The Performance Gap of Policy Information Systems: A Knowledge Infrastructure Assessment Framework

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Executive Summary: Digital technologies' development and their ubiquity has significantly changed the way information is collected and shared. These changes are also observed in the ways that knowledge and information used to design and implement Science, Technology, and Innovation (STI) policies are increasingly made accessible via digital platforms. Lacking, however, are evaluation frameworks to measure the performance and effectiveness of public information systems used for STI policy work. This limits what we know about what aspects work for whom, when, and why. As a response to this gap limiting our collective capacity for improving their utility, this paper presents an assessment framework tool for STI policy-focused digital knowledge platforms. Our proposition is informed by theoretical lessons from the areas of work on Knowledge Infrastructures (KIs) and Next Generation Repositories (NGRs), and practical experiences from policy professionals working in STI policy domains. The tool's architecture is structured around three interdependent thematic pillars of performance in the production, aggregation, distribution, and maintenance of knowledge in digital information platforms: the *communities* pillar, the *technical systems* pillar, and the *sustainability* pillar. To test the design and utility of our proposed evaluation framework, we applied it on a digital platform of STI policy instruments maintained by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the Global Observatory for Science, Technology, and Innovation Policy (GO-SPIN) platform. We conclude with reflections on future areas for evaluation framework development.

I. Introduction

The internet's expansion and the global use of digital technologies has led to a significant shift in how information is produced, collected, and shared. Expertise is moving from a professional or studied individual perspective to the wisdom of crowds, "noisy and endlessly contentious, but also rich, diverse, and multi-skilled" (Borgman et al. 2013, 7). In this context, Schatz (1991, 88) defined the concept of electronic community system as "a computer system which encodes[1] a community's knowledge and provides an environment which supports manipulating that

[1] "Encode" is "changing information into a form that can be processed by a computer". Oxford's Learner's Dictionary, Oxford University Press.

knowledge" (Schatz 1991, 88). Schatz noted that scientific research was a good domain to investigate these systems, as the community of scientists needs access to a wealth of knowledge in order to carry out their research. In addition to formal scientific knowledge, Schatz observed that accessing and spreading informal knowledge more extensively via electronic systems could improve scientific research's quality and efficiency. The idea is that having access to such information might encourage novel interdisciplinary research among diverse scientists. Additionally, these benefits contribute to the sense of being part of a community. In order to support a community electronically, the technical system needs to encode as much of the group's formal knowledge, informal knowledge, and interrelationships as possible.

The concept of electronic community systems identified by Schatz later evolved into the idea of Knowledge Infrastructures (KIs), a term Paul Edwards coined (Borgman et al. 2013, 5). Edwards defined it as "robust networks of people, artefacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds" (Borgman et al. 2013, 5). Academia dedicated to analysing such infrastructures has widely used and explored the concept. Scholars characterise KIs as systems which have a radically blurred division between knowledge producers and consumers. The resulting open data sources strongly stimulate public interactions, making STI-related information readily available and abundant (Borgman et al. 2013, 5). In this way, KIs have challenged traditional ways in which knowledge was produced and consumed before the internet's existence (for example, publishing through printed journals or networking by attending conferences).

Due to their fast expansion and strong potential, KIs could bring enormous benefits by systematising and centralising STI-related information. In particular, this paper focuses on information related to designing and implementing STI policy. This information is a crucial driver for development and hence of great public value, key to achieving transformative changes in economic, social, environmental, and political systems. In 2015, all United Nations (UN) Member States adopted the UN's 2030 Agenda for Sustainable Development, providing a roadmap which has at its heart seventeen Sustainable Development Goals (SDGs)[2] to be achieved through a global partnership involving developed and developing countries.

