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RI PATHS
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Abstract: This deliverable summarises the outcomes of the second round of participatory workshops that took place in the period May-June 2019 at the premises of DESY and ALBA, close to the ELIXIR campus and in association with the MERIL conference in Lisbon. The report includes a synopsis of, first, suggestions for indicator selection and, second, further feedback on the IA framework as expressed by RI representatives during the workshops. Thereafter, it further specifies the long-lists of indicators and impact pathways as they were finalised subsequent to these workshops. Finally, it summarises the findings from a follow-up survey in which the (first and second round) workshop participants were asked to comment on and validate the finalised long-lists. Minutes and documentation from all workshops are appended to the report.

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List of acronyms

Abbreviation	Meaning
ALBA	Third generation synchrotron radiation facility located in the Barcelona
CERN	European Organization for Nuclear Research
ELIXIR	A distributed infrastructure for life-science information
ERA	European Research Area
ERASMUS	European Community Action Scheme for the Mobility of University Students
EU	European Union
IA	Impact assessment
KPI	Key performance indicator
NGO	Non-governmental organisation
PhD	Doctor of Philosophy
PR	Public relations
R&D	Research and development
RI	Research infrastructure
SME	Small and medium-sized enterprise
SSH	Social Sciences and Humanities
STEM	Science, technology, engineering and mathematics
UN	United Nations

Executive summary

This deliverable summarises the findings from the 2nd round of participatory workshops of the RI-PATHS project that took place between 8 May and 25 June 2019. Following on from the first round, these workshops focused on the role, available and utility of specific indicators. Nevertheless, it remains clear that it is the overall framework, more than an individual indicator that defines whether impact assessment approaches can be considered as worthwhile or not.

In the first sections, the report briefly summaries the discussions at the workshops. Subsequently, it elaborates on the core findings derived from the stakeholder exchanges, firstly, with a view to developing the previously identified impact pathways and, secondly, to narrow down the list of indicators relevant and feasible for tracking impact. Furthermore, the findings of a follow-up survey of more than 50 RI managers, an integral part of the 2nd stage of the participatory process, are reported. Finally, the report proposes a consolidated concept and a final shortlist of indicators that, together, form the prototype of the RI-PATHS model. The model will be further developed via the piloting phase (work-package 5).

Overall, the participatory phase once more revealed a persistent lack of general orientation in impact assessment exercises. Accordingly, it remains a core ambition of the RI-PATHS project to develop a list of indicators that is clearly structured by and cast into a **concise, yet sufficiently encompassing conceptual framework.**

In conclusions, the following main propositions are proposed as a consolidated foundation for the finalisation of the RI-PATHS model:

1. The future model will have to **distinguish between indicators for relevant activities and indicators for impact**. While the former can, and should, be the subject of internal monitoring efforts at RIs, the establishment or collection of the latter requires specific expertise with regard to estimation or the broader collection of empirical evidence. Usually, such efforts will have to be commissioned;
2. **Workshop participants and survey respondents overwhelmingly confirmed that there can and will be different objectives of impact assessments.** Among those, the most commonly covered areas of scientific and economic impact (for which most methodologies are available) are from both a managerial and (perceived) policy perspective often considered less relevant than societal impacts;
3. A future model will therefore have to allow RI managers to **adjust the objective of their planned internal monitoring or impact assessment and to select a specific set of indicators in light of this specific purpose**. Hence, the four fundamental impact dimensions put forward earlier will be maintained as a general framework to which all to-be-proposed indicators can be assigned to;
4. Workshop participants and survey respondents **overwhelmingly confirmed that they relate to the different pathways** that had been elaborated in the first round of participatory workshops and semantically refined since. Hence, it is seen as instrumental to at least broadly assign each monitoring indicator to a group of pathways in the future, as this has implications for the impact assessment methodologies that can be based on these indicators;
5. In a final step, a concept for a modular IA model is proposed. Most stakeholders agreed that certain indicators will be specific to either physical or virtual RIs respectively. Specific indicators may also be needed for RIs operating in various scientific fields (e.g. SSH RIs). In many cases, however, different modules will and should be used as complements and there will be much common ground.

1. Introduction

The RI-PATHS project engages research infrastructure (RI) managers and other relevant stakeholders in the co-design of a socio-economic impact assessment (IA) framework. This aim was addressed by organising a series of participatory workshops. This report summarises the outcomes of the second round of workshops and outlines how stakeholder contributions feed into the selection of an appropriate methodological approach and related indicators.

The overarching goal of the second round of workshops was to engage the RI community in the identification of suitable indicators and metrics that can, in practice, serve to measure the various impacts identified as relevant and feasible in the first round of workshops. The workshops focused on sourcing consensus on relevant indicators and data gathering routines that could be deployed in feasible IA approaches. As a follow up to the workshops a survey was sent to all first and second round workshop participants who were asked to review and comment on the long-lists of pathways and indicators.

Each workshop started with a short presentation of the project and the progress on key milestones. Next, the consortium team proposed a structure of pathways and a potential core indicator system based on outcomes from the first round of workshops (see deliverable D4.1 Concept note of modular impact assessment framework). Subsequently, the workshop participants were asked to scrutinise and develop further the proposed framework with a view to both relevance and feasibility.

The aim was to identify which additional types of indicators could be relevant and feasible for specific types of RIs. The outcome is a clear understanding of internal needs for indicator collection in RIs as well as the ability and readiness of RIs to report on issues that do not relate naturally to their 'core business'. This robust understanding of the general relevance and feasibility provides the foundation on which a detailed indicator system can be designed. Finally, this second round of workshops enabled the development of a first outline of the impact assessment templates that will be subsequently tested in the validation workshop and in the piloting phase.

The participatory workshops were convened at:

- DESY (Hamburg),
- ELIXIR (Whittlesford Parkway),
- ALBA (Cerdanyola del Vallès), and
- as a co-located workshop of the MERIL-2 project final conference (Lisbon).

They were structured keeping in mind the objective of exploring more in-depth each of the four main domains of impact assessment identified in the conclusions of D4.1.

- Straightforward impacts to be robustly captured in economic analysis,
- Non-quantifiable impacts captured by actor-based analysis,
- Complex network effects captured through exploratory approaches,
- Issues related to the practical implementation of a socio-economic impact assessment.

Further details on the orientation, scope and specific focus of the workshops is given below.

2. Workshops

2.1. Workshop at DESY, Hamburg

The first second-round workshop at DESY (Hamburg, Germany) focused on methodologies to measure **quantifiable economic impacts of research infrastructures**, drawing and elaborating on the Cost-Benefit Analysis (CBA) methodology developed by CSIL. Concrete experiences with economic impact assessments were presented by the host DESY (DORIS study) and by CERN. Subsequently, participants were invited to comment and rank indicators used in this methodology by importance and add those that they found missing.

The official invitation to the workshop noted: "*In the past decade, some large research infrastructures have begun to implement elaborate approaches for economic impact assessment with the ambition to clearly demonstrate their contribution to socio-economic development in monetary terms. In this context, in-depth methodologies have been developed to capture short-term effects caused by expenditure and employment as well as long-term impacts conveyed through knowledge spillovers, education and training, and innovation effects at qualified suppliers. This workshop intends to explain a selection of these methods in detail and to make related experiences available to a broader range of interested organisations. To that end, this workshop will bring together academic experts to introduce established indicator systems with practitioners from RIs to report on the costs, resources and competences required to collect relevant figures in practice.*"

2.2. Workshop at ELIXIR, Whittlesford Parkway

The second second-round workshop at ELIXIR (Whittlesford Parkway, UK) focused on possible **new ways of documenting network effects in research, innovation and training,** building on the introductory presentation from the EFIS Centre team. Concrete experiences were shared by the host (ELIXIR) as well as by CERIC-ERIC. Subsequently, participants were invited to comment on ways to assess and evaluate impact along those impact pathways that cannot be captured easily in economic terms.

The official invitation to the workshop stated: "*During the first round of RI-PATHS workshops it became evident that a number of specific impact pathways and mechanisms are especially (albeit not necessarily exclusively) relevant for distributed RIs. Due to their specific set-up these tend to generate particularly strong effects through the networking of diverse knowledge sources and the development of new ways of knowledge diffusion with implications for research, innovation and training. In this area, some distributed RIs have piloted a range of relevant methods of data collection and analysis which can be relevant for various types of RIs, including non-distributed ones. Against this background, this workshop will present and further explore concrete methodologies to collect data on network effects in research, innovation and training, highlight the analytical limits of quantitative methods in this context and explore qualitative approaches which could be applied to tackle the current challenges*".

2.3. Workshop at ALBA, Cerdanyola del Vallès

The third second-round workshop at ALBA (Cerdanyola del Vallès, Spain) explored **impact-relevant interactions between RIs and users** - focusing less on estimating the extent of impact, but more on ways to establish the extent of relevant interactions with users. Such interactions provide valuable information that can feed into suitable assumptions for later impact estimation. Experiences were shared by the host (ALBA) and ELI. Subsequently, due to an air traffic controller strike that prevented a number of workshop participants as well as members of the RI-PATHS team from participating in person, the discussion was organised in a more open manner than initially planned, focusing on the long-list of indicators prepared in advance of the workshop.

The official invitation to the workshop stated: "*Beyond their fundamental contribution by 'being there' as providers of theoretic knowledge, employers and buyers, many RIs consider it as a part of their core mission to offer specific services to a variety of external users. Beyond striving for excellent science, they seek to resolve problems articulated by economic and societal stakeholders in a targeted and coordinated manner. In the first round of RI-PATHS workshops, this aspect of science-society interaction was highlighted as potentially the most relevant by many participants. At the same time, there is an obvious lack of proven approaches to adequately account for such interactions. More precisely, capacities to leverage the accounting of the existing usage for the purpose of impact assessment needs to be further developed. Accordingly, this workshop will seek to establish what information on the external usage of facilities is already available and how these datasets could be improved to better serve impact assessment purposes. Furthermore, the workshop will explore how to collect additional, relevant information from external sources.*"

2.4. Workshop on the sidelines of the MERIL Conference, Lisbon

The fourth and final second-round workshop was held in conjunction with the final conference of the MERIL-2 project in Lisbon, Portugal. The workshop aimed to support RI-PATHS in developing comprehensive metrics for research infrastructures' socio-economic impact and related financial investments. Taking the opportunity of the RI community gathering for the MERIL-2 final event, the RI-PATHS project invited interested participants to join a session to further address issues related to the practical implementation of socio-economic impact assessments. The workshop benefited from the participation of a range of stakeholders, notably representatives from smaller or non-flagship RIs from a broad spectrum of countries and scientific domains, able to share their particular perspectives. In preparation of the workshop, brief reading material and guiding questions were circulated to the participants and participants were encouraged to provide their input before the meeting. At the meeting, opening presentations were held by RI-PATH Coordinator Elina Griniece (EFIS), Frédéric Sgard (OECD) and Dominik Sobczak (European Commission), followed by discussions in three break-out groups.

3. General Findings on Logics and Pathways

3.1. Preparation: grouping and interpreting the impact pathways listed in D4.1

In preparation of the workshops, the RI-PATHS team developed the pathways identified during the first round of workshops (see D4.1) structured in three main categories:

- **Socio-economic Impacts of Research**
  triggered by all RIs following their primary mission – enabling research
- **Conscious Use of Research for a Purpose**
  triggered by RIs contributing to problem solution in and for industry & society
- **Shaping Research's Foundations & Environment**
  triggered by RIs changing S&T communities, practice and their position in society.

