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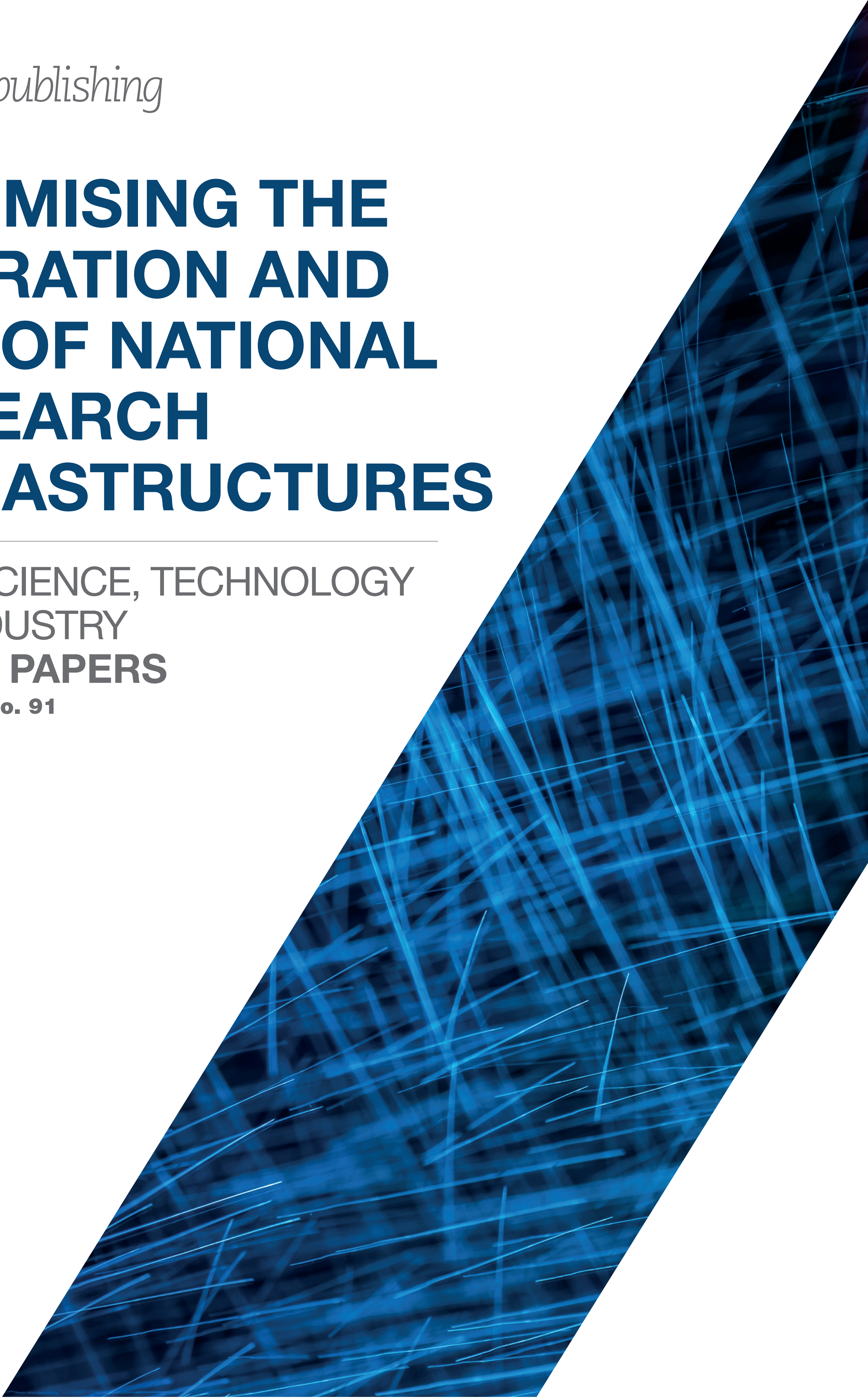

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OPTIMISING THE OPERATION AND USE OF NATIONAL RESEARCH INFRASTRUCTURES

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OPTIMISING THE OPERATION AND USE OF NATIONAL RESEARCH INFRASTRUCTURES

Abstract

Research Infrastructures (RIs) play a key role in enabling and developing research in all scientific domains and represent an increasingly large share of research investment. Most RIs are funded, managed and operated at a national or federal level, and provide services mostly to national research communities.

This policy report presents a generic framework for improving the use and operation of national RIs. It includes two guiding models, one for portfolio management and one for user-base optimisation. These guiding models lay out the key principles of an effective national RI portfolio management system and identify the factors that should be considered by RI managers with regards to optimising the user-base of national RIs. Both guiding models take into consideration the diversity of national systems and RI operation approaches.

This report also contains a series of more generic policy recommendations and suggested actions for RI portfolio managers and RI managers.

Keywords: research infrastructures; portfolio management; user-base; user access.

Foreword

This report follows and complements recent work undertaken by the OECD Global Science Forum and by Science Europe on the establishment, management and international cooperation of research infrastructures (RIs). It addresses the challenges faced by RI managers, operators and decision-makers in managing national portfolio of RIs and optimising their access and use.

Most RIs are funded, managed and operated at a national or federal level, and provide services mostly to national research communities. In a context of limited research budgets, governments and funding agencies are confronted with the challenge of supporting increasingly large and complex RI portfolios. Potential users of RIs are also increasingly diverse and numerous, particularly as the data produced by RIs becomes progressively more complex and varied. The operation and use of these national RIs therefore requires careful balancing and optimisation.

This policy report presents a generic framework for improving the use and operation of national RIs, including a number of options, which take into account the diversity of national contexts and of RIs.

The framework also includes two guiding models, one for portfolio management and one for user-base optimisation. These guiding models summarise the key principles of an effective national RI portfolio management system and the elements that should be considered by RI managers with regards to optimising the user-base of national RIs. Both guiding models take into consideration the diversity of national systems and RI operation approaches. Examples of uses of the guiding models are included.

This report also contains a series of more generic policy recommendations and suggested actions for RI portfolio managers and RI managers.

It should be noted that the COVID-19 crisis is likely to intensify some of the issues that are addressed in this report, and that were highlighted by discussions at the "European Research Infrastructures for a smarter future" conference (15 May 2020) related to COVID-19 and the promotion of remote access to RIs. Many national funders have diverted research funding to focus on the COVID-19 response, adding to the pressures on budgets available to support RIs. Many RIs have also set up rapid or fast track access to allow researchers to obtain results as soon as possible, to respond to the needs of researchers engaged in Covid-19 research, as well as making arrangements to release results earlier than is usually the case, highlighting the importance of optimised access mechanisms, data sharing and user support provision.

This report was co-written by the GSF-Science Europe Expert Group chair (Catherine Ewart), project consultants (Peter Fletcher and Isabel Bolliger), the GSF secretariat (Frédéric Sgard), the Science Europe Office (James Morris), with extensive input from Expert Group members.

We hope that this report will be informative and useful and we would be interested in receiving comments from readers. The Global Science Forum staff can be reached at gsforum@oecd.org and Science Europe Office staff at office@scienceeurope.org.

The OECD Global Science Forum (GSF)

The GSF is a Working Party of the OECD Committee for Science and Technological Policies. Its main objective is to support countries to improve their science policies and share in the benefits of international collaboration. GSF provides a venue for consultations and mutual learning among senior science policy officials of OECD member countries. It carries out analytical work on high-priority science policy issues. The GSF's principal customers are the government science policy officials who bring issues to the GSF for deliberation and analysis in an intergovernmental setting.
More information on our mission and activities is provided at http://www.oecd.org/sti/inno/global-science-forum.htm.

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Executive Summary

Most research infrastructures (RIs) are funded, managed and operated at a national or federal level, and provide services mostly to national research communities. There is demand for specific analysis of how to optimise the operation of these national research infrastructures. This is in a context where research budgets are limited and governments and funding agencies are confronted with the challenge of supporting increasingly large and complex RI portfolios.

RIs are extremely diverse and good practices and policies may not necessarily apply to all RI types. The study focused on RIs that provide access to their equipment/data/resources to external users outside their host institution. Underlying data/computing infrastructure, which connect and provide access to RI data, are included as well as data RIs that provide services to users.

This policy report presents a generic framework for improving the use and operation of national RIs. This includes a set of options which take into account the diversity of national contexts and of RIs. It is based on the results from a study that was structured to address two complementary areas: *Managing portfolios of RIs* and *Optimising the user-base*.

The activity was co-organised by the OECD Global Science Forum and Science Europe. It was supervised by an international Expert Group (EG) nominated by both organisations chaired by Dr Catherine Ewart (UKRI, United Kingdom). The EG conducted two surveys and held two international workshops. One survey was conducted among funders and decision-makers and the other among RI managers. A workshop in London discussed the initial findings from the surveys, and a second one in Seoul discussed the emerging recommendations.

Managing Portfolios

In response to the wide range of inputs received, the lessons learned were synthesised into a "Guiding Model" which summarises the key elements of an effective national RI portfolio management system. These are:

- A review or road-mapping process collecting bottom up and top down inputs to create a forward plan for RI needs in the context of the national Research and Innovation strategies;
- A means to act upon the forward looking plan and allocate resources, for capital and operations, to ensure that the highest priority RIs are funded;
- Processes to gather inputs from the research community, RI operators and other stakeholders in terms of research, data and operational needs;
- A management process that considers the whole portfolio of new and existing RIs together;
- A process that encourages cooperation between RIs and allows competition to ensure the highest priority facilities are supported or selected;
- The stimulation of international networking for national RIs, and embedding international RI options alongside national RI options to find the best solutions to deliver the research requirements of the national community;

- Appropriate means to monitor the performance of national and international RIs on an ongoing basis;
- A mechanism to identify, in good time, facilities that can be closed or divested to other managers;
- Transparency so that the criteria and processes for deciding on investment are clear to RI operators.

Optimising the User Base

Several major challenges emerge when considering user-base optimisation from an RI manager perspective. These challenges were analysed to develop a "Guiding Model" that recommends key elements that should be considered by RI managers with regards to optimising the user-base of national RIs. These elements are:

- The appropriate monitoring of RI users to inform strategies for the optimisation and management of user bases.
- Consideration of the variety of options to optimise the use potential of RIs, and the strategic evaluation of the benefits and risks of each.
- The provision and communication of clear and transparent mechanisms for accessing RIs, and consideration of how to extend access to new users/communities.
- The facilitation of access to data generated or managed by RIs, and the promotion of collaboration between RIs to establish and standardise transparent data policies.
- The promotion of data sharing by RI users and the establishment of appropriate mechanisms to monitor the secondary use of data generated or managed by RIs.
- The provision of 'free-from-costs' access for merit-based academic use, wherever this is possible, and the establishment of clear and transparent pricing policies for all potential users.
- Consideration of the resources devoted to users, both from a financial and personnel perspective, and the engagement of RI funders/decision makers to increase funding for extended support services, where beneficial.

