Interreg
EUROPEAN UNION
Danube Transnational Programme
ResInfra@DR

A Practical Guide on Monitoring Research Infrastructures

Interreg
EUROPEAN UNION
Danube Transnational Programme
ResInfra@DR

A PRACTICAL GUIDE ON MONITORING RESEARCH INFRASTRUCTURES

Project Acronym	ResInfra@DR
Project full title	Facilitating macro-regional scope and link up to socio-economic actors of Research Infrastructure in the Danube Region
Funding Scheme	Interreg Danube DTP
Project start date	01/01/2017
Project duration	30 months
Project partners	Centre for Social Innovation (ZSI) – Coordinator (Austria); University of Natural Resources and Life Sciences, Vienna (Austria); Applied Research and Communications Fund, Ministry of Education (Bulgaria); Ministry of Education and Sports (Croatia); Institute of Philosophy, Czech Academy of Sciences (Czech Republic); Centre for Economic and Regional Studies, Hungarian Academy of Sciences (Hungary); Executive Agency for Higher Education, Research, Development and Innovation Funding (Romania); Slovak Centre of Scientific and Technical Information (Slovakia); Ministry for Scientific and Technological Development, Higher Education and Information Society of Republic of Srpska (Bosnia and Herzegovina); Ministry of Education, Science and Technological Development (Serbia); Central European Initiative Executive Secretaria (Italy); National Authority for Scientific Research and Innovation (Romania); Academy of Sciences of Moldova (Moldova)
Contact	office@resinfradr.eu

ResInfra@DR is co-funded by European Union funds (ERDF, IPA) and the Government of Hungary.

PUBLISHER AND EDITOR:
ResInfra@DR project c/o Centre for Social Innovation
Linke Wienzeile 246, A-1150 Wien
institute@zsi.at

MAIN AUTHOR:
Doris Gangl (BOKU)

EDITOR:
Attila Havas (CERS HAS)

ACKNOWLEDGEMENTS: We thank all project partners who contributed to this publication. The feedback and other contributions provided by participants of the ResInfra@DR Concluding Consultation Meeting, held in Budapest on 27-28 November 2018, are gratefully acknowledged.

TECHNICAL EDITOR: Pamela Bartar (ZSI)

LANGUAGE EDITOR: Maureen Patricia McNeill

DESIGN: Krassimir Apostolov

YEAR OF PUBLICATION: 2019

PRINT RUN: 250

ISBN 978-3-200-06406-5

TABLE OF CONTENTS

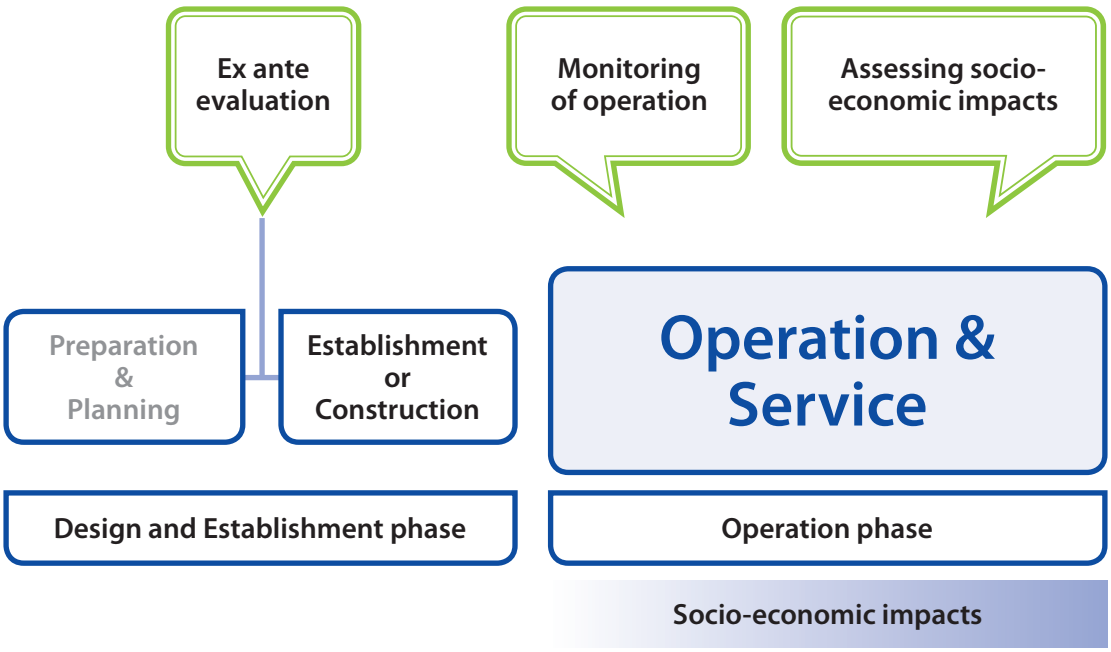
EXECUTIVE SUMMARY

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 at providing an overview of the relevant processes and methods to improve the management of RIs leading to a better utilisation of their precious and unique capacities, enhanced performance, and more pronounced socio-economic impacts.

