Demonstrating the transformative impacts of European research infrastructures.

A framework for ACTRIS.

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Abstract

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Recognizing the importance of value and impact demonstration, this research underscores the need for research infrastructures to effectively communicate their contributions. Demonstrating value and impact not only enhances transparency and accountability but also strengthens the ability of research infrastructures to attract funding, garner support from stakeholders, and foster continued collaboration. By achieving this, the research contributes to addressing the broader question of how the societal, environmental, and scientific contributions of research infrastructures can be effectively captured and demonstrated. The framework aids in elucidating the often intricate and interconnected impacts of research infrastructures, facilitating a more comprehensive understanding.

The primary goals and objectives of this research involve the development of a framework that allows for the identification, measurement, and communication of transformative impacts by applying service design and strategy design to enhance flexibility and user orientation in concept development, and creating a framework that matches the strategic objectives and goals of the organization.

ACTRIS, the Aerosol, Clouds and Trace Gases Research Infrastructure, is a large Pan-European research infrastructure in the field of atmospheric science. ACTRIS is the commissioner of this thesis as it has been recently established as a legal entity, relying largely on public funding. Hence, ACTRIS has a strong interest and needs to show its value to stakeholders. The framework developed in this study offers a valuable tool for organizations like ACTRIS to articulate their transformative impacts, thereby contributing to the broader discourse on the societal and scientific significance of research infrastructures. The main questions that needed answers were, what are the benefits of including an impact framework in the organization’s strategy, how to account for the diversity of expectation and demands from stakeholders and how can values and impacts be effectively communicated to stakeholders.

To address these questions, a design process following the Design Council’s (n.d.) Double Diamond approach was adopted. Service and strategy were used as the broader framework of the development project. Stakeholders from the ACTRIS community participated in the development project in the form of survey, meeting and feedback.

Key findings include the development of impact management and assessment framework, and a prototype of a digital interface to demonstrate ACTRIS impacts with qualitative and quantitative indicators, ensuring the effective communication of ACTRIS values and impacts.

In conclusion, this thesis offers a valuable contribution to the field by addressing the unique challenges of impact assessment for research infrastructures. The proposed framework not only fills a critical gap in ACTRIS's strategy but also provides insights applicable to similar research infrastructures seeking to convey their value and societal impact systematically.

Keywords: value capture, impact framework, communication, research infrastructure.

Contents

1 Introduction

The importance of research infrastructures demonstrating their values and impacts cannot be overstated. As these facilities receive substantial public funding and play a crucial role in shaping scientific understanding and policy decisions, transparency and accountability are paramount. By showcasing their values and impacts, research infrastructures provide stakeholders, including policymakers, funders, and the public, with a clear understanding of their contributions to society. This demonstration not only enhances trust in the scientific community but also ensures that the societal benefits of these infrastructures are widely recognized. In an era where the alignment of scientific endeavors with societal needs is paramount, the ability of research infrastructures to articulate their value propositions and impacts becomes a cornerstone for fostering continued support, collaboration, and the advancement of knowledge for the collective benefit of humanity.

The knowledge basis and project development within this thesis provide insights into the advantages, challenges, and viable solutions for demonstrating the values and impacts of distributed research infrastructures, specifically emphasizing the case of ACTRIS.

1.1 Background

Assessing the values and impacts across multiple domains, whether scientific, economic, social, or environmental, requires a multidisciplinary approach and collaboration between experts from different fields, which can be challenging to coordinate, and significant resources, including time, funding, and specialized expertise. This is particularly crucial for distributed research infrastructures, where evidence of values and impacts need to be collected across many countries and the subsequent multi-scalar dimension (e.g., local, regional, pan-European, country-specific regulation and funding schemes) add a layer of complexity to the task.

Impacts are multifaceted and often interconnected. Determining causal relationships and separating the influence of other factors can be complex, particularly when assessing long-term impacts. Counterfactual analysis, which involves comparing the outcomes with and without the presence of the infrastructure, is also often challenging due to the absence of control groups or alternative scenarios. Impacts may not materialize immediately and can have long-term effects creating difficulties to capture and predict these effects accurately. Additionally, uncertainty surrounding future trends, technological advancements, and societal changes can make impact assessment more challenging. Obtaining comprehensive and

accurate data, especially pre-existing data, to establish a consistent comparative analysis framework can be problematic as the availability of data on relevant indicators may vary across different regions or sectors.

The concepts and approaches are applied to the case study of the Aerosol, Clouds, and Trace Gases Research Infrastructure (ACTRIS). ACTRIS was established in April 2023 as a European Research Infrastructure Consortium by the European Commission. This milestone formalizes ACTRIS as a legal entity functioning as a non-profit organization, predominantly dependent on public funding through membership contributions and projects supported by the European Commission. Therefore, demonstrating ACTRIS values and impacts to stakeholders is crucial for the long-term sustainability of the whole organization. Moreover, ACTRIS's large-scale and distributed nature and its complex organizational structure represent a challenge in coordinating the identification and collection of data and information needed to keep up-to-date the portfolio of ACTRIS value propositions and impacts. This work is developed with the objective of designing a tailored framework that enables an effective demonstration of ACTRIS values and impacts.

1.2 Research objectives

The purpose of this thesis is to examine and bring clarity on the development process of an impact assessment framework that captures the values and demonstrates environmental, scientific, social and economic impacts of a large and distributed research infrastructure. The work follows the research questions:

1. Which factors influence research infrastructure to integrate impact frameworks into their strategies?
2. How to account for the diversity of demands?
3. How can evidence of impacts be effectively collated and communicated?

The knowledge basis centers on the concepts of values and impacts, the processes of value creation and impact assessment, elucidating their interconnection and how these processes deliver essential information for strategic communication and engagement with stakeholders to achieve long-term sustainability, particularly within the context of research infrastructures.

The chosen scope and emphasis stem from the development project's central theme of showcasing benefits to stakeholders. The project's scope was collaboratively determined with the thesis commissioner. It's important to note that the discussion on impact assessment and its advantages extends beyond the confines of research infrastructure within the thesis. This

inclusivity is intended to render the study pertinent and useful to a broader audience, particularly those engaged in non-profit enterprises and consortia.

The development work includes strategy design, a mix of strategy and design thinking, to align organizational objectives and goals with foreseen impacts. While shaping the mechanisms to capture impacts, the Theory of Change is presented as a valuable resource to map expected short-, medium- and long-term impacts. Empirical evidence is collected through research, textual analysis, surveys, interaction with stakeholders and benchmarking using material gathered from early stages of ACTRIS. Based on the collected data, insight and criteria are defined and solutions, including an impact assessment framework, an intervention logic, and an interface prototype, are developed. The aim is to develop a solution that can be effectively put in use by a research infrastructure such as ACTRIS to effectively communicate and demonstrate its value propositions and impacts to stakeholders.

1.3 Structure of the thesis

Chapter 1 frames the broader context of this thesis work, its goals and objectives.

Chapter 2 builds a knowledge basis on the key concepts related to impacts and their assessment for research infrastructures.

Chapter 3 reveals the core work undertaken in the development of the project focusing on the case study of ACTRIS. The development project work is structured adopting the double-diamond model from service design to mark the different phases of the development project collecting and the adopted processes for collating empirical evidence are also presented. Strategy design is applied to define the requirements and components and align these with the purpose of the development project.

Finally, in Chapter 4, the results of the development project are presented following the marked phases of the double diamond model. The “discovery phase” explores theories and practices as well as the results of several existing frameworks and guidelines, including corresponding challenges and consider strategic aspects of research infrastructures and the expectations from stakeholders. The guiding question for this section is: “What has been done already?”. The “define phase” of the double-diamond model frames the necessary calls to actions. In this section, the purpose and the components of the framework are defined and inserted into the ACTRIS ecosystem. This phase aims at answering the question “Where do we stand in ACTRIS?”. The “develop phase” provides relevant tools available for the implementation of the framework for impact management and assessment, namely the

impact intervention logic and the impact interface prototype. The guiding questions for this section are: “Is the solution effective?”,” Is it understandable?”.

Chapter 5 “Conclusions” wraps the project up with reflections and managerial implications of this work, possible future developments, and a few personal comments from the author of this thesis.

2 Knowledge basis

The knowledge basis introduces the relevant concepts contributing to comprehension of the development and discussion that steer this work.

During the initial stages of the research conducted to establish the informational foundation, the emphasis was placed on academic articles subjected to rigorous peer-review processes. The goal was to assemble a comprehensive and broad sample. Specific case studies and discussions situated far beyond the study's scope were omitted unless they significantly contributed to a particular subject under consideration.

Primarily, the research process involved utilizing electronic libraries, accessed through Google Scholar with relevant keywords. Google Scholar was chosen for its extensive coverage. Valuable information was also derived from reference lists within academic articles, proving to be a particularly fruitful source. This may be attributed to the interconnected nature of the subject matter, creating a pathway of information between the useful article and those to which it refers. However, relying solely on articles referenced in a limited selection might introduce bias and overlook entirely different perspectives, so this approach was not emphasized.

The central focus of this thesis centers around impact demonstration, aligning with all three research objectives outlined in Section 1.2. Initially, attention is directed toward comprehending the concepts connected and encompassed within impact assessment and elucidating their connections. Subsequently, the focus shifts to research infrastructures, highlighting the critical need for them to establish an evidence-based framework for demonstrating value to stakeholders. The thesis also explores how research infrastructure can be viewed as a non-profit organization engaged in co-creating value with stakeholders through the provision of services.

In the final phase, the focus transitions to value co-creation and its influence on shaping business models within the context of research infrastructures. The objective is to establish a

systemic perspective where value co-creation, impacts, business models, and organizational strategy are integrated into a cohesive whole. This holistic approach allows for the discussion and analysis of the dynamics influencing the system formed.

2.1 Key concepts

2.1.1 Impacts

Impacts, in the context of fields such as environmental science, business, and social development, represent the tangible and intangible effects or consequences resulting from specific actions, events, or projects.

Impacts can be classified into different dimensions, such as social, economic, scientific, and environmental. Environmental impacts, for instance as discussed in the work of Glasson, Therivel, & Chadwick (2012), can include changes to ecosystems, biodiversity loss, and alterations in air and water quality due to human activities. Social impacts encompass the effects on communities, cultures, and individuals, considering aspects like health, well-being, and societal cohesion (Vanclay 2003). Additionally, economic impacts involve changes in financial conditions, employment, and market dynamics, often crucial for decision-making in business and policy realms (Wood 2003; Sadler 1996).

The multifaceted nature of impacts necessitates a thorough understanding and assessment to gauge their significance and implications. Impacts can be categorized as positive or negative, direct or indirect, and short-term or long-term. Impacts can be categorized as positive, when bringing favorable changes or benefits, or negative, when resulting in adverse effects or drawbacks. Direct impacts occur immediately and are easily attributable to a specific action, while indirect impacts are secondary or unintended consequences that may arise over time. Some impacts are immediately noticeable (short-term), while others may only become apparent over an extended period (long-term). Impacts can be measured and expressed quantitatively (in numerical terms) or qualitatively (described through qualities or characteristics). Understanding impacts is crucial in assessing the consequences and outcomes of various activities, policies, or initiatives in diverse fields and disciplines.

Effectively addressing impacts requires a comprehensive understanding of interconnected systems and consideration of long-term consequences. The United Nations Sustainable Development Goals provide a global framework that emphasizes the importance of mitigating negative impacts while promoting positive outcomes in areas such as poverty reduction, climate action, and social equity. As society becomes more conscious of the interconnectedness of various systems, the recognition and management of impacts become

integral components of responsible decision-making and sustainable development of organizations and businesses.

2.1.2 Impact management

Impact management is the ongoing process of strategically and proactively overseeing, optimizing, and adapting the effects, both intended and unintended, of an organization's activities, projects, or initiatives. This involves setting clear goals, monitoring progress, and making informed adjustments to improve the effectiveness and sustainability of an organization's efforts (Epstein and Yuthas 2017). It includes stakeholder engagement, data collection, analysis, and the implementation of strategies to enhance positive impacts and address any unforeseen challenges. Impact management includes a focus on internal operations and external impacts and involves integrating impact considerations into organizational strategies and operations.

2.1.3 Impact assessment

Impact assessment is a systematic process of evaluating impacts to demonstrate the effects of an organization's activities to stakeholders. It is a structured process to measure, analyze, and communicate the scientific, social, environmental, and economic consequences of such activities. This process typically involves the identification, prediction, and evaluation of the likely impacts, considering various dimensions such as scientific and technological innovation, environmental sustainability, social equity, and economic feasibility. The process of impact assessment is specifically geared toward measuring and communicating the effects of these activities to stakeholders, including investors, funding agencies, users, regulators, and the community. It provides a way to transparently showcase the organization's contributions and commitments to the world.

In the realm of project management and policy formulation, impact assessment serves as a vital tool to systematically analyze and predict the potential outcomes of proposed actions (Stjernborg 2023). The evaluation of impacts facilitates informed decision-making by identifying risks, benefits, and trade-offs associated with various alternatives. Moreover, impact assessment contributes to the mitigation of negative consequences and the enhancement of positive outcomes, fostering sustainability and responsible practices. The field of environmental impact assessment, for example, employs methodologies to evaluate the potential effects of projects on the environment, aiding in the identification of strategies for sustainable development and resource management (Petts 2009).

2.1.4 Value creation and capture

Within the field of organizational management and strategy, value refers to the worth or importance of a solution, service, experience, often in the context of advantages, or benefits. Organizations and individuals aim to create or deliver value, whether in business (Porter 1985, c.4), education (Anderson & Krathwohl 2001), science (Etzkowitz & Leydesdorff 1997), healthcare (Porter & Teisberg 2006), or other fields, by providing offerings that meet or exceed the expectations and needs of stakeholders. As described in Zeithaml & Gremler (2006), the dimensions of value can vary based on the context, industry, and perspectives, but, generally, they include various aspects that contribute to the perceived worth. Common dimensions of values are, for example, functional value, experiential value, financial value, environmental value, and innovation value. How the value is perceived can be subjective and may vary among individuals or stakeholders (Normann & Ramirez 1993). Understanding and defining value is crucial for decision-making, as it guides choices about resource allocation, product development, and the evaluation of outcomes in diverse settings. Organizations and businesses often elaborate comprehensive value proposition statements that communicate the entire value of a solution or service, including benefits, features, and uniqueness.

Value creation is a fundamental concept in business and economics, focusing on the generation of value for stakeholders. Value creation refers to the process of generating or enhancing value, often in the context of products, services, or initiatives. It involves activities and strategies aimed at increasing the overall worth, utility, or satisfaction derived from a particular offering. Value creation can take various forms, including financial gains, technological and scientific innovation, improved user experiences, social benefits, and environmental sustainability. Value creation is not limited to the business sector; it is a concept applied across various fields, including nonprofit organizations, government initiatives, and societal endeavors. In essence, it involves identifying opportunities to contribute positively to stakeholders, whether they are customers, employees, communities, or the environment, fostering mutual benefit and sustainable development. As this thesis considers the realm of research infrastructures, it is important to note that value creation in science might be more nuanced and the terminology extends to vocabulary terms such as knowledge creation and innovation.

Traditionally, value is often seen as embedded in products (goods-dominant logic). However, the service-dominant logic, proposed by Vargo & Lusch (2004), a paradigm shift in marketing and business theory that challenges this perspective, emphasizes the creation of value through interactions between service providers and users or the service (co-creation of value). The service-dominant logic places services, interactions, and relationships at the

center of exchange, moving away from the goods-centric view to a more dynamic perspective, where value is co-created through the application of resources, including assets and services (Vargo & Lusch 2008; Grönroos 2011). In the service-dominant logic, services are not merely activities but the fundamental basis of exchange, and value is a collaborative, ongoing process (Lusch & Nambisan 2015).

Customer-dominant logic is a foundational perspective that places stakeholders, particularly customers, at the core of value creation processes. In this approach, the focus is on co-creating value through active engagement and collaboration with customers. Rather than viewing value as something created by companies and delivered to passive stakeholders, this perspective recognizes that value is co-created through interactive and participatory processes (Lusch & Nambisan 2015). The customer-dominant logic emphasizes the importance of understanding and responding to the diverse needs, preferences, and expectations of stakeholders to ensure a more tailored and satisfactory experience (Vargo & Lusch 2004).

Value capture can be understood as the deliberate and strategic process of retaining and leveraging the value generated within a business or organization, ensuring that it contributes to sustained competitive advantage, growth, and overall success. In the context of strategy, value capture involves optimizing how the organization captures and retains value from its activities, innovations, and market positioning to reinforce its strategic objectives and maintain a strong market position (Porter 1996).

2.1.5 Frameworks

A framework is a conceptual structure that provides a systematic way to approach, understand, and address a particular set of issues, problems, or challenges within a specific context (Kaplan & Norton 1992). It serves as a guide, offering a set of principles, concepts, and methodologies to organize and analyze information, make decisions, or develop solutions. Frameworks are commonly used in various disciplines, including business (Porter 1985), research (Creswell 2014) and problem-solving (Ackoff 1978), providing a structured foundation for decision-making and strategy development. Frameworks typically involve defining the problem or issue, specifying the objectives, identifying the activities to be undertaken, and articulating the anticipated outcomes and impacts. This aids in clarifying the purpose and components of a framework, making it a valuable tool for project management, assessment, and communication. It is widely used in various sectors, including development projects, public policy, and program evaluation, to ensure that efforts are strategically aligned, progress is measurable, and outcomes contribute to the intended goals.

Methodologies that help guide organizations in creating and evaluating their strategies are, for example, business model frameworks and impact frameworks. Both the business model framework and the impact framework provide structured approaches for understanding and evaluating an organization's activities, but they diverge in their primary focus and key elements. Both frameworks offer a systematic structure to enhance understanding and analysis. They provide a way to organize complex information, facilitating communication and strategic decision-making. Additionally, both frameworks contribute to transparency, helping stakeholders comprehend essential aspects of the organization's operations. The business model framework centers on how a business creates, delivers, and captures value in the market. It encompasses elements like value proposition, customer segments, and revenue streams. In contrast, the impact framework is designed to assess and measure the broader consequences of organizational activities, including social, environmental, or economic outcomes. It incorporates indicators, metrics, and methodologies for evaluating positive and negative impacts.

2.1.6 Business Model

A business model serves as a comprehensive framework that delineates how an organization generates, delivers, and captures value and consequent impacts. It offers a strategic perspective on the operational dynamics of a company, encompassing revenue generation, customer interactions, and overall sustainability.

Amid an extensive body of literature of business plan definitions, the article of Fjeldstad & Snow (2018) brings clarity to the theoretical underpinnings of the business model concepts and establishes connections with five essential elements: customers, value propositions, product/service offerings, value creation mechanisms, and value appropriation mechanisms. This categorization is similar to other literature reviews such as Shafer, Smith & Linder (2005) and Al-Debei & Avison (2010). Secondly, Fjeldstad & Snow (2018) connect business models and organizational strategy, illustrating how organization design is shaped by value configuration and how emerging collaborative organizational structures facilitate open and agile business models. Effective communication is crucial for conveying the value propositions of the business model to both internal and external stakeholders. Communication strategies must be aligned with the organizational design to ensure clarity and efficiency towards long term sustainability.