More precisely, the following pathways were discussed:

A) Pathways I: Socio-economic Impacts of Research

- demand-side regional impact pathway
- publication-citation-recognition pathway (incidental, undirected spillovers)
- technology transfer & licensing pathway (actively supported spillovers)
- learning- and training-through-procurement pathway
- learning- and training-by-users pathway

B) Pathways II: Conscious Use of Research for a Purpose

- user interaction and industrial problem solution (in projects) pathway
- user interaction and societal problem solution (in projects) pathway
- benefits of data editing and preparation for external users

C) Pathways III: Shaping Research's Foundations & Environment

- changing fundamentals of research
- contribution to standards
- communication and outreach pathway
- increased societal participation
- networking and community creation.

While the pathways were not explicitly reflected on step-by-step, related issues were either raised in the discussion by participants themselves or by the RI-PATHS team, in order to gain clarity on certain aspects. The following sub-sections note key highlights of the discussions that took place during the four workshops.

3.2. Findings from the Workshop at DESY, Hamburg

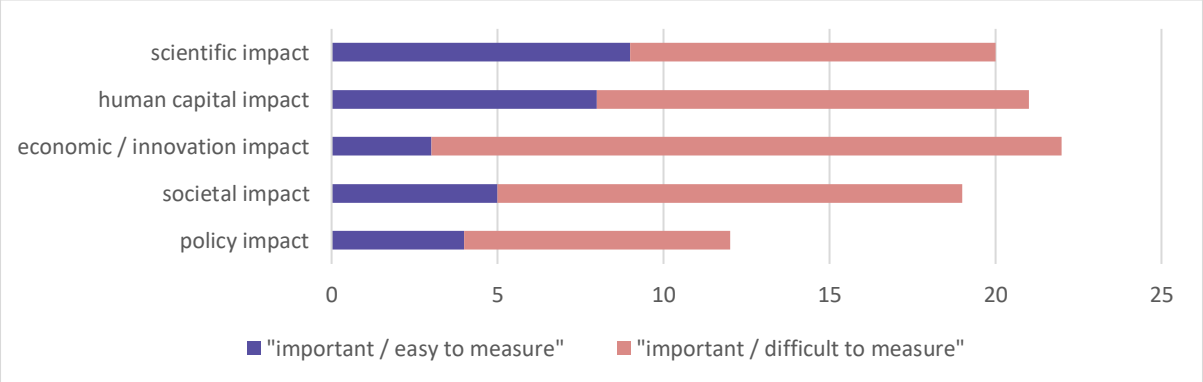
In Hamburg, in a first instance, the discussion focused on the learning effects through interactions with users and suppliers. It was emphasised that an interaction with qualified suppliers creates substantial learning effects as they do not simply supply off-the-shelf products on clearly defined specifications. Instead, there is a complex process of mutual learning before equipment can be delivered according to requirements. Moreover, non-scientific users do contribute to synchrotron facilities' impact, even if their share of usage may be low (5-10%). This was illustrated during the subsequent guided tour when operational staff reported that their interactions with users from industry and the public sector were in a certain way more intense than those with scientists acquainted with the facility. This also results from different modes of using the facilities: while research proposals are assessed in a competitive way and selected scientists may use the facility free of charge, industrial users are charged for their beamtime use. Consequently, the latter are intensively supported both with respect to using the facility and to analysing the results. At the same time, the DESY staff pointed out that the RI cannot solve problems, only contribute to

problem solution efforts of third parties who know what they need the experiments for. Participants underlined the role of outreach and communication while they disputed contributions to policy. The audience's assessment gathered during the on-site kahoot! survey underlines that economic impact is regarded as the most important category, while, in general, respondents remained sceptical about available options to reliably measure anything but scientific and human capital impact.

The second discussion group focused on the human capital dimension, on various forms of collaborations and their effects and challenges to measure impacts through tracking publications. Human capital was considered highly important, and in addition to mere counting (of courses, participants, etc.), the added value of education was discussed. Although challenging to measure, participants emphasised the importance of this aspect. The second part of the discussion strongly focused on interactions/ collaborations/ joint developments in networks and their economic impacts as well as their added value. While the number of collaborations with partners, e.g. in the context of external stakeholders using the facilities or of joint projects, can be counted, the added value and the economic impact of being in a consortium were considered difficult to measure. Some participants reported that they approach this topic through surveys (about the use of, benefits from, satisfaction with their collaboration with RIs), but nevertheless the perception prevails that this does not cover the full impact. Remaining questions refer to assessing the counterfactual situation, to knowledge increase through collaboration for all partners involved. It was acknowledged that knowledge does not only flow in one direction. Further, the issue of industrial PhDs was raised, these students use RIs for their (industrial) doctoral thesis and are considered future promoters in the industrial value chain. It was questioned how these medium- and long-term effects can be traced. Hence, the need for a systematic case study approach was mentioned.

The third broad topic discussed was publications based on the results of experiments conducted in the RIs, since being able to track these is a prerequisite to trace publication-citation-recognition pathways. On this topic, participants had differing perceptions: some saw notable challenges due to incorrect or absent acknowledgements to the use of RIs in academic publications, others less so. The discussion suggested that RIs have limited legal means to ensure correct acknowledgement by RI users. There is feeling that tracking of publications is time-consuming and challenging. The discussion then turned to the question how this could be solved ("Why do RI's have the tendency to be so soft with respect to acknowledgements, given the fact that public money is spent for using the facilities, and that correct acknowledgement is a question of responsibility and compliance?"). In addition, participants agreed that better IT tools will gain importance in tracing impacts triggered along the publication-recognition pathways in the future, which is currently not possible.

Figure 1 Assessment of relevance of different impact categories



Source: own kahoot! on-site survey, 08/05/2019

3.3. Findings from the Workshop at ELIXIR, Whittlesford Parkway

At ELIXIR, it was recognised that there are very distinct challenges related to the impact assessment of distributed and virtual data RIs. The core functions of distributed RIs relate to the coordination, integration and maintenance of resources for research. These RIs enhance collaboration among in-house experts and user group communities across geographical boundaries which introduces a complex network dimension to the issue of knowledge and know-how transfer and the formation of social capital. This added value of RI pan-European cooperation is intangible and hard to express in quantitative terms.

With regards to data RIs, participants emphasised that users of data cannot be equated with users of physical facilities as open access to such research resources significantly limits the available user information. Several RIs reported that they did not register their users and, for legal reasons, did not have access to their users' IP-addresses. Consequently, the ability of these RIs to track the patterns of usage is quite limited.

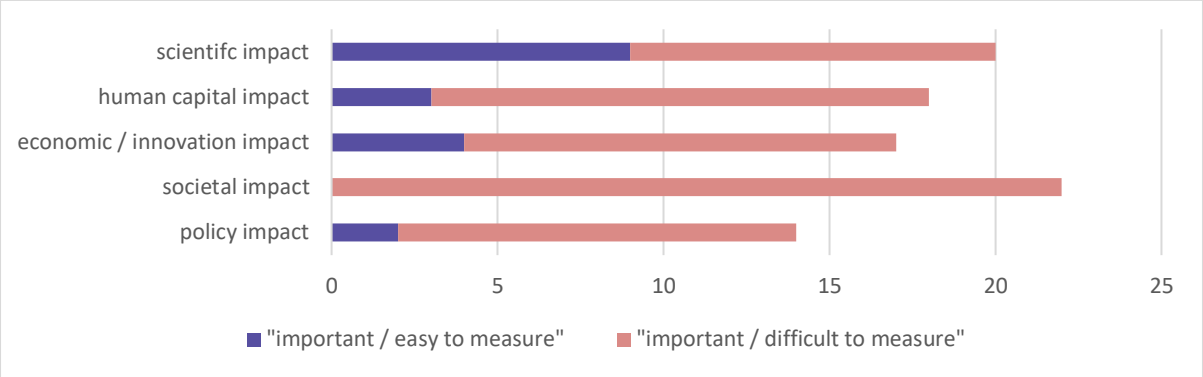
With respect to the 'communication and outreach' pathway the participants emphasised the need to include a stronger element of 'engagement'. Stating that mere communication was not enough to generate substantial impact, they proposed to focus on events of an interactive nature. Most underlined that their facilities had notable societal impact and that, in fact, generating this impact was part of their raison d'être.

Discussing the 'increased societal participation' pathway, the participants noted the necessity for RIs to have a comprehensive view on all types of users that their facilities are attracting. The role of targeted dissemination activities regarding the available services and tools was also recognised as a relevant proxy for further scoping the actual use of RI resources by various user groups. With respect to longer-term impacts, some participants acknowledged that it is not sufficient to trace only the number and characteristics of new entrepreneurial and start-up activities facilitated by RIs, but it would be necessary to better understand the economic and societal impact these companies are inducing.

Reflecting on the ways distributed and virtual RIs facilitate the creation of networks and communities of practice, the participants highlighted the need to deliberate all forms of engagements RIs are enabling now or could potentially enable in the future. It was agreed that a comprehensive typology of all possible types of 'productive interactions' with relevant stakeholder groups could be one useful outcome from the RI-PATHS project. Such a typology would allow RIs to assess which of those interactions are relevant to scope and measure in an IA exercise or to include in a future impact strategy.

In contrast to the discussion in Hamburg, the participants at ELIXIR workshop rated all impact categories, including policy impact, as important to measure. The common assessment from the workshop audience gathered through the on-site kahoot! survey underlines that societal impact is of key importance to many respondents, surpassing economic or even scientific impact. However, representatives from distributed and virtual RIs are even less confident than their colleagues from single site RIs about the availability of options to measure such impacts properly.

Figure 2 Assessment of relevance of different impact categories



Source: own kahoot! on-site survey, 09/05/2019, N=21-24

3.4. Findings from the Workshop at ALBA, Cerdanyola del Vallès

Some workshop participants repeatedly raised a concern that to measure the impact of science in monetary terms and/or industrial use value was mainly an act of compliance vis-a-vis interests of funders who have to legitimise their budgets. They felt that RI's should refrain from adopting a perspective that defines and appraises their performance *predominantly* based on the extent of external usage of their facility. Some suggested that, as a first step, the tracing of scientific impact (i.e. publications) needed to be improved. Without a robust understanding of which publications are attributable to the use of their facilities, they argued that at least the publication-citation-recognition pathway will be impossible to describe from the outset. Additionally, they underlined that some of the pathways required re-wording and explanation in order to allow RI managers to easily understand and put indicators against them. However, it was understood and appreciated that RI-PATHS was trying to chart the logical path to impact, rather than just produce a further list of indicators. Participants confirmed that besides delivering and enabling science, RIs also have extra layers of missions. Hence, some considered it an important task of RI management to articulate what can be measured and what can't.

Against this background, however, they suggested that it would be important to customise approaches to the specificities of RIs including mode of access (open calls, research grants) and missions. Some of the RIs were not designed as user facilities, others were, which matters. For example, as a laser facility, ELI has a natural fit with industry. In other facilities, demonstrating interaction with users is less natural and harder to demonstrate, if required. Most therefore agreed that logics and indicators will have to be weighted according to the RIs structure and mission but did not have immediate suggestions on how that could be technically done.

Several participants noted that training-by-usage is an important logic/pathway as some users spend a long period at RIs. Consequently, the resulting increase in skill and competencies can be substantial. With a view to broadening participation there is a concern of countries with smaller (and hence sometimes less excellent) communities. If this pathway is to be followed, brick-and-mortar RIs need to negotiate between guaranteeing broad access and not compromising scientific excellence (potentially different from virtual infrastructures). To an extent, single site infrastructures can hold, curate and host data as well, in a sense becoming themselves virtual. It was underlined that access policy affects a number of things: member contributions, user interest and participation, interactions with industry, data and IPR policies. Participants stressed that all indicators should be defined/collected with respect to a well-identified goal. There is no 'correct' indicator system as such, suitability depends on the context and purpose for which indicators are collected. Furthermore, it was stressed that qualitative aspects are also important and that funders are equally interested in case studies and success stories.