Conclusions and Recommendations

This work has identified a wide range of management practices, which impact on the optimisation of the operation and use of national research infrastructures. The diversity of national systems and RI operation approaches means that there is no single model to suit every country or RI, but some key factors or guiding principles have been identified ,which it is hoped will be useful to policy makers, funders and managers interested in improving or optimising their RI portfolios and user bases. These principles have been brought together into two Guiding Models (see chapter 5) to help policy makers, funders and RI managers.

Suggested actions:

- RI portfolio managers and RI managers should assess their portfolio management and user base approaches against the principles contained within each of the Guiding Models (see chapter 5) to aid the development of their management processes.
- RI portfolio managers and RI managers who have completed their assessments, should work with peers at national and international level to exchange experiences in using the Guiding Models. This can provide a basis for the creation of networks focused on continuous improvement and mutual learning. Funders and policy makers should consider ways of encouraging and providing support for the establishment of such networks.
- RI portfolio managers and RI managers should work together to reach agreement on standards and definitions for RI management and access including types of RIs and Users. They should agree the minimum information to be made publicly available on-line about RIs and the facilities, resources, and support that they offer.
- RI portfolio managers and RI managers should consider the relevance of the good practice examples presented in this report for their own RIs, and consider adopting similar approaches, where appropriate, within their own national contexts.

1. Introduction

1.1. Background and rationale

Large and/or international research infrastructures (RIs) have been the focus of many reports and initiatives in recent years to improve their governance, efficiency and sustainability (OECD, 2017[1]; 2014[2]; 2010[3]; GSO, 2019[4]; ESFRI, 2017[5]). However, most RIs are funded, managed and operated at a national or federal level (collectively referred to for this report as 'national RIs'), and provide services mostly to national research communities. While some may have benefited from the recommendations and guidelines generated by analysis of their international counterparts, there is a demand and opportunity for more specific analysis of how to optimise the operation of these national RIs. This is in a context where research budgets are limited and governments and funding agencies are confronted with the challenge of supporting increasingly large and complex RI portfolios.

National RIs have become increasingly important in many national research strategies as well as in some supranational regional contexts such as of the European Research Area (ERA). In this regard, Science Europe (which, like the GSF, counts 'Research Infrastructures' as one of its long-term priority areas) has led several initiatives to investigate how strategic priorities regarding RIs are established (Science Europe, 2016[6]), and, in earlier work, the GSF undertook an extensive survey of national and international road-mapping exercises (OECD, 2008[7]).

More recently, Science Europe organised a workshop on "Cross-border Collaboration and Portfolio Management of Research Infrastructures", which explored the challenges associated with designing and managing balanced RI portfolios through cross-border collaboration, and addressing questions such as investment in new vs. existing RIs, balancing discipline/field investment, and national RI investment vs. supporting international projects (Science Europe, 2017[8]).

The previous work of the GSF and of Science Europe on RIs has highlighted a clear need for a comprehensive study combining the perspectives of both RI funders/decision makers and RI managers specifically addressing the optimisation of the use and management of national RIs, from both a facility and national portfolio standpoint.

The Global Science Forum authorised at its 39th Meeting on 30-31 October 2018 the launch of an activity on optimising the use of national RIs. Considering the interest of Science Europe in the topic, a partnership was created between the GSF and Science Europe for this activity, which was carried out by a joint GSF-Science Europe international Expert Group (listed in Appendix 1), supported by both the GSF Secretariat and the Science Europe Office.

1.2. Terms of Reference and focus

The objective of this study has been to identify policies and procedures that can increase utilisation and improve the operation of national research infrastructures and prepare a report for the use of OECD and Science Europe members.

RIs are extremely diverse and good practices and policies may not necessarily apply to all RI types. The Expert Group therefore decided to focus on a subset of RIs that could potentially benefit the most from policy recommendations. RIs addressed by this study were required to have a long operational lifetime and not be virtual-only or loose associations of laboratories created to carry out a specific project. This study also focused on RIs that provide access to their equipment/data/resources to external users outside their host organisation. Underlying data/computing infrastructure, which connect and provide access to RI data, were included as well as data-driven RIs that provide services to users.

Several types of RIs were considered as less likely to benefit from this work (e.g. because their services apply only to a very specific niche set of users so that optimising the user base is not particularly relevant):

1. International RIs (those that are governed by a set of international partners);
2. RIs which are not open to users outside their host organisation or outside specific collaboration agreements;
3. RIs which are only used by a very small community of users with specific needs;
4. Research infrastructures that mostly serve private users or are for-profit organisations (including most Research Technology Organisations);
5. Archives and repositories that are freely accessible and require no interaction between user and provider, e.g. no significant accompanying services are offered.
6. The study was conducted in two complementary areas: 1) Managing Portfolios of RIs and 2) Optimising the User Base, recognising that optimising a portfolio of RIs has a strategic component reflecting the decisions made on which RIs to support and an operational component in how each RI within a portfolio is managed.

1.3. Managing portfolios of RIs

This study investigated the tools and options used by countries for long-term planning (e.g. landscape analyses, road-mapping, strategic surveys, user feedback, etc.), investment policies (e.g., national investment vs shared participation in international projects) and life-cycle management, including divesture or termination. An important aspect of this analysis was examining how portfolio managers (at agency or ministry level) reconciled the need for flexibility with financial constraints.

Another element of the study involved exploring the development of synergies between national (or between national and international) RIs, as well as with cyber infrastructures, for better services, efficiency and impact. How stakeholders can coordinate their action, including how collaborations may be incentivised to rationalise investments, was also examined. The scientific and socio-economic impact assessment of RIs were not covered in this study, but have been discussed in detail in a previous OECD Policy Paper (OECD, 2019[9]).

Policies and practices to make more efficient procurements, calls for tender, or purchase of equipment which might be developed through increased connections between RIs were not be investigated in detail during this study. However, it is hoped that as networking between RIs develops, as encouraged in the report, issues such as procurement will be explored by the managers of equivalent RIs in different locations.

Optimising the user-base

Optimising the user-base of RIs, for the purposes of this project, denotes the processes, mechanisms and policies that may be considered when attempting to maintain, improve, extend, or better manage the user base of an RI.

This included identifying policies that can facilitate the use of national RIs by broader user communities (e.g., international users, users from scientific disciplines outside the traditional remit of the RI, private sector users). Included in this assessment are policies relative to access, proposal solicitation and evaluation, communication and cost-sharing.

An important aspect of this activity was an assessment of how RIs maintain, extend and/or evolve their user base, as well as investigating potential opportunities (such as promoting new ideas and perspectives) and challenges related to enlarged user communities (e.g. increased need for developing career paths within RIs to deliver those services). A second aspect was how RIs address their complementary roles of being service providers as well as capacity builders that train the next generation of researchers and research support professionals.

1.4. Challenges

Optimising the selection, use and operation of national RIs faces a number of challenges, and constraints that often reflect existing working practices. This study identified a number of specific challenges related to both the potential broadening of RI user-base and the management of RI portfolios, which were investigated in depth. These include:

For portfolio management:

1. Addressing RI requirements in the context of the whole research base
1. Long term planning for RIs
2. Budget availability vs demand (including operating costs and balancing new and existing RIs)
3. National vs international investment
4. Transparency of decision processes (including research, strategic and socioeconomic factors)

For user-base optimisation:

1. Understanding and monitoring the current user base of RIs
2. Access mechanisms to facilities, resources, and services
3. Data access mechanisms
4. Cost sharing and pricing
5. Administrative and support services

1.5. Methodology

This activity was supervised by an international Expert Group nominated by both the OECD Global Science Forum and Science Europe organisations (Appendix 1) and chaired by Dr. Catherine Ewart (UKRI). Experts from international organisations interested in RI policy were also invited. The Terms of Reference of the work were proposed by a Scoping Group and approved by the Global Science Forum in April 2018.

A preliminary fact-finding exercise and discussion with the Expert Group was conducted to identify existing policies and practices, regarding the management of RI portfolios and generic RI user policies. This revealed a large diversity of practices and approaches. Surveys were conducted to obtain more detailed information and the results were further discussed with relevant stakeholders during international workshops. Case studies were also conducted to collect in-depth information.

Two surveys were carried out by the Expert Group:

- The first survey was conducted among funders and policy-makers using structured interviews carried out by Expert Group members and focused on RI portfolio management (Appendix 2).
- The second survey was conducted among RI managers through a detailed online questionnaire complemented by selected interviews. This was mostly focused on user-base issues, although it also contained questions regarding portfolio management. A broad range of RIs were selected (covering different scientific domains, RI types and geographical areas, see Appendix 3) to ensure appropriate representation.

It is important to note that the two surveys were designed to be illustrative rather than statistically representative and were focussed on elucidating interesting cases from a diversity of examples. The selected groups of participants for both surveys do not reflect an exhaustive sample of all RI subtypes, but were deemed appropriate to capture heterogeneities and commonalities across national RIs and national RI portfolios.

Two international workshops were organised, in London (17-18 June 2019) and in Seoul (28-29 November 2019). The workshop programmes, participants and presentations are available on the GSF RI policy web space at https://community.oecd.org/community/cstp/gsf/ripolicy. Break-out sessions were organised during these workshops to facilitate discussion on selected topics.

Both workshops included presentations from portfolio managers and RI operators illustrating the systems they use and the challenges they faced in optimising their activities. The first workshop discussed the initial findings from the surveys, and the second the emerging recommendations identified from the information gathered.

Several interesting practices and policies were identified during the surveys and workshops and were the subject of further analysis to provide more detailed information on key challenges and good practices which could be used by relevant stakeholders.

1.6. Report

This policy report provides a generic framework for improving the selection, use and operation of national RIs. This includes a set of options which take into account the diversity of national contexts and that of RIs. The report contains:

1. Policy recommendations to governments, funders and RI management that can help enhance the efficient use of national RIs, maintain quality/excellence and foster synergies
2. Guiding models for portfolio management and user-base optimisation that summarise the lessons learned during the study
3. Illustrative examples that help to support specific recommendations and actions towards optimising the use and operation of RIs
4. Specificities for different fields of research or categories of RIs (where applicable) to highlight common or unique challenges

2. Managing portfolios of national research infrastructures

RI portfolio management may be led by a national ministry with research as part of its portfolio, an agency or research council acting with or on behalf of the ministry, or be a complex process involving multiple actors, especially in countries with strong federal systems.

As the number and diversity of RIs increases, in parallel with an increasing demand from scientific communities for new RI capacities, sponsors have to face difficult choices, and decision processes need to be properly informed.