An example of a business model framework is the business model canvas, a visual template that helps organizations describe, design, and assess their business models. By identifying the business components, that are activities, resources, partners, value propositions, user relationships, channels, user segments, cost structure, and revenue streams, it provides a

holistic view of how a company creates, delivers, and captures value (Osterwalder & Pigneur 2010). Hence, the concept of value creation is fundamental to understanding how a business generates benefits for its customers and stakeholders.

2.1.7 Impact Framework

An impact framework is a structured and systematic approach used by organizations to assess and measure the social, environmental, or economic consequences of their activities. It provides a comprehensive set of indicators, metrics, and methodologies designed to evaluate both positive and negative outcomes resulting from an organization's operations. The purpose of an impact framework is to enhance transparency, accountability, and understanding of the organization's broader contributions to society. By defining specific criteria and measurement tools, an impact framework enables organizations to gauge their effectiveness in achieving intended goals, identify areas for improvement, and communicate their impact to stakeholders. This framework may encompass various dimensions, such as social equity, environmental sustainability, and economic development, aligning with the organization's values and mission (Schaltegger & Burritt 2005; Eccles, Ioannou, & Serafeim 2014)

For example, the United Nation Sustainable Development Goals represent an impact framework. It consists of a set of 17 global goals adopted by United Nations member states to address issues such as poverty, inequality, climate change, environmental degradation, peace, and justice. The scope of such a global framework is to provide a common language and framework for organizations to align their strategies and activities with global sustainability objectives.

2.1.8 Embedding value creation and value capture into impact frameworks

Both the business model framework and the impact framework provide structured approaches for understanding and evaluating an organization's activities, but they diverge in their primary focus and key elements. Both frameworks offer a systematic structure to enhance understanding and analysis. They provide a way to organize complex information, facilitating communication and strategic decision-making, and contribute to transparency, hence helping stakeholders comprehend essential aspects of an organization's operations.

While the business model framework centers on how a value is created, delivered, and captured in the market, in contrast the impact framework is designed to assess and measure the broader consequences of organizational activities, including social, environmental, or economic outcomes. Nonetheless, the connection between value creation and impact is significant and multifaceted.

As previously discussed, value creation in organizations involves the process of generating and delivering value to stakeholders, whether they are users, employees, or the broader community. Creation of value can have various impacts, including economic, social, environmental, and cultural effects. Alignment between value creation and impact is often a central goal for sustainable and responsible organizations (Porter & Kramer 2011).

Consecutively, a value creation model, a framework that outlines how a value is generated and delivered to its stakeholders through its core activities, resources, and relationships, and impact assessment framework are also interconnected in the sense that they both contribute to understanding and improving the overall performance and sustainability of an organization. Nonetheless, value creation models and impact assessments serve distinct purposes, and their implementation can vary.

A value creation model breaks down an organization's activities and focuses on identifying areas where value is created in delivering a service, considering both internal and external stakeholders, creating competitive advantage. These processes are closely linked to the organizational or business operations which can often be straightforward to implement. The directness of a value creation model lies in its emphasis on optimizing internal processes, improving product/service quality, and enhancing user satisfaction. It directly aligns with operational improvements and strategic goals. Monitoring a value creation model typically involves tracking metrics that can provide immediate feedback on the success of implemented changes (Porter 1985).

Impact assessment framework, especially those aiming to evaluate broader social, economic, and environmental impacts, can be more complex to implement. They may involve gathering diverse data sources and engaging with external stakeholders. Monitoring the impacts of organizational activities often requires ongoing data collection, stakeholder engagement, and periodic assessments. The time lag between actions and measurable impacts can make monitoring a more extended process (Ioannou & Serafeim 2017).

The choice between a value creation model and an impact assessment depends on the organization's primary goals. If the focus is on internal efficiency and user satisfaction, a value creation model may be more direct. If the emphasis is on societal contributions and sustainability, an impact assessment may be necessary. Understanding stakeholder expectations is crucial. Some stakeholders, including investors and users, may prioritize tangible outcomes related to value creation, while others, such as funding agencies and community members, may seek broader societal impacts.

Value capture and impact frameworks are intimately connected in the realm of organizational strategy and sustainability. Value capture involves the intentional extraction or retention of value generated by an organization, encompassing both economic gains and broader societal benefits. This process aligns with the organization's strategic objectives, focusing on optimizing returns from its activities, innovations, and market presence. The captured value, however, extends beyond mere financial gains to include the positive impacts an organization can have on various stakeholders and the community at large.

The link between value capture and impact frameworks becomes apparent in the strategic alignment of these endeavors. Organizations aiming for sustained success recognize that value capture strategies should not only bolster their economic standing but also contribute meaningfully to societal and environmental well-being. Hence, impact frameworks provide the structured methodology to assess, measure, and manage these broader consequences of value capture activities. By integrating impact considerations into the strategic planning process, organizations can ensure that their value capture initiatives contribute to positive social, environmental, and economic outcomes, fostering a holistic and sustainable approach to organizational success.

This work focuses on the development of an impact assessment framework which is designed to comprehensively evaluate the effects of organizational activities across various dimensions, encompassing the value creation model and value capture strategy. This is accomplished by:

- Defining comprehensive impacts that allow for the inclusion of activities and outcomes related to internal processes and external stakeholders (Section 4.1.1);
- Identifying and including specific indicators or metrics that reflect the organization's value creation efforts such as operational efficiency, user satisfaction, product/service quality, and other factors associated with creating value for stakeholders (Section 4.2.1);
- Using the feedback and insights gained from the impact assessment to inform continuous improvement efforts, not only in terms of operational efficiency but also in optimizing value creation processes and outcomes (Section 4.2.1);
- Considering both perspectives and expectations of internal and external stakeholders (Section 4.2.2);
- Integrating the goals and objectives of the organization's value creation model into the impact assessment framework, hence ensuring alignment between the organization's internal focus on creating value and its broader impacts on society and the environment (Section 4.2.3);

- Creating a holistic evaluation of the organization's performance to account for both value creation and broader impacts (Section 4.3.1).

By integrating elements of a value creation model into an impact framework, organizations can create a more comprehensive and nuanced understanding of their contributions and performance. This approach supports a balanced evaluation that considers both internal operational efficiency and the broader impacts that organizations have on the world around them. The interpretation of the connection between value creation, impacts, and the impact framework is illustrated in Figure 1.

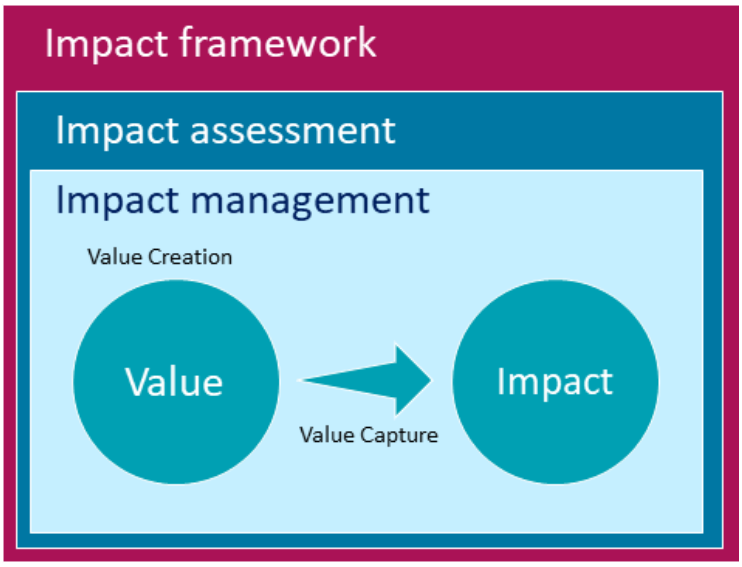

Figure 1. Representation of the key concepts involved in this work and how they are interconnected. Value creation generates impacts. Impacts represent the long-term effect of value creation and can be observed if strategies to capture values are set in place. These mechanisms are implemented through impact management processes. The process of impact assessment is specifically geared toward measuring and communicating with stakeholders. The impact framework encompasses all these processes.

2.2 Research infrastructures

European research infrastructures are large-scale facilities, resources, and services that support scientific research on an international scale. These infrastructures are collaborative, often involving multiple countries and institutions, and are designed to provide researchers with cutting-edge tools and capabilities that might be beyond the reach of individual nations (European Commission 2020a). European research infrastructures cover a wide range of scientific disciplines and fields, including but not limited to data and digitalin computing,

energy, environment, health and food, physical sciences and engineering, social and cultural innovation (ESFRI 2021). In Europe, the establishment and maintenance of cutting-edge research infrastructures are crucial for maintaining the continent's competitiveness in various scientific fields. The European Commission, the executive branch of the European Union, plays a central role in coordinating and supporting research infrastructures across member states. Through dedicated programs such as Horizon 2020 (European Commission 2020b) and its successor, Horizon Europe (European Commission 2021), the European Commission allocates funds to facilitate the development and operation of research infrastructures that address the evolving needs of the scientific community.

The European Strategy Forum on Research Infrastructures (ESFRI) serves as a key mechanism for identifying and prioritizing strategic research infrastructure projects at the European level. ESFRI's efforts contribute to the integration of national research infrastructures and the promotion of collaboration among member states. By aligning priorities with the European Commission, ESFRI ensures a cohesive approach to research infrastructure development, fostering synergy and optimizing resource allocation (ESFRI 2021). This collaborative framework enhances the efficiency and impact of research infrastructure investments, promoting scientific excellence and addressing global challenges. ESFRI periodically issues the ESFRI Roadmap, a strategic document detailing the vision for the development of research infrastructures in Europe, aligning with the mandates of the European Council and strategic objectives, and offering an analysis of Europe's most relevant and competitive research infrastructures. The roadmap identifies scientific needs, and existing gaps, and provides guidance for future strategic investments aimed at maintaining Europe's leadership on the global stage. Being recognized and featured in ESFRI reports is a coveted achievement for research infrastructures, signifying their advanced and highly competitive status, motivating them to actively engage with ESFRI's invitations and initiatives, and regarding ESFRI as one of their primary stakeholders.

Research infrastructures can be likened to enduring nonprofit businesses, often spanning decades, and their sustained value as cornerstones of European research and innovation, as outlined in the ESFRI White Paper (2020), hinges on their long-term sustainability, a challenge of paramount significance not only for the infrastructures themselves but also for stakeholders like policymakers and funders (European Commission 2010).

2.3 Applications of business logics to research infrastructures

Business logic emphasizes the importance of performance measurement and impact assessment (Van Looy & Shafagatova 2016). In the domain of research infrastructure, value creation and impact assessment are essential for justifying the existence and support of these

facilities. This includes the creation of knowledge, scientific advancements, and positive impacts on society, the environment, or specific industries.

In this perspective, research infrastructures and business logic intersect in various ways, especially as research organizations and institutions increasingly recognize the importance of applying strategic business principles to ensure sustainability, effectiveness, and societal impact. Research infrastructure, often funded by a combination of public and private sources, must develop sustainable business models. This involves identifying revenue streams, managing costs, and demonstrating value to stakeholders. By integrating business logics, research infrastructures can enhance their effectiveness, contribute to societal progress, and ensure long-term success.

Research infrastructures are platforms for shared resources, knowledge exchange, and the co-development of innovation and scientific outcomes by fostering strong collaborations, engaging with user communities, and understanding the evolving needs of stakeholders, also including the private sector. In this perspective, research infrastructures act as service providers where the unit of exchange is the application of expertise and knowledge transfer that contribute to the co-creation of value and impacts with the user communities. Through this lens, research infrastructures create value propositions together with the stakeholders, who determine the value at stake (Vargo & Lusch 2004). These characteristics fulfill the definition of a service-dominant business logic. Research infrastructures, adopting service-dominant logic, continually adapt their services, resources, and collaborative approaches to meet the changing demands and expectations of the stakeholders. In fact, as already introduced in Section 2.1.8, the service-dominant logic emphasizes the collaborative co-creation of value through dynamic interactions and relationships.

An additional business logic that is fit to research infrastructures is the customer-dominant logic. Adopting a customer-dominant logic in research infrastructure is imperative for its sustained success and relevance. As introduced in Section 2.1.8, This approach, aligned with contemporary service paradigms, places stakeholders at the center of decision-making and service co-creation. By actively involving researchers, funding agencies, industry partners, and the broader community, the infrastructure becomes more responsive to their evolving needs and expectations (Vargo & Lusch 2004). This stakeholder-centric approach not only improves user satisfaction but also enhances collaboration and engagement. Furthermore, a customer-dominant logic contributes to long-term sustainability. Satisfied stakeholders become advocates, attracting additional support and resources (Edvardsson, Gustafsson & Roos 2005). The approach also provides a competitive advantage in a landscape where research infrastructures vie for attention and collaboration. It sets an infrastructure apart by

ensuring it is more attuned to the diverse needs and expectations of its user base. Embracing this logic is not just about meeting current demands but about strategically positioning the infrastructure for the future, aligning with contemporary service theories and maximizing its overall impact on the research ecosystem.

2.4 Impact assessment in research infrastructures

Research infrastructures primarily rely on public funding and, under the Horizon Europe program (2020-2027) by the European Commission, they are allocated 2.4 billion euros with the overarching goal of "strengthening Europe through globally competitive and accessible research infrastructures, integrated into the broader European research and technology infrastructure landscape" (European Commission Decision 2022/2975). The substantial investments made by European and national funding agencies in research infrastructure projects underscore the need for comprehensive assessments of their societal, scientific, economic, and environmental impacts (European Commission 2020). Given the substantial and long-term nature of these investments, there is a logical demand and expectation for a dependable and comprehensible evaluation of the return on investment to facilitate informed decision-making. Consequently, research infrastructure’s managers routinely field requests from various quarters, including national and regional authorities, the European Commission for project reporting, and ESFRI, among others, seeking evidence of their progresses, benefits and impacts. Therefore, the capacity to capture both potential and actual direct and indirect effects is paramount for the governance and administration of research infrastructures. Failing to seize opportunities to demonstrate added value carries the risk of diminished support from funding agencies and waning relevance among stakeholders.

Effective communication of impacts to stakeholders is pivotal for fostering engagement and garnering support, a particularly vital aspect for research infrastructures that typically operate with constrained and variable financial resources. Sharing an organization's achieved impacts openly nurtures trust with stakeholders. When stakeholders witness tangible proof of the organization's effectiveness and the positive outcomes of its endeavors, they are more inclined to continue backing the organization and its initiatives.

3 Design and research methods of the development project

In this thesis, we examine the case of the Aerosol, Clouds, and Trace Gases Research Infrastructure (ACTRIS) with the main goal of developing a customized framework that facilitates the assessment of its values and impacts.

3.1 Strategy Design

Strategy design is a comprehensive process that involves the formulation and planning of an organization's overarching goals and objectives, coupled with the delineation of the actions and resources necessary for their achievement. It encompasses a forward-thinking approach to align an organization's internal capabilities with external opportunities and challenges, often incorporating considerations related to competitive landscapes, stakeholder engagement, and sustainable practices. In essence, strategy design provides a roadmap for an organization, guiding decision-makers in making informed choices to navigate complex environments and achieve desired outcomes (Mintzberg, Ahlstrand, & Lampel 1998).

Why does strategy design represent a good approach for developing this thesis? When developing an impact assessment framework, strategy design plays a pivotal role in ensuring alignment between the organization's mission, goals, and the intended impacts it seeks to achieve. By integrating strategic elements, such as stakeholder engagement strategies, sustainability practices, and long-term objectives, into the impact assessment framework, organizations can foster a more holistic and coherent approach to understanding and managing their impacts. This not only enhances the organization's ability to assess the effectiveness of its initiatives but also facilitates the integration of impact assessment into broader organizational strategies, ensuring that social, environmental, and economic considerations are embedded in decision-making processes (Vanclay, Esteves & Aucamp 2015). Strategy design, therefore, serves as a crucial foundation for developing impactful and sustainable initiatives while providing a structured approach to assess and refine their outcomes.

3.2 Service Design

For the readers unfamiliar with the concept of service design, this section presents an overview on service design and the double diamond model used in this work. Service design, known also by design thinking, is a multidisciplinary and integrative field that choreographs processes, tools, and interactions in complex systems. The mindset of service design is collaborative as it sees and listens to both perspectives, the users' and the service providers' needs, and offer user-centered processes and tools to collect insights and co-create new and improve services (Stickdorn & Schneider 2018). Why does service design represent a good approach for developing this thesis? When it comes to coordinate a project that is rooted in multidisciplinary - in this case, including communication, strategy, stakeholder management, value chain- a structured sequential process is beneficial to guide and organize the work allowing to consider the requirements of the stakeholders affected by the service in a collaborative and iterative approach. For these reasons service design is the right framework

to tailor the service design development work according to the needs and expectations of ACTRIS stakeholders as well as ACTRIS' strategic objectives and design an appropriate solution. The external stakeholder requirements and expectations are presented in a downstream manner, whereas there has been proactive involvement with internal stakeholders in the development of this thesis.

In the context of this project, the starting point (A) represents the challenge: ACTRIS impacts are not well managed. Improvements *could be* made to collect information and tell better stories about ACTRIS solutions. The end point (B) is the outcome, a clear idea or plan of how ACTRIS *should* structure its impact management system (Figure 2).

Figure 2 The challenge of the design process is to move from the point (A) where it is not known how it could be to the point (B) where it is known how it should be. Adapted from Design Council (2015).

Based on the Double Diamond model by the British Design Council (2015), the service design process leads the journey from A to B through two stages (Figure 3). The first stage is about setting up the right strategy to *do the right thing*: here the focus is on posing the right questions to answer or setting the right problem to solve, and the outcome, based on research and collated experience, is the establishment of a set of requirements for service (experience strategy). The second stage is about the design and *doing the thing right:* here the focus shifts on finding a proper solution that executes the experience strategy. While the first diamond focuses on the problem to make sure we are solving the right problem, the second one focuses on solving the problem in the most appropriate way, so that the solutions suggested are fit-to-purpose.

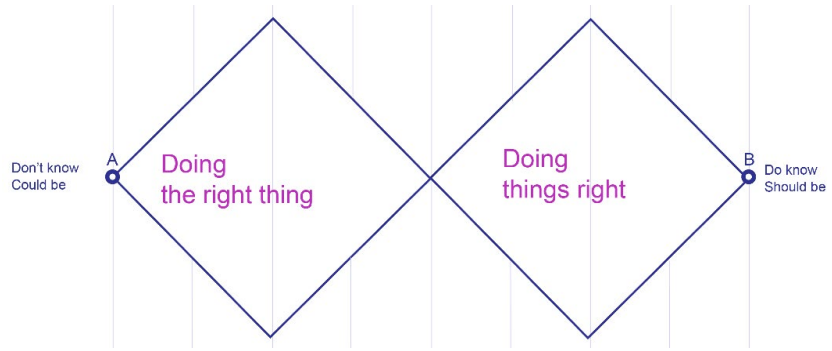

Figure.3. The double diamond model is driven towards two goals: doing the right thing during the first stage and doing thing right in the second stage. Adapted from Design Council (2015).

The two phases are broken down into four sequential phases (discover, define, develop, deliver), each one including diverging and converging thinking (Figure 4). Divergent and convergent thinking can be used as a generic, high-level lens when planning for or managing a service design process: divergent skills create a large knowledge base with enough material to have multiple ideas, alternatives, opportunities while convergent skills draw the focus back on the target and ensure that the project stay on track with all possible constraints (time, budget) and – in the end – move forward.