At its core, the 2030 Agenda aims to end poverty and other deprivations affecting access and quality of health and education, reduce inequality, and incentivize economic growth while tackling climate change and working to preserve and protect the environment. Three months prior to the 2030 Agenda, the Addis Ababa Action Agenda was adopted as an outcome of the 2015 Third International Conference on Financing for Development. Nearly all UN member states, the International Monetary Fund (IMF), the World Bank (WB), the World Trade Organization (WTO), representatives from the private sector, and civil society leaders attended. The Addis Ababa Action Agenda called for establishing an online platform as a gateway for information on existing STI policy initiatives, mechanisms, and programs within and beyond the UN (Walsh, Murphy, and Horan 2020, 6). Supporting a similar idea, in his blog posting dated March 20, 2020, in *geoffmulgan,* G. Mulgan 2020 argues for the need to orchestrate collective intelligence around each of the SDGs, by bringing together evidence, useful knowledge, peer networks, and datasets.

Given this new UN initiative and reliance on online platforms to share STI-related policy knowledge that is key to development, a clear need exists for an evaluation framework that can assess the performance and effectiveness of such multi-layered public information systems to evaluate their ability to generate public value through developing science policy. This would inform knowing what works for whom, when, and why. Yet, an extensive literature search revealed that adequate frameworks to properly evaluate such platforms are lacking. Therefore, this paper

[2] SDG 1: No poverty; SDG 2: Zero hunger; SDG 3: Good health and well-being; SDG 4: Quality education; SDG 5: Gender equality; SDG 6: Clean water and sanitation; SDG 7: Affordable and clean energy; SDG 8: Decent work and economic growth; SDG 9: Industry, innovation and infrastructure; SDG 10: Reduce inequality; SDG 11: Sustainable Cities and Communities; SDG 12: Responsible Consumption and Production; SDG 13: Climate Action; SDG 14: Life Below Water; SDG 15: Life On Land; SDG 16: Peace, Justice, and Strong Institutions; SDG 17: Partnerships for the Goals. See: https://sdgs.un.org/goals (Accessed January 12th, 2023).

argues for an assessment tool with the objective of making STI policy information more salient for current and potential users involved in different knowledge areas (scientists, researchers, universities, private sector, international organisations, among others). The need for adequate online platforms to share information of high public value became even more evident with the global COVID-19 pandemic. During the pandemic, a coordinated policy response was crucial, yet available knowledge and technologies were unable to provide reliable and timely information (da Silva, Chammas, and Novaes 2021, 3).

This paper is divided into five sections. The first section describes the theoretical framework on which the work is built. The second one explains the methodology used to develop the assessment tool, which includes an extensive literature review, semi-structured interviews, and surveys. The third section unpacks the assessment tool, explaining its three main pillars. The fourth section uses the Global Observatory for Science, Technology and Innovation Policy (GO-SPIN) platform maintained by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a case study to showcase the tool's implementation. Finally, the fifth section discusses the work's findings and conclusions.

II. Digital platforms for science, technology, and innovation (STI) policies: An assessment gap

An extensive literature review revealed adequate frameworks to properly evaluate STI policy-related online platforms are lacking. Nonetheless, the two main fields of research, which are centred around the concepts of KIs and Next Generation Repositories (NGRs), respectively, both emphasise applying guiding principles in the design phase, useful for building an assessment tool. In this section we first explore the concepts associated with KIs, followed by the ones associated with NGRs. We then build upon these to describe our design of the assessment tool in section three.

After identifying KIs' main characteristics, Borgman later expanded on the idea of networks, underlining that KIs are multi-layered efforts of numerous systems, each with unique origins and goals. Such systems interoperate "by means of standards, socket layers, social practices, norms and individual behaviours that smooth out the connections among them" (Borgman et al. 2020, 3). This includes, for example, having an engine to search across various STI policy datasets, as well as publications' metadata from key international organisations and academic journals. Such an association interconnects the platform to various sources that build knowledge on different layers (Paunović, 2008,2-3). The concept of electronic community systems later evolved into the idea of KIs, such as Common Language Resources and Technology Infrastructure (CLARIN).