This document considers the major aspects of monitoring RIs already in operation. Monitoring is the systematic process of collecting, analysing and using relevant information to track the performance of a certain programme, project or organisation in reaching its objectives and to guide management decisions. It can be a powerful tool for RI managers and policy-makers alike. For RI managers, monitoring can significantly improve the structure, processes and methods of management, and thus help improve operations and performance. For policy-makers, monitoring provides the necessary data to assess the efficacy of public investment in RIs.

Preparatory steps for adequate monitoring include: the definition of a mission and goals, the development of an operational framework, the development of a suitable monitoring process, and the collection of baseline data. Organising a monitoring process presents some challenges, which are presented in this document, together with possible solutions. Monitoring has historically been primarily initiated by funding bodies, but nowadays RIs also recognise the need for an adequate monitoring system. Monitoring can be performed by a team of internal or external experts. The advantages and disadvantages of both approaches are discussed in this document. Following some guiding principles can help in designing a relevant monitoring system. First, key issues and areas to monitor should be defined, while keeping stakeholders and their needs in mind. Then a decision should be made as to *which* information will be collected and *how* it will be collected and recorded. A quality assurance system has to be developed and adherence to ethical and data protection regulations needs to be ensured. Finally, it is important to interpret collected data correctly and infer the desired information from these analyses. Methods to collect required data include the routine collection of performance data, the use of national databases, the collection of data in the framework of financial audits and project reports, as well as the manual collection of performance data. A list of commonly used indicators and good practice examples are presented in the annex of this document.

1 INTRODUCTION

Background

The monitoring of research infrastructures (RI) is still an emerging practice facing considerable hurdles in many countries of the Danube macro region. The benefits to stakeholders are often unknown, and it is also generally unclear which methods are most useful and which indicators to use. With input from international experts at four dialogue workshops and a concluding consultation event, the ResInfra@DR consortium has compiled the present guide as an aide to establish and promote monitoring practices tailored to the specific needs of a given RI. Since there is no single approach applicable to all RIs, it is crucial to devise a monitoring process suited to the particular needs of managers of a given RI. The present document provides guidance on the purpose of monitoring, the organisation of a monitoring process, the selection of relevant indicators and presents monitoring methods.

This guide has been developed by the ResInfra@DR consortium, with input from 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.

Definition of monitoring

Monitoring is the systematic process of collecting, analysing and using relevant information to track the performance of a certain programme, project or organisation in reaching its objectives, as well as to guide management decisions. Monitoring usually focuses on processes, such as when and where activities occur, who delivers them and how many people or entities they reach. From the perspective of research infrastructures, the purpose of monitoring is to track operations, processes and output systematically, and measure the efficacy and efficiency of a given RI. Monitoring forms the basis for assessing the quality of conducted activities and, if necessary, for changing the operations of a given RI. It can be used to demonstrate that efforts have had measurable impacts, contributed to expected outcomes and been implemented effectively. Monitoring is essential to help RI managers, planners, policy-makers and funders acquire important information to make informed decisions about RI operations.

Benefits of monitoring

Monitoring helps identify the most valuable and efficient use of resources. It is critical in developing objective conclusions regarding the extent to which RI operations can be considered a "success". Monitoring provides relevant data to guide strategic planning and design, the implementation of programmes and projects, as well as the allocation or re-allocation of resources in better ways. Other types of information and assessments complement and underpin monitoring activities.

Monitoring aims to assess the quality and cost performance of an RI, and can be used as a diagnostic measurement tool to enable improvement. Therefore, it can be a useful tool for RI managers and policy-makers alike. For RI managers, monitoring can significantly improve the structure, processes and methods of management, and thus help improve operations and performance. A systematic monitoring of performance can provide information for more effective strategic planning. This, in turn, can lead to an increase in scientific output and user numbers, a more effective user-access strategy, and help in attracting highly qualified staff. An RI which has performed systematic monitoring activities

may have better chances to attract additional funding. For policy-makers, monitoring provides the necessary data to assess the efficacy of public funding for RIs. It allows policy-makers to plan future investment with higher confidence, calculate the value for money invested and perform cost–benefit analyses. It can also help re-orientate RIs towards novel – scientific, economic, and societal – challenges and opportunities, or increase capacity in critical fields where scientific, technological, and innovation pressures are the strongest

Preparatory steps for adequate monitoring

To ensure that monitoring is a constructive and valuable element supporting major managerial decisions, there are important steps to be taken, including:

Define mission and goals

Before a monitoring system can be designed and implemented, an RI's mission and goals need to be defined and discussed with key stakeholders. At certain stages of an RI's life cycle, it may become necessary to re-evaluate or adapt the goals and mission.