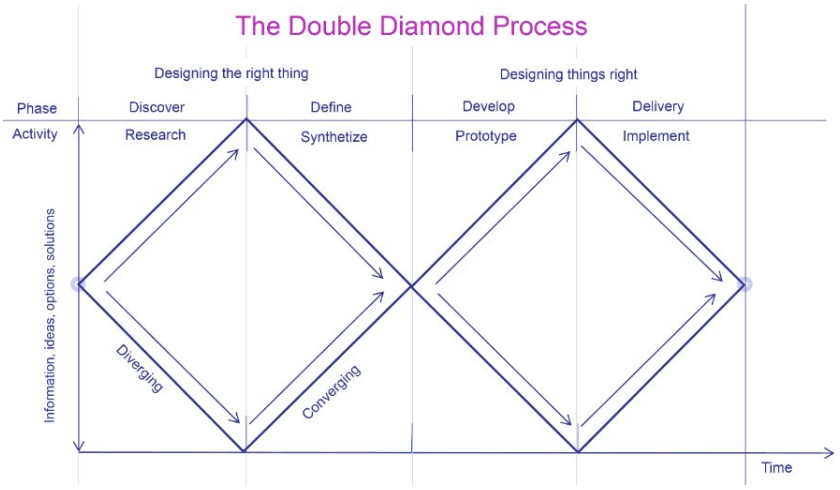

Figure 4. The double diamond model consists of diverging and converging thinking throughout the discovery, design, develop and deliver phases. Adapted from Design Council (2015).

In the initial "discover phase" (Section 4.1) information is sought through desk research and discussions with ACTRIS leadership. In the "define phase" (Section 4.2) key insights from the previous phase are synthesized, visualized and presented. The "develop phase" (Section 4.3) consists in the ideation of solutions and prototypes. Targeted feedback and results from a

survey are used to refine the results of the development process, namely the ACTRIS impact intervention logic and the ACTRIS impact interface. The final phase “deliver” is outside the scope of this thesis and the effort is limited to present a prototype of the service. The three phases of this development project with their corresponding sequence of sub-steps, activities, approaches, tools and outcomes are briefly described in Table 1.

Table 1. Overview of the tools and intermediate outcomes in function of the design process phase.

Phase	Activity	Thinking approach	Tools	Outcome	Section
Discover	Research	Diverging	• Desk research • Discussions with leadership	Brief	Section 4.1
Define	Synthesis	Converging	• Text analysis • Discussions with leadership	Definition of purpose, requirements and key components	Section 4.2
Develop	Ideate	Diverging	• Survey • Discussions with leadership • Community meeting	Impact framework Impact interface	Section 4.3

3.3 Data collection

To implement the user-centric service design methodology in the development of this thesis, an active engagement had been primarily adopted towards ACTRIS internal stakeholders, with a particular emphasis on involving ACTRIS leadership in monthly project progress reviews. Indirectly, internal stakeholder engagement is also considered by referencing minutes and internal documents from prior meetings that have addressed topics pertinent to the development of this thesis.

The wider ACTRIS community, that comprises internal and external stakeholders, including the private sector, was encouraged to get involved in the project by means of a 20-minute presentation held during the ACTRIS week, a community meeting which took place in

Heraklion, Greece, in October 2023. Any feedback pertaining to the presented work was documented in the event's minutes, which are publicly accessible on the ACTRIS website, along with the presentation slides. To foster discussions and allow both in-person and remote participants to contemplate the presented ideas and offer feedback, a survey was launched using the Google Forms platform. The questionnaire was designed to provide background information and supplementary materials to facilitate participation regardless of the participant's level of knowledge. The questions were structured to align with the content of the presentation, reflecting the outcomes of this thesis's development. This approach was chosen to enable the analysis and validation of the concepts and results presented in this thesis.

All the data and responses collected in the questionnaire are anonymous, with no possibility of extracting names, details, or any other identifying information from the questionnaire. Only the identification of the stakeholder group is required in the survey, ensuring that the respondent's identity remains confidential. The same level of anonymity is maintained in data storage. The data is stored on a Google Drive with exclusive access granted to the thesis author and retained for twelve months, with all data scheduled for deletion no later than October 24, 2024.

Appendix 1 provides a comprehensive view of the survey questions and the complete survey responses.

4 Results of the development project

This chapter outlines the outcomes of the design process. Starting with the “discovery phase”, the analysis of documents and existing impact assessment frameworks, insights, and challenges of the case project of ACTRIS are presented. The “define phase” establishes the requirements to carry on the development for the case study: the objectives of the impact assessment framework are formed, and the necessary key components are defined. Relevant tools for the implementation of the framework are as well identified. Finally, the impact intervention logic and a prototype of an impact assessment interface are ideated and presented in the “develop phase”.

It's important to acknowledge that the content forming the discussion of this chapter and the results presented herein are susceptible to the author's subjective interpretations. Other readers may interpret the data differently.

4.1 Discovery Phase

This chapter represents the “discovery phase” of the double-diamond model. This phase involves divergent thinking, that reflects open-mindedness, curiosity and a willingness to dive into research to gain a deeper understanding of the challenge at hand and gather insights exploring new opportunities and existing solutions. In fact, this phase aims to pinpoint not only the needs but also the pain points experienced by ACTRIS, thereby enhancing our understanding of the situation, and paving the way for more effective problem-solving and assessment efforts.

During the “discovery phase”, the primary objective is to understand the challenge and insights of the project commissioner and gather in depth information via desk research on existing guidelines and frameworks related to impact assessment within the context of research infrastructures. This process also entails conducting online searches for documentation from external organizations and research infrastructures. Throughout this phase the guiding questions are such as: "Why is impact assessment essential for ensuring the long-term sustainability of research infrastructure?", "What are the necessary steps to embark on the impact assessment journey?", "What components are needed to conduct an impact assessment?", and "What are the associated challenges?". The next sections shed light on answering these questions and overall work towards resolving the first research objective “Which factors influence research infrastructure to integrate impact assessment into their strategies?”

4.1.1 Existing impact assessment frameworks

Numerous impact monitoring and evaluation frameworks have emerged to gauge the operational efficacy of research infrastructures and assess their contributions beyond science and extending to society and the economy. The choice of methodology for impact evaluation hinges on the purpose of the assessment, whether it be advocacy, accountability, resource allocation, or education, with no one-size-fits-all solution (Guthrie, Wamae, Diepeveen, Wooding, & Grant 2013). In recent times the focus has shifted towards motivating and justifying funding allocation from societal and economic perspectives. Considering economic impacts, funding agencies are increasingly interested in understanding how research infrastructures enhance productivity and growth, often relying on data related to job profiles and turnover for economic modeling, as discussed by Florio & Sirtori (2014), Florio, Giffoni, Giunta, and Sirtori (2018) and Ravet et al. (2018). A technological impact evaluation requires the integration of other data types, such as intellectual property rights (e.g., trademarks and standards), which still remains a challenge, as highlighted by Van den Besselaar, Flecha & Radauer (2018). Furthermore, defining and measuring societal impacts are similarly intricate

endeavors and often demand mixed methods. While quantitative approaches are known for their transparency, comparability and suitability for frameworks oriented towards accountability and resource allocation, these approaches may not inherently yield easily digestible evidence for demonstrating impacts, which are better elucidated through qualitative means.

Reviewing literature four main steams were identified in impact assessment of research infrastructures. Analytical approaches relying mainly on quantitative methods are the best fit for micro- and macro-economic models which rely on neoclassical economics (Walras 2006) and growth theory, such as cost-benefit analysis. Empirical studies demonstrate that such methodologies for assessing socio-economic impacts often demand substantial resources and expertise and involve substantial ad hoc data collection, thus implying a lack of repeatability. Research infrastructures, which frequently rely on managers with scientific backgrounds, may not always have access to the financial resources required to enlist external companies or specialists, leaving them to learn how to handle these tasks effectively as they go.

A second mainstream found in literature is related to the application of multi-methods and multi-indicator approaches. This approach is very important in science policy and management literature, and it is applied, for example, in the Organisation for Economic Co-operation and Development (OECD) framework. The framework delineates five impact areas (scientific, technological, training and education, economic, and societal) and seven strategic objectives evaluated through a comprehensive list of 58 indicators (OECD 2019a). This extensive list constitutes a valuable database from which any research infrastructure can select indicators that best align with its own specific needs. The critiques extended to such method is the lack of solid theoretical referenced in evaluation and problems related to the aggregation of interpretation.

A third mainstream is a theory-based approach that mixes qualitative and quantitative methods applying the theoretical frameworks of the Theory of Change (Weiss 1995). This approach identifies casual mechanisms via context and impact pathways analysis (Chen 1990; Suchman 1967; Weiss 1987; Donaldson 2007). These works show the identification of logical narratives and assumptions to connect activities, outputs, and expected outcomes demonstrating causal pathways. Pathways are a representation of how a strategy is expected to lead towards desired changes by testing assumptions and hypotheses and recognizing that different contexts may produce different results. A multitude of names are used in literature to describe this approach, including programme logic (Funnell 2007), Theory of Change (Weiss 1995), intervention logic (Rogers 2008) and impact pathways analysis (Kuby, van de Fliert, & Schulz 2003).

The Theory of Change approach has become an evaluation standard in the European Commission with the introduction of the Better Regulation Agenda and linked guidelines (European Commission, 2017) and impact pathways have become largely used in project management and research infrastructure assessment. At its core, the Theory of Change is a simple and likely causal pathway that links inputs, activities, outputs, outcomes, and impacts (Figure 5). Sketching impact pathways helps understand the underlying assumptions behind an activity or operation and provides a logic for monitoring, evaluating, and adjusting strategies over time. Pathways help in illustrating the chain of events or processes through which inputs and actions lead to specific outcomes, both in terms of short-term and long-term effects. It promotes a deeper understanding of the context and the factors that contribute to or hinder change, allowing organizations to make more informed decisions about their programs or initiatives. It's important to note that a Theory of Change, and its implementation model of impact pathways, is not a guarantee of success but rather a tool for planning and learning. It encourages continuous reflection on assumptions, gathering of evidence, and adopting iterative strategies based on new insights and feedback.

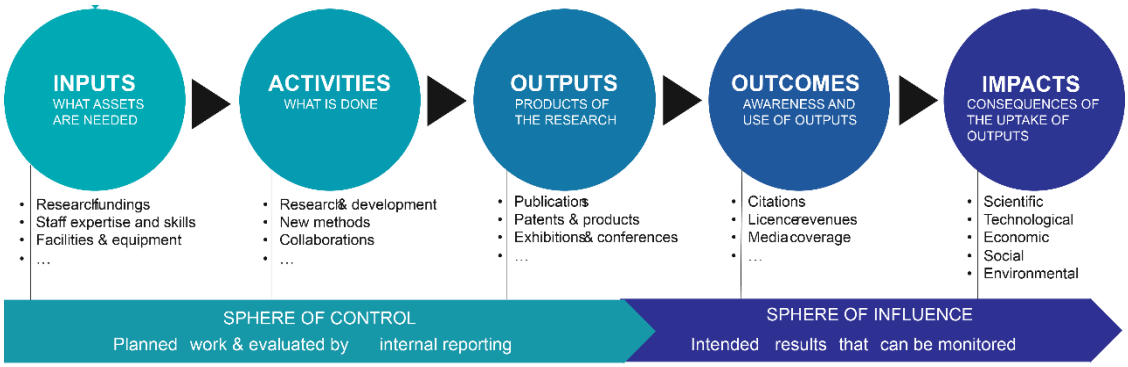

Figure 5. Representation of the components of impact pathways adapted to the research infrastructure context. Adapted from Griniece at al. (2020).

Here are the key components of a pathway, also graphically shown in Figure 5:

- Inputs: These are the assets, such as funding, personnel, or infrastructure, that an organization or initiative brings to the table.
- Activities: These are the actions or services carried out using the available inputs. Activities can include training programs, services, awareness campaigns, or policy advocacy.
- Outputs: Outputs are the direct and immediate results of activities. They represent the products, services, or deliverables generated because of the intervention.
- Outcomes: Outcomes are the changes that occur because of the outputs. They reflect the short to medium-term changes in knowledge, attitudes, behaviors, or conditions

of the target population or system. Outcomes are out of the sphere of control, hence they can only be monitored.

- Impacts: Impacts are the long-term changes or effects that result from the outcomes. They represent the broader changes in society, systems, or environments that are influenced by the outcomes.

Figure 5 also defines the boundaries of a sphere of control and a sphere of monitoring. The sphere of control encompasses the components of inputs, activities and outputs that can be planned, monitored and evaluated through, e.g., internal reporting. The delivery of activity and its resulting output to stakeholder represents the process of value co-creation presented in Section 2.1.4 and discussed in section 2.1.8 and demonstrates how the model of value creation is embedded within the impact framework. The sphere of influence, on the other hand, comprising of outcomes and impacts, represents the intended results that can be foreseen or set as goals.

An example of the application of the impact pathways approach is represented by the Horizon 2020 RI-PATHS project, which has developed an interactive toolkit providing guidance for impact assessment. This work, presented by Griniece et al. 2020, outlines the most common impact areas for research infrastructures and offers examples of suitable monitoring and reporting tools, along with methodologies for impact measurement. The framework defines four impact areas (human resources, economy and innovation, society, policy), 14 high-level impact pathways observed in the operations of various research infrastructures, and a comprehensive list of indicators for activities, outcomes, and impacts (Griniece et al. 2020). Most importantly, the toolkit equips readers with the general knowledge and basic steps needed to start developing an impact framework. Similarly, ESFRI (ESFRI 2019) has proposed an impact pathway framework encompassing 9 strategic objectives under common themes suitable for EU research infrastructures and 21 key performance indicators to aid research infrastructure demonstrating their success. Additionally, ESFRI has recently released a policy brief to support the development of impact assessment (ESFRI 2023). This report serves as a valuable entry point for newcomers to the topic as it reviews existing impact assessment methodologies, assesses their applicability to different types of research infrastructures, and incorporates insights from other research infrastructure initiatives. The brief also provides approaches and guidelines for further development and future impact assessments of research infrastructures, aligning with ESFRI's strategy and responding to ESFRI's requirements.

A fourth stream is identified by an approach based solely on case studies, both within and cross- cases, mixing both qualitative and quantitative methodologies following the causation

theory (Castelnovo, Florio, Forte, Rossi, & Sirtori 2018). The main critique related to this method is its high subjectivity and biases.

This overview of existing key recommendation from high-level stakeholders, such as OECD and European Commission through ESFRI, underscores that while the literature on defining and measuring impact of research infrastructures has expanded in recent times, there is no one-size-fits-all framework; rather, it must be tailored to the context, scale, and nature of the individual research infrastructure. Approaches and recommendations have been put forth by influential entities such as the European Strategic Forum for Research Infrastructures (ESFRI), the ERIC Forum, the Organisation for Economic Co-operation and Development (OECD), and initiatives like the Horizon2020 project RI-PATHS. These entities unanimously advocate for a combination of qualitative and quantitative approaches to comprehensively capture impacts, which is the motivation to adopt this solution in the “define phase”.

4.1.2 The case project: ACTRIS

In this section ACTRIS, the commissioner for this thesis, is introduced.

The Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is a European research infrastructure that focuses on atmospheric observations and measurements. It plays a key role in advancing scientific understanding of aerosols, clouds, and trace gases in the Earth's atmosphere. The mission of ACTRIS is to provide open and easy access to resources and services related to atmospheric science to a broad user community from academia and the private sector world-wide to conduct excellent research, foster innovation and provide high-quality information to decision makers to tackle societal challenges related to air quality, climate change and health.

ACTRIS has been under development for the last decade through the financial support granted by the European Commission. In April 2023 ACTRIS was established by the European Commission (Implementing Decision 2023/900/EU) as a European Research Infrastructure Consortium (ERIC), a title that officializes ACTRIS as a non-profit legal entity. The establishment of ACTRIS as an ERIC is a transformational change at the organizational level as summarized below:

- Legal and Governance Structure - As an ERIC, ACTRIS gains a solid legal and governance structure. ERIC is a legal framework established by the European Commission to support the long-term operation of research infrastructures on a pan-European scale. This transformation ensures a stable and sustainable organizational structure for ACTRIS, providing a strong foundation for its operations.

- Enhanced Collaboration - ACTRIS, as an ERIC, can facilitate increased collaboration and coordination among European research institutions, stakeholders, and countries. It promotes the pooling of resources, expertise, and data, leading to a more efficient and coordinated approach to research on aerosols, clouds, and trace gases. This enables better integration of efforts, fosters interdisciplinary collaboration, and maximizes the impact of research outcomes.
- Long-Term Stability - The ERIC status provides long-term stability to ACTRIS by ensuring funding continuity, operational support, and access to resources. This stability is crucial for the sustainability and growth of the infrastructure, allowing it to plan and implement long-term research strategies, develop advanced instrumentation, and attract talented researchers and scientists.
- Access to Funding - As an ERIC, ACTRIS gains access to various funding mechanisms at the European level, such as Horizon Europe, which is the EU's flagship research and innovation program. This expanded funding potential enables ACTRIS to secure financial resources for infrastructure development, maintenance, and upgrades, as well as for conducting cutting-edge research and technological advancements.
- International Recognition - The establishment of ACTRIS as an ERIC enhances its international recognition and visibility. The ERIC status signifies that ACTRIS has met rigorous scientific, technical, and administrative standards, making it an authoritative and credible research infrastructure in the field. This recognition can attract international collaborations, foster partnerships with other research infrastructures globally, and promote the exchange of knowledge and expertise.

Overall, the transformation of ACTRIS into an ERIC brings about a significant change in its organizational structure, governance, funding, collaboration potential, and international standing. These changes must be reflected in ACTRIS long-term strategies and including a clear evidence-based demonstration of impacts.

The challenge of ACTRIS: communicating its values and impacts

As illustrated in Figure 6, ACTRIS operates based on a well-defined business model that aims to efficiently handle resources, provide a robust and accessible research infrastructure, create values through continuous interaction with stakeholders, and offer services that have applications in different operating scenarios and relate to current megatrends (ACTRIS Business Plan 2023). While clear processes and operations define a strong base for the value creation model, a weak point has been identified in the business model. The ACTRIS Scientific and Innovation Advisory Board (SIAB) , during its 9th ACTRIS SIAB meeting held in Heraklion in October 2023, reported to the ACTRIS General Assembly that the “SIAB strongly recommends

that the added value of ACTRIS ERIC is clearly expressed in its strategies and care is taken to portray ACTRIS' role as enhancing and adding to the value of existing partners and value chains, including a flow chart diagram that clearly describes the role of ACTRIS in the value chain". Such statement reinforce that the value creation model is currently missing the further connections linking the results of ACTRIS operations to the values created and consequent impacts. In fact, ACTRIS does not currently have an official document describing its impact nor a clear path for planning, managing, monitoring and communicating values and impacts. It is in the recognition of this pitfall that this thesis idea was developed. Although this gap doesn't hinder ACTRIS from running its operations and the delivery of its services, it may prevent ACTRIS from leveraging its full value proposition portfolio when interacting with stakeholders.