3.5. Finding from the workshop co-located at the MERIL Conference, Lisbon

In relation to potential differences in impacts between RIs addressing natural sciences and social sciences and humanities (SSH) it was concluded that, independently of the research area, all RIs have potential impacts on economy and society although these materialise in different ways. In particular, it may be difficult to monetise some SSH related impacts on the economy. All RIs also share the concerns that the pathway connecting the outcomes of the research to policy impacts has many challenges as it requires the uptake by politicians of recommendations produced by the research community.

3.6. Synthesis

As a result of the above discussions, the RI-PATHS team decided to re-phrase the initial set of pathways as follows:

Impacts as a Result of RIs Enabling Science (i.e. performing their primary mission)

- employment & standardised procurement
- publication-citation-recognition (incidental spillovers)
- technology transfer & licensing (supported spillovers)
- learning- and training-through-specialised procurement
- generic learning- and training-through-usage

Impacts as a Result of RIs Supporting Problem Solution (by providing services to users)

- interactive industrial problem solution
- interactive public sector problem solution
- provision of specifically curated/edited data to industry
- provision of specifically curated/edited data to public sector
- other interactive societal problem solution

Impacts through Shaping the Fabric of Science and Society

- changing fundamentals of research practice
- contribution to formal standards in science
- creating and shaping scientific networks and communities
- creating and shaping networks between science and society
- communication, outreach and engagement.

For the later development of the model, these differentiations are important as they define that methodology that will have to be applied to estimate impacts based on relevant information collected. As will be illustrated, RIs can collect various types of pertinent indicators on impact-relevant RI activities through internal monitoring efforts. How these can be used to conclude on possible impacts, however, depends on the assumptions we take on the mechanisms of causation that they we take them to trigger. These, however, are in a concise manner well expressed through the different pathways. While assigning monitoring indicators to pathways is thus only a first step towards defining methodologies for impact assessment, it is an important an indispensable one.

In summary, we are thus likely to eventually see at least three main groups of methodologies to be applied - in line with the three main groups of pathways. The first domain yields itself naturally to methods of estimation, the second one calls for the informed analysis of networks of interaction and the third one calls for the application of more complex, oftentimes part qualitative approaches. Moreover, differences between individual pathways likely will also trigger differences in the approaches identified with the respective groups. For example, methodologies to estimate impact based on publications will differ substantially from those based on human capital related training activities. Likewise, attempts to capture the impact of RIs contribution to creating and shaping scientific networks and communities will differ from those triggered through communication, outreach and engagement.

4. Findings on Indicators

4.1. Preparation: the long list of indicators

In preparation of the workshops, a long list of indicators was compiled based on past working groups, ongoing projects and related activities. The list compiled all available indicators under the main headings proposed by the RI-PATHS project: scientific impact, human capital impact, economic & innovation impact, societal impact and policy impact. Duplications were removed to the extent possible and indicators were sorted in two main groups of a) those that can (in principle) be monitored by RIs themselves through internal procedures and b) those whose collection or estimation will definitely require additional efforts involving third parties. This initial long list of indicators is included in Annex to this report.

4.2. Findings from the Workshop at DESY, Hamburg

The participants at the DESY workshop showed a lot of interest in quantitative indicators related to economic and innovation impacts. Building on the first round of workshops, however, there was now a clearer focus and a more articulate debate on impact beyond the domain of science. Overall, participants were able to place individual indicators in a coordinated system of relevance and availability with a surprising ease and unanimity, even given their often-dissimilar organisational background. A limited number of discussions arose from different views on how to position indicators that were in substance far from the core mission, but in practice obviously required by policy. The long list of indicators was not explicitly discussed in Hamburg but provided as inspiration during the concluding working phase on whiteboards.

Figure 3 Discussion at DESY Workshop in Hamburg

Source: Own photo, by RI-PATHS team

4.3. Findings from the Workshop at ELIXIR, Whittlesford Parkway

In line with the workshop's emphasis on distributed and virtual infrastructures, the discussion in large part focused on the options to trace and assess usage of virtual resources. While various participants pointed out that they are aware of the principle merit of indicators listed on the long list, they had difficulties in seeing how those could be collected in practice. In particular, open access principles were mentioned as a key obstacle to put in place ways and mechanisms to trace and collect relevant information for impact assessment (e.g. user-registration can be perceived as a barrier to data-sharing). Hence, while in theory distributed and virtual RIs have the potential to trace impacts through diverse web-based techniques, in practice this can currently be hardly exploited, although notable exceptions exist.

Drawing on examples of how advanced data analytics could potentially be applied to IA, the representatives from ELIXIR provided insight into their efforts to trace scientific impact using a text-mining approach with specific search terms. They concluded that these types of exercises need to be designed so that they are light-touch and repeatable; in combination with some manual curation can provide usable results. This type of techniques could potentially be tested also in tracing socio-economic impacts, such as policy impact. Yet, it has been underlined that improving citation practices of the use of RI resources is an essential prerequisite for future IA.

Discussing in more depth the topic of training impact, the participants acknowledged that the number of training events and the number of trained people represent only a bare minimum of data needs to make credible impact statements. Collected data (e.g. through surveys) needs to reflect how participation in a training course improves someone's understanding and awareness of a particular domain/topic, leading to change in their research/professional development as well as passing on if the gained skills and knowledge to others. The awarding of 'digital badges' was mentioned as a good practice to ensure that training impact assessment is taking into account the most relevant aspects - the skills gained, achievements and contributions of trainees. In a similar vein, participants emphasised that such indicators as the number of meetings and events (e.g. with policy makers, citizens) do not suffice for IA; RIs need to gather further insights what was achieved in those meetings/events and to get an indication on multiplier effects (esp. through 'train-the-trainer'). Among the useful ways to deal with intangible impacts, the participants named approaches such as confidence/perception scoring and capacity self-assessments. Others mentioned "lobbying effects": RI activities give policy funders ideas for funding programmes, e.g. H2020 (possible indicators: number of events with policy-makers involving RIs; RI representation in high-level expert groups).

Due to the very qualitative nature of the network effects and tangible benefits RIs bring about, a separate part of the discussion was dedicated to the requirements for good impact narratives/case studies. While some participants confirmed that all expected impacts are collated in the development strategy of their RI and the main activities are clearly linked to an impact plan, others admitted that no such thinking is included in their strategic plans. It was acknowledged that an awareness of the expected impacts is needed across all RI team to maximise these benefits in a strategic way. It was suggested to instigate a competitive culture with respect to impact tracking among the nodes of a distributed RI to draw attention to this topic. In any case, many felt that it will remain a challenge to demonstrate the added-value of pan-European coordination and cooperation, knowledge exchange and the reduction of fragmentation to funders.

4.4. Findings from the Workshop at ALBA, Cerdanyola del Vallès

After a general group discussion, the participants worked in pairs on the suggested list of indicators with a task to identify the most important and relevant ones from the RIs' perspective and highlight any potential difficulties in collecting needed information and using indicator metrics.

To start with, the representatives of the RIs commented that all indicators should have clear definition which would help to take away any potential confusion and mis-representation. The definitions are particularly important for terms such as 'utilisation' and 'usage'. Introducing clear definitions will help avoid unclear wording such as "use of information'.

The participants proposed that some indicators may be pooled as they are more or less measures of the same thing, or at least are part of the same logic as with innovations that precede sales increases. For example, this was mentioned with respect to indicators on students trained. Also, it was emphasised to avoid indicators that were obviously too difficult to obtain. Overall, many confirmed a shortage of resources for IA purposes, e.g. one single person in charge of statistics dealing with diverse non-standardised queries. Indicators need therefore be viable and practical.

With a view to publications it was mentioned that procedures currently in place are mostly non-systematic, including keeping in contact with users, mailing systems to track former and current users' publications and (more as an option still) asking users to provide results of previous works when they reapply. Several RIs stated that users should be obliged to cite RI in acknowledgements but there is apparently no legal basis for imposing this. Nonetheless, ALBA stated that they do not see tracking publications as the most pressing challenge. However, single-sited and distributed RIs face different challenges. In single sited RIs, the process of tracking publications seems easier and, by and large, better established. ALBA not only tracks publications, but also measures impact by tracking citations because publications are different with various impacts and citing papers. CERIC counts co-authored publications by internal staff and those ones that are not co-authored by the internal staff but published thanks to CERIC.

With a view to external users, some suggested to distinguish at least between academic users, SMEs, other industry and public sector users. However, an important challenge arises from the fact that private sector stakeholders collaborate with university teams and benefit indirectly - which is even harder to trace as income from such cooperation would then usually not be listed in the RIs' accounts under the 'right' heading. Especially for distributed RIs it can be difficult to count the number of firms accessing the RI as these de facto access facilities located in a given country so that the central hub of the RI cannot necessarily track their number due to legal and technical hurdles. Furthermore, it was noted that it could on a technical level (in the books) be difficult to distinguish between public sector users, such as museums, and government users in an official capacity, such as police. Moreover, participants suggested that it would be important to monitor the quality of access (N of accepted proposals/total N of received proposals) and the frequency of subsequent access to documentation and statistics (N of accesses, data downloads per user per year). A further suggestion was to focus industry usage on proprietary access that amounts to 3-5%.

In additional domains, participants reported they are sometimes requested to track indicators that are difficult to measure. For example, some funders wanted to measure the impact of RIs contribution to PhD training which means that they need to artificially fix the user/students profile of subsequent achievements at a point, which, in substance, is not a good approach. Others mentioned that e.g. information on outreach and inclusiveness could be collected partially by tracking which countries / continents users are coming from.

Some participants underlined that differences between disciplines, missions and RI set-ups made it quite hard to identify overarching indicators. Hence, usage and access to data could

be such an overarching indicator as well as usage of physical RI facilities (if any) for third party experiments.

In order to promote training and exchange on best practices, some RIs organise regular user meetings once a year to share ideas on research results. Where this is the case, therefore, a useful additional set of indicators could be N of users' meetings in a year, training events, N of participants to those events, etc. Some noted that RIs are increasingly asked to produce FAIR data, but there are no indicators on how to measure the extent to which data are FAIR. With a view to qualitative studies, some suggested to simply count the N of so far existing case studies related to an RI.

4.5. Synthesis

As a result of the above discussions, the RI-PATHS team decided to rework the initial long-list of indicators - before it was once more put forward to the stakeholder scrutiny in a follow-up survey. Due to its length, the resulting full long-list has been moved to the Annex.

Overall, the findings on indicators can be summarised along the following main lines:

- There is a substantial group of indicators on which many participants can agree, generally speaking, the level of agreement on those was surprisingly high;
- Typically, RI managers cannot easily relate to impact indicators proposed by external experts - which can only be obtained through (to them unknown) methodologies;
- Repeatedly virtual RIs did not feel well represented by the currently existing indicator lists that they perceived as tailored more towards physical RIs;
- Various indicators were considered as "probably useful in principle" - but hard to finally assess failing further specification or semantic improvement;
- A certain number of indicators was considered irrelevant, duplicate or as ill-defined so that they should best be dropped swiftly.

In summary, the workshops revealed a notable degree of agreement on the utility indicators and demonstrated that relevant stakeholders can relate to what is already there from other projects. However, many participants were very sceptical about the general, and in particular their own, ability and/or capacity to collect information on a substantially larger number of aspects than currently. Moreover, many discussions reflected a notable lack of understanding of the objective of impact assessments. While most RIs support the notion that impact assessments are important, few have made up their minds for what exactly, beyond complying with external requests. This is noteworthy as it was repeatedly stated that the type of indicators that are most commonly requested by funders and policy makers are not necessarily those that RIs would choose or prefer to report on with a view to their mission and perceived main contribution.

5. Findings of the Follow-up Survey

5.1. Follow-up Survey: Design and Objectives

The option of an additional follow-up survey was discussed before the workshop and announced during the three workshops of the second round. The main benefits of this survey are to gather additional evidence on workshop participants' assessments, regarding the findings that the RI-PATHS project established so far. It is an essential next step towards the consolidation of the RI-PATHS model before the piloting phase.