Develop an operational framework

A framework should be developed which explains how a given RI will work, how it will accomplish its objectives and how it will operate within the structure of already existing research organisations and RIs.

Develop the monitoring framework

On the basis of these considerations, a monitoring framework can be developed which describes the process of how RI performance will be tracked, examined and assessed. Clearly, the reporting obligation to funders and expected output over time will influence the monitoring framework, timing and process. The monitoring framework can also be developed using a bottom-up approach, together with experts from the field, staff from the RI or its host organisation and relevant stakeholders, including funders and users from various sectors, both national and foreign.

Collect Baseline data

At the beginning of the monitoring period, data need to be collected to establish a baseline to which future monitoring data can be compared (see also the ResInfra@DR guidance document on ex ante evaluation for more details : http://www.interreg-danube.eu/approved-projects/resinfra-dr).

The purpose of monitoring

Monitoring – together with ex ante evaluation and socio-economic impact assessment – is an integral part of RI planning and management processes and should be considered along the entire decision-making cycle. It should be viewed as an integral part of RI management and considered before any intervention takes place. Running an RI successfully requires monitoring and periodically assessing activities through various phases: from proposal to implementation and operation, and finally to termination and decommissioning or alternatively to updating or re-orientation of the mission. Monitoring should relate to, and build on, data from an ex ante evaluation, which assesses the needs, goals and feasibility of a planned RI. It also provides data for the assessment of the socio-economic impacts of an RI.

TABLE 1: TYPICAL QUESTIONS ADDRESSED BY MONITORING

Are the proposed activities being carried out in the manner outlined? Why/ why not?
What services are provided (e.g. R&D, measurements, testing, scientific training, etc.) to whom, when, how often, for how long and in what context?
Are services accessible? Is the quality of services adequate? Are the target groups/stakeholders being reached?
Have there been any unforeseen consequences as a result of the activities?
Are activities leading to expected results?
Do assumptions or RI management decisions and operations need to be amended in any way?

Main types of research infrastructure

RIs are rather different, and thus it is crucial to distinguish at least the main types here, and address them from various angles. In practice, of course, a more fine-grained distinction is needed, e.g. when a monitoring framework is devised, a set of indicators are selected, and collected pieces of information are interpreted, assessed and used to assist managerial decisions.

According to the **level of maturity** (life cycle of research infrastructure)

- proposal phase
- design and construction phase
- operation phase
- decommissioning.

According to its **structure**

- single-site RI (placed in a single location, example: MYRRHA; EST, European Solar Telescope)
- distributed RI (located in several different locations, examples: CERIC; DANUBIUS RI; ELI)
- e-infrastructures (example: PRACE).

According to their **geographical scope/relevance**

- regional
- national
- macro regional
- pan-European.

RIs can also be distinguished by two main functions; data collection and classical research. Examples for the first type would be RIs dedicated to geological surveys, present in almost every country, or biobanks which collect and store biological material. Examples for classical RIs would be telescopes, entire laboratories or sets of major equipment. The monitoring of each of these RIs requires a different setup. Therefore, it is important to link the monitoring system to the specific objectives and mission of a given RI.

2 ORGANISING AND MANAGING A MONITORING EXERCISE

Organising a monitoring process presents some challenges; these are listed in Table 2, together with suggested solutions. In general, the monitoring system should always be adapted to the context of a specific RI. It may become necessary to revise it if the RI's circumstances change or it moves to a different life cycle phase. The monitoring system therefore needs to be flexible and should also be periodically assessed to see whether it is still relevant and applicable.

TABLE 2: CHALLENGES IN THE MONITORING PROCESS

Challenges	Possible solutions
It is demanding to define what success means, given the specific features of RIs.	Gather stakeholders' opinions and discuss the definition (main features) of success with them.
Rigorous statistical methods might be difficult to apply.	Identify the level of statistical analysis relevant to the needs of a given RI.
Monitoring plans often lack a clear, appropriate conceptual framework.	Develop a suitable monitoring system already at the RI's planning stage. The monitoring framework needs to be assessed regularly and adapted, if necessary.
Interpreting data is often challenging and requires significant capacity. In many cases, external experts may be needed, which can be costly.	Design a monitoring system on the basis of the RI's actual needs to avoid unnecessary cost.
Sufficient resources are often not allocated for monitoring (and evaluation), which require a substantial financial commitment.	Have a backup plan. Consider monitoring the most salient parts of the RI first. The use of internal experts is often cheaper than employing external experts.
Monitoring requires a strong commitment to reflect on specific results and outcomes to achieve continuous improvement.	Raise awareness on the importance of monitoring among the RI's staff.
RIs often lack the human resources or experience required for a successful monitoring.	Have a backup plan. Train staff to conduct in-house monitoring either before an RI becomes operational or during its initial phase.
Routinely collecting data for monitoring can be a huge burden for RI staff, who may have to conduct monitoring on top of other obligations.	Train staff to focus on monitoring only essential aspects of the RI. This will avoid the collection of unnecessary data, which could lead to overwhelming and demotivating staff.
More detailed monitoring provides more data, but is also more costly.	The monitoring should be linked to the mission and objectives of the RI. Care should be taken that only useful and relevant data is collected.