The idea is not to enter the details and technicalities of the implementation of such impact framework, but rather create an overarching strategy that will support the future work of ACTRIS management in defining the necessary steps and protocols to better capture and understand ACTRIS knowledge output and analyze and validate ACTRIS output to better review and assess potential applications for value proposition and impact demonstration.

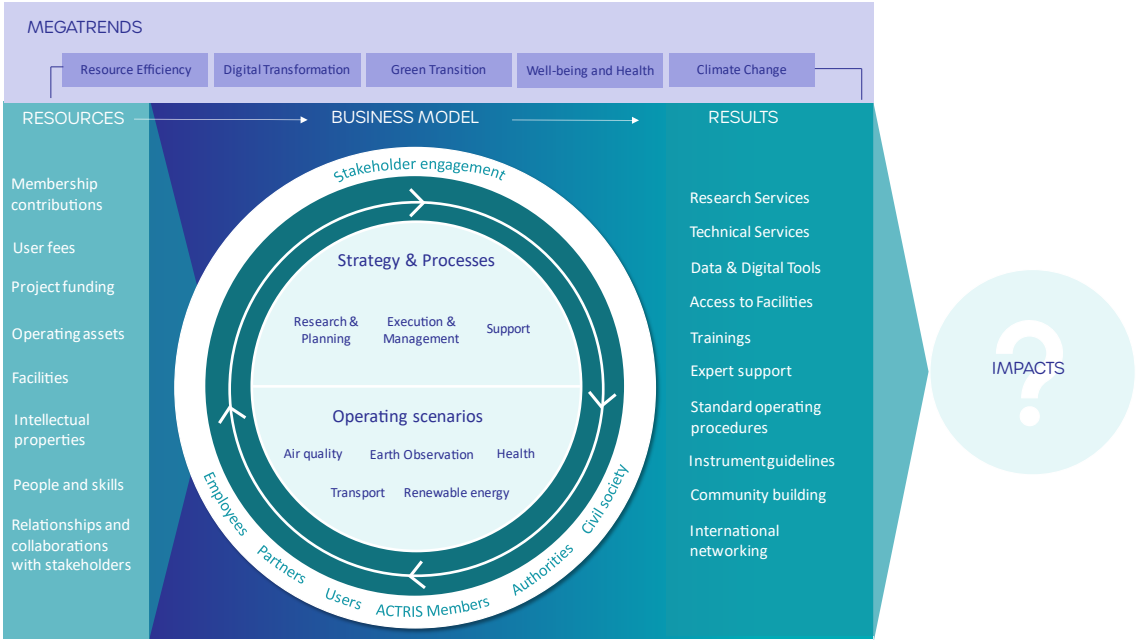

Figure 6. ACTRIS business model. The current set up of the ACTRIS business model lacks a clear connection with added values and impacts. Adapted from the ACTRIS Business Plan (2023).

Where do we stand in ACTRIS?

Reviews of internal sources (e.g., project deliverables, meeting minutes) shed light on the current set-up of ACTRIS, thus delineating more clearly the key challenges and opportunities for this project following the guiding questions “How do we start the process?” “Does ACTRIS start this process from scratch? “.

Since the genesis of ACTRIS as an project funded by the European Commission, actions taken to increase ACTRIS’ visibility with stakeholders (European Union and its various body and agencies, intergovernmental organizations, national funding agencies, and other scientific communities) have been manually tracked via formal knowledge management and transfer, e.g., via consultations responses, answer to requests of varied nature, publication of position papers, organization of and participation to events targeting stakeholders. Such an approach is not optimal and not successful on a long-term perspective.

A first evaluation of the socio-economic impacts of ACTRIS (ACTRIS 2021a) has been conducted in the context of the preparation phase of ACTRIS during the EU funded project ACTRIS PPP. The study adopted a quantitative approach based on input-output analysis; results indicated that for every € 1 million spending in developing, maintaining, and operating ACTRIS infrastructures the European economy would benefit through an increase of the value added by € 1.39 million and the creation of 17.93 person-years of new employment during the period 2021-2025 and an increase of the value added by € 1.43 million and the creation of 17.83 person-years of new employment for 2026.

While such ad-hoc impact analysis is useful, an overall process that transfer knowledge from sources to targeted potential stakeholders is needed to maximize the exploitation of results and outputs and the create more effective impacts on society and industry. Exploitable outcomes are considered valuable assets resulting from ACTRIS activities and operations, and their successful exploitation can lead to various benefits, including economic growth, innovation, knowledge dissemination, and societal advancements. Examples of exploitable results in ACTRIS are technological innovations, intellectual properties, data and datasets, instrument prototypes, best practices, policy recommendations, educational resources, and commercialization opportunities. Impact assessment consists in a range of activities and processes that aim at capturing and evaluating how knowledge, skills, competencies are transferred from those generating them to those who will transform them into added value outcomes, and impacts. By focusing on identifying what key exploitable outcomes have key potential applications and impact, it is possible to fast track them, providing a faster impact on external stakeholders.

ACTRIS has defined a preliminary set of key performance indicators to facilitate the effective monitoring and quantification of various type of socio-economic impacts, including those on human capital creation, scientific activity, innovation, economy, and society (ACTRIS 2018; ACTRIS 2019a; ACTRIS 2019b), however these recommendations lack the causality aspects that demonstrate the linkages to how the impacts were created through the value provided to stakeholders.

In the view of ensuring ACTRIS sustainability and longevity, the question driving the next steps of this work is whether does ACTRIS have a clear strategy for tracking and monitoring impacts? ACTRIS has established mechanisms and processes that represent key components of an impact assessment framework, such as a communication strategy (ACTRIS 2023b), business plan (ACTRIS Business Plan 2023), and innovation strategy (ACTRIS 2021b; ACTRIS 2023a) as well as legal and intellectual property regulations. Mechanisms for monitoring the progress of value creation and evaluating its effectiveness against predefined objectives and key performance indicators have been defined in the ACTRIS management plans by dedicated focus groups and strongly based on the ESFRI recommended indicators. At this stage, the indicators should be satisfactory to draw a basic analysis of ACTRIS performances within the sphere of control. While the solution is realistic and not too resource-intensive in its implementation (considering the number of indicators and their level of details), it lacks the dimension of the long perspective that is crucial to capture and evaluate the sphere of influence and impacts of ACTRIS. More importantly, once the reporting data, e.g. on activities and outputs, is collected, ACTRIS has not clearly identified how such information will be disseminated to ACTRIS stakeholders (e.g., annual report, executive summary of the periodical report, website, or other documents) and this needs to be clarified. It's also important to introduce the ACTRIS internal community to the reasons behind the necessity of implementing these processes. It is crucial the key internal stakeholders are motivated to actively participate in the activities related to the impact assessment.

4.1.3 Considerations and challenges

Impacts are deeply rooted into the strategy of research infrastructures. Impacts mirror the outcomes or changes that a research infrastructure seeks to achieve, and help shape and evaluate the organization's direction, priorities, and strategies towards long-term sustainability. These constitute the main factors for which an organization shall develop an impact assessment, especially if an organization such as ACTRIS is largely supported by public funding and provide an answer to the first research question of this work. Strategic goals are the specific objectives or targets that an organization sets to achieve its mission and vision. They represent the key areas or priorities that need to be addressed for the organization's

success and impacts are instrumental in driving strategic goal setting and evaluation. When defining strategic goals, organizations consider the impacts they want to create or the changes they want to see (Hamel & Prahalad 1993). The impacts serve as indicators of progress towards these goals and guide decision-making processes to align resources, activities, and initiatives with the desired impacts. The mission statement defines the core purpose and reason for an organization's existence. It clarifies what the organization aims to achieve and whom it serves. Impacts are directly linked to the mission as they represent the desired outcomes or changes that the organization wants to create in the world. The mission provides the overarching direction for identifying and prioritizing the impacts that align with the organization's purpose (Bart & Baetz 1998). The vision statement outlines the desired future state or the long-term aspirations of the organization. It paints a picture of what the organization hopes to become or accomplish. Impacts contribute to the realization of the vision by representing the tangible outcomes or changes that demonstrate progress towards the desired future. Impacts provide a measurable and observable way to assess whether the organization is moving closer to its vision.

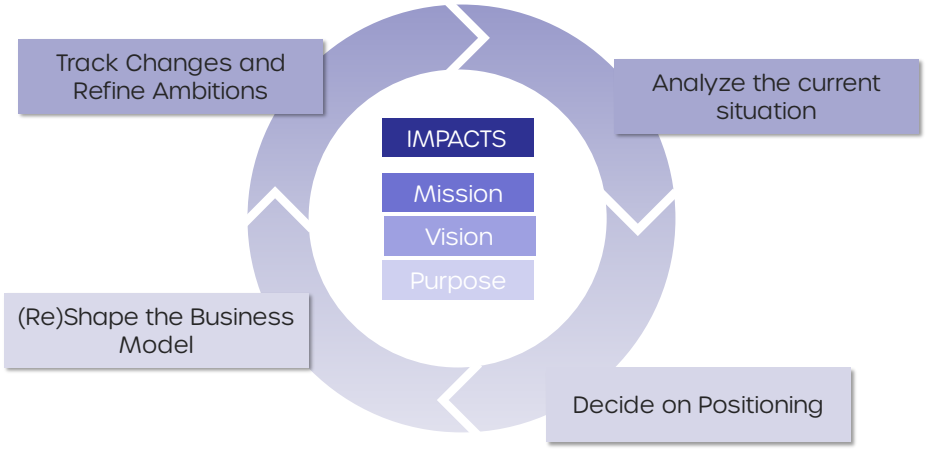

Figure 7. The circularity of impacts is rooted in the mission, vision and purpose of the organization.

By aligning impacts with the mission, vision, and strategic goals, organizations can ensure a holistic, cohesive, and purpose-driven approach to their operations and decision-making (Bart, Bontis & Taggar 2001). This approach is clearly nonlinear, and there is a transformative circular feature as shown in Figure 7. The circularity of impacts enables us to assess the performance of achievements based on plans and strategies (e.g., the business model) and generate a feedback loop to revise the strategic objectives as mission and vision evolve over time.

It is important to consider and reflect on the goal and approach of the impact assessment as a function of the lifecycle of research infrastructures. As a research infrastructure evolves from implementation to reach its full operational phase, it is not possible to evaluate performance and impacts using a fixed approach. It seems to be more logic and pertaining to consider the mission, strategic objectives, activities and operations within the specific phase of the research infrastructure lifecycle: activities and outputs monitoring in implementation phase and long-term impact in operational phase when maturity is reached. This key consideration indicates that the expectations, in terms of the resulting impacts, evolve in time entailing that the framework shall be, firstly, flexible, modular and, secondly, tailored to the specificity of the research infrastructure.

While examining ACTRIS's situation within the realm of value creation and impact assessment, it became evident that the elements directly under ACTRIS's control, such as operational objectives, activities, and outputs, along with their corresponding key performance indicators, have been well-defined and meticulously planned. However, a critical aspect that was missing is the overarching framework that effectively maps ACTRIS's mission, objectives, and anticipated impacts through a systematic pathway. This is the work undertaken in this thesis. Having such an overarching view is of strategic importance as it allows for a comprehensive understanding of the entire assessment process, connecting ACTRIS's strategy to the foreseen impacts through logical pathways.

Given ACTRIS' specific requirements and context for the development of an impact assessment framework, the impact pathways model has been selected as the preferred approach for this project. This choice stems from its suitability in crafting a framework that ensures the collection of essential data across key dimensions where impact is sought. The decision to adopt the impact pathways model is particularly advantageous for situations where there may be limitations in terms of time and budget, preventing the commissioning of extensive impact studies from external service providers. This method offers a practical and cost-effective alternative, characterized by its streamlined and resource-efficient nature.

Another notable benefit is its flexibility, which allows for easy repetition of the impact assessment process. For instance, periodic focus groups can be convened to collaboratively work on guiding templates, as illustrated in Figure 8. To fulfill this crucial role, impact assessment grids emerge as a highly suitable tool, facilitating the connection of impact pathways to the mission, operational goals, and strategic objectives, thus enabling a holistic perspective on the assessment procedure. Alternatively, ad-hoc surveys can be conducted to capture and manage key exploitable results. These mechanisms enable managers to

continuously track, and update information related to usage, benefits, and impacts, ensuring that the assessment remains current and aligned with ACTRIS' evolving needs and objectives.

Moreover, this strategy combines a blend of qualitative and quantitative methodologies, elaborated upon within the theoretical framework of the Theory of Change. The subsequent sections will introduce the key components of the ACTRIS impact pathway framework and both qualitative measures (indicators) and quantitative measures (surveys and impact stories), each of which is highly relevant in providing a comprehensive perspective of the overall impact landscape of ACTRIS.

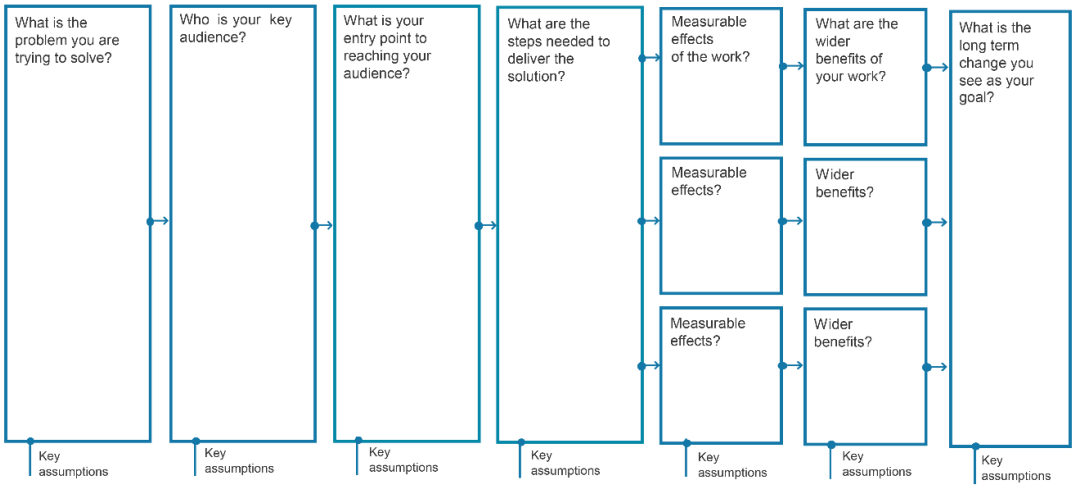

Figure 8. Theory of Change template. Adapted by Development Impact & You by Nesta 2014. Copyrights: Development Impact & You by Nesta licensed under a Creative Commons Attributions for Non-Commercial Shares. 4.0 International Licence.

Other challenges can arise from various factors, including the complexity of measuring impacts, the diversity of stakeholders and perspectives involved, and the dynamic nature of research environments.

Research infrastructures can have indirect and spillover effects that extend beyond the immediate beneficiaries. These effects may not be easily measurable or quantifiable, making it difficult to capture the full extent of the impacts. Research infrastructures involve diverse stakeholders, including researchers, industry partners, policymakers, local communities, and the public. Each stakeholder group may have different priorities and expectations regarding what is valuable to them. Incorporating these diverse perspectives and capturing the full range of impacts is complex.

Only through a continuous improvement and learning from previous assessments can help refine methodologies and overcome challenges to ensure more robust and comprehensive assessments of impacts for research infrastructures. Addressing these challenges requires careful planning, agile approaches, and collaboration among stakeholders involved in the assessment process.

4.2 Define phase

Whereas the preceding chapter was dedicated to collecting insights on the case study, the "define phase" shifts its focus towards adopting a purposeful and unequivocal perspective for ACTRIS. It centers its attention on crafting a precise solution for the challenge identified in the "discovery phase". The "define phase" leverages the information collected in the "discover phase" to discern the specific requirements of the ACTRIS case study necessary to solve the challenge.

4.2.1 The purpose of the framework

The framework for monitoring and evaluating the impacts of ACTRIS is designed with the primary objective of demonstrating the worth of ACTRIS, in terms of values and impacts, to stakeholders. Nonetheless, impact management, that represents the mechanisms necessary to deploy impact assessment evaluations, also serves a valuable purpose for internal processes by gauging the efficiency, effectiveness, and relevance of ACTRIS and its activities. An additional aspect that is to be considered is the support towards ACTRIS leadership in formulating strategies, justifying long-term investments, and enhancing operational decisions. Consequently, the general purpose of the framework is divided into three objectives with corresponding actions as described in Table 2.

Table 2. Three objectives and actions are identified and recommended as pillars in supporting impact management.

Purpose: Impact management	
Objective	Action
Tracking impacts to design	Collect and understand
Indicators support the design of the ACTRIS strategic plans and operational activities	Capturing internally knowledge outputs that are systematically collected and collated to monitor progresses of ACTRIS. A careful

	identification and description of ACTRIS outputs ensure that all key information is understandable by internal key actors.
Tracking impacts to improve	Analyse and validate
Quantitative and complementary qualitative evidence provide a holistic approach to assess the efficiency, effectiveness, and relevance of ACTRIS and its added values to stakeholders.	Knowledge outputs are reviewed and assessed for potential application and impact.
Tracking impacts to demonstrate	Transfer and exploit
This allows for maximizing the impact of the investments in ACTRIS and better ACTRIS alignment with European priorities and disseminate the added value of ACTRIS.	Carry out and report on activities and impacts.

There is a circular relationship among these objectives and visually represented in Figure 9. Each objective is essential to impact management and for achieving a thorough implementation of impact assessment that addresses internal requirements and aligns with the overarching goal of the impact framework.

Figure 9. The three objectives of impact management that support the implementation of the impact assessment framework.

To support the three objectives, the impact assessment framework must be developed to reach well beyond a mere summative assessment. The approach seeks to be informative about the performances of ACTRIS with a formative approach. Such a formative aspect is key towards reaching long-term sustainability as it fosters a continuous improvement of the design and conceptions of ACTRIS services through reflecting on the value effectively created versus the expected impacts.

The assessment framework shall be codesigned with ACTRIS representatives, for example, in regard to how the reporting will be implemented, the definition of a report template and how data will be collected. To be relevant and useful for a long-term effort, the impact framework should be continuously made to shape the approach to encompass a range of megatrends, sectors, focus studies and scenarios addressed by ACTRIS. As these themes change with time the framework should be built in a flexible way that adapts to the likely changes brought by ACTRIS developments and changes in scientific, social, economic and environmental contexts. Moreover, linking the ACTRIS impact framework with global perspectives, such as the United Nations Sustainable Development Goals, necessitates translating ACTRIS terminology into a univocally comprehensible language accessible to external stakeholders.

A set of evaluation criteria for the set-up of the ACTRIS impact framework are presented in Table 3 along with its rationale, and suitable examples of indicators and data sources. It consists of quantitative and qualitative methods that will be used to triangulate evidence. These criteria shape the approaches to be implemented in the impact management mechanism,

Table 3 Evaluation criteria embedded in the framework with example of recommended indicators and data sources.