The European Research Infrastructure Consortium (ERIC) originally governed and coordinated CLARIN with initial financial support from the European Commission. Participating countries (mainly from the European Commission) currently fund CLARIN. CLARIN's objective is to sustain a system for sharing and using language data and tools for research in the humanities and social sciences from all over Europe. It provides access to digital language resources and tools and connects different types of institutions, such as universities, research centers, libraries, and public archives. Its language resources are interoperable (they can be combined and chained from different sources) and interconnected (they can be explored through a unified catalogue of repositories or by accessing them individually). The repositories include tools for disseminating digital research data, phonetic tools, and other language resources. Each of CLARIN's member countries has a national consortium, usually consisting of various types of centers (universities, research institutions, libraries, and public archives). The designated head of each national consortia participates in the National Coordinators' Forum (NCF). The NCF together with the Standing Committee for CLARIN Technical Centres (SCCTC), consisting of the center directors (or representatives that center directors designate), ensures cross-center and cross-country collaboration, integration, and interoperability of the infrastructure components.

CLARIN's governance frequently organises conferences, workshops, and other events.
Since KIs have both a human and technological dimension, they include complex socio-technical factors (Borgman et al. 2020, 2). Their technical systems and standards serve communities interested in creating and sharing knowledge. Therefore, the systems of layers from which KIs are built upon include both social arrangements and the technologies serving them, as they continuously shape and constrain KI's interaction

(Pasquetto 2018, 6-7). As a consequence, even though the process of sharing and consuming knowledge has become more distributed and participative, its complexity makes KIs challenging to understand for both those studying them and those involved in developing and using them (Karasti et al. 2016, 2).

In spite of KIs having significant benefits, a system where data is flowing in readily exchanged open formats can lead to misunderstandings. For example, scientists from one discipline misinterpreting or misusing data produced by another. In these types of systems, data is often crowdsourced, and therefore its quality might be weak or have a suspicious origin (Borgman et al. 2013, 7). This problem is particularly important in science where the meaning of data is dependent on how, where, and when it is collected and disseminated (Borgman 2013, 6).

From the perspective of information studies, Borgman *et al.* observed that any data can be used as evidence if it complies with the community's definition of what evidence is and its "representations of observations" (Borgman et al. 2018, 4). Pasquetto (2018) stresses the role of transparency and data creation's conventions in influencing data's evidentiary power (Pasquetto 2018, 10-13). Aside from distinguishing the need for data's ability to be reused, the literature also raises concerns regarding negative factors associated with KIs. Borgman *et al.* (2013) mentions that KIs tend to develop and elevate certain types of knowledge, while also undermining and limiting access to other types. Additionally, KI business models can constrain participation to modes that only generate profit for the platform's creators (Borgman et al. 2013, 11). These discussions become complex in policy issues as they convey decisions that are not solely technical but also social and political. This is especially problematic in the case of STI policy, given its proximity with science, which may overshadow its social and political aspects.

While the KI literature concentrates on developing the theoretical concepts of communities and understanding the processes existing within these infrastructures, the NGR concept developed by the Confederation of Open Access Repositories (COAR[3]) mainly focuses on developing and uncovering the common practices that these systems need to adopt to operate better. The primary difference between KIs and NGRs is the more theoretical focus of the former and the more practical application of the latter.

From COAR's perspective, since repository platforms technologies and protocols used in NGRs were designed before Internet access and wide use of digital devices, repositories were developed as passive, siloed recipients of digital data. This has prevented them from exploiting their full potential (Shearer et al. 2016, slide 5). To address this issue, COAR identifies best practices, protocols, principles, and uniform behaviours that repositories should follow to increase their reach, impact, and usability for creating digital repositories for the next generation (Rodrigues et al. 2017, 6).

According to COAR, NGRs should be built around six guiding principles: distribution of control, blurring the line between data providers and data users; inclusiveness and diversity of different types of users to respond to different needs and contexts; data should be treated as a public good and thus made available for everyone; openness and accessibility should be guaranteed following internationally recognised FAIR and TRUST principles to maximise data reuse[4]; sustainability should also be considered in order to ensure continuity and consistency in the long-term; and, interoperability should be a priority, to be able to connect with other repositories, and build networks of knowledge (Rodrigues et al. 2017, 8). They should actively preserve and update the content held in NGRs, as well as make sure that easily exchanging information with other repositories is possible (Shearer et al. 2016, 9).