2.1 Who initiates and performs the monitoring process?

Until recently, funding bodies were the primary initiators of a monitoring process. However, in recent years, RI managers have also realised the importance of adequate planning and thus monitoring. An effective monitoring system can assist RI managers in making decisions on a day-to-day basis, and also provide valuable information for decisions over a longer timeframe (e.g. whether or not to invest in upgrading the entire RI or its major elements).

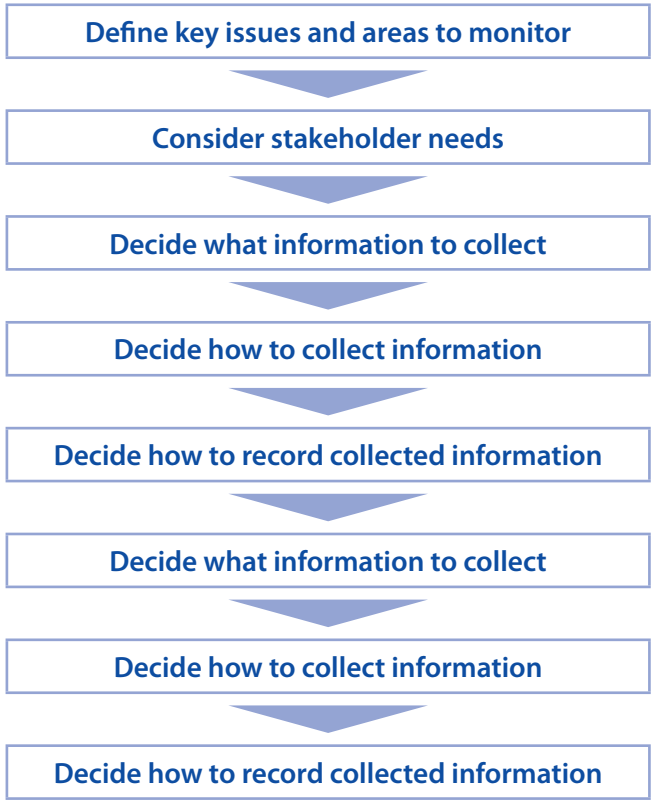
Monitoring of RIs is usually conducted by a team of internal experts (i.e. the RI's staff). It is important to implement quality assurance procedures to ensure that the collected information is relevant and accurate. In some cases (or at certain points in time) it can be helpful to additionally involve external experts or stakeholders of the RI in question. This can help continuously review and improve the monitoring

process. In some cases, funders may also insist on hiring external experts to conduct monitoring. Table 3 shows the advantages and disadvantages of monitoring conducted by internal vs. external experts.

TABLE 3: INTERNAL VERSUS EXTERNAL MONITORING

	Internal	External
Pros	■ Better knowledge of the RI and its context (including political aspects) ■ Access to the RI and its personnel ■ Reduced cost ■ Increased availability for meetings/ activities when required ■ Capacity to collect information in case the RI is unwilling to divulge important information to external experts	■ More adequate and specialised skillset and expertise ■ Could be more open and objective, as external experts have no direct stake in the RI ■ Capacity to collect information (sometimes people find it easier to open up to strangers than to colleagues)
Cons	■ Increased risk of subjectivity ■ Experts might fear potential negative professional and social consequences and could therefore be less willing to monitor critical data ■ Lack of monitoring expertise	■ Higher costs (fees, potential transport and accommodation costs) ■ Decreased availability for participation in meetings/ activities or greater difficulty in organising such activities ■ Reduced understanding of the RI's specific features compared with internal experts ■ External experts might face similar difficulties in staying objective (e.g. if there is a high degree of participation), or may fear professional and social consequences

2.2 How to organise a monitoring process?



When organising a monitoring process, it can help keeping a few guiding principles in mind ensure that the information collected is relevant, useful, timely and credible.

- **Define key issues and areas to monitor**

  It is unlikely that RIs will have enough human and financial resources to monitor all possible aspects at any given time. Posing specific questions to address key issues the RI is facing may help (e.g. insufficient funding, not enough qualified personnel, etc.).

- **Consider stakeholder needs**

  When designing a suitable monitoring process, the RI's stakeholders and their information needs should be kept in mind. A useful monitoring process can be a powerful tool for RI management, and can serve as a basis for both internal and external evaluations, as well as for accounting purposes (project reporting, financial reporting).

- **Decide what information to collect**

  Keeping the above-mentioned issues in mind, a list of relevant indicators needs to be selected. These should address the identified questions and issues and be SMART (specific, measurable, attainable, relevant, and time-bound).