Assessment Criteria	Example of Indicators	Example of Data Sources
Effectiveness Looks at the main outputs, outcomes and impacts towards achieving scientific, economic/technological, societal and sustainability impacts	• Operational Key Performance Indicators (e.g., Share of ACTRIS Data Sets, No. of international workshops) • Barriers and drivers to ACTRIS progress	• Project Reporting • Data usage statistics • User feedbacks

Efficiency Looks at the performance of implementing processes of administration and management, project application and selection processes, as well as funding allocation	• Funding distribution (thematic, geographic, etc.) • Stakeholder satisfaction • Time-to-grant	• Analysis of management data • Interviews • Surveys
Relevance Looks at the adequacy, complimentary, interactions, gaps and overlaps of ACTRIS service provision with other relevant programs, priorities and initiatives	• Systems in place to foster synergies with other RIs, networks and organization • Stakeholder satisfaction • Consultation of stakeholders to identify needs and issues to be addressed • Use of evidence when creating strategies	• Analysis of other documentation on priorities, policies and programmes • Analysis of scientific, economic, and technological trends • Interviews • Stakeholder consultations • Case studies
Added Values Estimate what would be the situation without ACTRIS at national and European level	• Scale, speed and scope of scientific activity and technological growth	• Project reporting • Annual reporting • Publications databases • Survey • Case studies

4.2.2 Stakeholder engagement

The expectations and interests of stakeholders are multifaceted. For instance, researchers from academic and industrial backgrounds may exhibit more interest in ACTRIS's services, which can facilitate their scientific and technological endeavors. Meanwhile, ACTRIS managers may seek well-structured and transparent internal management processes. Policymakers often seek data-driven evidence to inform and shape their policy decisions, and governments aim to showcase their competitive advantages, strategically positioning their countries within the European or global landscape, whilst funders require substantiated evidence to evaluate the returns on their investments. For a comprehensive overview, Table 4 outlines the principal stakeholder groups and their primary interests.

Hence, it is paramount to design the framework with a deliberate intention to accommodate their diverse perspectives, capture pertinent evidence, and effectively communicate it through appropriate channels and messages. To cater to these diverse stakeholder interests, it is essential to elaborate information with the specific intent of providing stakeholders with relevant evidence that fosters a shared understanding of ACTRIS's value propositions and impacts.

From a stakeholder engagement perspective, the impact framework devised for ACTRIS serves a dual purpose: it seeks to establish robust relationships with stakeholders, both internal and external, while also acknowledging the mutual roles in value creation. The development of the strategy for impact management and assessment should be viewed as a collaborative effort, necessitating active engagement from both ACTRIS's internal and external stakeholders. To facilitate this engagement, regular surveys focused on shedding light on how outcomes and impacts are materializing and suggestions for improvement can be conducted. These surveys can be initiated either directly by ACTRIS as part of its internal operations, such as user feedback analysis or post-event surveys, or outsourced to external companies for professional and large-scale surveys. For instance, surveys involving citizens contributing to support ACTRIS operations can be considered.

Table 4. ACTRIS main stakeholder groups and their interests towards impact assessment.

Stakeholder	Interest
ACTRIS Managers	Periodic monitoring of impacts to improve performances and collect evidence to demonstrate funders why investment is worth
ACTRIS Staff	How ACTRIS improve their daily work and provide improved working conditions
ACTRIS Funding Members	Value for money, maximize return of investment. While scientific and technological impacts are usually the priority, funder often demands evidence of additional benefits

ACTRIS Research Performing Organizations	Demonstrate the value of ACTRIS in terms of scientific attractiveness, education, and networking
Scientific Community	New scientific knowledge and developments, opportunities.
Civil Society	Value for money, general benefits to society (e.g., air quality, health, climate change) and connection to local environment and population.
Policy makers	Learn about the overall results of impact assessment with clear communication supported by understandable and solid evidence.
Local/Regional Authorities	Justify investment and increase attractiveness of the area bringing benefits to local businesses and economy; raise attractiveness of local research performing institutions and organizations
National Authorities	Justify large and long-term investments to ministries and political authorities. Demonstrate leadership and attractiveness at national and international levels. Get an overall view of impacts, focuses on the scientific and economic return on public investments.

Recommended tools for engaging with the above-mentioned stakeholder groups are presented in following sections.

Perception survey

Post-event perception surveys are a type of survey conducted after an event or experience to gather feedback and insights from participants, attendees and users. These surveys are designed to assess the participants or users' perceptions, opinions, and satisfaction with the event or service, allowing organizers or service providers to review the success of the event and identify areas for improvement. Typically, post-event perception surveys are administered through online questionnaires. The survey questions can be a mix of closed-ended (multiple-choice) and open-ended (comment-based) questions to gather both quantitative and qualitative feedback.

Post-event perception surveys represent a valuable tool for engaging with stakeholders to express their thoughts and opinions about the experience. This feedback can cover various aspects such as the content, organization, logistics, activities, and overall experience. By analyzing survey responses, event organizers or service providers can identify the strengths and areas that require improvement or adjustments in future iterations. The insights gained from post-event perception surveys can shape or reshape the organizational objectives and decision-making processes.

Impact stories

Impact stories are a qualitative narrative of the processes at stake and their synergies with socio-economic, scientific, political, and environmental context (Griniece et al 2020). An impact story provides a qualitative assessment of the values brought around a specific case study or topic that could not be fully captured with a quantitative assessment. Impact stories are usually developed by a communication officer with a combination of desk research, interview and, possibly, interactions with stakeholders or users. Impact stories should be enriched with visual ways (images, infographics) to create alternatives to extensive narrations. Investing in communication is key to build perception and create a strong link between activities and the information provided to a broad set of stakeholders.

Communication bridges the organization’s strategy to impact, by decoding scientific, managerial, political, economic jargons into a language understandable to all stakeholders. It is logical to think that a combined qualitative and quantitative analysis provides more value than a strictly quantitative approach. Therefore, it should be recognized that some indicators, especially those measuring impacts, which are often intangible, are better described as impact stories rather than numerical metrics.

4.2.3 Defining the key components of ACTRIS impact framework

ACTRIS internal documentation was exploited to define the key components necessary to build up the impact framework following the impact pathways approach discussed in "discovery phase" (Section 4.1.1). The components extend beyond the elements presented by the Theory of Change by including elements that explicitly represents the cornerstones of ACTRIS strategy. These are described in the following sections.

Strategic pillars

ACTRIS strategic pillars are overarching elements or areas of focus within a strategic plan that guide ACTRIS' goals and actions towards its long-term vision. Based on the analysis of ACTRIS documentation, a set of strategic pillars were identified.

- Research – as the provision of assets and resources that propel scientific development.
- Innovation – as the provision of assets and resources that propel scientific, technological breakthroughs.
- Skills (human capital development) – as the strategic efforts to improve education, training, and professional development of ACTRIS staff and external users.
- Science Diplomacy – as the application of scientific expertise and collaboration across national borders to build relationships, promote international cooperation, and address shared issues such as climate change, public health, and technological innovation.
- Management of ACTRIS is included to show evidence related to the organizational performance of ACTRIS and benefits related to the coordination of a large, distributed research infrastructures, and the consecutive benefits to members of the consortium and other interested stakeholders such as the ESFRI, and European Commission.

Impact areas

ACTRIS has defined its operational and management plan as activities that focus on demonstrating evidence of its scientific, economic, technological, societal and sustainable values. Therefore, ACTRIS impact areas have naturally surfaced as a result of reviewing existing internal documents. Considering ACTRIS strategic objectives and their alignment with global and European priorities and challenges, ACTRIS strategic pillars translate into four complimentary and non-exhaustive impact categories (Figure 10):

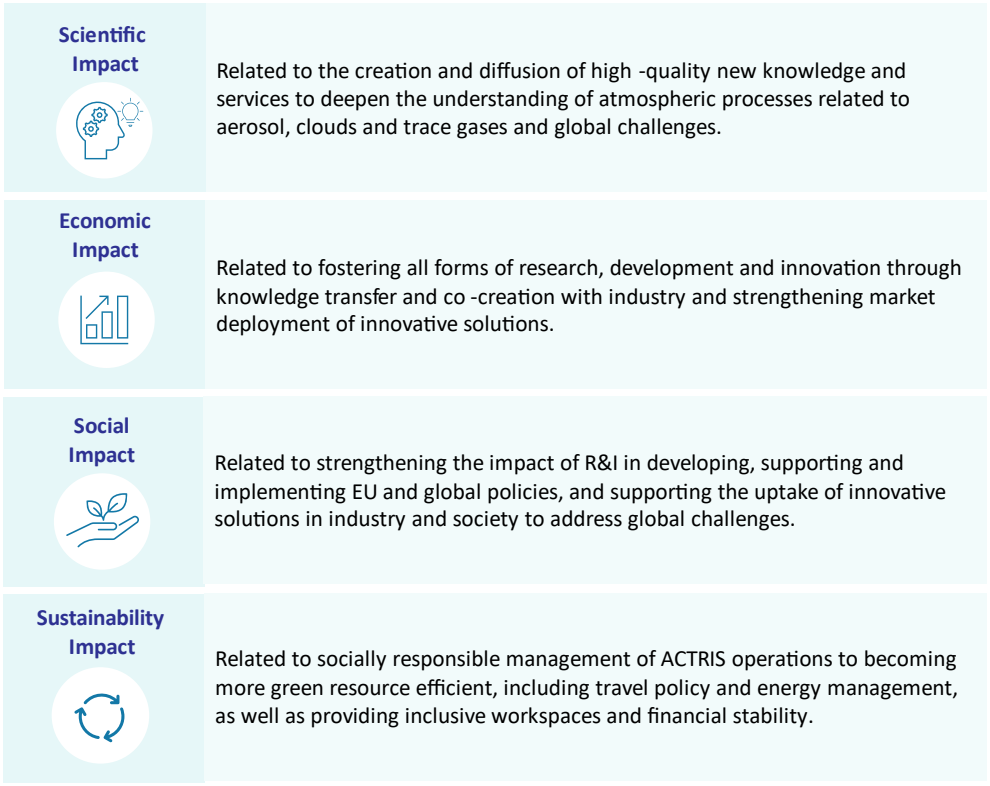

Figure 10. The identified areas of ACTRIS impacts.

Strategic and operational objectives of ACTRIS

The strategic objectives are defined to provide guidance for resource allocation, positioning, service development, partnerships, and other major initiatives that impact the future of the research infrastructure. Considering the ACTRIS Business Plan (2023) four strategic objectives were identified:

- Data Management,
- Service Management & Development,
- Networking & Collaboration, and
- Knowledge Transfer.

Operational objectives are the means through which the strategic objectives are realized. The achievement of operational objectives, reached by successful completion and delivery of ACTRIS activities and operations, collectively leads to the accomplishment of strategic objectives. Operational objectives are more detailed and concrete, closely bound to specific activities and tasks, addressing various functional areas within the organization. Through the

textual analysis of internal documents, the following operational objectives of ACTRIS are identified.

- Increase research efficiency
- Increase ACTRIS resource uptake
- Enhance and facilitate ACTRIS international dimensions
- Enhance and support innovation
- Foster knowledge transfer and collaboration with industry
- Create ACTRIS scientific legacy
- Promote educational outreach
- Provide support and information to policy-makers
- Be an attractive investment
- Assume social responsibility towards society

The list considered may not be exhaustive. Additional operational objectives driven by external factors may require attention and cause adjustments to the operational objectives of ACTRIS.

ACTRIS impact pathways

ACTRIS impact pathways stem from the identified strategic pillars, evolving through strategic and operational objectives, to the foreseen impacts through causal connections and supported by means of evidence. Pathways are built with the intent to build narrative to support the demonstration of ACTRIS values and impact structure. The meaning of pathways is to design a concrete assessment and communication logic (RI-PATHS Glossary).

Based on independent exploitation of internal documentation, in line with the impacts identified for the research infrastructure and that underlie the saliency of ACTRIS strategy framework, fourteen high-level impact pathways are identified to best describe ACTRIS the causal relationships between resources, activities, outputs, outcomes and optimally fit with the impact areas previously defined (Figure 11).

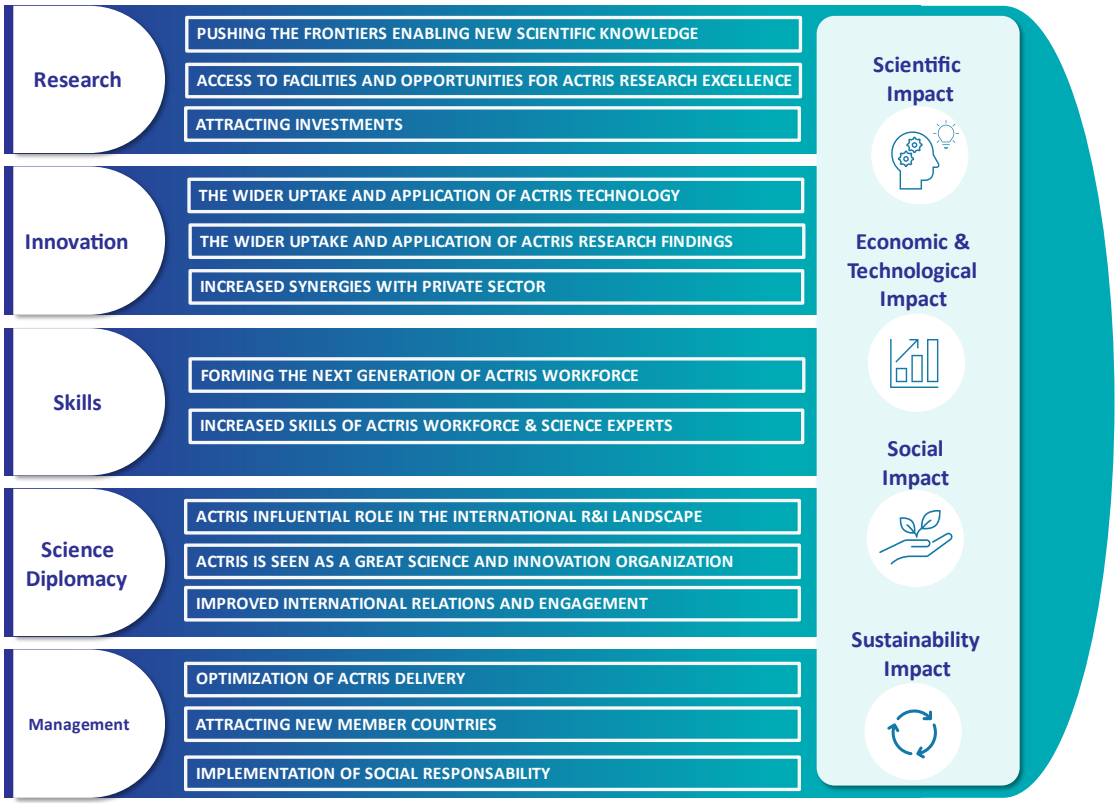

Figure 11. The proposed ACTRIS impact pathways. Drawing upon independent analysis of internal documentation and aligned with the identified impacts crucial for ACTRIS, this figure illustrates the salient features of the ACTRIS strategy framework. Fourteen high-level impact pathways are discerned, providing a comprehensive depiction of the causal relationships between resources, activities, outputs, and outcomes. These pathways are strategically tailored to optimally align with the impact areas previously outlined.

Looking more in details the dimensions cut to track evidence towards each impact area, the pathway to scientific impact “Pushing the frontiers enabling high-quality new scientific knowledge” focuses on monitoring how ACTRIS is being recognized as a global leading entity for developing high-quality standards and standard operation procedures, and other requirements in atmospheric measurements, offering services used by researchers worldwide and its contribution to international networks. Additionally, scientific impacts are created, directly or indirectly, via ACTRIS multi-disciplinary and multi-dimensional data that are accessible through a unique simplified environment. By collecting information through the application and usage of unique identifiers, the back end of the data system behind these pathways should be mining public data automatically from external databases (e.g., publications, citations, acknowledgements, user surveys). The pathway “Access to facilities and opportunities for ACTRIS research excellence” focuses on creating mobility among

researchers fostering cross-border knowledge transfer. The high-level scientific relevance of ACTRIS will be recognized by new research project fundings represented by the pathway “Attracting investments”.

The pathways “The wider uptake and application of ACTRIS technology” and “The wider uptake and application of ACTRIS research findings” focus on collating evidence on the extent to which ACTRIS, acting as an innovation platform, contributes to generating innovation-based growth. The pathway “Increased synergies with private sector” facilitates work and collaboration with actors in the private sector, working towards lowering the limitations and barriers (social, organizational, legal, etc.) that could inhibit interactions between ACTRIS and the private sector. This evidence is based on tracking individual’s outputs (e.g., patents, trademarks and other IPR assets) and well as participation of small-medium enterprises and businesses in ACTRIS related activities. It is planned to introduce identifiers for IPR applications to enhance an automatic retravels of IPRs related to ACTRIS in external databases.

Considering the pathways leading from “Science diplomacy” towards societal impacts, “ACTRIS influential role in the international R&I landscape” focuses on the position of ACTRIS towards becoming a global research infrastructure with activities and opportunities fit for a wider agenda for a, while “Improved diplomatic relations and engagement” focuses on the exchange with national and international authorities about the challenges faced by our society. It tracks data to show how ACTRIS contributes to European policy priorities, such as EU missions, Green Deal, UN SDGs, which collates examples of activities undertaken to reinforce its global significance and impact, following a format (e.g. structured around the Grand Challenges) that resonates with its intended policy sphere audience. A specific pathway “ACTRIS is seen as a great science and innovation organization” focuses on how ACTRIS is perceived by governments, organizations and businesses and their inclination to engage with ACTRIS.

The strategic focus area of “Skills” originates pathways that overlap across social and economic impacts. By the pathway “Forming the next generation of ACTRIS workforce” ACTRIS tracks engagement activities in developing the future generations of science experts bringing benefit to society by increasing the enthusiasm in scientific fields among young generations and promoting science literacy while an increased STEM uptake and job attractiveness bring benefits to the economy. The pathway “Increasing skills of ACTRIS workforce and Science Experts” focuses on the various activities that proving learning opportunities for ACTRIS staff and external users to gain new knowledge skills and experience that can be deployed more widely, increasing quality of scientific outputs, productivity, and

values. It includes teaching ACTRIS staff, users, and other stakeholders how to disseminate ACTRIS achievements and reach put to the public, awakening interest in ACTRIS science and promoting science literacy.

The last set of pathways connect the ACTRIS strategic focus on “Management” to its impact on Sustainability. The pathways, however, should be considered transversally relevant to all the others. If ACTRIS does not prove its sustainability, all the pathways will cease to exist. The pathway “Optimization of ACTRIS delivery” considers all the internal processes devoted to ensuring running ACTRIS operations seamlessly. Sustainability is also reinforced if ACTRIS acquires long-term commitment incomes by attracting new members. Finally, ACTRIS must comply with the most relevant socially responsible conduct to ease its operational impact on the environment.

The fourteen suggested pathways are meant to fit the current phase of ACTRIS. These are not exhaustive and shall be periodically revised to best fit the lifecycle of the research infrastructure and better define the causal link between activities and impacts. Furthermore, to enhance the narrative of ACTRIS added values, the impact pathways, feeding the evidence pool of the three impact areas, can be linked to global framework such as the United Nation Sustainable Development Goals. A proposition is presented in Figure 12. However, it is worth noting that alternatives, or additional global frameworks, could be considered to be included in ACTRIS strategy.

Figure 12. ACTRIS impacts contribute toward creating solutions to support the fulfillment of the selected United Nation Sustainable Development Goals.

