tend to look for information on the aggregate measure of the broader economic impact of an RI investment.
- Less useful for RI managers, as the approach does not provide any detailed insight regarding governance improvements and management structures, only offering broad information about causes of possible impacts.

3) Cost-benefit analysis (CBA)

- CBA is an analytical tool for assessing the costs and benefits of an investment. It answers the question whether a project generates a net benefit to society, or in other words, whether the cost of investment can be justified by the outcome and impact.
- Unlike the financial methods described above, CBA evaluates a project's contribution to social welfare; it reflects the social opportunity cost of goods and services, instead of their market price. CBA therefore does not consider only investment and operating costs, but also social costs, such as negative environmental externalities, for example.
- CBA is the mandatory methodology for assessing major infrastructure projects applying for funding by ESIF (European structural and investment funds), and it is also recommended in the ESFRI Roadmap 2018. The H2020 Work Programme 2018–2020 explicitly indicates CBA as a basis for the preparatory phase of new ESFRI projects.
- The method assesses the net benefit of a project to society. The net benefit, or net present value, consists of benefits to firms in an RI's supply chain; scientific impact (knowledge output generated by an RI in the form of publications, preprints, participation in conferences, and possible increases in the productivity of scientists); human capital accumulation (benefit to students, researchers, scientists trained by an RI); cultural and outreach effects (visits to an RI, exhibitions, website, social media, other dissemination activities); benefits accruing to external users (non-academic users) stemming from an RI's research activities and/or its services; scientific discovery as a public good.
- The method considers the following costs: initial investment; labour costs of scientists; labour costs of administrative and technical staff; other operating costs; negative externalities.

Strengths:

- The CBA model can – and indeed must – be tailored to any RI, as benefits and costs are specific to a given RI and are estimated for a given RI.
- CBA is among the most scientifically robust and methodologically sound analytical frameworks to support decision-making for major public investment decisions.

- CBA is excellent for comparing positive and negative socio-economic impacts of an RI investment and is able to capture most impacts expected from the operation of an RI.
- CBA, if conducted properly, is accurate in assessing the incremental contribution of individual RI investment decisions to society using a long-term perspective.

Shortcomings:

- CBA cannot explain the factors determining performance of an RI (contextual factors).
- CBA has frequently been applied to assess benefits in the educational, environmental and cultural sectors, but tools and procedures for other types of benefits are much less developed.
- CBA is quite a complex method. It can be costly and time-consuming and demands adequate finances, data, and human resources, from both the evaluator and the assessed RI.

Relevance:

- Exceptionally relevant and practical for policy-makers: it helps identify RI investment projects that offer the highest rate of return, and informs decisions about the most efficient allocation of resources.
- RI managers obtain a clear understanding of the conditions under which various impacts appear and a good overview of the relative contribution of different types of benefits to the total net effect.

4) Approaches based on multi-method, multiple partial indicators

- These approaches are specifically developed to evaluate the socio-economic benefits of publicly funded research.
- The basic premise is that all research projects and organisations generate a variety of research outputs that can have a large number of different impacts. This multidimensionality can only be properly assessed by using a range of relevant indicators and a combination of methods.
- Standardised indicators for multi-method assessment:
  - 24 Core Impact Indicators (CIIs): a restricted list of indicators that are most relevant to the development of infrastructure over the years and which inform taxpayers and stakeholders whether a structure is well managed and fulfils criteria for excellence;
  - A more detailed list of 58 standardised indicators grouped in six general impact categories: scientific impact; technological impact; training and education impact; direct economic impact; indirect economic impact; societal impact.

TABLE 11: CORE IMPACT INDICATORS AND DETAILED STANDARDISED INDICATORS

Objective	Core Impact Indicators	Detailed Standardised Indicators
Scientific performance	1) Publication output 2) Number of publications in high- impact factor journals 3) Number of scientific users 4) Quality and extent of scientific collaboration 5) Funding grants received 6) Data use	Number of publications Number of citations Number of publications in high-impact factor journals Number of scientific users Number of projects granted RI access User satisfaction Data openness Digital resource openness User project excellence Collaboration excellence Papers co-authored with universities Number of national and international grants Number of collaborations with businesses
Innovation support	7) Collaborative projects with business partners 8) Patents with commercial use 9) Projects co-funded by companies 10) Commercial data use	Patents Co-patenting with firms Innovations co-developed with firms Joint technology development projects between the RI and businesses Students working for businesses using the RI Projects funded by firms Collaborative projects with businesses
Regional collaboration support	11) Number of full-time equivalent researchers within the RI 12) Number of high-ranked full-time equivalent researchers 13) Relationship with regional universities and academia 14) Number of regional firms using the RI 15) Number of suppliers	Economic impact on regional area Economic impact on local area Number of full-time equivalent researchers within the RI Public procurement and contracts Spin-offs Spin-outs Economic impact linked to tourism Number of graduates (regional) Number of regional firms using the RI Collaborative projects with regional businesses
Education outreach and knowledge diffusion	16) Number of students trained within the RI 17) Public visibility of the RI 18) Knowledge sharing and improvement 19) Educational and outreach activities	Openness to the public Educational and outreach activities Public awareness Public visibility of the RI Popularity of the RI (among the public and users) Number of employees Knowledge sharing and improvement Use of open data Careers of students trained within the RI Grants for trainees Students trained Training programmes for high school students