- **Decide how to collect information**

  After having decided on specific indicators, a suitable method for data collection needs to be selected (section 3.1). In most cases, a combination of several methods will be needed to collect all relevant data.

- **Decide how to record the information collected**

  Monitoring data should be collected in a uniform way to make sure it is easily accessible, comparable and understandable. In most cases it makes sense to collect monitoring data in a separate, dedicated database.

- **Quality control**

  Even the methodologically most refined monitoring system is useless if the gathered information is not reliable. Therefore, it is important to implement a quality assurance system to avoid mistakes. One easy-to-implement solution is to impose a system within which monitoring data are routinely cross-checked by at least two people.

- **Adhere to ethical and data protection regulations**

  When designing a monitoring process, it is essential to ensure that the processes and methods used to collect information adhere to ethical standards, as well as to national and regional data protection regulations.

- **Interpret collected data to infer desired information**

  Interpreting monitoring data is of crucial importance, and significant resources should be allocated for this. A detailed analysis of the data should be conducted by RI managers, together with the monitoring team and, if applicable, contributions from external experts. A comparison to similar RIs (benchmarking) can facilitate learning and thus improve the RI's operations and management.

3 MONITORING METHODS

A first step in designing a suitable monitoring framework is to define the areas of observation. It might not be feasible to collect all possible data at all times. For this reason, it can be useful to formulate specific questions, while keeping the RI's mission in mind. As monitoring should facilitate planning and day-to-day management of an RI, the monitoring process should be devised accordingly and assist RI managers by providing the relevant data.

In order to provide useful information, the collected data should be of a suitable quality. Therefore, a system has to be developed to record monitoring data in an easy and accessible way. The implementation of a quality assurance system is advisable to avoid errors and ensure that the collected data is accurate and relevant.

In the following sub-section, common methods for collecting monitoring data are presented.

3.1 An overview of main methods of, and approaches to, monitoring

1) Routine collection of performance data

Many RIs already collect a large amount of data which can be useful for monitoring purposes. Automatically collected data may include the number of users or the degree of capacity utilisation, while data collected manually could include the types of users or research output. These data serve as an excellent basis for monitoring and should be categorised and referenced in a suitable format.

2) National databases

Some countries routinely collect R&D data in a centralised way. If available, these databases can be valuable sources for monitoring data.

3) Financial audits and project reports

Financial audits and project reports are a prerequisite for funding in many countries in the Danube macro region. The information gathered and collected in a reporting context should also feed into an RI's monitoring process, as it can provide useful information. Again, data have to be categorised and formatted in an appropriate way, to ensure it can be easily understood and compared.

4) Manual collection of performance data

Formal questionnaires, structured interviews and surveys can be conducted to gather data which are not routinely collected. Qualitative methods can help in understanding collected data better and putting them into context.

5) Group workshops

In certain cases, it can be useful to collect "soft" data, such as staff happiness levels or stakeholder satisfaction with the services provided or framework conditions. Group workshops and focus groups can be relevant methods to these ends. Such qualitative methods can also help in collecting additional data or understanding and interpreting the information gathered.

3.2 Monitoring indicators

The ResInfra@DR project proposes a set of indicators to monitor the activity of a given RI (Annex II). The presented list is meant to serve as an overview, and the selection of relevant indicators is subject to the specific objectives of the monitoring exercise as defined by the RI (section 2.2). It is strongly recommended to carefully select relevant indicators to ensure that they are relevant and linked to

the mission, objectives and life cycle of the RI. When relevant, the specific needs of the host organisation should also be reflected in the choice of indicators (e.g. typically host organisation's staff will extensively use the RI).

The choice of indicators will influence the behaviour of the observed actors. For instance, monitoring the number of citations may lead to an increase in self-citations. Therefore, special care has to be taken when analysing data obtained from monitoring indicators. Another risk is that different people may interpret indicators in a different way. A detailed description of monitoring indicators should therefore be provided to the team collecting the data.

Interpretation of results should be done in collaboration with RI management, the monitoring team, key stakeholders and, where applicable, external experts. Qualitative methods like (micro) case studies can also be employed. In addition, the monitoring process and choice of indicators needs to be regularly assessed and adapted, if necessary.

4 CONCLUDING REMARKS

Investing in new research infrastructures, as well as maintaining and upgrading existing ones, is a major challenge for RI policy-makers and managers. The use of modern decision-making methods and practices, among them monitoring, can assist them considerably in their day-to-day activities. The need for these methods can be best demonstrated by highlighting three major RI issues.