Indicators as proxies of impact

Indicators play a crucial role in evaluating values and impacts, drawing data from inputs, activities, and outputs to reflect the operational performance of the research infrastructure. In the context of ACTRIS, it is imperative to adopt relevant indicators to feed the impact framework. Indicators should be chosen following the SMART (Specific, Measurable, Achievable, Relevant, Time-Bound) principles (Doran 1981), ensuring they provide consistent and pertinent information regarding operations aligned with ACTRIS's mission and strategic objectives. In fact, time-boundaries are a crucial aspect of these indicators, necessitating assessment within defined timeframes to monitor developments. However, flexibility is key, and indicators may need periodic revision, either by introducing new ones or removing obsolete ones, to effectively capture and measure evolving aspects as the mission and vision undergo organizational transformations. Moreover, it is essential to complement the indicator framework with the PATHS principles (Bruno & Kadunc 2019). It is relevant for ACTRIS to combine both sets of principles, SMART and PATHS, thereby establishing a comprehensive logic that can be referred to as SMART PATHS logic and visually presented in Figure 13. This logic aspires to create a streamlined and automated indicator management system, reducing the reporting burden on beneficiaries while harnessing ICT tools, such as data mining of unique persist identifiers. For instance, unique identifiers can serve as quantification

measures in reporting and filters to disaggregate indicators based on various criteria like types of actions, sectors, countries, etc., ultimately facilitating a continuous record of ACTRIS's work. These principles should be embedded in the processes of ACTRIS impact management.

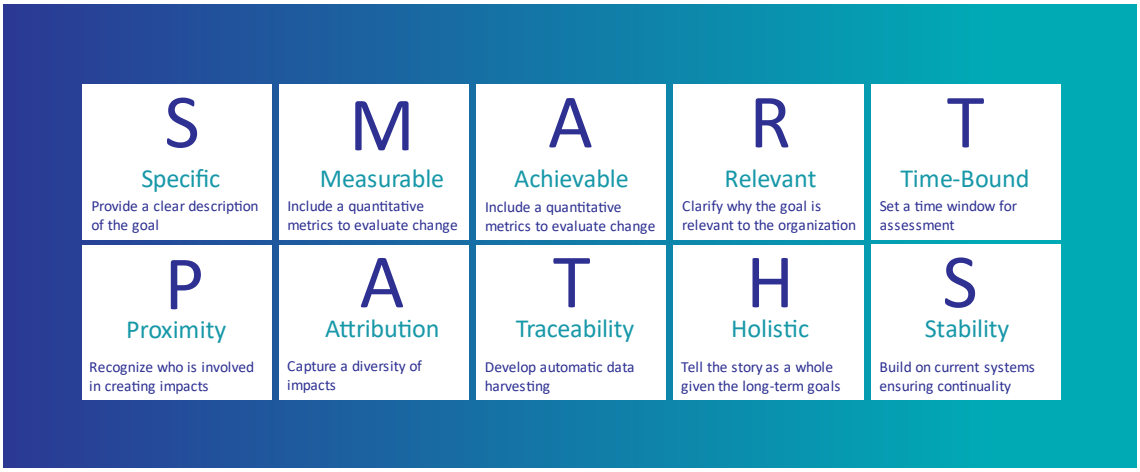

Figure 13. The combination of SMART and PATHS principles, hereafter named SMART PATHS, is recommended being applied to the selection of relevant indicators and metrics.

Therefore, a stronger focus on data collection and its usage can allow us to define and support with evidence concrete storylines. This is a key element in building a high quality and useful impact framework.

4.3 Develop Phase

The third and last stage of the design process is the “develop phase”. The outcomes of this stage are solutions that have been refined to be feasible to the case study of this thesis, as it is based on a thorough research analysis during the “discovery phase”, and tangible, as it builds a prototype of the service product based on the requirements identified in the “define phase”. As the solution concretizes at the end of this phase, stakeholders have been engaged to provide feedback at this stage.

4.3.1 ACTRIS impact framework

The proposed impact framework is based on state-of-art literature as well as learning by other research infrastructure and similar projects. The impact framework combines the key components identified in Section 4.2.3 and demonstrates how they contribute to achieving the overall strategy of ACTRIS. The framework provides a conceptual foundation for understanding the impact assessment for ACTRIS in a high-level structure, focusing on the big-

picture perspective and principles that guide thinking and decision-making, outlining the logical and causal sequence of resources, activities, outputs, and expected outcomes (Figure 14).

Figure 14. The ACTRIS impact framework. This visual representation combines the outcomes of the analysis of the research conducted in the "discovery phase" and the requirements established in the "define phase".

The framework can be iterated on three stages starting with baseline evaluation, followed by the prediction of expected impacts of ACTRIS ('ex-ante' analysis implemented via pathways logics) and completed with the effective measurement of the observed indicator ('ex-post' analysis). Four areas of impacts have been defined, as a cohesive and holistic direction to cluster the relevant impacts and indicators and structure the pathways and linked to relevant United Nation Sustainable Development Goals, as an exemplificatory connection to external influences although alternative solutions may be valid options as well. This utilization of the framework fulfils the primary purpose of the framework that is to inform and demonstrate, based on evidence and narrated via the pathways, of the values and impacts of ACTRIS to stakeholders. The framework also shows a feedback loop that, based on the evidence resulting from the impact assessment, allows for adjustments in the design of the operation and improve the delivery and performance, ensuring also that ACTRIS strategy fits into external and international priorities and directives of the European Commission, The European Strategy Forum for Research Infrastructures, EOSC, Horizon Europe, Europe Mission, for example.

Given the different timelines of the short-, medium, and long-term indicators, the expectation on leveraging the impact pathways and collecting indicators should respect the proposed timeframe of what can realistically be reported and when. To some extent short-term indicators, measuring outputs, have started being collected and reported in ACTRIS since 2018 and today ACTRIS is ready to deploy processes for annual reporting, effectively collecting output indicators. Medium-term indicators, relevant to assess outcomes, can be only partially implemented in each pathway. As this data mainly measures the dissemination and exploitation of the outputs, a full implementation is expected in the next few years. Long-term indicators, relating to impacts, and the wider effect achieved based on the diffusion of the outputs in the economy, society and in the scientific domain, will be taking the longest time to be reported and foreseen to start around 5 years after full operation are in place, thus making this available after 2030. Such a quantitative analysis is considered complementary to the qualitative analysis narrated by the storylines told by the impact pathways and impact stories. A combination of qualitative and quantitative components captures the largest value for stakeholders, keeping in mind the challenges posed by accessing and collecting the necessary data.

4.3.2 Feedback from the ACTRIS Community

The impact framework has been presented during the ACTRIS Week event, held in October 2023 in Heraklion, Greece, and ACTRIS' internal stakeholders have been actively engaged to provide feedback on each component of the framework and on the overall approach selected for the framework through direct discussions and a survey. Here below, the results of the survey on the impact framework are presented.

Most of the survey respondents consist of internal stakeholders affiliated with ACTRIS, with the inclusion of one participant from the private sector partnership. The survey asked participants to express how they would gain from a more defined understanding of ACTRIS impacts. Respondents were encouraged to provide brief input in the form of short sentences, and the subsequent comments were submitted:

- Help in activities related to the dissemination of ACTRIS values to stakeholders
- The increase of ACTRIS impacts will rase the community awareness of our activities
- In getting support of funding agency
- It would show more the impact and meaning of the ACTRIS community strength and opportunities
- Bringing results and standards more into other networks, public and explaining them to policy makers, e.g. European Particulate Matter (PM) limit regulations.

- Help make case for funding to UK Government and Research Councils
- Help with future project proposals related to ACTRIS
- To know what we could/should improve
- Would help to find out what needs to be improved
- Scientifically
- Support my scientific development
- A feeling of usefulness

These responses align seamlessly with the strategic pillars defined in Section 4.2.3.1, specifically Science, Innovation, Skills (Human capital development), Science Diplomacy, and the Management of ACTRIS, as shown in Figure 15. Two additional options, high and assured quality products and services and transnational and transdisciplinary services, were added by the respondents. These were not considered as are falling in the perimeter of the strategic pillars of Science and Innovation.

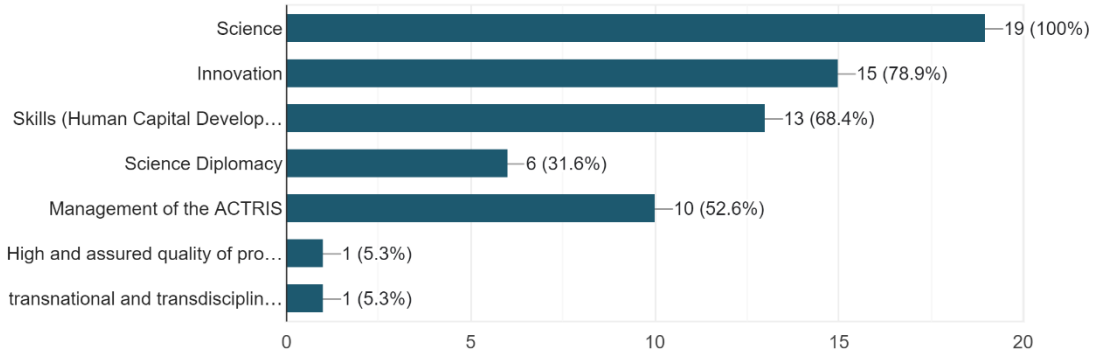

Figure 15. The outcomes of the 19 responses to the question of the survey related to the identification of ACTRIS strategic pillars. Participants could select as many options as needed as well as include their own suggestions. The initial five choices, specifically Science, Innovation, Skills (Human capital development), Science Diplomacy, and the Management of ACTRIS, are put forth as the results emerging from the “define phase”.

The objectives of the impact framework, defined in Section 4.2.1, are directly reviewed in Figure 16, and recognize the primary objective to be the delivery of value to stakeholders. This overarching goal is acknowledged by 90% of the survey respondents. Moreover, the mechanisms associated with impact assessment also serve a valuable purpose for internal processes. Indeed, the survey reveals that the second most significant objective of assessing ACTRIS impacts is to gauge the efficiency, effectiveness, and relevance of ACTRIS activities. The third most important purpose is to support ACTRIS leadership in formulating strategies and enhancing operational decisions. Additional suggestions revolve around justifying long-term investments and identifying areas for improving ACTRIS impacts.

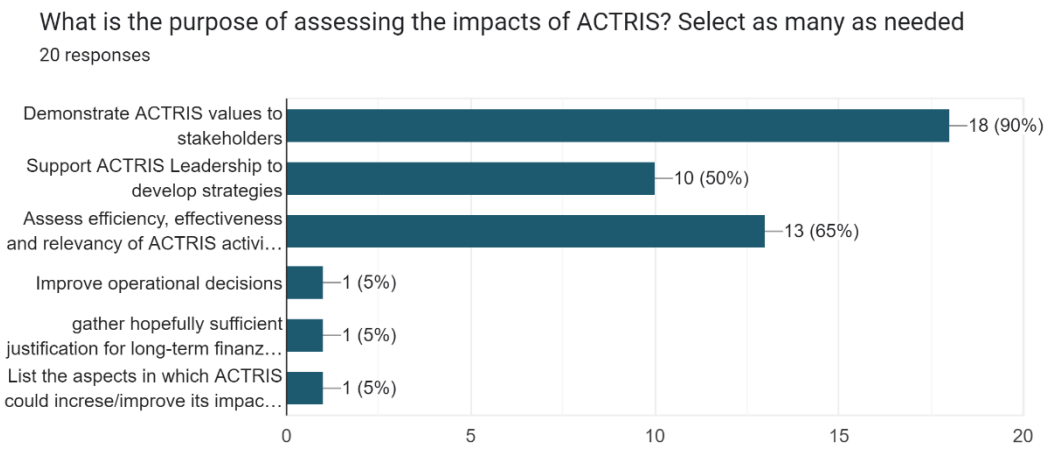

Figure 16. The outcomes of the 19 responses to the question of the survey related to the purpose of assessing ACTRIS impacts. Participants could select as many options as needed and add their own suggestions.

Survey participants were tasked with assessing the current state of communication and dissemination regarding the impacts of ACTRIS. As depicted in Figure 17, a majority of respondents conveyed a generally positive perspective on the promotion and visibility of ACTRIS impacts through various communication channels.

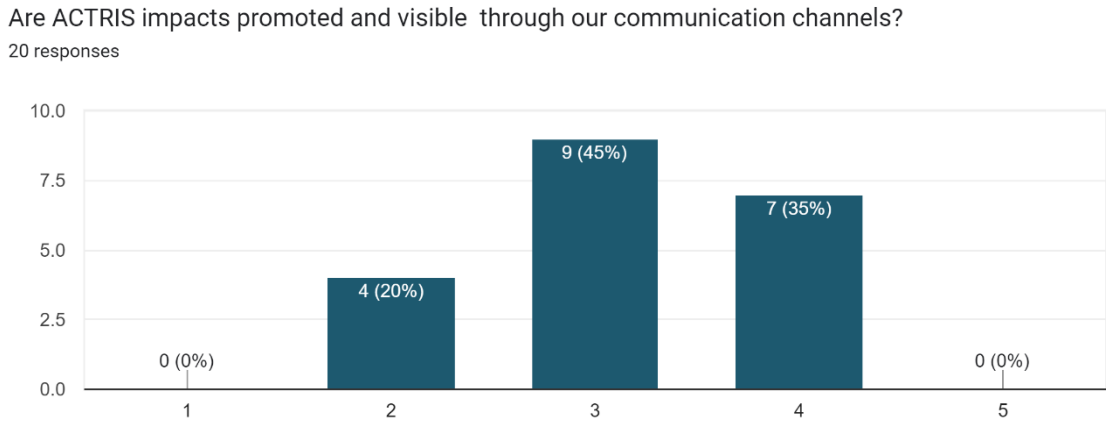

Figure 17. Survey responses on the promotion and visibility of ACTRIS impact via communication channels. The level of satisfaction ranges from 1 (completely dissatisfied) to 5 (extremely satisfied). The questions collected a total of 20 responses.

However, there is a lower level of contentment regarding the quality of explanations about ACTRIS impacts (Figure 18) and underscores the necessity of determining the most effective means of communicating this information to stakeholders, including internal stakeholders.

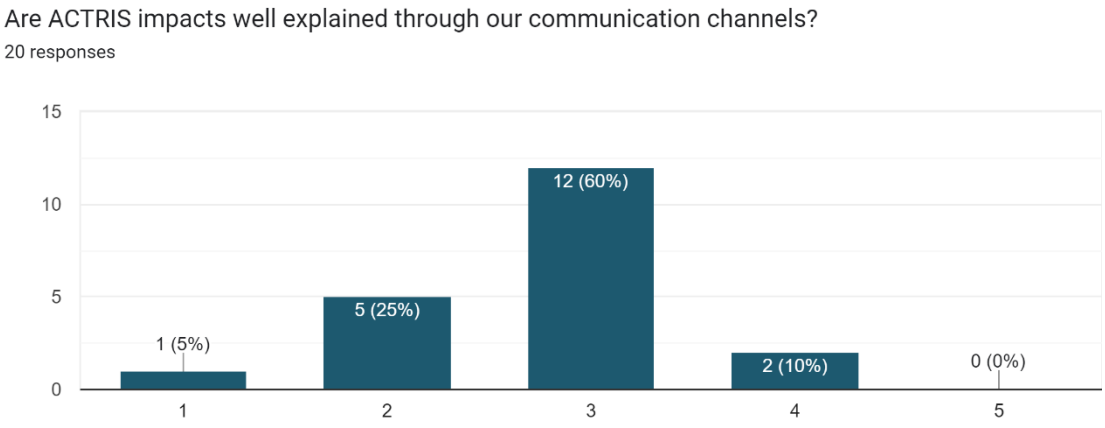

Figure 18. Survey responses on the clarity of ACTRIS impacts. The level of satisfaction ranges from 1 (completely dissatisfied) to 5 (extremely satisfied). The questions collected a total of 20 responses.

Interestingly, none of the survey participants have prior experience with activities related to the impact assessment, here encompassing impact management activities (Figure 19).

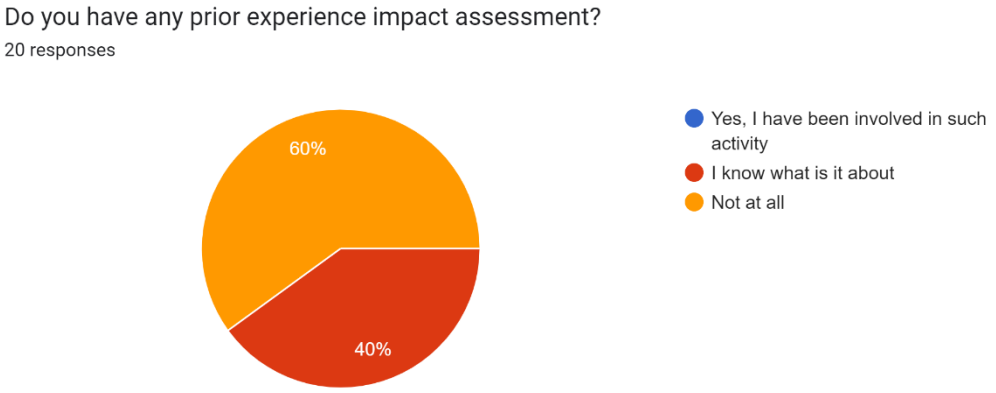

Figure 19. Survey responses on any prior experience with impact assessment. None of the respondents has had prior experience with impact assessment, while 40% of the respondents declare to be aware of what it is about. The remaining do not know what impact assessment means.

Yet, survey participants accurately identify relevant keywords and key concepts associated with the topic, as depicted in the word cloud in Figure 20. Notably, the terms of activity, value, effectiveness are well identified, and the aspects of economic, environmental, scientific and social impacts are the most occurring ones.

Figure 20. Word cloud created with the outcome of the survey representing keywords associated to impact assessment.

Survey participants were asked to indicate the accuracy of the operational objectives identified in 4.2.3. According to the survey outcome, the following operational objectives were prioritized (Figure 21):

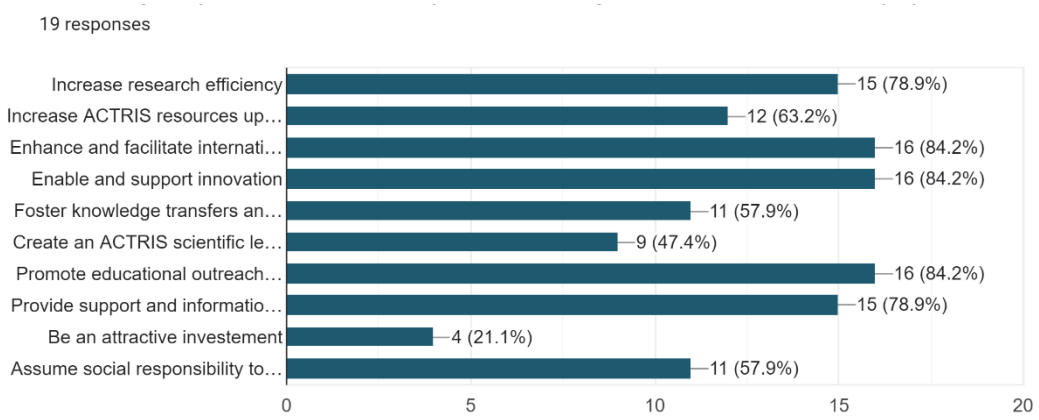

Figure 21. Responses (a total of 19) to the question of the survey targeting the identification of the strategic objectives proposed for the design of the framework. Participants could have selected as many options as needed and added their own suggestions.