The management of a research infrastructure portfolio typically involves several key elements:

- long-term strategic planning that involves appropriate landscaping mechanisms and community input
- transparent budgetary mechanisms that allow for flexibility and reduce redundancies
- balancing exercises, that take into account opportunities and priorities (new vs old, national vs international etc.)
- impact evaluation and foresight of the various investments as well as of opportunities and need for phasing out of activities
- taking into account external drivers in the decision-making process.
- On the basis of the information gathered, it is clear that no single model for RI portfolio management is being used globally. The models in Table 1 were identified from the nations contributing to this activity.

Table 1. Responsibilities for RI portfolio management

Portfolio Management Models	Countries
Ministry alone	*Australia, South Korea*
Ministry and Agencies	*France, Hungary, Ireland, Netherlands, Norway, Switzerland, UK*
Agencies alone	*USA*
Ministry, Agencies and regional authority	*Canada, Germany, Japan, Spain*

2.1. Findings

This analysis is derived from background material provided by Expert Group (EG) members from their national ministries and institutions alongside views given in the interviews conducted by EG members and the secretariat with portfolio managers (see Appendix 2). These illustrate the wide range of approaches being taken by national governments and agencies, where no two approaches are the same. Specific examples are given of the approaches taken by some countries to address each area of action. Feedback from the RI manager survey indicated similar concerns as those raised during the interviews with policy-makers.

Roadmap, Landscape and Community input

> *"Our 2018 Roadmap for Research Infrastructure has three components: Area strategies, large-scale research infrastructures of national importance, participation in International RIs."*[1]

> *"There is no set cycle of consistent tool usage for this type of planning – RIs are considered alongside other capital and resource investments."*

> *"Prior to the revision of the road map research institutions were invited to collaborate and prepare input to the area strategies on future needs for new or upgraded infrastructure in high priority areas."*

> *"Rather than identify priority areas ourselves, we require universities and colleges to develop their own Strategic Research Plans."*

While many countries have a road-mapping or planning process, these are not uniform in methodology or outcomes and may depend on the level of maturity of countries in relation to RIs. Top-down mechanisms usually include a means to receive input from the research community while, in more bottom-up processes, the scientific community sends in their wishes which are triaged by the relevant authority within their own framework. Survey feedback recommends that a holistic approach to be taken to science funding in which consideration is given to RIs in the context of the wider research landscape. It was also suggested that any roadmap process should include a comprehensive assessment of the RIs within the total R&I system. This can be achieved through a landscape analysis of current RIs and future requirements. Existing, well-coordinated communities may find this easier to provide than research communities new to RI projects or new users of existing RIs. Some countries prepare separate roadmaps at discipline level. Countries are also increasingly taking into account RIs beyond their national borders in assessing their national needs and include supranational inputs such as the European Strategy Forum on Research Infrastructures (ESFRI) or as recommended by the European InRoad Project (2018) (InRoad, 2018[10]).

Norway has a clear road-mapping process covering all RIs, managed by the Norwegian Research Council, funding the capital and start-up costs, with operational funding coming from user research grants from the same body, or institutional funds. Australia completes a roadmap every five years, then complements that with an investment plan every two years, which is developed on the basis of a top down strategic approach and includes co-investment by State Authorities.

The USA manages community input and planning at the discipline level, with inputs such as Decadal Reviews, Portfolio Reviews and Mid-Point surveys. In Germany, the federal ministry considers that there is a close relationship and contact between funders and the scientific community; many decisions are driven by research centres and research agencies. In South Korea, road-mapping is led by the ministry, but all decisions are made by experts recommended by the scientific community. In addition, RIs are analysed and included in a roadmap in the mid- to long-term development strategies of each science and technology area.

Budget – redundancy and flexibility

> *"Each proposal for a new RI must discuss the availability of similar infrastructure in the region or country, and justify the need for a new investment if there is duplication."*

> *"The funding model requires matching funding. We set aside envelopes for each competition however long it takes to expend the funds, so we don't have so much pressure on our budget."*

> *"The operating costs of the research infrastructure are to be covered by the projects that use it. Applicants seeking funding to establish a research infrastructure must include plans for how to achieve sustainable operation of the infrastructure."*

Some countries have clear mechanisms to avoid redundancy in new RI proposals by requiring applicants to co-ordinate in overlapping areas to present a single proposal, but others operate mainly through competition. The Netherlands has created an "Inventory of Memberships of RIs" across all Ministries to avoid duplication and asks universities and institutes to decide where to invest, including encouraging competitors to work together on joint proposals. These clusters set up a rolling agenda that is nearly a cluster-roadmap in itself. This may also lead to synergy by prioritising, aligning needs and perhaps even have more ambition than before. In France, the strategy is to promote complementarity rather than competition. There is no direct link between being on the French roadmap and funding; the ministry funds research performing organisations that in turn fund most RIs. In contrast, the system leans towards the competitive side in Germany, each project having to compete for its resources within a variety of funding mechanisms.

Flexibility in funding can be quite limited, but some countries offer to address new requirements outside the normal planning cycle, when necessary. If a broadening or extending of a RI's user base is considered, it needs to be clear who funds the associated extra user costs – the RI, the funding agency or the research community of the new users. In Canada, the Canada Foundation for Innovation (CFI) does not work to an annual budget so is able to adjust spending profiles to match project requirements if they change over time. Planning is done by communities with no overall national roadmap.

The adoption of in-kind contributions for international RIs is recognised as a means of enabling partners to engage actively in RI development, but adds complexity and risk, which must be understood from the outset. It was also noted that decision-makers may have to deal with a voluntary under-estimate of the costs of a project, which may be done by the proposers in order to have it accepted. There can also be problems due to poor budget management.

Having multiple funding sources can enable a RI draw in contributions from a wide range of interested parties, including host institutions and regional administrations, but can add complexity for managerial processes. Short funding timescales make it hard to plan the effective construction and operation of an RI. In South Korea, there is an evaluation process by the government at multiple stages (decision on initial fund, annual funding, detailed equipment construction), and the funds are adjusted accordingly. Input from the User base survey indicates that the costs of data management and storage are an increasing challenge, and if countries want to increase RI use by encouraging the re-use of data they need to ensure that such costs are recognised as part of the overall cost of the RI.

Balancing the portfolio

> *"The staff/operational costs to go along with the building costs are provided and managed separately."*

> *"The national funding scheme provides funding for new research infrastructure and upgrading of existing infrastructure, and the expansion of existing infrastructures in order to meet new need."*

> *"This is largely an opportunity mechanism which can be a bit chaotic… However, participation to international RIs is usually decided because there is no equivalent at the national level."*

A formal strategy and mechanism for balancing investments among facilities already supported vs new facilities is not always in place. Some countries report that they review new and existing proposals alongside each other, although this may only be for capital investment. Other countries evaluate investment in new RIs and the operation of existing RIs in separate processes. In Norway, the Roadmap process looks at request for new RIs and upgrades for existing RIs together to encourage the use of existing investments. In contrast, in Switzerland, the Roadmap is developed as a planning instrument for new RIs, with capital coming from Cantons and other agencies and operation costs managed by the host institutions. In Japan, the Ministry looks for "reasonableness" of investment in a tight budget environment, with a careful examination of the benefits of national or international investment. It considers three categories of shared research infrastructures: specific advanced large research facilities, shared research platforms, and "new shared facilities".

In general, decisions about international RI involvement focus on the applicants demonstrating, through a scientific case, that the necessary RI capacity cannot be delivered at national level. In Japan, added value for national partners is a key criteria when joining international projects. In Australia, project managers have a large autonomy in the use of funds and can decide whether to invest at national level or into international collaboration when facilities are not available in Australia.

Feedback gathered from experts in this study suggests that clustering should be encouraged and supported, including internationally, where similar RIs are proposed. There should be flexibility in the strategic process to allow for new RIs although some perceive that reinvestment in existing facilities often takes lower priority than new ones.

Monitoring of international participations and Closure

> *"It is about which option gives us best value for money rather than national vs international."*
>
> *"Yes, funding can be terminated but only as a result of the merit review process, not as an administrative decision."*
>
> *"There are few terminations. However, phasing out are now identified in the national roadmap."*

Although the initial decisions to participate to international RI projects are usually the object of detailed assessments, many countries report only a limited level of monitoring of the international RI commitments included in their national portfolios. For example, in Norway applications to the Research Council for participation in international research infrastructures must include a concrete description of the national contribution as well as the national role and commitments under the international participation. However, the Research Council has not fully established a system for evaluating previously signed agreements to international infrastructures.

Most countries evaluate joining and continuing membership of international projects through their roadmap or equivalent process, not through any formal review process. In South Korea, there is no theoretical extra benefit in participating in an international project for inclusion in the national roadmap. However, most of the RIs involving international cooperation are ranked highly on the roadmap because of their strategic importance. In Hungary, decisions on joining large international RIs and renewing memberships in international RIs are made on a case by case, considering the costs and benefits. A number of decision makers expressed a desire to do more on evaluating international RI contributions in the future.

Limited numbers of closures are reported, but there is a move in several countries to include full lifecycle planning in future strategic exercises. In most cases where funding is withdrawn, the RI is divested to other funders who can support the RI and benefit from the experience gained. If an RI is closed, then measures to mitigate the effects on the host institution, such as scientific reorientation, may be considered.

In Germany, when a facility has to be closed, the priority of the research ministry is usually to keep the site in activity, since this is where experienced human resources are located, so a new RI to replace the older is likely to be built at the same location. In the United Kingdom, when the national synchrotron reached the end of its lifetime, the decision was made to decommission the facility and build a new 3rd generation light source at another location. However, new activities have developed at the site of the former synchrotron. Similar decisions have been made around telescopes when funding constraints do not support investment in a new facility without the termination of support for old facilities. Generally speaking, many policy-makers consider that RIs are set up for very long periods of time and they are happy to delegate to the institutional players the responsibility to manage their eventual closing down. For phasing out of large RIs the policy interest is likely to be higher.

Transparency and External Drivers

> *"This is very variable but usually the higher the cost the stronger the influence of external drivers…"*
>
> *"Most critical RIs are inevitably influenced by external factors (political, regional, and social)."*
>
> *"All of these factors influence decision making with regard to an RI – it is funded because it has a benefit to society."*

While some countries assert that external (i.e. non-scientific) drivers play no role in decision-making, others are clear that such factors do play a part, and this may be difficult for RI managers to address in their proposals. The application process and the criteria being used for evaluation of projects for inclusion in a roadmap should be published clearly. Aspects of proposals that are compared when making funding decisions should also be clearly and transparently communicated to potential applicants.

An interesting case is Germany, which has multiple approaches and players that contribute to decision making regarding RIs and uses discussion panels with the various funders and stakeholders to identify gaps and needs for RIs. These help to allocate funding strategically and combine both top down and bottom up processes.

2.2. Conclusions from the survey

There is no consistent single model through which nations seek to optimise the selection and funding of their RI portfolios, whether activities are operated at national level or delivered through participation in international RIs. It can be observed that:

1. Portfolio management mechanisms are extremely diverse.
2. There are countries with strongly managed programmes and others operating largely responsively.