The most visible and pressing factor is the sheer cost of building new RIs and that of upgrading existing ones. Envisaged RIs, which are crucial to deal with fundamental scientific, environmental and/or socio-economic challenges, and thus which are expected to be built in the coming years, tend to be expensive. Simply stated, not all these new investments can be financed, and hence choices have to be made, as well as other sources of funding should be mobilised. Second, given the importance of RIs – their role in addressing major scientific, technological, societal, economic and environmental challenges, and thus the socio-economic consequences of their operation; the financial implications of building and maintaining appropriate RIs; etc. – demanding strategic decisions are to be made. Third, many RIs are exploited below desired levels. Some experts, therefore, suggest that a shift in emphasis is required – away from concerns about funding new or upgraded RIs and towards better use and management of existing RIs. Funding, interoperability, open access on the basis of merit, meeting educational and training needs, and data conservation are thus central management concerns. These issues require strategic responses that take a long view – but the necessary strategic capabilities are underdeveloped at many RIs. Moreover, better co-ordination of RIs is needed, both at national and EU levels, to achieve more efficient utilisation of resources and skills. Further efforts are also required to reduce the duplication and sub-optimal use of resources, given the current lack of co-ordination.

For the above reasons, ex ante evaluation, monitoring of RIs, as well as assessing their socio-economic impacts are of crucial importance when making major strategic decisions on new RI investments, or when making efforts to improve RIs' operation and performance. The ResInfra@DR project has compiled guidance documents on these three important decision-preparatory methods. Until recently, monitoring and evaluation of RIs has been regarded as a tool primarily suited to policy-makers and funding agencies. However, monitoring can be a powerful instrument for RI managers as well. The present guide has provided an overview of monitoring process and methods and can be consulted when devising a monitoring system, tailored to the specific needs of a given RI.

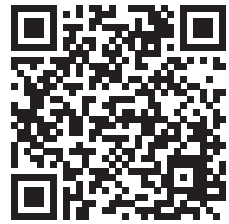
Monitoring is the systematic process of collecting, analysing and using relevant information to track the performance of an RI and guide management decisions. It can be a powerful tool for both RI managers and policy-makers. For RI managers, monitoring can significantly improve the structure, processes and methods of management, and thus help improve operations and performance. For policy-makers, monitoring provides the necessary data to assess the efficacy of public investments in RIs.

Preparatory steps for introducing an adequate monitoring system include defining the mission and goals, the development of an operational framework and suitable monitoring process, and the collection of baseline data. Organising a monitoring process presents some challenges; these have been laid out in this document, together with possible solutions. Monitoring can be performed by a team of internal or external experts. Advantages and disadvantages of each approach have also been considered. Further, guiding principles that can help in designing a relevant monitoring system have been offered. First, key issues and areas to monitor should be defined, while keeping stakeholders' needs in mind. Then it has to be decided *which* information will be collected and *how* it will be collected and recorded. A quality assurance system has to be developed. Monitoring processes and

methods also need to comply with the ethical and data protection regulations. Finally, it is important to interpret the collected data correctly and to infer the desired information from these analyses. Methods to collect the required data include the routine collection of performance data, the use of national databases, collection of data within the framework of financial audits and project reports, as well as the manual collection of performance data. A list of commonly used indicators and good practice examples are presented in the annex of this document.

While the main aim of monitoring is to assist RI managers in improving internal operations, different periods in the life cycle of an RI and different perspectives call for other evaluation methods. In the planning phase, an ex ante evaluation will provide insight into the feasibility of a project's goals, as well as the expected scientific, technological and socio-economic impacts. At a later stage, an assessment of the socio-economic impacts of an RI will provide valuable information for policy-makers, RI managers and other stakeholders.

The ResInfra@DR guidance documents discussing these methods and processes are available at http://www.interreg-danube.eu/approved-projects/resinfra-dr



SOURCES

ESFRI WG on Evaluation of RIs (2011). ESFRI Evaluation Report 2011

Griniece, E., Reid, A., and Angelis, J. (2015). Guide to Evaluating and Monitoring Socio-Economic Impact of Investment in Research Infrastructures, Technopolis Group, Tallinn, Estonia

Hass, J.L. (2013). Using the right environmental indicators: Tracking progress, raising awareness and supporting analysis. Nordic Council of Ministers, Denmark: TemaNord

Meek, V.L., and Van der Lee, J.J. (2005). Performance indicators for assessing and benchmarking research capacities in universities, UNESCO Office, Bangkok and Regional Bureau for Education in Asia and the Pacific

Ministry of Education, Youth, and Sport (2015). Roadmap of Large Infrastructures for Research, Experimental Development and Innovation of the Czech Republic for the years 2016–2022, Ministry of Education, Youth, and Sport, Prague

Monitoring and Evaluation for Sustainable Communities (2014). A step by step guide to Monitoring and Evaluation, Higher Education Innovation Fund, Oxford: University of Oxford

Odhiambo, F.O. (2013). Types of Monitoring in Monitoring and Evaluation. Retrieved from: https://evaluateblog.wordpress.com/2013/07/02/types-of-monitoring-in-monitoring-and-evaluation-me