Objective	Core Impact Indicators	Detailed Standardised Indicators
Support for public policy	20) Production/use of resources in support of public policy 21) Production/use of expert advice in support of public policy	Production of expert advice in support of public policy Production of resources in support of public policy Production of experimental observational data in support of public policy Contribution to the policymaking processes
Social responsibility	22) Gender balance 23) Fairness policy 24) Environmental impact	

Source: Giffoni et al. (2018): RI-PATHS project Task 3.2: State of play – literature, pp. 29–30

- It is important to note that these indicators should not be used to compare different RIs but can only be applied to assess the trends (annual progress) of a given RI, in order to compare objectives and actual results/impacts.

Strengths:

- Indicators provide a very informative and reliable description of impacts achieved by an RI, but only if data is collected using reliable methods (formal surveys and interviews with RI stakeholders, official documents and reports).
- The approach can capture the multidimensional nature of RI investment.
- Low to medium cost (depending on how many indicators are collected and project complexity).

Shortcomings:

- Indicators can be misinterpreted. As this approach is based on a combination of methods and indicators, no theoretical background exists on how to define and measure impact in a consistent manner, which means that results (observations and recommendations) can sometimes be inconsistent or even inaccurate.
- The accuracy of multi-indicator approaches can be limited for three main reasons: tendency to define too many indicators, which can lead to arbitrariness and possible double-counting and overlaps; the problem of aggregation: a multidimensional set of indicators makes it difficult to reach a comprehensive and synthetic conclusion concerning socio-economic impacts; indicators provide information about annual developments rather than a final assessment of achieved impacts.

Relevance:

- The information obtained through this approach is very useful for both policy-makers and RI managers, but has additional advantages for RI managers (measuring progress toward objectives, conducting comparison over time, facilitating the identification of problems and taking corrective action).
- Both policy-makers and RI managers should keep in mind the shortcomings mentioned above (limited reliability and accuracy).

5) Theory-based approaches

- The rationale behind theory-based approaches to impact assessment is to identify the mechanism behind the change generated by a policy intervention, rather than by measuring effects. The advantage of this method is that it considers a wider context, that is, external factors which may impact on the performance of an intervention.
- Theory-based approaches rely on the concept of 'causation' and aim to bridge the gap between data and the interpretation of data.
- The most popular theory-based approaches are:
  - Theory of change (provides an in-depth analysis of the logic chain of an intervention, develops an illustration of what should happen due to the intervention and explores which external factors have influenced a change).
  - Realist evaluation (seeks to understand what works, how, under which conditions and for whom; three steps: formulation of theory and hypothesis; data collection; data analysis and conclusions).
  - Contribution analysis (addresses the problem of attribution: were observed results accomplished due to programme activities or other factors; used to verify the theory of change, but also takes into consideration other factors).
  - Most significant change (participatory process involving the sequential collection of stories of significant change, which occurred as a result of the intervention. If done well, it can generate useful information on the specification and subsequent assessment of a theory of change).
  - Success case method (narrative technique using naturalistic enquiry and case study analysis: quick and simple; focuses on the very best and very worst results of an intervention, but also on the role of contextual factors driving this).
  - Qualitative comparative analysis (case-based method which identifies different combinations of factors that are critical to a given result, in a given context; not yet widely used in evaluation).
- Theory-based approaches can be very accurate in describing how and under what conditions investment in RIs produces socio-economic impacts, but this depends on the capacity to rigorously map the complex activities of RIs, change mechanisms and find a balance between too simplistic theories of causation and overly complex designs, if an exhaustive list of factors and assumptions is assembled.
- The application of theory-based approaches to impact assessment of RIs is still rare. (A logic model approach has been used in the evaluation of Bio-banking and Biomolecular Research Infrastructure, BBMRI).

Strengths:

- These approaches are sound, and can be replicated and generalised to suit different types of RIs. They can also help identify unintended side effects of RI investment.
- They map out the determining or causal (external) factors and an RI's characteristics, which are important for success, and also examine how they might interact with each other.

- Although theory-based approaches might not be the most accurate method, they produce a very good narrative or timeline that lists the sequence of effects.
- The cost, skills and time needed to implement this approach vary considerably (depending on the depth of the analysis and data collection), but in general, they are relatively low.