ACTRIS has defined its operational and management plan as activities that focus on demonstrating evidence of its scientific, economic, technological, societal and sustainable impacts. In the survey the ACTRIS community recognizes and confirms the impact areas proposed in Section 4.2.3, as shown in Figure 22.

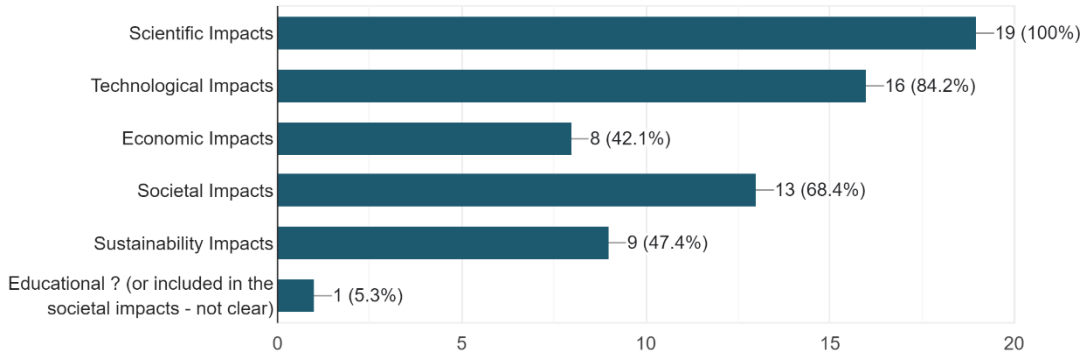

Figure 22. The outcomes of the 19 responses to the question of the survey related to the identification of ACTRIS impacts. Participants could select as many options as needed and add their own suggestions.

4.3.3 ACTRIS impact interface

As shown in Figure 23, the whole ACTRIS impact framework is in practice implemented by a digital interface consisting of a back-end interface, accessible to ACTRIS managers only, and a front-end interface, publicly available, to communicate the collected data visually and inform ACTRIS stakeholders. The back-end is connected to impact management processes, while the front-end relates to the needs for impact assessment and communication.

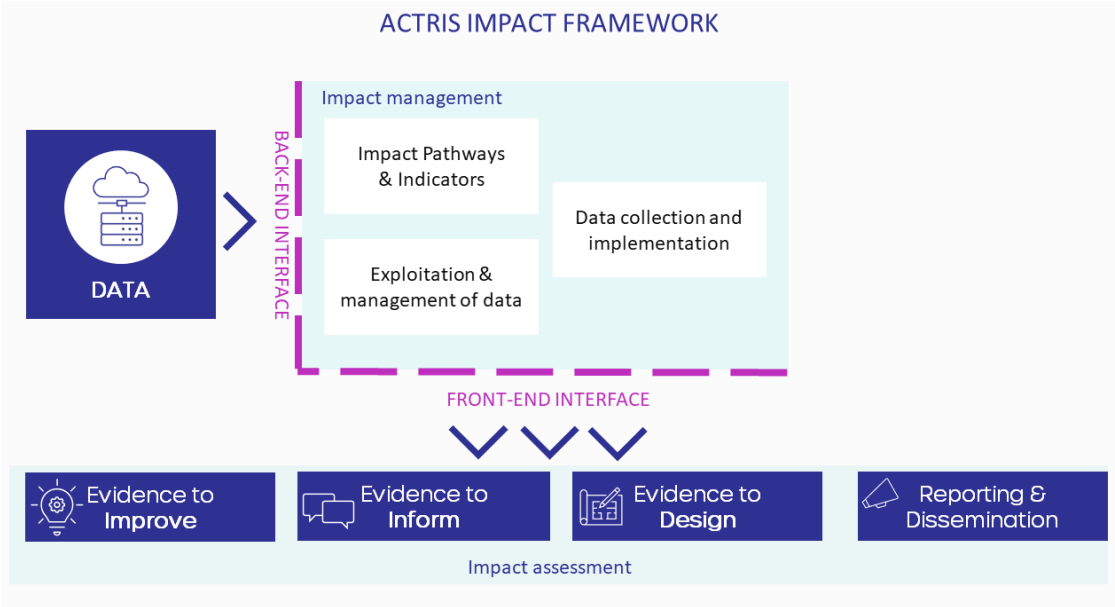

Figure 23. The connection and role of ACTRIS impact interface with the processes of impact management and impact assessment.

The whole system relies on data collection and exploitation following the principles identified in 4.2.3. The developed prototypes for the front-end and back-end offer recommendations and suitable tools that will level-up and optimize the exploitation of data monitoring and evaluation to better design, inform on and improve the services and delivery of ACTRIS. The following two sections describe the details of the back end and front-end mock-up interfaces.

What happens in the back-end?

The entire ACTRIS impact framework is based on data collection mechanisms embedded in the back end of the framework. Any process occurring in the back end of system is in the "backstage" and its processes are known and accessible only to those who are directly involved in managing and overseeing the operations (e.g., ACTRIS managers and leadership).

The indicators selected for quantitative analysis should be categorized into activities, outputs, and outcomes indicators. This categorization, together with tags or keywords, is expected to help data clustering and support the information system needed to build the front-end. Impact indicators are foreseen to be mainly qualitative, supported by triangulation of quantitative data, and follow a thematical categorization based on impact areas, megatrends and other topics. Regardless of being quantitative or qualitative, all indicators should be collected or compiled in an online based "Indicator Manual" where each indicator is described in detail.

Most of the data is provided by ACTRIS internal stakeholders through forms (proposal templates, periodic reporting templates, final reporting templates, periodic external questionnaires). The reporting templates should be designed with the goal of minimizing the administrative burden on the involved people and to simply allow the collection of the information crucial for impact monitoring. For completeness and accuracy stake, the data collected via templates should be complemented with external data sources for counterfactual analysis. This means that what was started by ACTRIS as manual tracking tasks for operational, dissemination and exploitation activities, it should be known become systematic through available ICT solutions and data mining tools.

ACTRIS framework of data – whether sourced from internal stakeholder via periodical reporting or external stakeholders via surveys - is gathered in the ACTRIS data portal, with the only exception for some of the longer-term impact indicators, that may be elaborated through dedicated case studies. Data is collected, stored and shared according to the FAIR (findable, accessible, interoperable and reusable) principles (Wilkinson et al. 2016) and made accessible on ACTRIS website through a set of digital analytical tools and reporting services.

Nowadays there is an availability of resources that facilitate enormously tracking impacts. For example, Overton.io is the world's largest searchable index web-based application that allows users to search and browse a database of policy-making related documentation. As shown by Martin et al. (2021) such a tool would be useful for tracking ACTRIS citation and mentions in the policy sphere but also to understand pitfalls in ACTRIS manual tracking and potentially identify gaps in the strategy. The collected data would build up evidence supporting the goals of the strategic pillar of Science Diplomacy. ACTRIS should develop an automated inventory of publications, citations, or acknowledgements. Citing and tracking mentions via text-mining should be implemented and displayed on ACTRIS website via widgets to demonstrate ACTRIS scientific impacts. Alongside, text-mining of grant agreement numbers and other relevant key terms should also be set up in ACTRIS to measure its own contribution to enhance scientific value linked to the developments of the research infrastructure and its resources. ACTRIS should build a dynamic and interactive ecosystem that takes advantage of text-mining resources and extrapolate results with programmatic tools (e.g., APIs) to create a citation harvesting pipeline. OpenAire (Open Science in Europe) represents one suitable option for ACTRIS: it promotes open science and offers a suite of tools that appear fit to purpose. The use of persistent identifiers in ACTRIS helps to monitor:

- the number of researchers supported through Transnational access programmes access.
- the publicly available information on research affiliation, mobility, career evolution, scientific production, IPR applications, etc. by linking the identifier to external databases.
- the evolution of companies supported through the programme and automatically access their scientific or innovation outputs, turnover, investment, etc. by linking the identifier to external databases.
- Build control groups to allow for counterfactual evaluation design, e.g. by comparing the added benefit of researchers and industry utilizing ACTRIS services versus those not benefitting from ACTRIS

ACTRIS activities are pushing forward co-creating innovative value with both academia and industry sector. Citations and mentions of ACTRIS resources in patent applications and other IPRs assets should be tracked and displayed as a public good to inform science and technology enabled problem solving and as evidence towards building evidence on economic and technological impacts. One valid option offering free, open, and secure patent search and analysis is the tool called The Lens (Lens PatCite). To concretely use the collected indicators, widgets (e.g., dashboards) offer a graphical interpretation of indicators and communicate statistics in an engaging and understandable way that can be easily digested by audiences that are either unfamiliar with ACTRIS or with the specific scientific knowledge behind

ACTRIS, as are found among ACTRIS stakeholders. Several tools are available to connect databases to websites with visualization. For example, data visualization tools such as Tableu (Tableu Dashboard Shocase) can be implemented to combine a variety of indicator visualizations. A prototype of the front-end interface is presented in the next section.

A large amount of ACTRIS coordination work is about connecting its facilities and experts to the scientific communities to foster the uptake and exploitation of ACTRIS services and growing the networks of trained atmospherics scientists, thus increasing research efficiency. It is already part of ACTRIS' operational tasks to collect post-service consumption user feedback through online forms. Such a post-event perception survey approach should be extended to capture the value of collaborating and cooperating by developing dedicated questionnaires to collect participants' perceptions on ACTRIS-funded trainings and flagship events. Perception survey trials could be tested as early as March 2024 during ACTRIS Science Conference where hundreds of attended are expected to participate.

What is shown at the front-end?

The ACTRIS impact dashboard, shown in Figure 24, shall be built as an intuitive knowledge platform created to help visitors to explore and visualize evidence on ACTRIS impacts whether it is for reporting, analysis, monitoring or decision-making purposes. As visual representations (charts, graphs, tables, and other visual elements) are often easier to comprehend and interpret than raw data in spreadsheets or text form, a range of visualization options should be available, allowing users to quickly gain insights from the data. The objective of the ACTRIS impact dashboard is to deepen the common evidence base, identify a toolkit of ready-to-use evidence of ACTRIS added values, and improve communication about the importance of pooling together assets and resources in ACTRIS and fosters a data-driven culture within ACTRIS, where stakeholders across different levels can access and engage with data to make informed decisions. The ACTRIS impact dashboard is an interactive web tool that provides a synthesis of ongoing ACTRIS activities alongside corresponding outputs, outcomes and impacts connected to live data sources, enabling real-time updates and allowing users to monitor changes as they occur, providing immediate insights into ongoing processes or events.

A prototype has been designed to illustrate the crucial role of a dashboard in helping ACTRIS stakeholders understand and digest data by providing a visual appealing and easily accessible representation of key information.

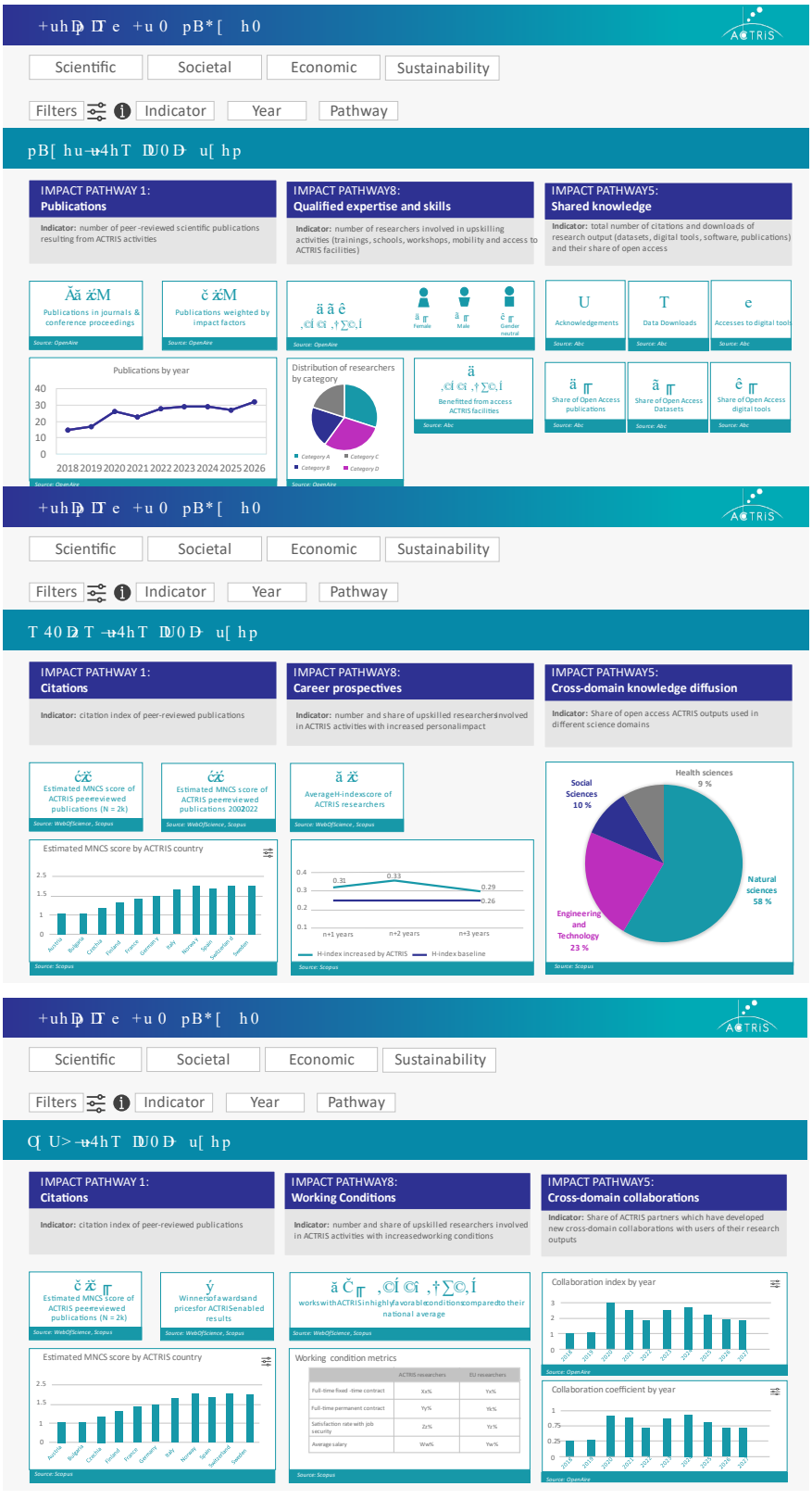

Figure 24. Mock-ups of ACTRIS impact dashboard for short, medium and long term impacts.

With time, it is expected that long-term key performance indicators will be available while key impact indicators will become available. With historical data displayed on dashboards, users will be able to analyze trends and identify long-term patterns. With a larger number of indicators at hand, the ACTRIS impact dashboard could become more customizable to suit specific user needs. Users could filter, sort, and interact with the data to view specific aspects or drill down into details. This interactivity would empower users to focus on the information most relevant to their interests and objectives.

This evidence base will be kept up to date as new contributions, and consecutively new evidence, emerge. It is hoped that a common base of evidence will promote coordination, coherence, consultations, and cooperation as ACTRIS internal and external stakeholders strive to address unprecedented disruptions to atmospheric science.

The activities done within ACTRIS explained with a narrative style often communicate better the impact. ACTRIS impact stories are collected in this section, where visitors can find a repository of impact stories and find the most relevant ones by making use of filters and keywords as shown in Figure 25.

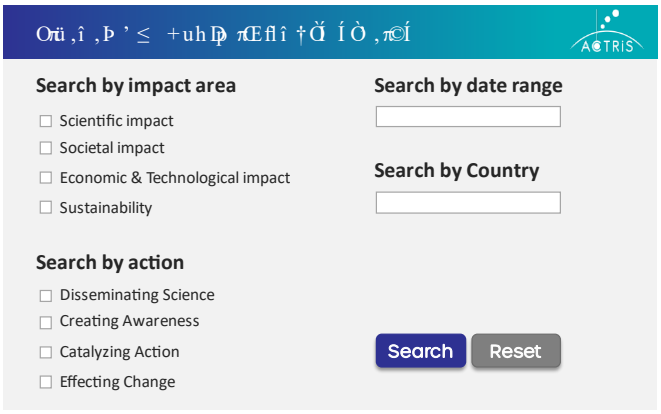

Figure 25. Mockup of library of ACTRIS impact stories

It would be beneficial to include a tag system using general themes to create additional filtering options. Table 5 presents suggested themes, called “actions”, that may be relatively easy to understand for the public and potential quantitative indicators.

Table 5. Actions categorization for tags and corresponding indicators.

Actions	Potential Quantitative Indicators
Disseminating Science	Publications

	Conferences Digital Media activities Trainings, Schools
Creating Awareness	Awards Feedbacks (surveys, focus groups,…) Joint projects Outreach and information sharing among stakeholders
Catalyzing Actions	Technology developments New funding (pilot/research) Participation at policy-making events Partnerships and collaborations Research & Innovation Sustainable Office practices
Effecting Change	Building expert capacity (workforce development) Policy change Social and behavioral change Change instilled (guidelines and recommendations, standards) Sustainable and scalable science
Shaping the Future	Continuous quality improvements implementation of new programs and initiatives Achievement of results towards SDGs

5 Conclusions

5.1 Summary

The purpose of this thesis was to develop an impact framework that supports ACTRIS, a large and distributed European research infrastructure in the field of atmospheric science financially operating as non-profit organization. The need originated from the absence of a clear strategy to demonstrate the organization's values and impacts to stakeholders, a crucial point when public funding is involved. As stated by the members of the ACTRIS Scientific and Innovation Advisory Board "We [the members of the SIAB] strongly recommend that the added value of ACTRIS is clearly expressed in the Business Plan, implementation strategy and other documents." ACTRIS recognized the importance of assessing impacts and the need for effective stakeholder engagement in the context of value co-creation. Therefore, ACTRIS expressed a keen interest in supporting and collaborating on this project, which addressed these critical areas of study. This was the raison d'être of this work.

The development project applied the methodology of service design to make the concept-development more flexible and more user-oriented. Throughout the whole process regular discussions with ACTRIS leadership provided a check point to calibrate the direction of the development project. During the "discovery phase", a thorough knowledge base on the available tools and case studies of research infrastructure impact assessment was built. The literature review provided insights to better understand the needs for ACTRIS as well as what is expected from external stakeholders. In the "define phase" the requirements and key components of the framework were identified. The "develop phase" proposed the impact framework, which combined the core elements and key principles identified in the "define phase", and a prototype for an impact interface to demonstrate values and impact to stakeholders. The impact framework was presented and discussed with the ACTRIS community, including the partners from the private sectors, an occasion to gather crucial feedback and insights. Whilst most of the ACTRIS community did not have previous experience with impact assessment, they showed a large interest in leveraging the ACTRIS values and impacts for their own purposes.

5.2 Answers to the research objectives

In the following section, the research questions initially established at the commencement of the thesis are outlined, accompanied by a subsequent discussion on the nature of the responses yielded throughout the thesis process.