3. Most countries choose mainly on the basis of the science case, not national or international location, and consider new and continuing RIs using similar criteria but not necessarily through the same process.
4. Most countries have some way of gathering research community input.
5. Funding, for capital investment and operational costs, is managed in many different ways.
6. RI managers may have a different perspective to portfolio managers.

2.3. Towards an effective model

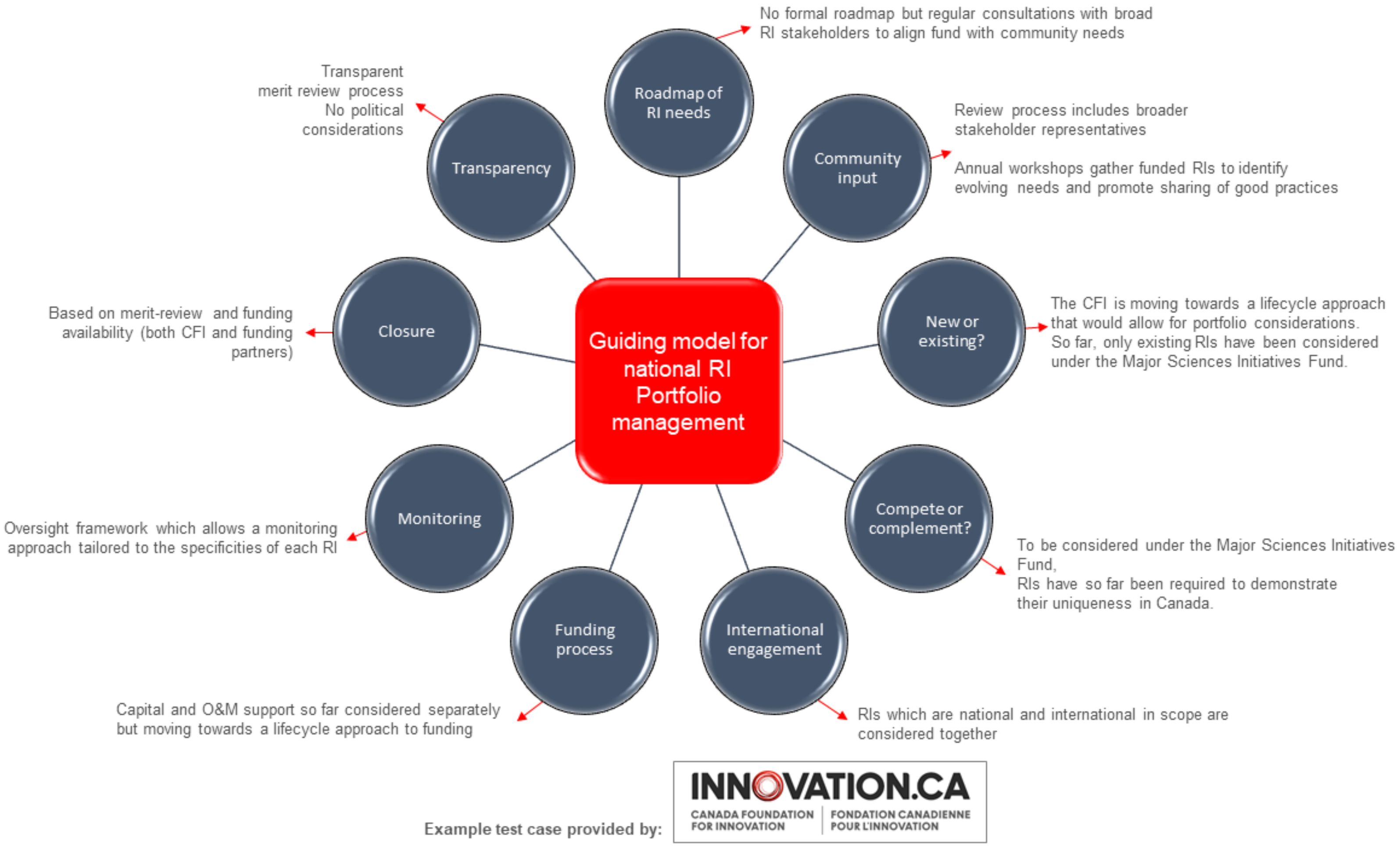
In response to the wide range of inputs received, it was concluded that many stakeholders would appreciate some indication of how an effective model for portfolio management should operate. A summary of the key elements that a national RI portfolio management system should incorporate has been developed and is presented in the conclusions chapter and discussed briefly below.

In implementing a portfolio management approach, countries should consider how the RI component is determined if it is not managed separately from other parts of the research base. It is also noted that Ministries or agencies may allocate capital and operating costs separately, may contribute to operations by providing funds on a project related basis, or may only offer a proportion of the overall costs, with the expectation that matched funds should be found from other sources. In such cases, when resources come from multiple sources, it is necessary to have an oversight mechanism to ensure that each RI is optimally funded.

In the course of the activity, the Canada Foundation for Innovation (CFI) evaluated its portfolio management approach for RIs funded under its Major Science Initiatives Fund (https://www.innovation.ca/awards/major-science-initiatives-fund) against the key elements identified in this report.

The following diagram illustrates the elements of the guiding model developed in this study and how this model can be used as a tool for national process optimisation.

Figure 1. Case study analysis of the model for portfolio management for the Canada Foundation for Innovation



Source: Canada Foundation for Innovation based on authors' model (see Figure 3)

3. Optimising the User Base of national research infrastructures

The user-base of any RI is a vital indicator of its role and potential impact. RI users may be direct users of facilities or equipment, or secondary users of the data produced or managed by a RI. Users may be extremely diverse; of local, national, or international origin; from the traditional discipline of the RI as well as from different scientific domains; and from the academic or private sector. Scientific achievements by the users can, in most cases, be attributed to a contribution from a RI. However, the degree to which this connection and/or reference is visible and transparent differs substantially and makes impact assessment challenging.

Knowing their user-base is very important for RI managers as well as for RI stakeholders. It is essential for understanding of the evolution of demand for a RI. It also constitutes a powerful lever for optimising the use of the facilities, resources, or services offered.

Each RI has a strong interest in optimising its user-base to achieve maximal impact. Optimisation of the user-base may entail improving the exploitation of the RI by the existing user-base, or broadening or expanding the potential user-base into new areas. On a strategic level, there is a keen interest from research institutions, funders and governments in ensuring the optimal access of various user communities to the RIs that they host and support.

3.1. Findings

The following findings have been obtained from an extensive survey that was conducted among RI managers (see details in Appendix 3). This used a detailed questionnaire and was complemented by selected interviews. Findings were further supplemented by feedback from discussion during the two international workshops. The findings and good practices, illustrated with examples from specific RIs, and policies are highlighted below.

Monitoring the user-base

The first element analysed regarding the management of the user base related to the mechanisms used for monitoring. The findings indicated that monitoring mechanisms are heterogeneous, ranging from automated processes to no monitoring at all. Examples of mechanisms include:

1. Collection of user access information during user meetings
2. Requests to users/principal investigators to provide information about their access
3. Regular surveys on facility or resource use
4. Extraction of information from the training records of users
5. Information compiled during annual reporting processes
6. Screening of publications that cite and/or acknowledge the RI
7. Extraction of data from proposals, user management portal, or facility/laboratory operations management systems.

A number of single-sited RIs have developed and implemented automated mechanisms, using portals for the managing applications and allocation of time. These can be used also used to track information about users.

Several RIs reported not tracking the users of their data. The examples given were of data-driven RIs that had moved away from log-in portals and other potential user-tracking mechanisms in favour of ease-of-access (i.e. the reduction of barriers). Importantly, the findings highlighted heterogeneity in the definition of what constitutes a 'user' of an RI. This issue was particularly acute for data-driven RIs that offer virtual, remote, and/or open access to their resources and services. Clear definitions are needed of what constitute the user of a national RI. The 'European Charter for Access to Research Infrastructures' (European Commission, 2016[11]) provides a definition of users, access units, and other RI management terms1 that may be helpful in establishing definitions at national RI level. A clear definition of an RI user is prerequisite for determining the need (or not) of an RI to optimise its user base. There is a broader need for the standardisation of national RI management definitions, which would necessarily include a definition of different RI user types.

Examples of interesting practice for user-base monitoring

At the German Electron-Synchrotron, the DESY Online Office for Research with Photons (DOOR) is an online system used to organise access to the RI. This allows for efficient management of: the submission of proposals, the review process, online safety training, submissions of declaration of substances, registration of participants, travel reimbursement, reports, registration of publications, user feedback and so forth. DOOR is also used to handle the communication between the RI and its users and enables the monitoring of relevant information for management purposes.

The European Magnetic Field Laboratory (EMFL) has an online user portal. Users of the facility must register in the portal to be able to submit their proposal online. After projects are performed at one of the EMFL laboratories, located in Dresden, Grenoble, Nijmegen and Toulouse, information about the number of hours or pulses measured is registered in a database. This enables the facility to automatically monitor the usage of the EMFL facilities.

Access mechanism

The second element analysed concerns access mechanisms. In the survey, differentiation was made between access mechanisms to physical facilities or resources and access mechanisms to data. This had an implication on the response rate of different types of RIs to this specific topic, as data-driven RIs provided more information with regards to access mechanisms for data (see ahead, Section 8.1.3.)

Most RI managers indicate that they use merit-based access, which is generally provided free of charge, or free-from-cost for academic users. There are more formalized access mechanisms in place when demand exceeds capacity. Mechanisms usually include competitive calls for proposals and evaluation through expert panels. In cases where the capacity is not fully exploited, access mechanisms tend to be less formalised and work on a 'first come/first served' basis or through personal contacts.

Interesting practices include provisions for remote access, particularly in the case of telescopes which can allow the conduct of observations at distance, and the possibility for rapid access through a fast-track system. It was noted that rapid access mechanisms may be particularly useful in the provision of paid industry/commercial use of RIs, where time constraints are often prevalent.

Examples of interesting practice for providing user access

The access mechanisms to the PETRA III and FLASH synchrotron beamlines at DESY include two calls for proposals every year. Additionally, a rolling procedure is implemented for some PETRA III beamlines and rapid access has been tested.

Depending on the facility requested and the scientific topic, project proposals are reviewed by one of the several international Research Project Review Panels (PRPs). Each PRP consists of approximately 5-15 external national and international experts (in total >100 scientific referees, nominated for a period of 3 years) and a DESY Photon Science representative acting as secretary. Referees are selected to cover the broad portfolio of both scientific fields of the submitted proposals and techniques available at the RI. The delay between submission deadline and access is typically about 10-16 months for FLASH with a success rate of approximately 40% in 2018 (ca. 70 proposals), and for PETRA III the delay is 4-10 months, with a success rate of approximately 50% (covering roughly 1 000 proposals) in 2018. For rolling procedures and rapid access, the delay is a few weeks.