Rossi, G. (2013). Proposal to ESFRI on "Indicators of pan-European relevance of research infrastructures" (Giorgio Rossi on behalf of the Expert Group on Indicators, October 1st, 2013). Retrieved from: https://www.ceric-eric.eu/2018/08/30/key-performance-indicators-of-research-infrastructures

ANNEX I: PRACTICAL EXAMPLES OF MONITORING

Monitoring conducted by the Austrian funding agency FFG

The Austrian Research Promotion Agency (FFG) has established a programme to specifically fund research infrastructure projects. To date, two calls have been launched and successful projects are required to issue reports on an annual basis. In addition, the FFG requires all funded projects to monitor use of their RI in order to adhere to EU regulations. Details of both types of reports for non-economic use can be found below[1]:

	Interim and Final Reports	**Monitoring report**
Purpose	Reports financial expenditure and project progress	Reports RI usage
Structure	Written report according to a template	Written report according to a template
Length	10–20 pages	10–20 pages
Contents	■ Achievement of goals ■ Information on progress of milestones and deliverables ■ Information on implemented activities ■ Report on project changes if applicable ■ Report on changes in the project team and co-operation if applicable ■ Report on RI use (scientific output, new collaboration, international visibility, added benefit for the region) ■ List of publications, dissertations, Masters theses, patents ■ Impact of results on other projects ■ Report on occurred costs and reasons for deviations from the plan (if applicable) ■ Report on unforeseen developments with legal relevance for the FFG (additional funding for the project, legal changes within the organisation, bankruptcy, etc)	■ RI use and operation ■ Percentage of commercial and non-commercial use ■ Names and affiliations of all users ■ Percentage of user time (if exceeding 5%) ■ Demand and degree of capacity utilisation ■ Adaptation of utilisation concept (if applicable) ■ Access policy for external users ■ Access mode for internal users ■ Short description of implemented activities ■ Declaration that commercial and non-commercial use have been separately accounted for ■ Declaration that any commercial usage doesn't exceed 20% of total capacity ■ Declaration that preferential access by co-funding users doesn't exceed the co-funding rate ■ Declaration that access to the RI is open and without discrimination ■ Declaration that market prices (total costs plus profit margin) were calculated for commercial use (minimum requirement) ■ Report of application and impacts of activities ■ Data protection policy ■ Measures to ensure financial sustainability
Frequency	Yearly	Yearly
Duration	While the project is running	Starts with operation; a minimum of 5 years

Source: FFG Austria, 2016

Monitoring conducted by CERIC

CERIC is a multidisciplinary research infrastructure in the field of materials, biomaterials and nanotechnology. Its monitoring system is closely tied to its mission and specific objectives. CERIC follows

1 Further information is available online at: https://www.ffg.at/FuE-Infrastrukturfoerderung_1_AS (retrieved 03/03/2019)

the principles of results-based management, leading to a life cycle approach to planning, monitoring and evaluation. Before implementation begins, specific goals are set, a results framework is defined, activities are developed and resources are allocated. Monitoring becomes an integral part of management once implementation begins, to assure that planned activities are being performed and interventions are leading to the achievement of specific goals. For an effective monitoring, indicators are defined for each specific objective (see the series of tables below) and should follow the SMART (specific, measurable, attainable, relevant, and time-bound) principle.

1) To offer free and open access to users, securing efficient service and optimum conditions for users

Key performance indicator	Description and type	Type of data required
RI use by researchers	Researchers who have access to the instruments of the consortium	Overall number of researchers
User interest	Interest in open access calls among the scientific community	Number of proposals received in calls for open access
International awareness	Awareness of the CERIC offer worldwide	Number of countries of principal investigator (PI) participating in open access calls
Scientific output	Peer-reviewed scientific publications in ISI-listed journals	Number of publications and average impact factor
Quality of support	Average score based on the "User satisfaction survey"	Average score

2) To further the integration of partner facilities into a unique, EU-level Distributed Research Infrastructure

Key performance indicator	Description and type	Type of data required
Volume of funded H2020 and ERDF/ESF projects for joint research and development	Monetary volume of funded H2020 and ERDF/ESF projects that involve multiple partner facilities	Volume (EUR)
Added value to the partner facilities through collaboration within CERIC	Volume of funds acquired by partner facilities nationally due to CERIC	Volume (EUR)

3) To make optimum use of resources and know-how, by co-ordinating RD, by joint training and by collaborating with neighbouring communities. To foster support to industrial development and users

Key performance indicator	Description and type	Type of data required
International and intersectorial collaboration	Volume of projects proposed with CERIC as partner, lead partner or beneficiary, together with institutes and companies outside the consortium and/or the region	Volume (EUR)
Use of RI by industry	Income generated by CERIC through proprietary research	Volume (EUR)

Co-development with industry	Number of peer-reviewed scientific publications resulting from CERIC scientific operations and co-published with industrial partners	Number of publications

4) To increase international visibility and support training for the upcoming generations of users

Key performance indicator	Description and type	Type of data required
Visibility of and interest for CERIC in different communities	Invitations to CERIC to conferences, workshops and other relevant events	Number of invitations
Expansion of the user base	Number of students trained in skills related to the use of research infrastructures	Number of trainees

Source: CERIC

ANNEX II: COMMON INDICATORS

List of performance indicators [2]

The following, non-exhaustive list should be used as an example of possible monitoring indicators. Specific indicators should be selected according to the mission and objective of a given RI, and the principles presented in this guide.