The survey was designed as an online survey (conducted with EFS Survey tool Questback). In order to make it as easy as possible for the respondents to add their experience and assessments, ratings for each indicator were transformed into a Likert scale, enabling the users to tick the suitable box. In addition, respondents could add comments in specific text boxes. Overall, the survey was filled in completely by more than 50 respondents, many of the initial questions received more than 60 replies. For a survey specifically addressed to RI managers, this coverage is quite remarkable.

5.2. Follow-up Survey: Results

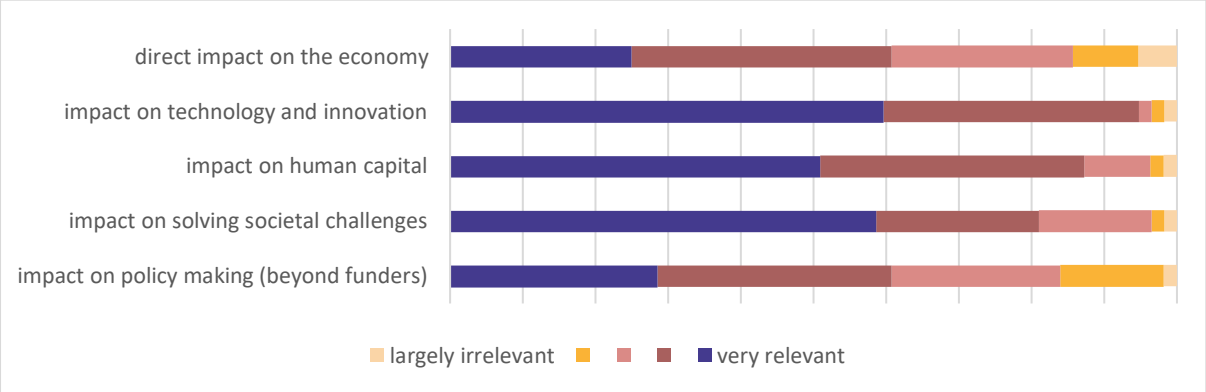
Confirming the core impact areas

In the first section of the survey, respondents were asked to assess the main impact categories discussed in the project. Quite unanimously, most respondents (between 80-95%) confirmed that they considered the proposed fields "relevant" or "very relevant" areas for impact assessment. In this context, it is remarkable that the RIs' direct impact on the economy through employment and procurement, which is often mentioned as a priority, received below average marks of only about 60%. Likewise, a below average share of respondents felt that RIs' direct impact on policy making was worthy of study.

With a view to the availability of suitable methods, the overall assessment was rather pessimistic. Even with regard to the more established fields of economic and human capital impact, for which some proven methodologies are known to be available, barely more than 45% consider that current methodologies are suitable. With respect to contributions to societal challenges, less than 10% were optimistic. Likewise, less than 20% believe there are good options to assess impacts on policy makers.

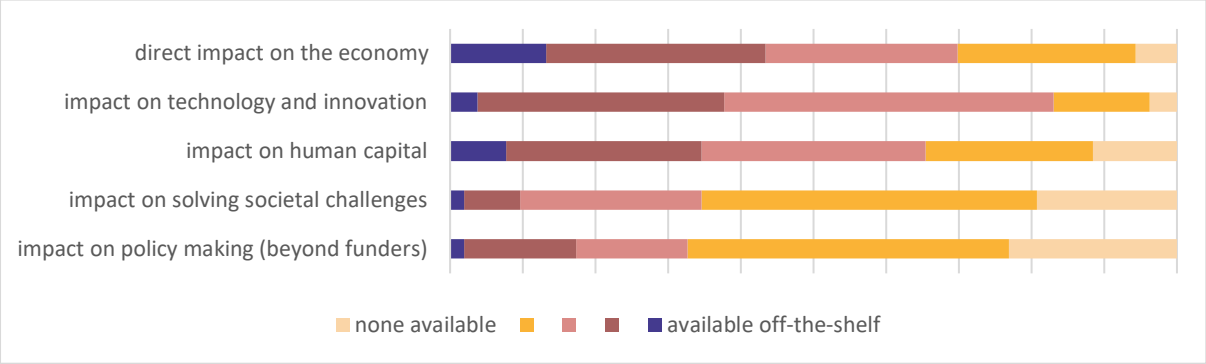
Overall, the availability of data seems to more or less correlate with the availability of methodologies: overall less than optimal and with a slightly better outlook for economic and human capital impact assessments than for broader ones. However, there is one notable exception: while only 10% of the respondents could think of methods to assess societal impact, more than 20% were optimistic that suitable data was in principle available.

Figure 4 How important do you consider the following fields of impact for future impact assessment?



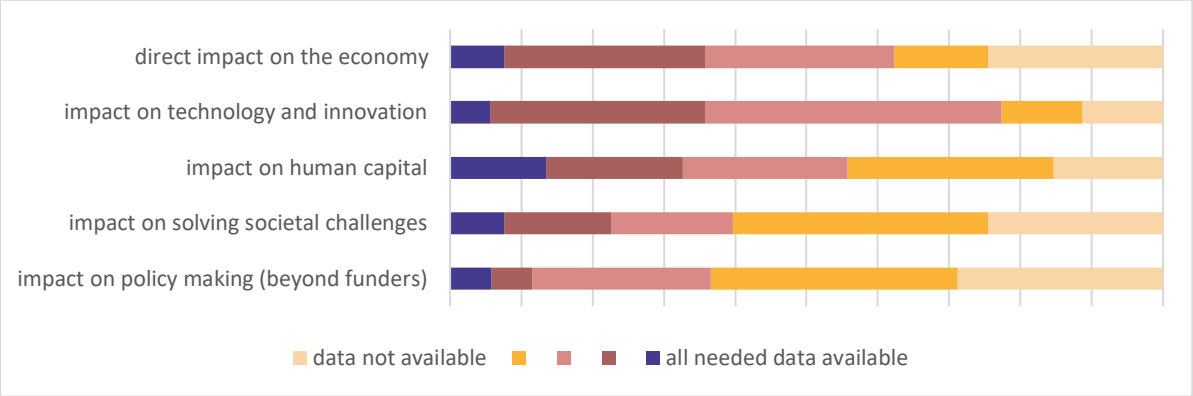
Source: own survey and analyses, RI-PATHS 2019

Figure 5 Awareness of suitable methods to capture impact in the following areas?



Source: own survey and analyses, RI-PATHS 2019

Figure 6 Availability of relevant data that institution could provide to future impact assessment teams?



Source: own survey and analyses, RI-PATHS 2019

Assessing the proposed pathways

Overall, the **following preliminary types of impact pathways** are derived from the participatory process organised during Work Package 4.

Impacts as a Result of RIs Pursuing their Primary Mission - Enabling Science

- employment & standardised procurement
- publication-citation-recognition (incidental spillovers)
- technology transfer & licensing (supported spillovers)
- learning- and training-through-specialised procurement
- generic learning- and training-through-usage

Impacts as a Result of RIs Interacting for Problem Solution

- interactive industrial problem solution
- interactive public sector problem solution
- provision of specifically curated/edited data to industry
- provision of specifically curated/edited data to public sector
- other interactive societal problem solution

Impacts through Shaping the Fabric of Science and Society

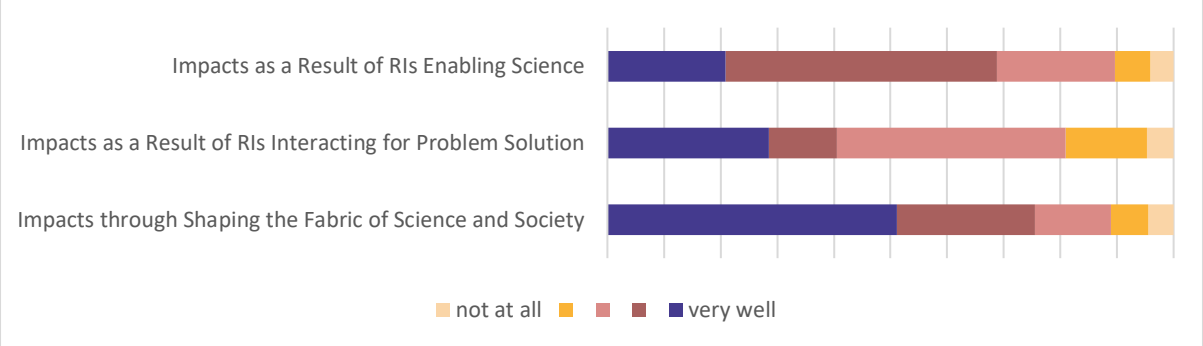
- changing fundamentals of research practice
- contribution to formal standards in science
- creating and shaping scientific networks and communities
- creating and shaping networks between science and society
- communication, outreach and engagement

Considering these pathways, a majority (60-70%) of respondents easily relate to those proposed under the heading of "impacts as a result of RIs enabling science" as well as those for "impacts through the shaping of the fabric of science and society". Among the two, strong consent ("can relate very well") was strongest with about 50% for those under the heading "impacts through the shaping of the fabric of science and society" whereas those resulting from scientific advances in a more direct manner were confirmed strongly by a mere 20%. This is relevant, in particular, as the first group includes not only standard economic effects through employment and procurement but also those pathways that were mentioned, in many workshops, as being most intuitive: publication-citation-recognition and technology transfer and licensing. In short, the RIs contribution is more structural and systemic and cannot easily be captured in terms of "capitalisation on science" alone.

At the same time, consent rates were somewhat lower than expected for pathways related to the RIs' direct contribution to problem solving in industry and society. For the pathways proposed under this heading, only 30% could relate "very well" and a further 10% "well". However, it is noteworthy that a further 40% have an ambiguous position on this matter (compared to 10-15% on the other headings). Possibly, therefore, the issue is of a semantic nature in the sense that a significant group of respondents had issues with the precise wording of the pathways more than with the notion as such.

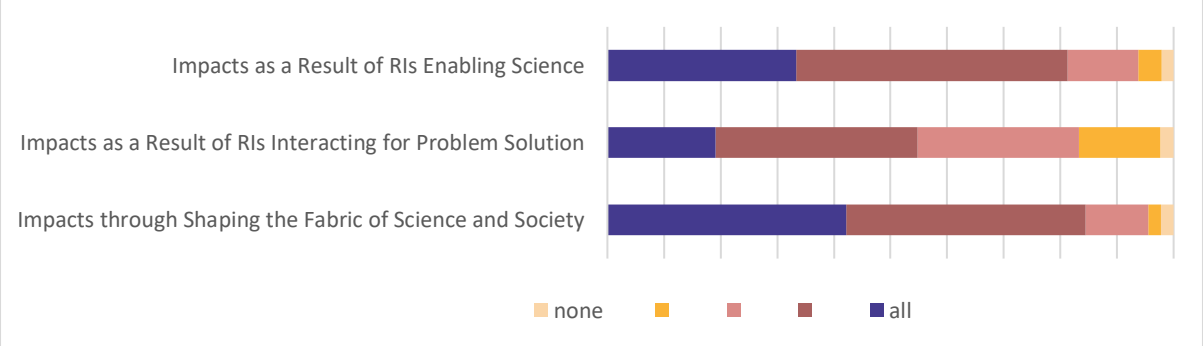
In parallel, an even higher share of respondents (more than 80%) agreed that the pathways presented under "impacts as a result of RIs enabling science" and "impacts through the shaping of the fabric of science and society" were relevant for their organisations. In line with the above interpretation, moreover, 55% stated that this was the case for "contributions to problem solving in industry and society" - notably higher than the abovementioned 40% that could "easily relate".

Figure 7 To what extent can you - in principle - relate to the abovementioned pathways?