Aside from the technical aspects, incorporating users' input and developing use cases that help to maximise repositories' usability and accessibility are necessary for achieving the NGRs' standards. NGRs should also have a system to monitor and evaluate their impact developed with users'

[3] Confederation of Open Access Repositories. 'COAR Next Generation Repositories: Vision and Objectives'. Available at: https://ngr.coar-repositories.org/ (Accessed February 27, 2022).

[4] FAIR and TRUST principles will be developed in Pillar 4 in section III "Results: The assessment tool" (when referring to the Technical system).

contributions. Furthermore, relevant repositories need to be aligned in terms of practices and taxonomies. This includes following common standards, developing pragmatic simple design, and encouraging machine readability. These behaviours are important to strengthen connection and cooperation among repositories, while favoring interoperability (Rodrigues et al. 2017, 9).

Both concepts of KIs and NGRs are useful for identifying best practices for STI platforms, in particular those pertaining to science policy. Note that since KIs make a more explicit distinction between social and technical dimensions, the term will be used throughout the paper when referring to repositories in the broad sense.

III. Methodology for developing an assessment tool

The proposed assessment tool draws from concepts in the KI and NGR described previously. Designing the assessment tool included a general literature review, a review of existing KIs, semi-structured interviews, and surveys.

The literature review's overall aims were to explore and understand digital knowledge platform initiatives and to engage with broader theories and concepts relevant for developing a comprehensive assessment tool. The literature review encompassed both academic sources (papers, books, theses, and formal presentations), which led to identifying sixty-three relevant documents. A review of existing digital knowledge repositories and their associated documentation focused on STI policy-oriented findings (data repositories that specific professionals or the general population can access to obtain information that helps decision-making). However, to expand on possible practices of data collection, management, and delivery, a few other platforms that could have similar user interfaces or usability were also considered. A total of thirty digital repositories were analysed (Appendix). All the literature (academic and repositories) included in the review was selected using a combination of keywords and snowball searching.

For the latter, standardised guidelines were created to ensure homogenous research practices within the team. The researchers searched for words or combinations of words, including "repository"[5], "digital knowledge infrastructure", "digital platform" and "STI repository", and "STI repository best practices", in English and Spanish. Both open source (Google) and academic (Scopus) search engines were used. The findings were summarised and organised in templates to facilitate content analysis and data comparability. In addition to the review of the literature and repositories, a total of nineteen individuals took part in semi-structured interviews between June and August 2020. Interviews were conducted to obtain in-depth first-hand information. They also allowed for more open conversations, better engagement, and for new relevant topics to emerge.

Three different types of experts were interviewed individually to gather relevant information on different aspects of how KIs are used. The interviews focused mostly on science policy-related KIs, but at times, other topics that could provide valuable information were explored. First, policymakers and STI policy officials from governmental and non-governmental contexts were interviewed. From these eight interviews, we identified common uses and practices within the STI and SDG research landscape.

Next, we interviewed six Information Technology (IT) and repository managers regarding technical insight and practices on supporting and maintaining digital repository platforms. Finally, five academic experts were interviewed on identifying different dimensions of KIs and NGRs, including what good practices to adopt for their sustainability.

Each interview was then transcribed using matrices. The transcription matrices were built according to the research objectives and based on a preliminary analytical framework created in light of both the literature review findings and the interviews' raw information. Once the individual transcription matrices were completed, a unified matrix was built. This process allowed for a transversal and comparative content analysis for each of the analytical categories to identify consensus, controversies, and distinctive ideas (Stemler 2001, 1). Data obtained via the various methods were triangulated (Denzin 1978, 295) to

[5] The paper understands the term repository and platform in a genus species relationship. Thus, platforms are considered to be digital repositories.

ensure the information's validity and to limit bias. Through triangulating, theoretical dimensions were tested and made more robust.