1) Scientific activity indicators

- Total number of users (domestic and foreign)
- Percentage of female users
- Types of users
- Number of peer-reviewed articles published as a direct result of research with or within the RI
- Field normalised citation rate (indicator of the impact of publications)
- Proportion of top 10% publications, that is, the proportion of publications stemming from a given RI (direct results of research with or within that RI) that belong to the top 10% most frequently cited publications, compared with other publications in the same field and in the same year
- Number of participation in domestic and international grant schemes
- Number of new or siginificantly improved methods developed
- Number of Bachelor theses completed (by using the RI)
- Number of Master theses completed (by using the RI)
- Number of PhD dissertations completed (by using the RI)
- Number of PhD and post-doc positions advertised and number of applications
- Number of scientific events organised on research topics directly related to the RI's services
- Number of collaborative research projects (with national and foreign research institutes)
- Number of international co-publications

2) Gender specific indicators

- Gender pay gap per staff category (female salaries are …% of male salaries)
- Glass ceiling index

3) Technology transfer indicators

- Number of R&D projects with firms and applied research institutes
- Number of technologies, prototypes and industrial designs developed

2 Adapted from Technopolis Group, 2015 and Nordic Council of Ministers, 2013

- Number of start-ups and spin-offs established based on research conducted at the RI
- Number of feasibility or market studies for industrial investment and application of technologies
- Number of projects (e.g. proof of concept, prototyping) that move to the stage of industrial investment
- EU or international patents granted and published patent applications (all types)

4) Environmental indicators

- Total water withdrawal
- Energy consumption
- Physical emissions
- CO_2 emissions
- Hazardous and non-hazardous waste generated
- Ecological footprint

5) Output indicators

- Number of outreach events, including data on participants' satisfaction
- Number of press articles or social media news items on the RI
- Accounts of improved local infrastructure, community services, increase in local cultural/ recreational activities due to the RI
- Number of indirectly created jobs due to the activities of RI stakeholders, e.g. local suppliers who increase their capacity due to collaboration with the RI

6) Human resources capacity indicators

- Number of (i) scientists (by academic degree), (ii) technicians, (iii) administrative and management staff
- Percentage of female (i) scientists (by academic degree), (ii) technicians, (iii) administrative and management staff
- Number of newly created jobs within the RI by category (scientific/ technical/ administrative/ management)
- Percentage of international staff members and students (number of foreign staff members and students as a percentage of total staff and student numbers)
- Number of Bachelor, Master, and PhD students trained at the RI
- Percentage of female Bachelor, Master, and PhD students trained at the RI
- Number of international co-publications

7) Economic indicators

- The number of scientists, students, publicly funded R&D institutes and other organisations (e.g. NGOs, non-profit organisations) or private enterprises that benefitted from RI services (e.g. testing, development of methodologies, contract research)
- The total amount of funding generated (e.g. from services, grants and joint projects with businesses)
- The total amount of expenditure in different cost categories (e.g. personnel, operations, maintenance)
- Total RI capacity utilisation: RI access hours as a percentage of total available access time
- RI capacity utilisation by business users: access hours used by businesses as a percentage of total available access time
- Net income of the RI (measured as the difference between total income and total expenditure)

8) Qualitative indicators

- User feedback
- Stakeholder feedback

GLOSSARY

Benchmarking	Benchmarking is a direct performance comparison between comparable organisations to promote progress and learning.
Ex ante evaluation	Ex ante evaluation is the evaluation which takes place before an intervention is undertaken.
Indicators	Indicators are specific measures of performance for which data can be collected.
Socio-economic impacts	Socio-economic impacts describe a wide range of potential effects on society, economy, technology and knowledge generation.
Stakeholders	Stakeholders are a group of people who have a qualified interest in the object in question.

ABBREVIATIONS

CERIC	Central European Research Infrastructure Consortium
DANUBIUS-RI	The International Centre for Advanced Studies on River-Sea Systems
ELI	Extreme Light Infrastructure
EST	European Solar Telescope
FFG	Österreichische Forschungsförderungsgesellschaft Austrian Research Promotion Agency)
MYRRHA	Multi-purpose hybrid Research Reactor for High-tech Applications
PRACE	Partnership for Advanced Computing in Europe
RI	Research infrastructure
R&D	Research and Development

LIST OF TABLES

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.

ISBN 978-3-200-06406-5