Source: own survey and analyses, RI-PATHS 2019

Figure 8 How many of these pathways/logics are relevant for your organisation?



Source: own survey and analyses, RI-PATHS 2019

To avoid lengthy listings, details on the survey's findings on all individual pathways are annexed. Nonetheless, the following paragraph will present a short overview of those that were most widely acknowledged under the respective main headings.

Under *"impacts as a result of RIs enabling science"* prominent pathways were publication-citation-recognition and technology transfer & licensing with about 80% approval respectively while all other pathways received approval rates of 60%. This clearly indicates an emphasis on thematically specific spillovers rather than generic functions, while the differentiation between incidental and managed spillovers is apparently considered less important than could be expected.

Under *"contributions to problem solution in industry and society"* prominent pathways were interactive public sector problem solution and the provision of specifically curated/edited data to public sector with above 60% approval each. While the differences with the others (between 50-60%) are in fact rather minor, it is interesting to note that, in RI managers perceptions, the relevance of RI contributions to the public and the industrial sector are at least on par.

Under *"impacts through the shaping of the fabric of science and society"*: creating and shaping scientific networks and communities and creating and shaping networks between science and society had 90% approval ratings. Overall, however, they hardly stand out in a situation where all proposed pathways received above 85% approval ratings. Most notably, all pathways under these headings were considered "very relevant" by at least 50% - up to nearly 75% for creating and shaping scientific networks and communities.

Availability of methods

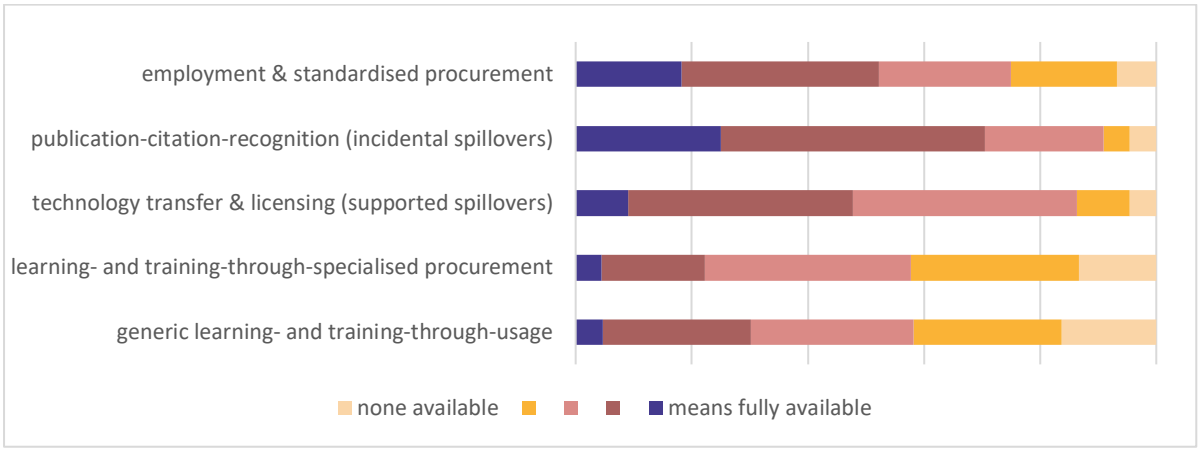
In line with the above findings on impact areas, the RIs current confidence on being able to assess impact along certain pathways were generally more cautious and particularly sceptical for certain domains.

With a view to "*impacts as a result of RIs enabling science*" about half were optimistic that they could track generic economic effects through employment & procurement as well as those through technology transfer and licensing. Even more (70%) suggested that they could develop some form of impact assessments based on the tracking of publications. With a view to learning and training effects, to the contrary, a mere 20-30% felt that sufficient means were at their disposal. With a view to contributions to problem solving, the figure drops to 20-30%, with hardly more than 5% stating that they consider means fully available. Even when including ambivalent statements, the share of those seeing options for assessing impact barely exceeds 50%. With a view to "impacts through the shaping of the fabric of science and society" the picture is once again slightly more optimistic with rates of between 35% (creating and shaping networks between science and society) and 60% (communication, outreach and engagement). Moreover, it is encouraging that 10-20% consider they have the means "fully available" which provides a basis for learning within the RI community.

In summary, this analysis confirms four main findings from the second-round workshops:

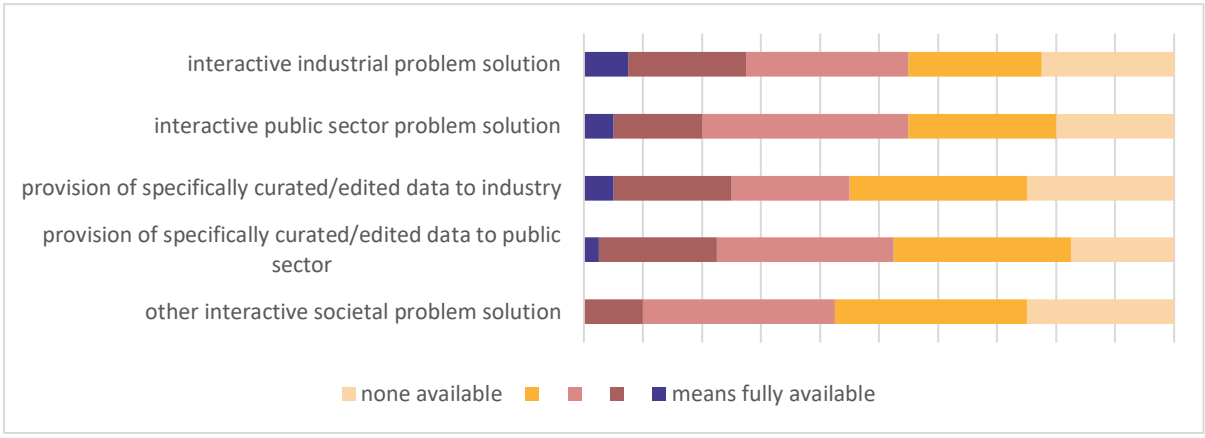
- RIs are most focused in a number of impact domains that correspond to more 'traditional' impact pathways. Beyond these pathways, a large majority of RIs do not seem sufficiently oriented towards tracking impact;
- These 'traditional' aspects of impact assessment do not correlate strongly with the domains that the RIs themselves consider most representative of the impact that they believe to effectively generate;
- RIs are very, perhaps unduly, pessimistic about their options to measure the contribution they are making through collaborations with users,
- RIs seem to have more ideas than might be expected on how to capture networks effects as well as structural and systemic impact that could be built upon.

Figure 9 To what extent does your RI have means (not least: suitable data) available to track these pathways?



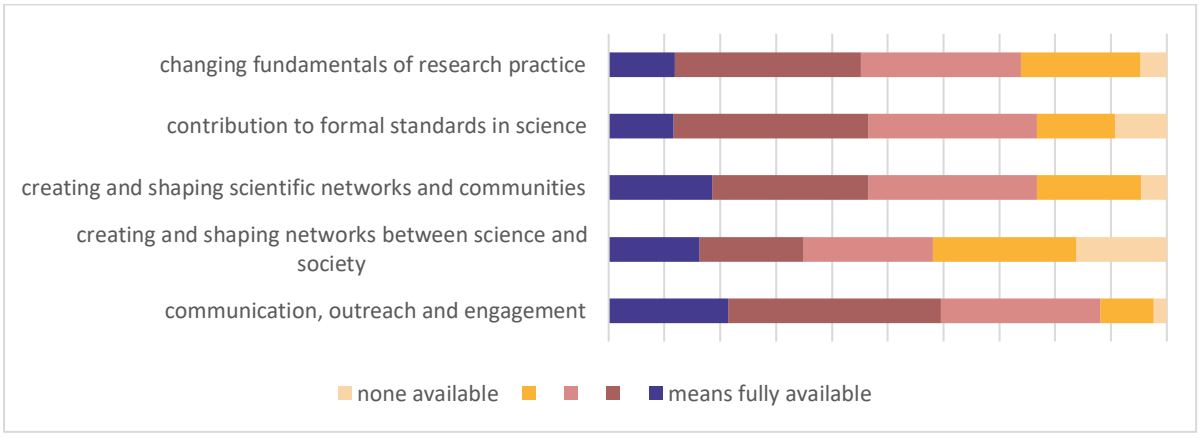
Source: own survey and analyses, RI-PATHS 2019

Figure 10 To what extent does your RI have means (not least: suitable data) available to track these pathways?



Source: own survey and analyses, RI-PATHS 2019

Figure 11 To what extent does your RI have means (not least: suitable data) available to track these pathways?



Source: own survey and analyses, RI-PATHS 2019

Assessment of indicators

A further role of the model is to assess the relevance of specific indicators under the main impact domain headings. To that end indicators were structured into

- monitoring indicators (that cover activities relevant for specific pathways); and
- impact indicators (that cover the final materialisation of relevant impacts).

For all indicators, the respondents could vote whether

- they found the indicator important;
- believed that it was in principle measurable; and
- believed that sufficient information was currently available to RIs to report it.

Subsequently, the RI's assessments were aggregated and a proposal for the shortening of the long list of indicators was developed based on the following general principles:

- on **importance**, RIs are best placed to answer if an indicator is relevant for them, so if it fails to meet a minimum threshold, it should be dropped. A 40% approval was applied as a minimum threshold to label candidates for removal;
- on **availability**, RI can give valid indications on how much effort the collection of these indicators might practically require. Even being optimistic, all indicators with below 20% percent approval must be considered as challenging to implement and all with below 10% as problematic, these became further candidates for removal;
- on **measurability**, it is unrealistic to expect RIs to be methodological experts, but an interpretation of what they consider measurable can be indicative of what RIs will actually be able to obtain internally and what definitely needs external support.

As a result, some indicators could be labelled as "clearly in", "clearly out" but a number of cases remained either ambiguous or, with a view to assessment, counterintuitive. These cases were discussed by the core team members to arrive at the following conclusions.

A clear distinction should be made between indicators for the monitoring of impact-relevant activities, to be collected by the RI, and indicators for final impact, to be estimated or generated, mainly, through dedicated studies. The latter need not necessarily refer to an external contractor (although it often will), but more generally to the fact that the provision of these indicators requires the involvement of individuals and/or teams with specific expertise to estimate impacts or obtain in principle not available data through dedicated surveys. In short, impact studies cannot be performed by the accounting department or a single impact officer within an RI. The survey has made very clear that this distinction is well understood among most RIs.

To remain focused on the RI-PATHS projects' core ambition, indicators from the domain of science remained thus included insofar they constituted indicators for the monitoring of impact-relevant activities (which may give rise to impact pathways under the first heading: impacts as a result of RIs enabling science). On the contrary, genuine impact indicators concerning the domain of science were included for further consideration.

The detailed findings of this selection are presented in the eight following overview tables. In summary, there are three central findings that will be considered for subsequent activities under Work Package 5, taking into account also the overall conclusions:

- RIs are most positive about their ability to cover scientific and human capital related activities, so these may not need to be the central focus of the pilots,
- there are major methodological issues with a regard to a few, specific indicators (regarding in particular the usage of facilities and data),
- there are remaining conceptual issues in the sections on societal and policy impact that lack clear definition of purpose which is reflected in the indicators.