In order to optimise the access capacity of PETRA III and FLASH the number of operation hours and availability was increased in 2018. The operation of several new beamlines was initiated also in 2018.

Data Access mechanisms

Two major approaches are apparent with regards to access mechanisms for data. Firstly, as described in Section 8.1.2, data-driven RIs often do not have complex access mechanisms in place, as they mostly provide open access. Such access often means reducing the number of steps needed by a user to gain access to data. This can have knock-on implications for the ability of RIs to accurately monitor user access: for instance, the removal of login portals that were previously used to provide data access statistics.

A second finding was that user facilities do not often provide access to the data from experiments carried out within their facilities to other users who are not part of the experiments because of ownership agreements. In many cases the data is considered as belonging to the team conducting the experiments and it controls access or access is embargoed for an agreed period of time.

Policies relating to data sharing, data curation and data regulation have been discussed widely and at length by many stakeholders, and many scientific disciplines and RIs are considering a need to adapt their practices in relation to the emerging advice and recommendations. Examples were given of RIs that openly share the (limited) data that they 'own' as a facility (SNOLAB shares all baseline environmental monitoring data that it owns, for instance), but the difficulty of ensuring that users, who are data owners, also provide access to their data was highlighted.

Requiring users to submit Data Management Plans (DMPs) prior to the provision of access to an RI may encourage users to consider compliance with FAIR (Findable, Accessible, Interoperable, Reusable) data principles whilst planning their project (Wilkinson et al., 2016[12]). The alignment of requirements for Data Management Plans (Science Europe, 2018[13]) used for RI access provision and those used more generally in academic research should be considered to facilitate their adoption by researchers.

Means of incentivising data sharing were discussed during this study (reduced access costs for those that commit to open data or FAIR agreements, for instance), but it was recognised that incentivising data sharing is also a wider systemic research policy issue, not limited to RIs. While respondents from data-driven RIs were more likely to indicate an under-exploitation of their open datasets, managers from service-driven or user facility RIs reported challenges with the storage and management of the increasing amount of data their RIs produce. The increasing costs incurred to store and maintain evermore data at facility-level were highlighted as a concern for some RIs, and RI managers reported the need for greater support for data-related activities and the management of data repositories at national and/or international level.

The two opposing extremes, described above, of either FAIR / open access or very limited data access provision, highlight the diversity in approaches of national RIs towards data access, and the lack of clear policy guidance. Such policies are particularly needed with regards to privacy regulations and ethical considerations, which were indicated as a particular challenge by respondents from Health and Biology RIs. This may be a challenge experienced by all RIs dealing with personal data, and therefore is also relevant for RIs in the field of humanities and social sciences (see (OECD, 2016[14])).

The current situation for many RIs, for which there is little monitoring of data use as well as underdeveloped secondary use of data, suggests that there is great potential to increase operational effectiveness. Monitoring of data use provides valuable information for decision-makers and funders. Trends in both access and data use are important for informed science policy development. Further, the secondary use of data offers a way to indirectly increase the user base of RIs when the primary access capacity is already fully exploited. The development of data access and reuse opportunities and associated services is a long-term process that should be actively pursued in conjunction with the wider scientific community and other relevant stakeholders.

Example of interesting practice for data access

At Canada's The Centre for Phenogenomics (TCP) all users have an information management system (IMS) account that provides each user with access to all shared data in the IMS as well as to their own data within the IMS. Each user is given secure credentials to access their IMS account which dictates data restrictions for their profile.

In addition to data access, requests for research services are submitted through this centralised IMS. The IMS provides a single point of access to data and also enables TCP to collect use and re-use metrics based on user access. The centre uses Google Analytics to analyse website data use and re-use metrics.

Regular measures are taken to ensure 24/7 web-enabled access to TCP's IMS. This includes support for in-house maintenance, including regular upgrades.

Cost models and pricing

The cost models of most RIs differentiate between user groups of academic and industrial origin. Access and use are usually provided for free or with very limited fees for academics at RIs where operational costs are constant and not use-dependent, while industrial use (where permitted) is often charged. Policies regarding RI use by industry vary widely between countries. Respondents from all types of RIs indicated that increasing operational cost are challenging the sustainability of their existing business models. It was indicated that funders do not always include all these operational costs in funding provisions. Ensuring sustainability against a background of increasing operational costs has led to some RIs implementing a freemium / premium model for access charges: where basic access is given for free, and premium access is charged. An example was given from a South African RI where data access is charged according to the transfer speed (in bandwidth) requirements of the user, where transfer speeds of up to 1.5 Mbps were provided for free, but higher transfer speed requirements (of up to 50 Mbps) were charged at a monthly rate.

For data-driven RIs, the cost of long-term maintenance is often not fully taken into account (although an example was given from Norway of a funding system that requires full costing, including data maintenance, to be included in proposals by RI managers). The high cost of work related to essential referencing and indexing was also mentioned as a key concern. Such work is often not prioritised or rewarded as the current research system favours new data/new analyses over research related to checking and reproduction of existing data, analyses, and ideas. RI managers stressed the need for existing data to be considered as a critical resource for research, which should facilitate the funding and continued management of key datasets.

Managers from single-sited RIs reported lack of funding to cover travel and housing of users. RIs in remote locations also face logistical challenges with regards to physical access.

Examples of interesting practices for pricing models

At the South African Astronomical Observatory (SAAO), users do not pay for the use of the telescope, only for their accommodation and meals at the SAAO hostel. National users are usually subsidised for accommodation and meals, and therefore pay slightly less than international users. Hosted facilities (which include telescopes from institutions from the USA, the UK, Germany, Russia, Poland, South Korea, Japan, and The Netherlands, that are mostly robotically and remotely operated) pay an annual site fee which covers the routine operational requirements of the hosted facility, including daily checks, minor routine maintenance, and data retrieval (if needed). The site fee also covers a share of the costs of maintenance of the on-site infrastructure and basic services, such as roads, electricity infrastructure, water supply, sewage, security, and access to internet connectivity. Hosted facilities that require larger bandwidth than that which is covered in the site fee pay a monthly fee for that. For the operation of the Southern African Large Telescope (SALT), which is situated at the SAAO field station, the pricing model is based on the shareholder percentage. Each partner contributes an amount equivalent to their percentage of their share to the total annual operation costs.

At the Italian Synchrotron Elettra, users coming through the peer reviewed access mechanism do not pay for the use, but only a limited number of external users can get travel support via existing funding schemes. Industrial users pay for use, the prices being set by an internal Industrial Liaison Office. The cost model is based on the hours used. In order to calculate the cost of one hour of beam-time at the Elettra storage ring and FERMI free electron laser, an internal calculation method has been developed. The resulting numbers are updated every year after approval of the annual budget of the RI.

Administrative and support services

The limited feedback received on this topic from the survey indicates that the majority of RIs have some capacity to provide technical/scientific and administrative support to external users. Further, some indicated having data administrators also providing support. RI managers reported a general lack of funding provided for administrative and support services from funders.

An example was given from The Netherlands, where no specific funds are available for supporting processes to expand the user bases of RIs. Thus, any money allocated by an RI to support services in this regard must come from a pre-existing budget line. It was noted that mechanisms for optimising the use of national RIs (as described above, in section 8.1.2) often require a significant investment of resources and funds. For instance, attracting users from different and new disciplines may necessitate outreach activities, which require a time investment from a range RI staff.

It is also recognised that internal capacity building is key to expanding user-bases: attracting less experienced users necessarily requires a higher level of internal support. Thus, additional demands on technical and administrative support staff must be included in planning and decisions related to user-base changes.

Some RIs report difficulties in retaining professional research support staff because they cannot offer the right conditions and incentives for them. This must receive attention if expanding the user base increases the demands on such staff. The Japanese Nanotechnology Platform showcased a flexible strategy, with the ability to hire temporary support staff in line with the changing demands on their facility.

Overall, it was agreed that RI managers should engage with funders and decision-makers to ensure that necessary support for users is included in funding provisions. However, it was considered that a 'standard practice' model for such support systems would not be feasible due to the diversity of RIs, different support needs and differing priorities.

3.2. Lessons learned

A number of major challenges emerged when considering user-base optimisation from a RI manager perspective:

1. Challenges and practices vary greatly across different types of RIs. This is seen most clearly when comparing observational single-sited RIs, service-driven RIs and data-driven RIs. More fundamentally, there is difficulty in grouping, characterising, and defining RIs (by access provision type, for instance). RI managers described the need for the standardisation of definitions, highlighting that this would help to further define common challenges and best practices across the community.
2. A prerequisite to the targeted optimisation/improvement of the user base of an RI is a thorough understanding of its current usage and user base, and preferably an understanding of recent trends in usage also. Such an understanding is important in determining whether additional policies and mechanisms to optimise the user base of a RI are needed. Further, understanding and monitoring the user base of a RI can provide data that is of use for: 1) the accurate assessment of operational costs, 2) justification of future or continued funding, and 3) as a rationale for adapting management strategies.
3. Thorough consideration of the costs, benefits and risks of implementing mechanisms to broaden the user base of RIs should be a pre-cursor to any decision to adapt a RIs strategy with regards to its use. Various mechanisms to optimise the use of a RI can be used. Two major factors should be taken into account:
    - Firstly, user base optimisation should be considered according to the type of RI in question.
    - Secondly, optimising a RIs user base should be considered according to whether the facility, resource, or service in question is running at capacity, has limited capacity to expand its use, has unlimited capacity of use, or is considered to be running at over-capacity. A table detailing the potential benefits and risks of different forms of user base optimisation is provided below (Table 2).

A number of common challenges expressed within similar RI categories indicate that RI managers can benefit from mutual learning and exchange of good practices with their counterparts. Exchange and collaboration to jointly elaborate harmonized solutions, such as automated monitoring mechanisms or data policies would allow for cost sharing and/or cost saving.

There are also challenges that cut across all RI types, and require cooperation and exchange across the entire RI landscape. This applies particularly to many issues related to data, where user facilities can benefit from the experience of-, and potentially collaborate with, data-driven RIs with regards to storage and management of large amounts of data.

The need for transparency and clarity in the information presented to potential users was universally recognised. Regarding access mechanisms, for instance, a wide variety of access pathways are available to potential users. Whilst many RIs offer access through a proposal evaluation scheme (merit-based), others provide access on a 'first come, first served' basis. And others offer training-oriented access, or rapid access opportunities. Different access mechanisms have their own associated benefits and costs, which are themselves case dependent. Further, access mechanisms at RIs may change according to temporal demand, and such flexibility in access processes may help in reducing administrative and management costs.