Shortcomings:

- Different approaches (e.g. contribution analysis, realist evaluation, and so on) deliver different theories of change, which can be either weak or strong, and this limits their reliability.
- The possibility of combining different statistical and narrative techniques (multipliers, indicators, case studies) can produce inconclusive and unclear judgments about the best theory of change and the impact of RIs, particularly if data collection routines are not yet well established.

Relevance:

- Understanding how investment in a given RI leads to a specific impact can meaningfully support RI managers in the design of operational strategies to enhance impact.
- The method is somewhat less relevant for policy-makers and funding agencies.

6) Case studies

- Case studies are among the most wide-spread qualitative analytical tools in social sciences.
- They can be extremely varied and their exact design depends on the purpose of the study. The usual research methods include desk research, surveys, interviews, statistical data collection and analysis.
- Two main groups can be distinguished: within-case studies and cross-case studies. Within-case analyses focuses on one single case in-depth, while cross-case analyses uses a comparative approach to draw conclusions regarding two or more cases. Case studies often use a mix of the two types.
- Practical implementation of case studies consists of a preparatory phase, fieldwork phase and analytical phase.

Strengths:

- Case studies are widely used to assess the socio-economic impacts of RIs because they better reflect the uniqueness and complexity of RIs.
- The outcome of a case study is essentially a story that provides a detailed picture of various processes that lead to certain impacts, which are described in qualitative terms.
- Case studies often produce information that cannot be obtained through other approaches.
- The method is very widespread and recognised by policy-makers, funding agencies and RI managers alike.
- Unlike some other approaches, the case study method takes into account the context in which an RI operates. This highlights the influence of different actors (users, suppliers, etc.) involved in the activities of a given RI.

- Case studies are a powerful tool to communicate results. They produce simple and inspiring results by combining different methods and triangulating information throughout the analysis.
- The cost and time required to implement a case study can vary, depending on the scope and depth of the analysis, but might be lower compared to other approaches.

Shortcomings:

- Assessment results (even within the same type of RI) can rarely be reproduced, which makes it almost impossible to generalise results.
- Successful cases are most often selected for analysis, which can result in an "optimism bias" and emphasis on positive impacts, while negative aspects (cost, potential negative impact on environment, etc.) are neglected.
- There is a risk of simplified or superficial analysis with the use of simple data easily understandable by a wide audience.

Relevance:

- Case studies are able to address larger audiences than other methods and efficiently explain how society benefits from an RI. This makes them highly relevant for policy-makers and funding agencies.
- They are somewhat less informative and useful for RI managers, as they lack technical aspects (e.g. related to accountability and the allocation of resources).

GLOSSARY

Core impact indicators	A limited list of indicators focused on the socio-economic impacts of RIs.
Data	Data is all information necessary to inform an indicator about the level of achievement.
Economic impact	The economic impact refers to direct and indirect economic wealth created by an RI or its presence in a defined area.
Life cycle	The different phases of a RI's lifecycle, i.e. preparatory, construction, operation and upgrade/maturity.
Impact	Mid- to long-term changes attributable to an activity (e.g. general quality and visibility of local research).
Indicator	Indicators are elements related to an activity. Good indicators are valid (reflecting properly what is being measured), reliable, and usable (easy to collect, non-ambiguous). Example: the indicator "impact on suppliers" will assess the impact of an RI on suppliers by measuring the RI's expenses with suppliers.
Key Performance Indicators	KPIs are dedicated to monitoring the process and its efficiency in delivering an outcome, by measuring performance effectiveness. KPIs are determined by comparing their actual value against thresholds defined ex ante.
Output	Goods and/or services produced/delivered by an activity (e.g. RI services to the scientific community).
Societal impact	Social and societal impact refer to positive or negative effects on society (environment, well-being, social relations, education etc.)
Strategic objective of an RI	based on the mission of an RI, strategic objectives are negotiated with stakeholders and implemented in relationship with priorities and resource commitment.

ABBREVIATIONS

CIE	counterfactual impact evaluation
ELI-ALPS	Extreme Light Infrastructure – Attosecond Light Pulse Source
ESFRI	European Strategy Forum on Research Infrastructures
RI	research infrastructure
STEM	science, technology, engineering and mathematics

LIST OF TABLES AND FIGURES

This guide has been developed by the ResInfra@DR consortium, with input from research infrastructure (RI) policy-makers, managers, and experts at several workshops and a concluding consultation meeting. It is part of a series of three guidance documents, dealing with ex ante evaluation, monitoring, and the assessment of socio-economic impacts of RIs. Together, these three documents aim to provide an overview of relevant methods and processes which can be used to improve the planning and management of RIs, leading to better utilisation of their precious and unique capacities, enhanced performance, and more pronounced socio-economic impacts.

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