Table 1 Assessment of monitoring indicators for Scientific Activities triggering diverse Impact Pathways

Scientific Activities triggering diverse Impact Pathways	share deemed important & available	share deemed important	share deemed measurable
Number of publications	55,1%	61,2%	52,38%
Number of publications in high impact factor journals (above threshold)	44,9%	53,1%	50,79%
Number of publications weighted by impact	22,4%	53,1%	41,27%
Number of scientific users (teams or individuals, by occasion of use)	42,9%	59,2%	49,21%
Funding grants from national/supra-national funding sources	40,8%	59,2%	49,21%
New scientific instruments/infrastructure developed	30,6%	57,1%	41,27%
Excellent collaborations (visits by world leading teams)	18,4%	61,2%	33,33%
Hosting of (high-level) scientific events (e.g. conferences)	28,6%	51,0%	42,86%
Use of open data (within science)	16,3%	61,2%	26,98%
Presence in relevant committees that define scientific norms	16,3%	49,0%	36,51%
Applications to use data produced by RI	14,3%	59,2%	28,57%
Research results fed into shared data sets/repositories	10,2%	53,1%	36,51%
Scientific collaborations with other RIs (joint projects)	32,7%	61,2%	50,79%
Satisfaction of scientific users [yet to define: key criteria]	26,5%	61,2%	49,21%

Source: own survey and analyses, RI-PATHS 2019

Table 2 Assessment of monitoring indicators for activities most directly relevant for Human Capital Impacts

Activities directly relevant for Human Capital Impacts	share deemed important & available	share deemed important	share deemed measurable
Persons employed by RI (FTE)	38,8%	55,1%	50,00%
Number of continuously employed scientists (entire RI)	44,9%	55,1%	51,61%
Number of higher education students trained within RI	32,7%	49,0%	45,16%
Number and duration of stays of M.Sc./Ph.D. students	28,6%	46,9%	48,39%
Number of continuously employed scientists (local site)	42,9%	44,9%	53,23%
Number and duration of stays of Post-Docs/Professors	30,6%	44,9%	50,00%
Number of technical staff	32,7%	44,9%	51,61%
Number of long-term higher education training programmes	26,5%	40,8%	46,77%
Number of students from local universities using the RI	12,2%	40,8%	45,16%
Number of administrative/ research management staff	28,6%	38,8%	51,61%
Number of conferences/seminars hosted/organised by RI	24,5%	38,8%	54,84%
Satisfaction of people trained [yet to define: key dimensions]	8,2%	61,2%	41,94%

Source: own survey and analyses, RI-PATHS 2019

Table 3 Assessment of monitoring indicators for activities directly relevant for Economic / Innovation Impacts

Activities directly relevant for Economic / Innovation Impacts	share deemed important & available	share deemed important	share deemed measurable
Collaborative projects with industry	26,5%	61,2%	44,83%
Number of projects funded by industry	20,4%	49,0%	41,38%
Joint technological developments with industry	22,4%	55,1%	39,66%
Co-patenting with companies	14,3%	42,9%	36,21%
Use of accessible data sets outside RI (by firms)	2,0%	38,8%	20,69%
Number of students working in enterprise and using RI	4,1%	40,8%	31,03%
Number of firms using facilities for testing (by type)	16,3%	42,9%	31,03%
***Extent** of private utilisation of RIs facilities for testing*	14,3%	36,7%	32,76%
Number of non-patented technologies developed	8,2%	53,1%	29,31%
Number of non-patented technologies licensed	16,3%	49,0%	36,21%
Number of spin-offs created	20,4%	57,1%	44,83%
Number of spin-offs surviving to date	12,2%	51,0%	37,93%
Number of patents filed	24,5%	40,8%	44,83%
Number of patents licensed	24,5%	49,0%	39,66%
Number of regional (and total) suppliers	18,4%	40,8%	51,72%
Volume of regional (and total) supplies	18,4%	42,9%	50,00%
***Number, volume, nature** of procurement (by supplier type)*	16,3%	36,7%	37,93%
No/Volume of collaborations for problem solution (public)	6,1%	49,0%	18,97%
No/Volume of collaborations for problem solution (industry)	6,1%	44,9%	20,69%
Firms using a novel technique or procedure	0,0%	42,9%	25,86%

Source: own survey and analyses, RI-PATHS 2019

Table 4 Assessment of monitoring indicators for activities directly relevant for Societal & Policy Impacts

Activities relevant for Societal Impacts	share deemed important & available	share deemed important	share deemed measurable
Contracts with public services (related to problem solution)	14,3%	38,8%	26,79%
Visitors at RI (by type)	36,7%	53,1%	54,39%
Open days/other promotion events: number of visitors	36,7%	46,9%	50,88%
School classes and or university courses visiting	34,7%	46,9%	52,63%
RI at events engaging the public (exhibitions, fairs...)	26,5%	42,9%	50,88%
People reached and engaged in outreach activities	18,4%	53,1%	38,60%
Use of open data made available by RI	16,3%	61,2%	26,98%
Public awareness: Visitors on RI website	20,4%	44,9%	50,88%
Presence of RI related topics in the press	22,4%	53,1%	47,37%
Presence of RI related topics in social media, Nr of followers	20,4%	51,0%	42,11%
Presence of RI in (local, regional) online media	18,4%	55,1%	49,12%

Source: own survey and analyses, RI-PATHS 2019

Activities relevant for Policy Impacts	share deemed important & available	share deemed important	share deemed measurable
Presence of RI in relevant standardisation committees	10,2%	55,1%	42,86%
Presence of RI in relevant thematic committees	20,4%	57,1%	44,64%
Participation of RI in local/ regional networks (e.g. clusters)	8,2%	65,3%	41,07%
Provision of expert advice in public policy	4,1%	49,0%	23,21%
Contracts with public services (related to policy)	14,3%	38,8%	26,79%
Provision of empirical data in support of public policy	4,1%	42,9%	12,50%
Provision of databases in support of public policy	4,1%	40,8%	16,07%

Source: own survey and analyses, RI-PATHS 2019

Table 5 Assessment of monitoring indicators for activities directly relevant for Societal & Policy Impacts

	share deemed important & available	share deemed important	share deemed measurable
Academic career advances after leave (promotion, ...)	4,1%	49,0%	19,35%
Salary increase of researchers after leaving	2,0%	40,8%	17,74%
Career advances through administrative qualification	2,0%	36,7%	19,35%
Career advances through technical qualification	2,0%	38,8%	20,97%

Source: own survey and analyses, RI-PATHS 2019

Table 6 Assessment of monitoring indicators for activities directly relevant for Societal & Policy Impacts

	share deemed important & available	share deemed important	share deemed measurable
Improved job opportunities in the region/nation	8,2%	61,2%	17,24%
Increased economic activity in the region/nation	4,1%	59,2%	20,69%
Aggregate value of RI-owned patents and other IP	6,1%	49,0%	29,31%
Technology level impact: Nr. of new technologies & designs	4,1%	53,1%	25,86%
Industrial sales impact: Number of new products, services	2,0%	46,9%	17,24%

Source: own survey and analyses, RI-PATHS 2019

Table 7 Assessment of monitoring indicators for activities directly relevant for Societal Impacts

	share deemed important & available	share deemed important	share deemed measurable
Contribution to environmental sustainability: Energy issues	4,1%	46,9%	15,79%
Contribution to environmental sustainability: Waste issues	2,0%	46,9%	15,79%
Solution of societal challenges: Health, Ageing etc.	0,0%	59,2%	8,77%
Solution of public sector challenges: Culture, Admin,...	0,0%	44,9%	7,02%
Inclusion of topics in schools and academic curricula	0,0%	53,1%	19,30%
Increased trust in science	4,1%	71,4%	12,28%
Impact on wellbeing and perceptions	0,0%	51,0%	10,53%

Source: own survey and analyses, RI-PATHS 2019

Table 8 Assessment of monitoring indicators for activities directly relevant for Societal Impacts

	share deemed important & available	share deemed important	share deemed measurable
Take up of new topics proposed by RI as funding sections	6,1%	53,1%	16,07%
Notable changes in funding decisions	2,0%	51,0%	17,86%
Notable changes in relevant regulations	0,0%	42,9%	10,71%
Notable changes in policy decisions	0,0%	55,1%	14,29%

Source: own survey and analyses, RI-PATHS 2019

6. Conclusions

Work Package 4 has developed the foundations for and, increasingly, the details of an 'Impact Assessment Model' that is one of the key outputs of the RI-PATHS project. Importantly, the semantics of the proposal do not refer to 'model' in the sense of a generic, simplified representation of reality. Instead, the RI-PATHS model will be a **guiding framework of reference** to overarchingly structure RI stakeholder's thinking about impact. At the same time, the model should be flexible enough to customise measurement methodologies to specific cases. It will seek to alleviate the above-mentioned lack of orientation in impact assessment that is currently observed, both with a view to the different purposes for which it can be conducted and the different logics of causation.

Despite the known challenges of providing a single framework applicable to a spectrum as comprehensive as the entire range of research infrastructures, the RI-PATHS project team propose that only a structured approach can help to further advance existing approaches for impact assessment. At a point in time where various lists of indicators and classifications have come into existence in parallel, the findings challenge claims from some in the big data community that understanding causal mechanisms is secondary to prediction as long as predictions are ultimately accurate.

In contrast, the RI-PATHS project suggests that indicator systems need to be structured by the political demands to which RIs seek to respond to *(impact areas)* on the one hand and with a view to the activities that may trigger impact in these areas (*origins of impact pathways*). Prediction of impacts that lack such a framework will in our view easily fail to become politically meaningful and/or relevant in management terms. While non-targeted impact assessments that simply produce an 'assortment of numbers' may be sufficient for formal compliance they will be less useful with a view to strategic decisions on the RIs activities or mission. To really make a difference, RI managers need to make clear *which* impact they expect to make and *how* they want to achieve it. For this, is essential to understand the potential outcomes that activities can lead to and how (*impact pathways*).

Overall approach

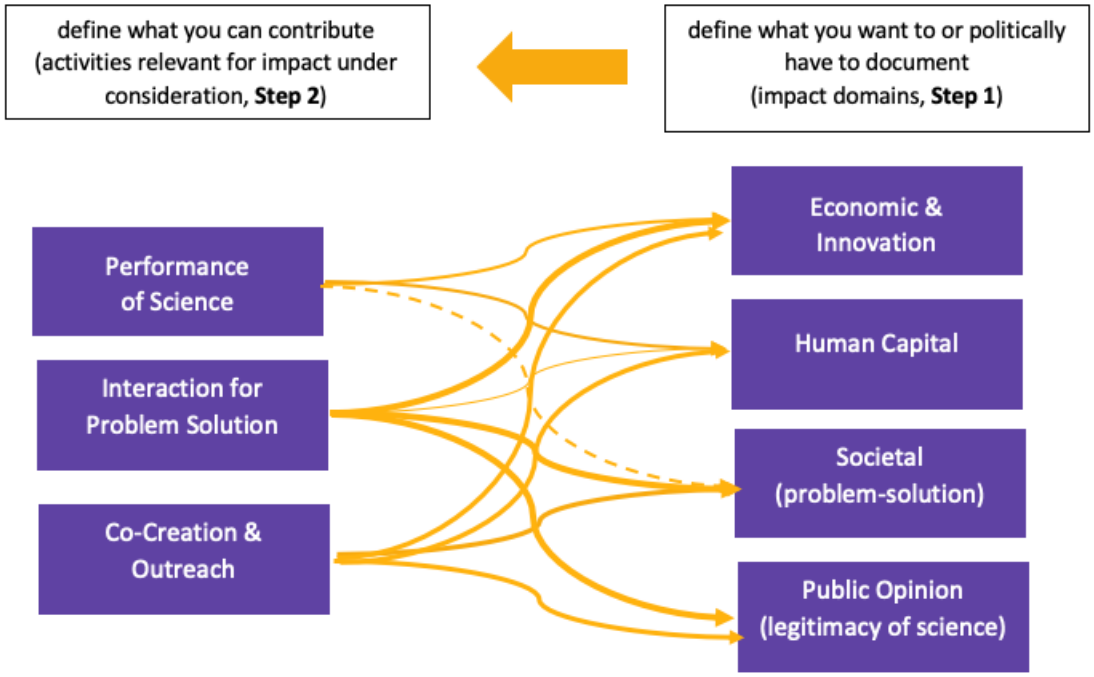
Accordingly, the 'Impact Assessment Model' should fulfil **two central functions** for the subsequent elaboration and piloting of an IA indicator system.