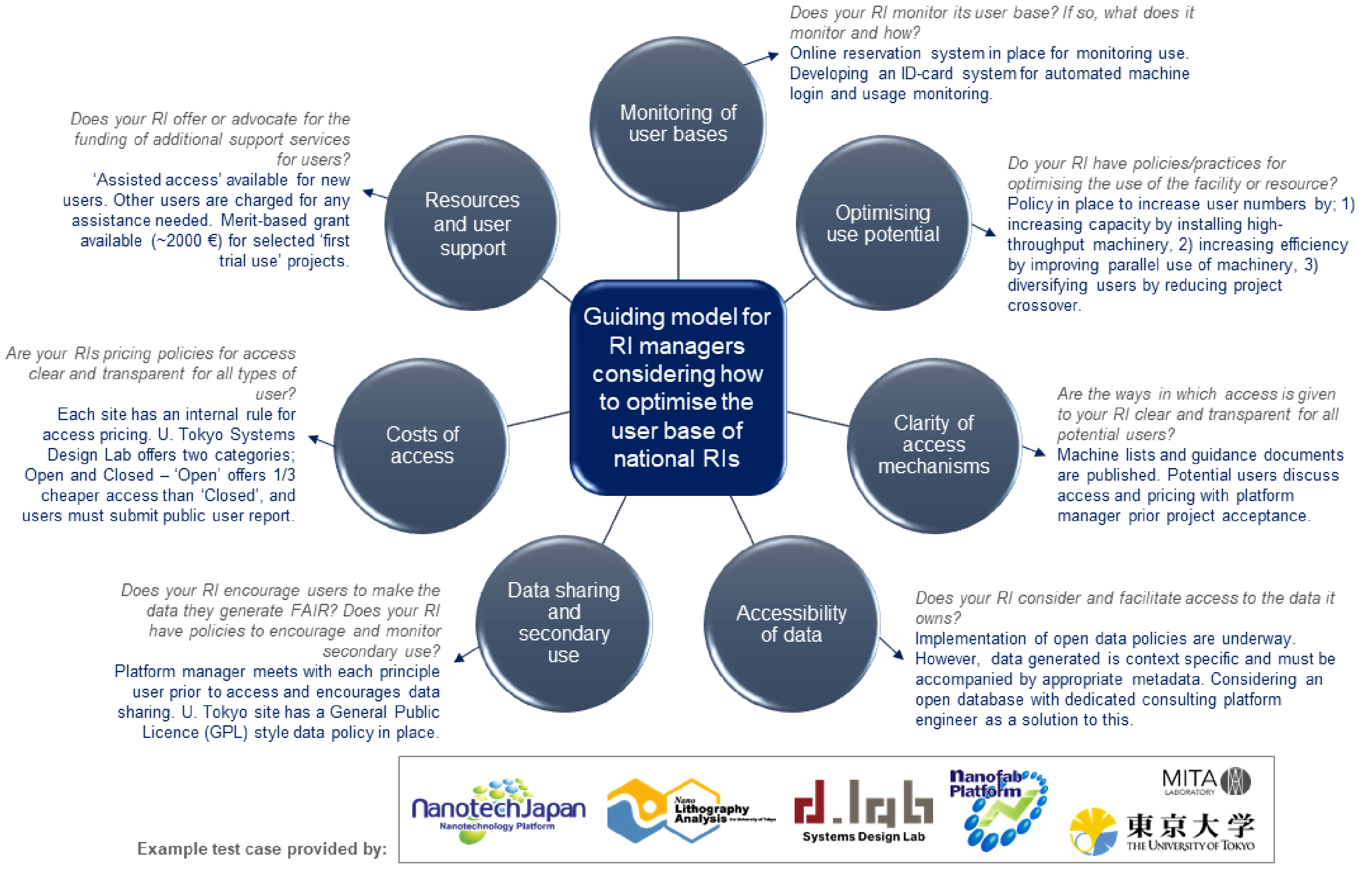
The minimum information to be made publicly available about RIs and the facilities, resources, and services/support they offer, and how both physical access and access to data is provided should be agreed upon. This will help all stakeholders, but particularly potential users, in understanding the types of service on offer to them (useful examples of digital platforms can be found in (OECD, 2017[15])).

A number of key elements are commonly considered by RI managers when appraising or reappraising their strategies towards the optimisation and management of RI user-bases. Assessing RI policies and practices according to each of these elements may help guide RI managers in understanding where a change of strategy may be most beneficial to their RI. A summary of these key elements and questions are shown in a Guiding Model in Figure 2 alongside a set of answers provided by one of the responding RIs (the Nanotechnology Platform, Japan).

Table 2. Examples of the benefits and risks of different strategies employed by RI managers to optimise or improve the use of their RIs

Capacity to increase the number of users	Strategy	Benefits	Risks
Limited capacity – *may be due to time limitations on use, space limitations, or limitation in the size of the potential user-base for highly specialised RI resources.*	Optimise RI use by existing user base	– Improves exploitation of existing RIs and provides possibility to be more selective according to quality criteria. – Strengthens the position of RI with regards to their original mission.	– Increases pressure on evaluation procedures and support services. – Potentially requires more investment in support and administrative staff. – May lead to increased competition with other similar RIs.
	Increase diversity of academic users *(diversity can be seen in terms of career stage, country of origin, or by discipline).*	– Promotes more international and/or multi-, inter, trans-disciplinary collaborations. – Attracts new sources of funding and	– May cause dilution of core mission of RI and/or jeopardize relevance for primary user group. – Requires more support and administrative effort. – May reduce / dilute the competitiveness of overall research outputs, particularly with regards to the core mission of the RI.
	Allow non-academic use	– Possibility to charge for use. – Promotes greater industry/commercial – academic links and technology transfer potential. – Brings greater visibility to the RI.	– Results/data are less likely to be shared openly. – May reduce availability of the facility/resource for academic use.
	Promote secondary use (of data)	– Better potential exploitation of experimental results by the wider research community. – Brings greater visibility to the RI. – Provides further justification for funding and may help to attract new sources of funding (particularly for data sustainability).	– Complexity and cost of providing FAIR data. – May pressure primary users / data owners to exploit results prematurely. – Immediate opening of data may have unintended consequences, e.g. on early career researchers. – Secondary use may be hard to track, and therefore more difficult to justify the cost and effort associated with promoting it.
Unlimited capacity – *most commonly associated with data infrastructures, where the resource provided may potentially be exploited by any interested user.*	Increase number and diversity of users	– Promotes more international and/or multi-, inter-, trans-disciplinary collaborations. – Attracts new sources of funding and brings more visibility – Promotes specialised expertise of researchers at different career stages.	– May require more support and administrative effort. – Will require promotion of the RI, which requires resources.
Over subscription – *in re-appraising its user base, a RI may consider that a reduction in user numbers overall, or a reduction of selected user groups may improve the overall scientific functioning of the RI.*	Reduce number of users overall, or from selected user groups	– Improve the concentration of user activity towards the core mission of the RI. – Reduce pressure on management and support services and allow for better support towards targeted user groups.	– Reduce the attractiveness of the RI to potential new users. – May reduce the ability of the RI to attract funding from a wider range of sources.

Figure 2. Case study example (the Nanotechnology Platform, Japan) of the elements and questions that an RI manager may wish to consider when seeking to optimise the user base



Source: Nanotech Japan based on authors' model (see Figure 4)

4. Conclusions and recommendations

This activity has identified a wide range of practices in RI portfolio management and operation which impact on the optimisation of the operation and use of national research infrastructures. The diversity of national systems and RI operation approaches means that there is no single model to suit every country or RI, but some key factors or guiding principles have been identified in this study which it is hoped will be useful to policy makers, funders and managers. These principles can be brought together in two Guiding Models (see below).

Suggested actions:

- RI portfolio managers and RI managers should assess their portfolio management and user base approaches against the principles contained within each of the Guiding Models (see Figures 3 and 4) to aid the development of their management processes.
- RI portfolio managers and RI managers who have completed their assessments, should work with peers at national and international level to exchange experiences in using the Guiding Models. This can provide a basis for the creation of networks focused on continuous improvement and mutual learning. Funders and policy makers should consider ways of encouraging and providing support for the establishment of such networks.
- RI portfolio managers and RI managers should work together to reach agreement on standards and definitions for RI management and access including types of RIs and Users. They should agree the minimum information to be made publicly available on-line about RIs and the facilities, resources, and support that they offer.
- RI portfolio managers and RI managers should consider the relevance of the good practice examples presented in this report for their own RIs, and consider adopting similar approaches, where appropriate, within their own national contexts.

A Guiding Model for RI portfolio management

Countries seeking to operate an active RI portfolio management programme should incorporate some or all of the following elements in their approach:

Strategic planning

A strong review process is required, collecting bottom up and top down inputs (which may also include societal challenge perspectives) to create a forward plan for RI needs in the context of the national Research and Innovation strategy. The strategic document produced may be aspirational or only involve funded RIs. Landscape analysis, putting new RIs in the context of the existing RI portfolio, can assist. The process, focussing attention on the case for each RI, can be as important as any resulting roadmap. The output should retain some flexibility to address changing requirements, and should be publicised to promote further (international) coordination and cooperation.

Community input

Processes should be set up to gather inputs from the research community, RI operators and other stakeholders in terms of research, data and operational needs. This can be through the strategic planning process or separate subject community reports. Research communities with less experience of RI operation and use may require support to create collective inputs, including where RIs are broadening their use base or new RI types are being added to the portfolio.

Inclusiveness

The whole portfolio should be considered so that there is the opportunity to examine new and existing RIs together, which may require a process that can look at both capital investment and operating (including personnel) costs.

Competition and complementarity

Portfolio management should ensure that new RI proposals identify existing capacity and justify new requirements. Cooperation should be encouraged between smaller scale centres through a clustering approach but competition allowed ultimately at the strategic planning stage to ensure the highest priority facilities are selected. Ensure that regional policies do not lead to duplication of RIs and sub-optimal investment and usage.

International engagement

The stimulation of international networking for national RIs, and embedding international RI options alongside national RI options is necessary to find the best solutions to deliver the research requirements of the national community, and also promotes an international perspective within national systems.

Funding process

This should take into account strategic planning as well as resources allocation (capital and operating funds), to ensure that the highest priority RIs are properly funded. This may be by via centralised allocation or competition. The full life cycle costs of the RI should be recognised, including the cost of management and long-term storage of data, and funding allocated for adequate periods to enable the RI to achieve its planned goals.

Monitoring

There is a need to develop efficient mechanisms to monitor performance of national and international RIs in terms of research, benefits (impact), management and governance.

Closure

The consultation and strategic processes need to identify facilities that can be closed or divested to other managers. This should be embedded as early as possible in long-term plans to optimise spend profiles and allow for an orderly transition.

Transparency

There is a need to ensure that the scientific community is clear on the process for project selection, especially where additional factors such as economic, political or social may be taken into account for funding decisions.