1. Which factors influence research infrastructure to integrate impact framework into their strategies?

Having an impact framework is immensely beneficial for non-profit organizations as it provides a systematic and structured approach to understanding and measuring the outcomes of their activities. Such a framework allows non-profits to assess the effectiveness and efficacy of their programs and initiatives in achieving their intended goals. By defining clear indicators and metrics, these organizations can not only demonstrate the tangible impacts of their work to stakeholders but also enhance accountability and transparency. Furthermore, an impact framework enables non-profits to adapt and improve their strategies based on evidence, fostering a culture of continuous learning and development. Ultimately, the framework serves as a valuable tool for enhancing the organization's overall impact, strengthening its ability to create positive change, and attracting support from donors, partners, and the community.

2. How to account in impact frameworks for the diversity of demands from stakeholders?

Addressing the diversity of demands from stakeholders within impact frameworks requires a thoughtful and inclusive approach. One key strategy is to engage in extensive stakeholder consultation and participation during the development and implementation of the impact framework. This involves actively seeking input from a broad spectrum of stakeholders, including beneficiaries, community members, partners, and funders. By incorporating diverse perspectives, the impact framework can better capture the varied expectations and priorities of stakeholders.

Additionally, employing a flexible and adaptable framework is crucial. Recognizing that different stakeholders may have distinct needs and interests, the impact framework should allow for customization and tailoring of assessment criteria and metrics based on specific stakeholder groups. This flexibility enables the framework to accommodate the diverse demands and expectations, ensuring that the assessment process is relevant and meaningful to a wide range of stakeholders.

Communication is another essential element. Clearly articulating the goals, methods, and intended outcomes of the impact framework to stakeholders fosters understanding and alignment. Regular and transparent communication channels, such as reports and feedback mechanisms, further facilitate ongoing dialogue with stakeholders, enabling them to contribute to the evolution of the impact framework over time. Ultimately, creating an inclusive, participatory, and adaptable impact framework is essential for capturing and accounting for the diverse demands of stakeholders.

3. How can evidence of impacts be effectively collated and communicated?

Effectively collating and communicating evidence of impacts involves a multifaceted approach that combines quantitative and qualitative methods. Implementing an interactive dashboard for quantitative indicators is a valuable tool, allowing stakeholders to visually explore and comprehend data trends. This facilitates a more accessible and engaging presentation of numerical impact metrics, enhancing comprehension among diverse audiences. Additionally, incorporating impact stories as part of the communication strategy adds a qualitative dimension, providing narratives that illustrate the real-world effects of initiatives. These stories humanize the impact data, making it relatable and compelling.

Moreover, it is essential to tailor communication strategies to various stakeholder groups, recognizing that different audiences may have distinct preferences for receiving information. Utilizing diverse mediums such as reports, presentations, and multimedia channels ensures that the evidence of impacts reaches a broad audience effectively. Regular and transparent communication, coupled with opportunities for stakeholder engagement, fosters a continuous feedback loop and allows for the dynamic evolution of impact narratives over time. In essence, a well-rounded approach that combines quantitative tools like interactive dashboards with qualitative elements like impact stories ensures a comprehensive and impactful communication strategy for evidence of impacts.

5.3 Applicability and managerial implications

This thesis showed ways to consolidate organizational practices and paved the way towards the implementation of a sustainable business and value creation models. The current global situation represents an important period for organizations creating innovative and sustainable solutions that help understanding and mitigating the grand challenges faced by our society. Impact assessment is not a secondary goal any longer: it is a core approach for creating values at multiple levels (scientific, economic, technical, societal and environental) for a variety of stakeholders.

The proposed framework was designed to not exclusively focus on assessing impacts of ACTRIS but also provided a feedback loop to improve the strategy and offers of ACTRIS through a proactive stakeholder engagement. Co-design and co-creation of value ensured that the framework is flexible and contextual through the changes of ACTRIS itself and the surrounding scenario. Flexibility is essential for the limitations and challenges identified in impact assessment. ACTRIS and its services are continuously being developed in a constantly changing environment, where science-based information on, e.g., climate change, air quality, is only one of the many factors affecting stakeholder’s decision making. Therefore, isolating the

relative contribution of ACTRIS to a given decision is not trivial and it is important to consider that correlation doesn't imply causality when interpreting the results of the assessment, especially the medium- and long-term impacts. The timescale for capturing impacts poses another challenge. As ACTRIS hasn't yet reached its full scale of operations, it might take years to observe its long-term impacts. This represented a key issue for evaluators, who might be after concrete evaluation before due time. This means that the interpretation of the assessment results must be pragmatic and honest to avoid misinterpreting the impact of ACTRIS and its services, either by overestimating or understating them. While collecting and monitoring ACTRIS management and operational data is relatively straightforward, the challenge in impact assessment lies in devising an indicator framework that allows to capture the outputs, results, and impact over time, while minimizing administrative burden and problems related to uncertainty, attribution and time-lag by adopting the SMART PATH principles. ACTRIS has direct control on activities and outputs, but can only directly influence the extent to which those outputs are used by others and indirectly influence what might change in society because of the uptake of ACTRIS services. But this is no reason to be passive: ACTRIS ought to do what possible to steer ACTRIS research and services towards positive impacts.

As a personal consideration, the knowledge base itself proved to be the biggest value of this development work for the commissioner. Considering that ACTRIS has no specialized staff in this field, ACTRIS leadership now has an overview of what is relevant for ACTRIS and why. This development project journey represented for me an opportunity for professional growth and solidifying my position in strategic communications. The time constraints represented the biggest challenge for the maturity of the framework presented, in particular considering the aspect of co-designing and stakeholder engagement. Time limitations had a toll on the outcomes. Retrospectively, it would have been useful to allow for at least one workshop with internal stakeholders and, possibly, one interview sessions with targeted external stakeholders, e.g., representative of strategic bodies for research infrastructures. A longer period would have perhaps allowed more participation in the survey.

5.4 Transferability of the results

The big picture of this thesis presents approaches to assess impacts of research infrastructure and explains why such framework is a key component of any strategy towards sustainability. This work's outcome highlighted that an intentional and fit-to-purpose design of an impact framework is crucial. This means that the design and its implementation is bound to the organization in consideration thus its transferability depends on organizational similarities. Nonetheless, this work convey also external value as the knowledge base is applicable to any

other research infrastructure or non-profit organization, while the development project as well as the final output of the project- the impact intervention logic- can be used as a blueprint and molded to any other specific organization.

5.5 Future developments

This work is also about change – exploring what is next. It frames the current picture of ACTRIS, that has just undertaken the organizational transformation of becoming a legal entity, about to embark on its next lifecycle towards full operationality. The change in the organization requires a corresponding transformation and update of internal strategy and process to answer new demand and expectation from stakeholders. Change is also what the impact framework is trying to predict, capture, assess and inform in a sustainability context.

Despite the limitations of the framework, the framework is a needed tool to guide ACTRIS managers and leaders through the steps involved in converting ACTRIS operations into change. It will direct ACTRIS Head Office towards leading activities to activate internal discussions to improve and expand the proposed framework so that it can be purposefully adopted by ACTRIS units and put to work. Embedding the framework on ACTRIS activities will pave the way to define more structured and robust strategies (e.g., Sustainability plan, Value chain and Business plan) and to be promptly ready to provide evidence of ACTRIS impact in annual reporting or external requests. Furthermore, it will help ACTRIS voice to speak louder with focused messages that can be communicated using ACTRIS storylines (pathways) or adjusted to megatrends and other widely discussed topics.

Another valuable aspect of the development process has been also illustrating how service design could be applied to research infrastructure. Through this process, ACTRIS took steps to identify the key components of its impact pathways while paving the way for further reflection and collaboration to create transformational communication content.

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Figures

Tables

Appendices

Appendix 1: The survey utilized to collect insight and validate the proposed concepts and solution.

Uncovering ACTRIS impacts

We are thrilled to invite you to be part of the "Uncovering ACTRIS impacts" survey. Your voice is vital to the future of our community, and we believe that together, we can uncover the transformative impacts of ACTRIS.

ACTRIS has always been at the forefront of atmospheric research, and now it's time to reflect on how our collective efforts have influenced and will continue to impact the scientific landscape, environmental policies, and so much more. Your insights will be the key to understanding the ripple effect that ACTRIS has on the world.

Your thoughts and experiences matter, and this survey is your opportunity to share your valuable perspective. By participating, you'll help us shape the future of ACTRIS and ensure that it continues to make a significant difference in the field of atmospheric research and beyond.

The survey is completely anonymous and the data will be used in the Deliverable 10.4 of the ACTRIS IMP project as well as in other publications and dissemination activities. The data will be stored for 12 months, after which it will become obsolete and deleted.

What is your role in ACTRIS? *

- [ ] National Contact Person
- [ ] Member of ACTRIS Central Facility teams
- [ ] Central Facility Leader
- [ ] Member of the RI Committee
- [ ] Project Beneficiary
- [ ] National Facility representative
- [ ] Representative of private sector
- [ ] Representative of another RI
- [ ] Member of the SIAB
- [ ] Other...

What *keywords* do you associate with impact assessment? *

Short answer text

Do you have any prior experience impact assessment? *

- ( ) Yes, I have been involved in such activity
- ( ) I know what is it about
- ( ) Not at all

Part 2 - Tell us about ACTRIS impacts

Description (optional)

ACTRIS creates (select as many as needed): *

Scientific Impact 	Related to the creation and diffusion of high-quality new knowledge and services to deepen the understanding of atmospheric processes related to aerosol, clouds and trace gases and global challenges.
Tech & Economic Impact 	Related to fostering all forms of research, development and innovation through knowledge transfer and cocreation with industry and strengthening market deployment of innovative solutions.
Social Impact 	Related to strengthening the impact of R&I in developing, supporting and implementing EU and global policies, and supporting the uptake of innovative solutions in industry and society to address global challenges.
Sustainability Impact 	Related to socially responsible management of ACTRIS operations to becoming more green resource efficient, including travel policy and energy management, as well as providing inclusive workspaces and financial stability.

- [ ] Scientific Impacts
- [ ] Technological Impacts
- [ ] Economic Impacts
- [ ] Societal Impacts
- [ ] Sustainability Impacts
- [ ] Other...

Are ACTRIS impacts promoted and visible through our communication channels? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very well

Are ACTRIS impacts well explained through our communication channels? *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very well

What is the purpose of assessing the impacts of ACTRIS? Select as many as needed

- ☐ Demonstrate ACTRIS values to stakeholders
- ☐ Support ACTRIS Leadership to develop strategies
- ☐ Assess efficiency, effectiveness and relevancy of ACTRIS activities and operations
- ☐ Other...

How would the analysis of ACTRIS impacts be beneficial to you?

Long answer text

Part -3 Give your input to design ACTRIS Impact framework. See image at full resolution here

What are ACTRIS strategic pillars? *

Strategic pillars are fundamental, overarching elements or areas of focus within a strategic plan that guide an organization's goals and actions towards its long-term vision.

Select as many options as needed.

- [ ] Science
- [ ] Innovation
- [ ] Skills (Human Capital Development)
- [ ] Science Diplomacy
- [ ] Management of the ACTRIS
- [ ] Other...

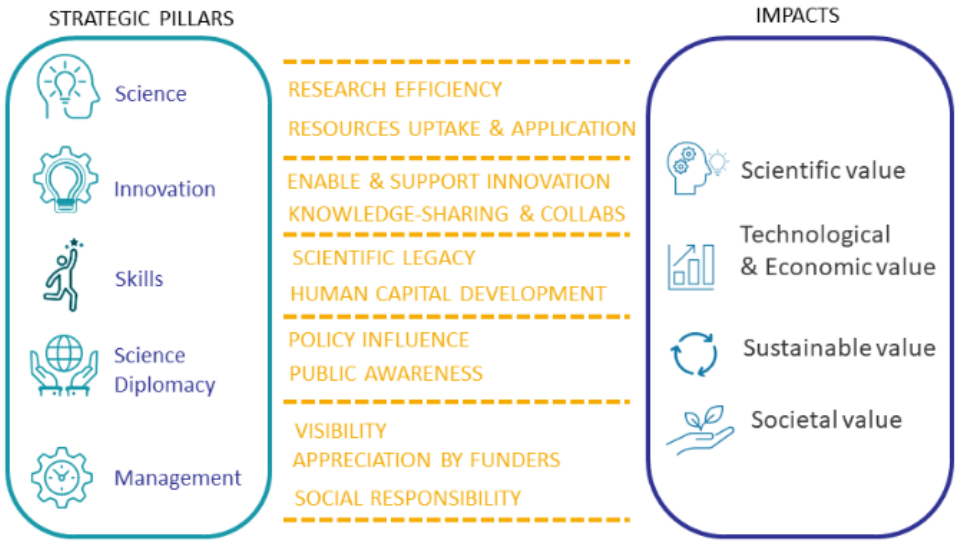
What are the strategic objectives of ACTRIS? They provide guidance for resource allocation, positioning, service development, partnerships, and other major initiatives that impact the future of the research infrastructure. *

Select as many options as needed.

- [ ] Data management
- [ ] Service management & development
- [ ] Networking & collaboration
- [ ] Knowledge transfer
- [ ] Other...

What are the operational objectives of ACTRIS? Operational objectives are the means through which the strategic objectives are realized. Operational objectives are more detailed and concrete, closely bound to specific activities and tasks, addressing various functional areas within the organization.

Select as many options as needed.



- [ ] Increase research efficiency
- [ ] Increase ACTRIS resources uptake and applications
- [ ] Enhance and facilitate international collaborations
- [ ] Enable and support innovation
- [ ] Foster knowledge transfers and collaboration with industry
- [ ] Create an ACTRIS scientific legacy
- [ ] Promote educational outreach and knowledge diffusion
- [ ] Provide support and information to policy-makers
- [ ] Be an attractive investement
- [ ] Assume social responsibility towards society
- [ ] Other...

ACTRIS' research activities create scientific impacts by (select as many as needed) : *

- [ ] pushing the frontiers of new scientific knowledge with purposeful services and solutions
- [ ] offering access to facilities and opportunities
- [ ] enabling the wider uptake and application of ACTRIS-related research findings
- [ ] increasing possibilities for international collaboration and large-scale research projects
- [ ] Other...

ACTRIS' human capital development activities create impacts in our society by (select as many as needed): *

- [ ] forming the next generation of atmospheric experts
- [ ] forming highly skilled RI managers
- [ ] provide highly skilled scientific experts and workforce
- [ ] enhancing job creation indirectly (expert jobs, new business opportunities)

ACTRIS' activities with industry create economic and technological impacts by (select as many as needed) : *

- [ ] facilitating the transfer of measurement technologies and techniques from research to commercial appli...
- [ ] encouraging joint-projects, leading to the development of new tools, instruments, and methodologies
- [ ] stimulating economic growth via collaborative projects between research and industry
- [ ] leading to job creation in areas such as instrument manufacturing, data analysis, and environmental con...
- [ ] by advancing our understanding of atmospheric processes and air quality,which can have positive econo...

ACTRIS' activities focused on science diplomacy create impacts in our society by (select as many as needed)**:** *

- [ ] promoting transparency and facilitating international efforts to address societal grand challenges by ado...
- [ ] Enhancing international collaboration and scientific cooperation across borders
- [ ] influencing policy decisions and leading to more informed and effective environmental regulations and in...
- [ ] building scientific capacity in less-developed regions via collaborative projects
- [ ] promoting cultural exchange and understanding, fostering a sense of global community
- [ ] Other...

ACTRIS' management has impacts on the long-term sustainability of ACTRIS by (select as many as needed) **:** *

- [ ] developing and executing a strategic plan that aligns with ACTRIS long-term sustainability goals
- [ ] maintaining the infrastructure and support needed for ongoing research via efficient allocation of resour...
- [ ] engaging with stakeholders, including funding agencies and the research community, and fostering supp...
- [ ] carrying-on activities that help maintain data quality and instrument reliability, crucial for the credibility a...
- [ ] adapting to changing environmental and research needs to ensure the continued relevance and impact o...
- [ ] by implementing and fostering a socially responsible conduct
- [ ] Other

Connecting ACTRIS Impact framework to external policies and priorities

The United Nations Sustainable Development Goals (UN SDGs) represent a globally recognized blueprint for a more sustainable, equitable, and prosperous future for both people and the planet. These 17 interconnected goals address a wide range of critical challenges, including poverty, environmental degradation, inequality, and climate change. You can find more about the UN SDGs here.

ACTRIS, as a leading player in atmospheric research, has a unique role to play in contributing to the achievement of these goals. By aligning its strategies with the UN SDGs, ACTRIS can leverage its expertise and resources to address pressing global issues and create a more sustainable and resilient world. This integration of the UN SDGs into ACTRIS strategies not only underscores its commitment to global well-being but also enhances its relevance and impact in an increasingly interconnected and sustainable-focused world.

It's worth noting that we acknowledge the existence of other initiatives and frameworks (e.g., the Paris Agreement, the Sendai Framework, Circular Economy Principles, and the One Health Approach) that share common objectives with the UN SDGs, all directed at addressing global challenges. Nevertheless, we maintain a primary focus on the UN SDGs due to their central importance in guiding our efforts.

You can find more about the UN SDGs here.

ACTRIS scientific impacts contribute to the following UN SDGs (select as many as needed)

- [ ] SDG 13 Climate change
- [ ] SDG 12 Responsible consumption and productions - via responsible and relevant innovation in atmosphe...
- [ ] SDG 9 Industry, Innovation and Infrastructure - via responsible and relevant innovation in atmospheric sci...
- [ ] SDG 16 Peace, Justice and Strong Institutions - via user satisfaction
- [ ] Other...

ACTRIS technological and economic impacts contribute to the following UN SDGs (select as many as needed)

- [ ] SDG 8 Decent Work and Economic Growth - via innovation and new business opportunities
- [ ] SDG 9 Industry, Innovation and Infrastructure - via innovation and new business opportunities
- [ ] SDG 12 Responsible Consumption and Productions - via responsible innovation culture
- [ ] SDG 16 Peace, Justice and Strong Institutions – via user satisfaction
- [ ] Other...

ACTRIS impacts on society contribute to the following UN SDGs (select as many as needed)

- [ ] SDG 3 Good Health and Well-being – via health, occupational and operational safety
- [ ] SDG 4 Quality Education – via evidence-based communication, outreach and support
- [ ] SDG 8 Decent work and economic growth - via health, occupational and operational safety
- [ ] SDG 11 Sustainable Cities and Communities – via evidence-based communication, outreach and support
- [ ] SDG 13 Climate Change - via evidence-based communication, outreach and support

ACTRIS impacts on sustainability contribute to the following UN SDGs (select as many as needed)

- [ ] SDG 4 Quality Education – via evidence-based communication, outreach and support
- [ ] SDG 8 Decent work and economic growth - via health, occupational and operational safety
- [ ] SDG 10 Reduced Inequality - via equal opportunities
- [ ] SDG 16 Peace, Justice and Strong Institutions – via implementing a trustworthy governance
- [ ] SDG 12 Responsible Consumption and Productions - via responsible management of resources
- [ ] Other...

This space is for you to leave any further comment.

Long answer text

Thank you for your contribution!

Description (optional)