First, to **define impact domains** where research infrastructures can in principle play a role. While political expectations may be continuously shifting, findings from the RI-PATHS participatory workshops and surveys have unambiguously confirmed that impact assessment can no longer be solely be considered as motivated from a purely compliance-oriented perspective. Increasingly, many research infrastructures are openly articulating their mission to broader societal contributions. Moreover, next to all research infrastructures have to at least position themselves vis-à-vis the same overarching political demands. Hence, for good reason, the RI-PATHS project and many related exercises have converged towards a categorisation of impacts covering the **domains of scientific, human capital, economic and innovation, societal (i.e. problem addressing) and policy impact**. Across various studies, the differences in classifications are largely semantic so that this overall framework of reference can be adopted as a central element of the RI-PATHS model.

It is the core point of reference answering the question 'what for' an RI is performing an impact assessment. In the RI-PATHS Model, this core framework of impact domains serves as a fundamental underlying classification for **monitoring and impact indicators** from which interested RIs can choose according to their strategic interests and political requirements.

Second, the model helps to define the **logic of impact causation, or impact pathways**, through which impact of different types materialises. Understanding these pathways can assist decision making by RI managers in terms of launch or intensifying specific internal activities or collaboration and engagement with external partners. On this basis, the relevant measurement approaches can be adapted to specific RI needs in an appropriate manner. However, it is evident that various, important, pathways remain not only undocumented but conceptually under-acknowledged in principle. RI managers may know what their facility does and in collaboration with whom, but too often fail to **make the connections between activities and relevant impact domains**. In practice, only a pathway approach can help make these connections visible and define which of them are more relevant for specific (types of) research infrastructures than for others. For an effective impact assessment, it is not enough to know what is to be measured, but also to know which RI activities are likely to contribute to this particular type of impact.

Figure 12 General conceptual approach of RI-PATHS model



Source: own concept and figure

On modularity

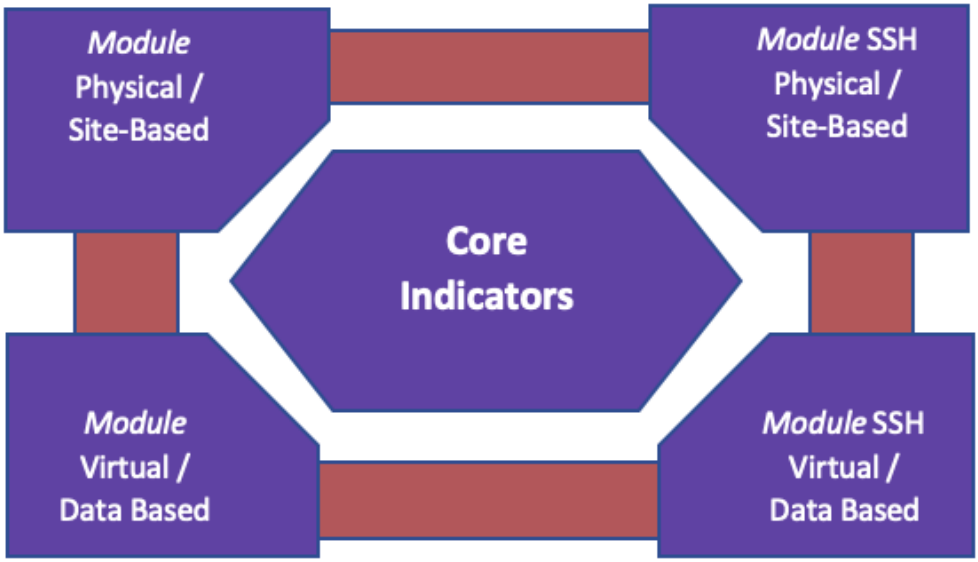
In addition to a further sorting of proposed indicators by their primary relation to impact domains and impact pathways, **three further aspects** need to be considered in more depth to finalise the Impact Assessment Model. In order to establish a clear-cut "first-stage modularity" at a level that can be easily handled and understood by future users, the following fundamental distinctions should be articulated clearly and their consequences for the selection of methodologies and indicators spelt out precisely.

First, the **game-changing nature of distributed and virtual infrastructures** remains fundamentally underexplored to date. So far, very few of the dedicated network effects that they help create are systematically acknowledged from a conceptual perspective, let along documented empirically. A key building-block of the RI-PATHS model will be to develop substantiated propositions for this type of RIs. Based on Work Package 3 and 4, a number of proposals are already available, but their relevance needs to be further explored in Work Package 5.

Second, there is an undeniable difference between "traditional" research infrastructures in the natural sciences and those in the **Social Sciences and the Humanities (SSH).** which, at the same time, are often of the virtual type. Importantly, this is relevant not only with a view to differences in pathways of impact that they feed, but also with a view to the overarching impact domain that they contribute to. For example, many SSH infrastructures will, by mission, relate much more directly to societal and policy-oriented questions than traditional hard science facilities.

Against this background, our preliminary suggestion of a model to support upcoming piloting of IA methods and indicators under Work Package 5 is as follows:

Figure 13 Modularity of the RI-PATHS model



Source: own concept and figure

In general, as many indicators as possible should remain at the core of the model, while a number of them will remain specific to virtual, distributed or single sited research infrastructures, or those that are within the SSH domain.

With a view to exploitation, it remains crucial to communicate on the process of "model design" to the broader RI community and to validate broadly the findings, in particular those from Work Package 5, before reaching a final conclusion. Subsequently, further efforts will be invested in communicating the project's findings, including a "manual" on how to proceed when applying the RI-PATHs approach to designing suitable and meaningful impact assessment methodologies for diverse types of research infrastructures.

Finally, the model will have to take into account **regulatory, political and normative contexts**. It should state under which conditions (e.g. open access vs. pay-per-use) certain pathways can materialise. At the same time, it should be explicit about the limits to tracing activity and, hence, impact assessment that some of the framework conditions may impose (e.g. strict open access provisions limit the tracing of usage and hence precludes RI from tracing network effects). Furthermore, it must allow, even encourage, RI managers to set clear priorities based on their organisation's mission, irrespective of the complete array of pathways that they could in principle trigger.

Annex

Annex 1: Revised Long-list of Indicators

Long-List of Indicators to determine Scientific Impact

Indicators that can in principle be captured through internal monitoring

- Number of publications
- Number of publications in high impact factor journals
- Number of publications weighted by impact
- Number of software tools above a relevant impact threshold
- New scientific instruments/infrastructure developed
- Research results fed into shared data sets/repositories
- Applications to use data produced by RI
- Use of open data (access and download)
- Presence in relevant committees that define scientific norms
- Number of scientific users
- Satisfaction of scientific users
- Scientific collaborations with other RIs (joint projects)
- Excellent collaborations (visits by world leading teams)
- Funding grants from national/supra-national funding sources
- Hosting of (high-level) scientific events (e.g. conferences)
- Visits to (high-level) scientific events (e.g. conferences)

Indicators the collection of which requires an involvement of third parties

- First and second level citations for publications
- Prizes won by researchers having worked at RI
- Uptake of RI software tools outside RI (in science)
- Uptake of (immaterial) instruments outside RI (science)
- Uptake of accessible RI data sets outside RI (in science)
- Success rate of follow up funding applications (project level)

Long-List of Indicators to determine Human Capital Impact

Indicators that can in principle be captured through internal monitoring

- Number of continuously employed scientists (local site)
- Number of continuously employed scientists (entire RI)
- Number and duration of stays of Post-Docs/Professors
- Number and duration of stays of M.Sc./Ph.D. students
- Number and duration of (non-scientific) internships
- Number of (non-scientific) trainees
- Grants for trainees: Grants for trainees to follow RI trainings
- Number of technical staff
- Number of administrative/ research management staff
- Number of training measures
- Number of higher education students trained within RI
- Number of long-term higher education training programmes
- Number of conferences/seminars hosted/organised by RI

Indicators the collection of which requires an involvement of third parties

- Satisfaction of people trained
- Number of students from local universities using the RI
- Academic career advances after leave (promotion, ...)
- Salary increase of researchers after leaving
- Career advances through administrative qualification
- Career advances through technical qualification
- Prevention of local/national brain drain

Long-List of Indicators to determine Economic / Innovation Impact

Indicators that can in principle be captured through internal monitoring

- Persons employed by RI (FTE)
- New tax payers: employees living in the area for > 3 years
- (Local) expenditure of RI, employees & visitors
- Number of regional (and total) suppliers
- Volume of regional (and total) supplies
- Production capacities (of drugs, etc.)
- Grants for trainees: Grants for trainees to follow RI trainings
- Number of patents filed
- Patent citations
- Number of patents licensed
- Number of non-patented technologies developed
- Number of non-patented technologies licensed
- Co-patenting with companies
- Joint technological developments with industry
- Collaborative projects with industry
- Number of students working in enterprise and using RI
- Firms using a novel technique or procedure
- Number of projects funded by industry
- Number of spin-offs created / surviving to date
- No/Volume of collaborations for problem solution (industry / public)
- Number of firms using facilities for testing (by type)
- Extent of private utilisation of RIs facilities for testing
- Number, volume, nature of procurement (by supplier type)
- Use of software tools outside RI (business)
- Business usage of RI information (e.g. via browser)
- Use of accessible data sets outside RI (by firms)
- Corporate efficiency gains through use of RI data
- Stimulation of technology diffusion

Indicators the collection of which requires an involvement of third parties

- Aggregate value of RI-owned patents and other IP
- Industrial sales impact: Number of new products, services
- Technology level impact: Nr. of new technologies & designs
- Market creation impact: triggered sales volume
- Market expansion impact: increased sales volume
- Increased economic activity in the region/nation
- Improved job opportunities in the region/nation

Long-List of Indicators to determine Societal Impact

Indicators that can in principle be captured through internal monitoring

- Visitors at RI (by type)
- Public awareness: Visitors on RI website
- School classes and or university courses visiting
- RI at events engaging the public (exhibitions, fairs...)
- Open days/other promotion events: number of visitors
- Production capacities (of drugs, etc.)
- People reached and engaged in outreach activities
- Gender balance (employees, users

Indicators the collection of which requires an involvement of third parties

- Solution of societal challenges: Health, Ageing etc.
- Solution of public sector challenges: Culture, Admin,...
- Inclusion of topics in schools and academic curricula
- Presence of RI related topics in social media, Nr of followers
- Presence of RI related topics in the press
- Presence of RI in (local, regional) online media
- Contribution to environmental sustainability: Energy issues
- Contribution to environmental sustainability: Waste issues
- Contribution to social sustainability: CSR

- Contribution to social sustainability: Social inclusion goals
- Contribution to Gender balance (employees, users)
- Increased trust in science
- Impact on wellbeing and perceptions