A guiding model for optimising and managing RI user-bases

Managers of national RIs seeking to optimise the use of their facilities, and the data generated from them, should consider incorporating some or all of the following elements into their management strategies:

Understanding and monitoring of user-bases

An RI should have a clear understanding of its overall user base, and how access units (an RI-specific measure specifying the access offered to users), resources, and costs are distributed within that user base (including in-house users). Such an understanding will help in identifying any underused potential or limitations. A clear rationale should be defined prior to the implementation of measures to optimise the use of an RI and should be accompanied by a thorough analysis of benefits and costs. Further, an RI should establish and maintain appropriate measures for the continuous monitoring of its user base and these measures should be reappraised whenever the strategy of an RI is adapted. In this regard, RI managers should consider the automation of user monitoring processes, where this is feasible.

Optimising use potential

Where a capacity-limited RI is seeking to optimise its use, such optimisation may necessitate; 1) the adaptation of current user selection processes and quality assessment criteria, 2) the improved management of the time or space occupied by users, or 3) the promotion of remote, virtual, and/or secondary access. Where an RI has some or unlimited capacity to expand, then further consideration of the potential to optimise through broadening their user base by attracting new user groups may be beneficial. A broadening of an RI's user base may entail; 1) opening access to new groups of researchers; 2) encouraging researchers from different disciplines; 3) allowing use from other sectors, e.g. public sector and industrial, incl. commercial; or 4) opening access to international researchers.

Clarity of access mechanisms

An RI should be clear and transparent about the access mechanisms that are in place and the conditions that apply to different access modes to ensure that potential users understand the basis on which they may access an RI.

Accessibility of data

It is important that RIs have an open and transparent data policies in line with the FAIR principles to broaden their user base. Collaborating with other RIs to federate repositories and harmonize meta-data may be an important step in standardising open and transparent data policies across the RI community.

Promotion of data sharing and monitoring of secondary access

The data generated from national RIs is often unique and highly valuable. An RI should strongly encourage RI users (who are often the owners of the data generated) to develop data management plans (DMPs) for their activities, and to follow the FAIR principles within a reasonable (and agreed upon) time after projects are completed. In order to understand and highlight the benefits of facilitating secondary access, RIs should provide guidance on how to reference datasets and equipment, and ensure that persistent digital object identifiers (DOIs) are used wherever possible.

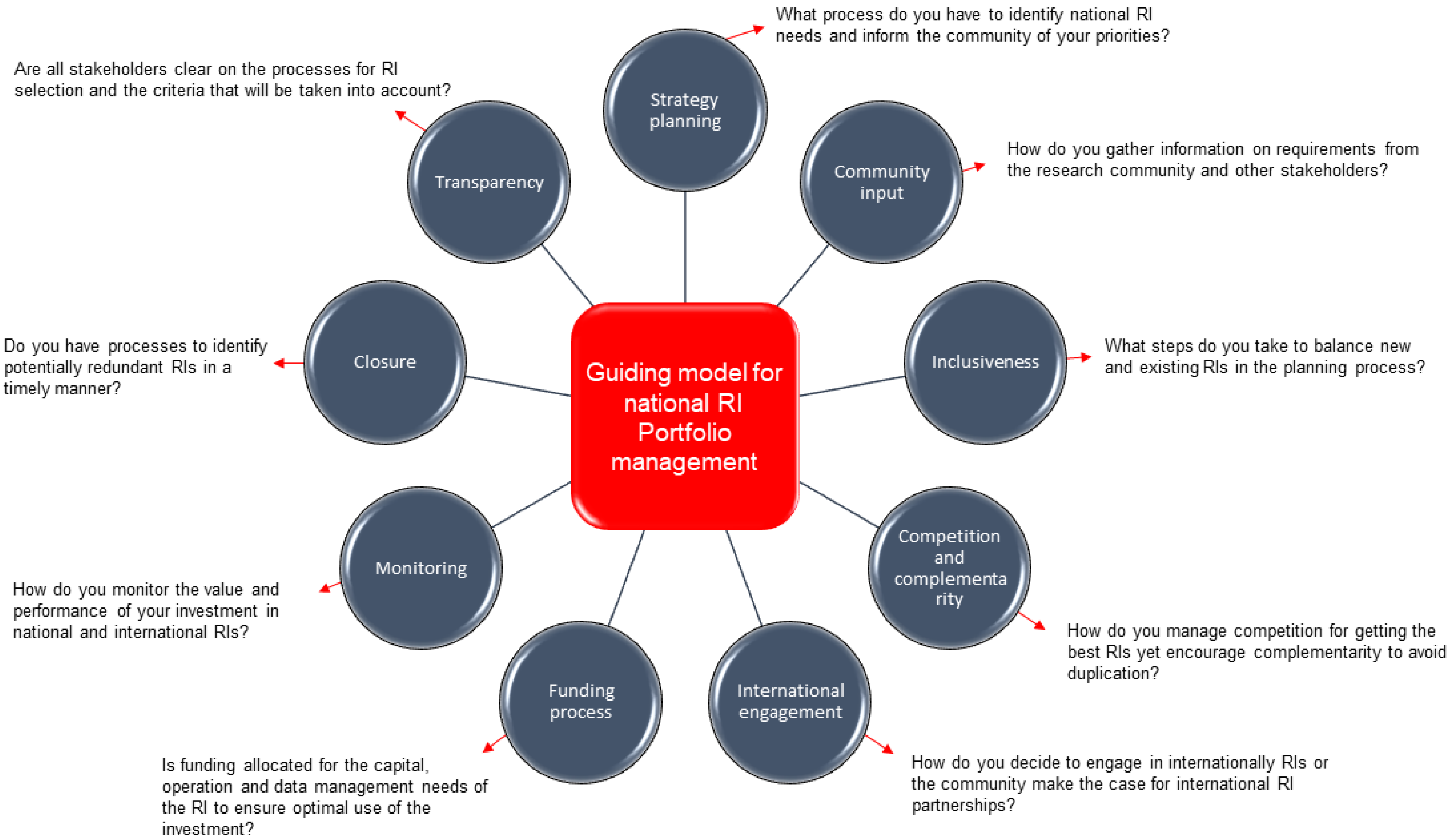
Costs of access

There are a wide variety of pricing policies, both between and also within individual RIs, and the need for some flexibility is recognised. RIs should ensure that their pricing policies for all access modes are clear and cost-transparent, and that merit-based academic usage is provided openly and 'free-from-costs', wherever possible.

Resources available to users, and user support

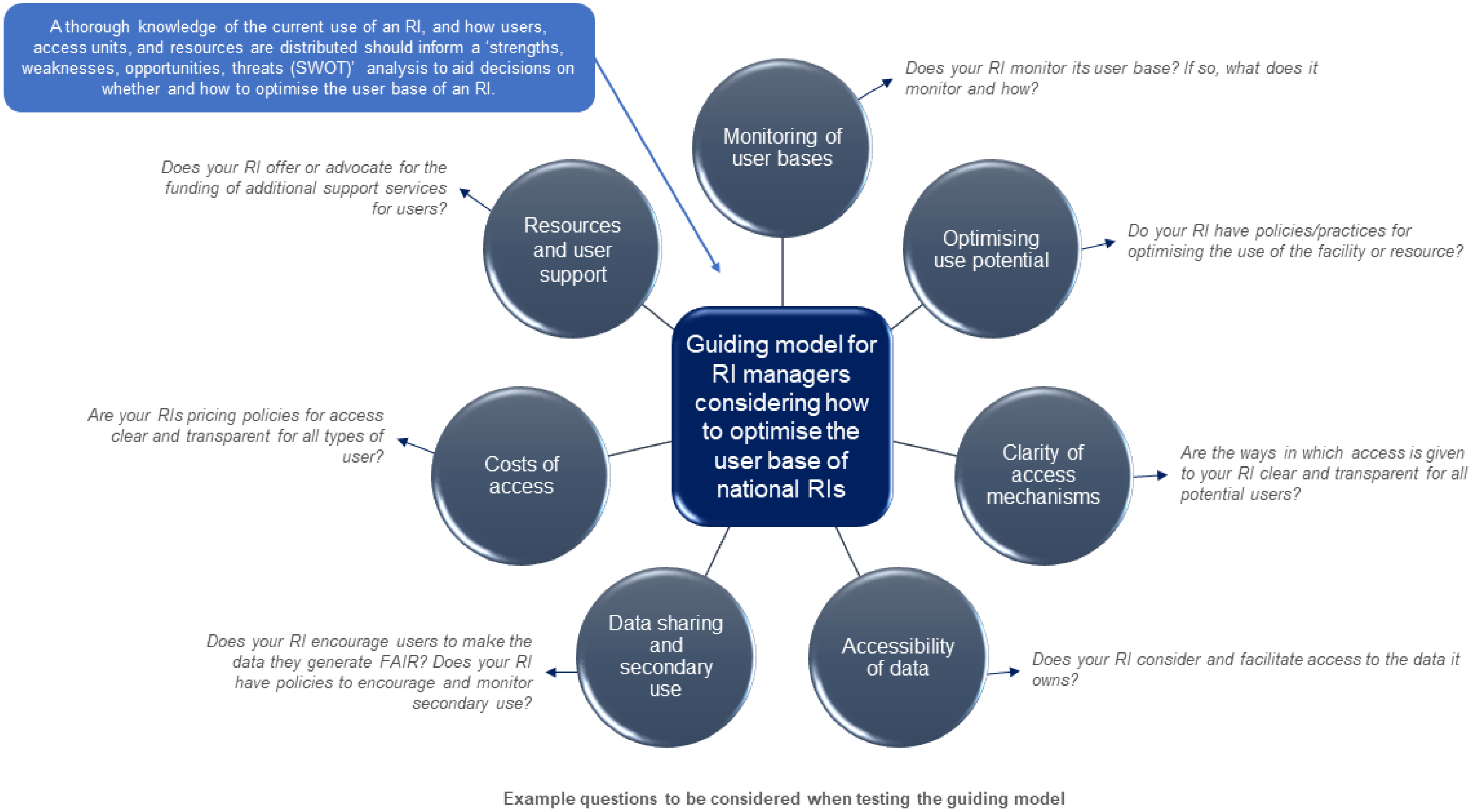
RI managers should ensure that they have good knowledge of the resources devoted to their users from both a financial and human resources perspective. Support services such as travel, training, and accommodation grants can improve the attractiveness of access for certain user groups. Where funding for dedicated support services are deemed necessary, an RI should engage with funder/decision-makers to highlight the benefits of offering such additional services. RIs of similar types should encourage the development of synergies and complementarities (via ad hoc networks, for instance) to reduce their costs, and potentially offer better services to users. Networking between data-driven RIs and physical RIs may also be considered as a way of offering unique complementarities.

Figure 3. Key questions to be considered when testing the portfolio management guiding model



Source: authors' original design

Figure 4. Key questions to be considered when testing the user-base guiding model



Source: authors' original design

Notes

[1] Introductory phrases, in italics, reflect insights from case study reports that were prepared by secretariat or expert group members who conducted interviews. They are extracts from these case notes and are not verbatim quotations

[2] 'Users' of Research Infrastructures can be individuals, teams and institutions from academia, business, industry and public services. They are engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of projects. Teams can include researchers, doctoral candidates, technical staff and students participating in research in the framework of their studies.