Long-List of Indicators to determine Policy Impact

Indicators that can in principle be captured through internal monitoring

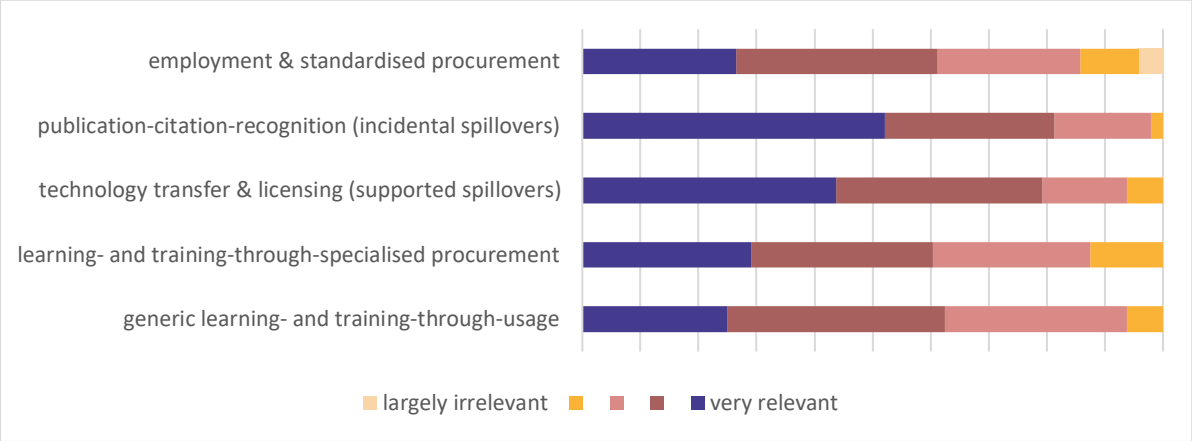
- Presence of RI in relevant thematic committees
- Presence of RI in relevant standardisation committees
- Participation of RI in exchanges with relevant policy makers
- Participation of RI in local/ regional networks (e.g. clusters)
- Contracts with a specific country, region, industry
- Public awareness / taxes going to RI
- Contracts with public services
- Number of reports / databases to support public policy
- Provision of expert advice in public policy
- Provision of empirical data in support of public policy
- Provision of databases in support of public policy

Indicators the collection of which requires an involvement of third parties

- Take up of new topics proposed by RI as funding sections
- Notable changes in relevant regulations
- Notable changes in funding decisions
- Notable changes in policy decisions

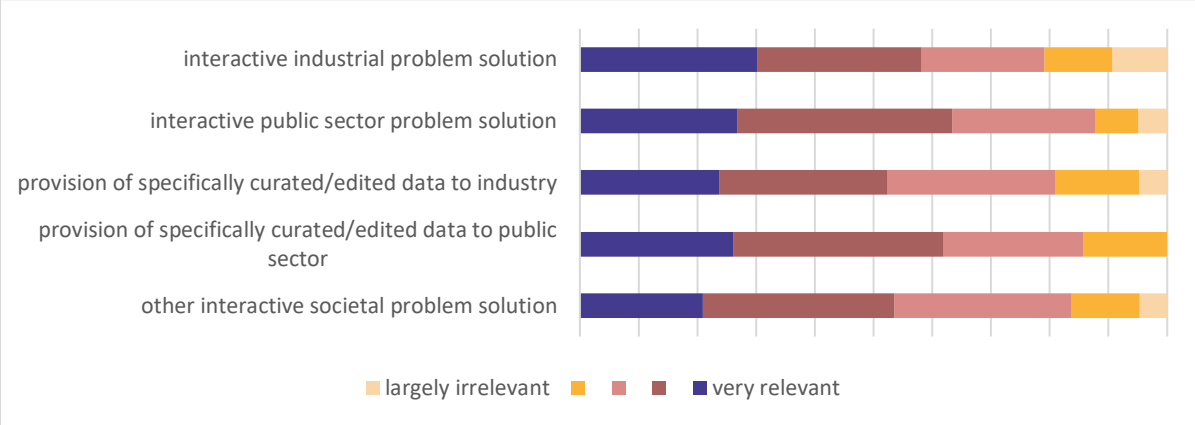
Annex 2 Importance of Impact Pathways

Figure 14 As how important do you consider the following impact pathways or logics?



Source: own survey and analyses, RI-PATHS 2019

Figure 15 As how important do you consider the following impact pathways or logics?



Source: own survey and analyses, RI-PATHS 2019

Figure 16 As how important do you consider the following impact pathways or logics?

Source: own survey and analyses, RI-PATHS 2019

Annex 3a: Shortened list of monitoring indicators with preliminary attributions to main pathway group and module

Scientific Activities triggering diverse Impact Pathways	**Main Pathway**	**Module**
Number of publications	*Impacts as a Result of RIs Enabling Science*	
Number of publications in high impact factor journals (above threshold)	*Impacts as a Result of RIs Enabling Science*	
Number of publications weighted by impact	*Impacts as a Result of RIs Enabling Science*	
Number of scientific users (teams or individuals, by occasion of use)	*Impacts as a Result of RIs Enabling Science*	
Funding grants from national/supra-national funding sources	*Impacts as a Result of RIs Enabling Science*	
New scientific instruments/infrastructure developed	*Impacts as a Result of RIs Enabling Science*	
Excellent collaborations (visits by world leading teams)	*Shaping the Fabric of **Science** and Society*	*physical**
Hosting of (high-level) scientific events (e.g. conferences)	*Shaping the Fabric of **Science** and Society*	*physical**
Use of open data (within science)	*Shaping the Fabric of **Science** and Society*	*virtual**
Presence in relevant committees that define scientific norms	*Shaping the Fabric of **Science** and Society*	*virtual**
Applications to use data produced by RI	*Shaping the Fabric of **Science** and Society*	*virtual**
Research results fed into shared data sets/repositories	*Shaping the Fabric of **Science** and Society*	*virtual**
Scientific collaborations with other RIs (joint projects)	*Shaping the Fabric of **Science** and Society*	
Satisfaction of scientific users [yet to define: key criteria]	*depends on dimension*	

*emphasis

Activities directly relevant for Human Capital Impacts	**Main Pathway**	**Module**
Persons employed by RI (FTE)	*Impacts as a Result of RIs Enabling Science*	
Number of continuously employed scientists (entire RI)	*Impacts as a Result of RIs Enabling Science*	
Number of higher education students trained within RI	*Impacts as a Result of RIs Enabling Science*	
Number and duration of stays of M.Sc./Ph.D. students	*Impacts as a Result of RIs Enabling Science*	
Number of continuously employed scientists (local site)	*Impacts as a Result of RIs Enabling Science*	
Number and duration of stays of Post-Docs/Professors	*Impacts as a Result of RIs Enabling Science*	
Number of technical staff	*Impacts as a Result of RIs Enabling Science*	
Number of long-term higher education training programmes	*Impacts as a Result of RIs Enabling Science*	
Number of students from local universities using the RI	*Impacts as a Result of RIs Enabling Science*	
Number of administrative/ research management staff	*Impacts as a Result of RIs Enabling Science*	
Number of conferences/seminars hosted/organised by RI	*Impacts as a Result of RIs Enabling Science*	
Satisfaction of people trained [yet to define: key dimensions]	*depends on dimension*	

Activities directly relevant for Economic / Innovation Impacts	Main Pathway	Module
Collaborative projects with industry	*Result of RIs Interacting for Problem Solution*	
Number of projects funded by industry	*Result of RIs Interacting for Problem Solution*	
Joint technological developments with industry	*Result of RIs Interacting for Problem Solution*	
Co-patenting with companies	*Result of RIs Interacting for Problem Solution*	
Use of accessible data sets outside RI (by firms)	*Shaping the Fabric of Science and Society*	*virtual RI**
Number of students working in enterprise and using RI	*Result of RIs Interacting for Problem Solution*	*physical RI*
Number of firms using facilities for testing (by type)	*Result of RIs Interacting for Problem Solution*	*physical RI*
***Extent** of private utilisation of RIs facilities for testing*	*Result of RIs Interacting for Problem Solution*	*physical RI*
Number of non-patented technologies developed	*Impacts as a Result of RIs Enabling Science*	
Number of non-patented technologies licensed	*Impacts as a Result of RIs Enabling Science*	
Number of spin-offs created	*Impacts as a Result of RIs Enabling Science*	
Number of spin-offs surviving to date	*Impacts as a Result of RIs Enabling Science*	
Number of patents filed	*Impacts as a Result of RIs Enabling Science*	*physical RI*
Number of patents licensed	*Impacts as a Result of RIs Enabling Science*	*physical RI*
Number of regional (and total) suppliers	*Impacts as a Result of RIs Enabling Science*	*physical RI*
Volume of regional (and total) supplies	*Impacts as a Result of RIs Enabling Science*	*physical RI*
***Number, volume, nature** of procurement (by supplier type)*	*Impacts as a Result of RIs Enabling Science*	*physical RI*
No/Volume of collaborations for problem solution (public)	*Result of RIs Interacting for Problem Solution*	
No/Volume of collaborations for problem solution (industry)	*Result of RIs Interacting for Problem Solution*	
Firms using a novel technique or procedure	*Result of RIs Interacting for Problem Solution*	
Activities directly relevant for Societal Impacts	**Main Pathway**	**Module**
Contracts with public services (related to problem solution)	*Result of RIs Interacting for Problem Solution*	
Visitors at RI (by type)	*Shaping the Fabric of Science and **Society***	*physical RI**
Open days/other promotion events: number of visitors	*Shaping the Fabric of Science and **Society***	*physical RI**
School classes and or university courses visiting	*Shaping the Fabric of Science and **Society***	*physical RI**
RI at events engaging the public (exhibitions, fairs...)	*Shaping the Fabric of Science and **Society***	*physical RI**
People reached and engaged in outreach activities	*Shaping the Fabric of Science and **Society***	*physical RI**
Use of open data made available by RI	*Shaping the Fabric of Science and **Society***	*virtual RI**
Public awareness: Visitors on RI website	*Shaping the Fabric of Science and **Society***	*virtual RI**
Presence of RI related topics in the press	*Shaping the Fabric of Science and **Society***	*virtual RI**
Presence of RI related topics in social media, Nr of followers	*Shaping the Fabric of Science and **Society***	*virtual RI**
Presence of RI in (local, regional) online media	*Shaping the Fabric of Science and **Society***	*virtual RI**

*emphasis

Activities directly relevant for Policy Impacts	Main Pathway	Module

Presence of RI in relevant standardisation committees	*Shaping the Fabric of **Science** and Society*	
Presence of RI in relevant thematic committees	*Shaping the Fabric of **Science** and Society*	*SSH*
Participation of RI in local/ regional networks (e.g. clusters)	*Shaping the Fabric of Science and **Society***	*SSH*
Provision of expert advice in public policy	*Result of RIs Interacting for Problem Solution*	
Contracts with public services (related to policy)	*Result of RIs Interacting for Problem Solution*	*SSH*
Provision of empirical data in support of public policy	*Result of RIs Interacting for Problem Solution*	*SSH*
Provision of databases in support of public policy	*Result of RIs Interacting for Problem Solution*	*SSH*

Annex 3b: Shortened list of genuine impact indicators with preliminary attributions to main pathway group and module

Human Capital Impact	**Main Pathway**	**Module**
Academic career advances after leave (promotion, ...)		
Salary increase of researchers after leaving		
Career advances through administrative qualification		
Career advances through technical qualification		

Economic / Innovation Impact	**Main Pathway**	**Module**
Improved job opportunities in the region/nation		*physical RI*
Increased economic activity in the region/nation		*physical RI*
Aggregate value of RI-owned patents and other IP		
Technology level impact: Nr. of new technologies & designs		
Industrial sales impact: Number of new products, services		

Societal Impact	**Main Pathway**	**Module**
Contribution to environmental sustainability: Energy issues	*Result of RIs Interacting for Problem Solution*	
Contribution to environmental sustainability: Waste issues	*Result of RIs Interacting for Problem Solution*	
Solution of societal challenges: Health, Ageing etc.	*Result of RIs Interacting for Problem Solution*	
Solution of public sector challenges: Culture, Admin,...	*Result of RIs Interacting for Problem Solution*	
Inclusion of topics in schools and academic curricula	*Shaping the Fabric of Science and **Society***	
Increased trust in science	*Shaping the Fabric of Science and **Society***	
Impact on wellbeing and perceptions	*Shaping the Fabric of Science and **Society***	

Policy Impact	**Main Pathway**	**Module**
Take up of new topics proposed by RI as funding sections		
Notable changes in funding decisions		
Notable changes in relevant regulations		
Notable changes in policy decisions		