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5. Appendices

Appendix 1: Expert Group

Country	Name	Affiliation
Canada	Heidi Bandulet	Senior Program Officer, Canada Foundation for Innovation (CFI)
China	Qijiang Zhai	Ministry of Science and Technology (MOST)
France	Isabelle Diaz	Research and innovation general directorate, Ministry for Higher education and research
Hungary	Attila Havas	Senior Research Fellow, Institute of Economics, Centre for Economic and Regional Studies, Hungarian Academy of Sciences
Japan	Toshiki Nagano	Program Officer, Nanotechnology Platform Japan, Fellow, Center for Research and Development Strategy (CRDS), Japan Science and Technology Agency (JST)
Korea	Myeun Kwon	Research Fellow, National Fusion Research Institute
	Yong-Joo Kim	Policy team, National Research Facilities and Equipment Center (NFEC)
	Eun Ju Lee	Korea Basic Science Institute
Netherlands	Jeannette Ridder-Numan	Senior Advisor Ministry of Education, Culture and Science Department for Research and Science Policy
Norway	Robert Bjerknes	Vice Rector and Professor, University of Bergen (UiB)
South Africa	Clifford Nxomani	Deputy Chief Executive Officer National Research Infrastructure Platforms, NRF
Switzerland	Stefan Janssen	Head - User Office, Paul Scherrer Institute PSI, CH
	Mirjam van Daalen	Head of staff of the photon science division, PSI
United Kingdom	Catherine Ewart (chair)	Associate Director, Stakeholder and International Relations, UKRI- Science and Technology Facilities Council (STFC)
United States	Samuel Howerton	Deputy, Office of International Science and Engineering National Science Foundation

ERF AISBL	Robert Smith (Chris)	Senior Advisor for Facilities for MPS, National Science Foundation
	Andrew Harrison	Chair, Association of European-level Research Infrastructure Facilities
	Florian Gliksohn	Executive secretary, European-level Research Infrastructure Facilities
Science Europe expert	Jean-Luc Barras	head of international cooperation, Swiss National Science Foundation / SNSF, Switzerland
Science Europe expert	Michael Royeck	Programme Officer, Scientific Instrumentation and Information Technology, German Research Foundation / DFG
Science Europe expert	Oonagh Ward	Programme manager, Health Research Board / HRB, Ireland
Science Europe expert	Joaquín Tintoré Subirana	Research Prof., Spanish National Research Council / CSIC and Director SOCIB RI, Spain
OECD	Frédéric Sgard	GSF secretariat
	Carthage Smith	GSF secretariat
	Peter Fletcher	GSF consultant
Science Europe	Maud Evrard	Science Europe Office
	James Morris	Science Europe Office
	Isabel Bolliger	Science Europe consultant

Appendix 2: Ministries and agencies interviewed on portfolio management

Australia

Tony Rothnie, Director, National Research Infrastructure Program Management Team, Department of Education, Australian Government

Canada

Dr. Heidi Bandulet, Senior Programs Officer, Canada Foundation for Innovation

France

Christian Chardonnet, Head of Department for Large RIs, Ministry for Higher education, research and innovation

Germany

Peter Wenzel-Constabel, Head of Division: Infrastructures for Research, BMBF

Dr. Sören Wiesenfeldt, Head of Department Research, Helmholtz Association

Annika Thies, Director, Brussels Office, Helmholtz Association

Hungary

Dr. István Szabó, Vice-President, National Research, Development and Innovation

Japan

Toshiki Nagano, Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT)

Korea

Dr. Jung Euh-duck, Chairman, National research Facilities and Equipment Center (NFEC)

Dr. Kim Yong-joo, RI Policy Team, NFEC

Netherlands

Stan Gielen, Chair of the Board, NWO (funding agency)

Lutgarde Buydens, Dean of Science Faculty, Radboud University

Rob Mudde, Vice-president/vice-rector of the Board, Technical University Delft

Frank Zuydam, Director Academic Affairs, University of Amsterdam

Hans van Duijn, Chair, Permanent Committee for the Roadmap for Scientific Infrastructures

Oscar Delnooz, Deputy Director Research and Science Policy, Ministry of Education, Culture and Science

Christa Hooijer, Director, NWO-i (funding agency separate part for their institutes)

Erik Drop, Director Strategy and government relations, TNO (institutes for applied science)

Wim van Saarloos, President, Royal Academy of Sciences (KNAW)

Norway

Solveig Flock, Department Director, The Research Council of Norway

Switzerland

State Secretariat for Education, Research and Innovation (SERI)

ETH Board

United Kingdom

BEIS, the UK Government's department for Business, Energy & Industrial Strategy.

Mark Thompson, Executive Chair of the Science and Technology Facilities Council, part of UK Research and Innovation

USA

Robert Smith (Chris), Senior Advisor for Facilities for MPS, National Science Foundation

Appendix 3: Online survey of RI managers

55 RI managers responded to the online survey to date, in a varying degree of detail. The first section of the survey included questions on metadata to classify the type of responding RI. The respondents were able to select multiple answers, but it should be clarified that the respondents might have different understandings of the classifications that were indicated, and may have identified with multiple categorisations. The following tables summarise the responses to the self-classification survey section:

Type of RIs

National	International	Distributed	Single-sited	e-Infrastructure
26	8	8	11	6

Disciplinary scope of responding RIs

Social Sciences and Humanities	Health/ Biology	Environment	Material Sciences/ Engineering	Physics/ Astronomy	Information and Communication Technology
5	16	14	19	21	9

The main mission of the responding RIs

Service-driven	User facility	Data-driven	Other
15	27	10	9

The location of the responding RIs

Europe									N	S	Asia		Africa
									America				
UK	DEU	DNK	ESP	FRA	IRE	CHE	ITA	NLD	CAN	CHL	JPN	KOR	ZAF
1	7	1	1	1	1	1	1	2	7	1	7	1(19)*	5
16									8		13 (31)*		

The responding RI managers were asked to describe characteristics and trends regarding their user-base, incl. the distribution of external vs. internal users, the specific use of the facility (equipment, primary, or secondary use of data), as well as the distribution of international vs. national vs. local users and their disciplinary background. It should be noted that the information provided for these questions varied greatly with regards to the depth of answer received. Nonetheless, the responses reveal a diverse picture regarding the user bases of national RIs.

* In Korea, the response was centrally coordinated by a single unit that covered 19 individual RIs. In this case, individual RIs did not respond directly via online survey, and the information was gathered centrally. The level and detail of information provided for each RI was less than for RIs from other countries where RI managers responded individually via the online survey.

Managers from the following RIs took part in the survey:

** = signifies an RI that did not respond via online survey but provided information directly – here detail of responses may vary.*

Region	Country	Research Infrastructure (RI)
Africa	South Africa	iThemba LABS
		South African Astronomical Observatory (SAAO)
		South African Environmental Observation
		South African Institute for Aquatic Biodiversity
		South African Radio Astronomy Observatory, (SARAO)
North America	Canada	The Canadian Light Source Inc
		*Canada's National Design Network (CNDN)
		The Canadian research icebreaker *CCGS Amundsen*
		Érudit
		Ocean Networks Canada
		SNOLAB
		The Centre for Phenogenomics
South America	Chile	Platform for sequencing and omics technologies
Asia	Japan	Advanced characterization nanotechnology platform (ACNP)
		*High Energy Accelerator Research Organization (KEK)
		Large Helical Device (LHD)
		Nanotechnology Platform Japan
		Magnetic Field Laboratory
		*RIKEN
		Subaru Telescope
	Korea	*KSTAR
		*Gyeongnam environmental toxicity center
		*Inhalation toxicity research center
		*Korea Chemical bank
		*Medium and large ion beam accelerator
		*Super permeable electron microscope
		*Test lines and hangars for magnetic levitation trains
		*15T Multipurpose Mass Spectrometer, Korea
		*Bio ultrahigh voltage transmission electron microscope
		*Korean VLBI Network
		*National Primate Research Center
		*Metallic material center
		*Large wind tunnel experiment center
		*Pohang Light Source
		*Mobile convergence technology center
		*International GNSS global data center
		*National Supercomputing Center
		*Global Science experimental Data hub Center (GSDC)
		*Advanced bioResource Information System (ARIS)
Europe	Denmark	ASTRID2 Synchrotron
	France	* Grand équipement national de calcul intensif (GENCI)
	Germany	Synchrotron Lightsource BESSY II of Helmholtz-Zentrum Berlin
		*Center for Biomolecular Magnetic Resonance (BMRZ) at the Goethe-University
		Deutsches Elektronen Synchrotron DESY
		Center for High-power Radiation Sources (ELBE)
		Ion Beam Center of Helmholtz-Zentrum Dresden-Rossendorf
		Jülich Centre for Neutron Science
		100-m Radio Telescope Effelsberg,

Ireland	Health Research Board Clinical Research Coordination Ireland (CRF)
Italy	Elettra Synchrotron Trieste
The Netherlands	*Netherlands Infrastructure for Ecosystem and Biodiversity Analysis (NIEAMBA)
	European Magnetic Field Laboratory (Dutch facility)
Spain	ALBA Synchrotron
Switzerland	*Solar Research Institute Locarno (IRSOL)
United Kingdom	* Clothworkers' Centre for the Study and Conservation of Textiles and Fashion

6. Glossary

Cyber infrastructures – computational systems, data and information management, advanced instruments, visualisation environments, and people, all linked together by software and advanced networks to improve scholarly productivity and enable knowledge breakthroughs and discoveries not otherwise possible

Data-driven RI – a RI whose main mission is to provide data to users for the facilitation of research.

Divestment – passing financial responsibility for the operation of an RI to one or more other bodies rather than closing the facility entirely

Free-from-cost – Also termed 'free at the point of access' - all associated costs are covered through central funding, and users are not charged for any aspect of their access.

Portfolio management – the process by which a country selects and funds the RIs it will make available to its communities of researchers, covering the planning, building, operating, upgrading, and termination of the RIs.

Research infrastructure – although there is no single definition of a research infrastructure, it is understood in this report as an organisational structure dedicated to deliver facilities, resources (such as data), or services for basic or applied research. In this report, the focus is on research infrastructures serving primarily academic research.

Service-driven RI – a RI whose main mission is to support staff/visiting researchers who are usually engaged with the RI through a contract.

Stakeholders – Planners, funders, operators and primary users of RIs, and all others with an interest in the output of an RI, e.g. secondary users such as policymakers using data or regional authorities interested in local impact

User base – all users (physical, virtual, and remote, external and in-house) of a facility, resource, or service, including secondary users of the data or science outputs generated by an RI.

User facility RI – a RI whose main mission is to provide external users with access to the shared facilities, resources, or services offered.