Finally, a qualitative online survey was disseminated through targeted emails and advertised via LinkedIn, with a total of twenty-seven non-state experts and twenty-nine civil servants responding. The purpose of the surveys was to reach out to a broader audience of digital knowledge repository users. The survey questionnaires contained similar questions to the ones used when interviewing policy makers and STI policy experts in order to validate ideas covered in those interviews, to find new issues, and to enrich the diversity of participants.

IV. Results: The assessment tool and theory of change

i. The assessment tool

The KI literature revealed both a gap in communication between the different theories (KIs and NGRs) and a lack of tools for assessing them. When assessing the platforms' usability based on the experience of data collectors', curators', and users' experiences, the analysis showed that KIs can only exist as the result of a set of relevant stakeholders interacting. These individuals form communities and rely on the repositories' technical systems. Additionally, a KI's success and relevance depends on whether it can sustain its operations over time. The analysis identified the three main themes of *communities, technical systems,* and *sustainability* as assessable themes of the KI skeleton. Therefore, the analytical tool was organised into three interdependent pillars that embody such themes, which are described below.

Pillar I: Communities

At the heart of KIs lies communities of people that drive the flow of knowledge within the system. Communities are essential to both generate and utilise the knowledge KIs provide.

Different stakeholders constitute communities. They are involved with the infrastructure and can act as users, data providers, or KI curators. Since a KI's success depends on its communities' support, knowing the communities and engaging with them is key to ensuring that a KI functions effectively. Therefore, the first pillar is concerned with how KIs characterise their communities and engage with them to understand their needs, expectations, and their organisational culture, practices, and governance structures. After characterising communities, the most adequate engagement strategy can be identified in order to obtain value from the information created and provided through the KI. This objective will be achieved if communities understand the importance of contributing to the KI, both by collecting the data for inputting in the KI and evaluating its usefulness. Implementing an adequate communication strategy to increase awareness of the platform is crucial for the latter.

We provide here further guidance in assessing Pillar I (*Communities*):

Characterization

- Who are the communities around the KI (e.g., intended users, data providers) and which groups of stakeholders constitute them (e.g., civil servants, researchers, industry)?
- What are their needs, expectations, and capabilities?
- How can each group contribute to the KI?

Engagement

- What is the best engagement strategy for each group of stakeholders?
- What is the mechanism to ensure that the communities understand the KI and recognize its value?
- What is the best way to encourage the communities to contribute to the KI (both when collecting and evaluating data)?
- What is the best communication strategy to increase awareness of the platform?

Governance Structure

- How are different groups of stakeholders (e.g., policymakers, academics, technicians) organised and governed?
- Can existing institutions or groupings be leveraged to maximise reach (e.g., academia, NGOs)?

Pillar II: Technical system

While the success of KIs depends on their communities' support, establishing reliable technical systems ensures their stability. Technical systems' reliability can be assessed through adhering to principles on the data characteristics contained in a digital repository (FAIR principles; Wilkinson *et al.* 2016, 4) and to the repository's attributes (TRUST principles; Lin *et al*. 2020, 2).

The "FAIR Guiding principles for scientific data management and stewardship" seek to address the lack of good practices for publishing scientific data. "F" stands for "findable", "A" for accessible, "I" for interoperable, and "R" for reusable. FAIR principles offer a set of specific and measurable qualities for data to have when published without specifying technological implementation (Wilkinson et al. 2016, 1). To ensure FAIR data, having digital repositories capable of managing and organising data through reliable infrastructure and policies is necessary (Lin et al. 2020).

In addition to implementing the FAIR principles, numerous standards and certifications to evaluate repositories' reliability exist. They focus on organising repositories, managing the digital objects they contain, repositories' technical infrastructure, and managing security risks (Lin et al. 2020, 2). While repositories' administrators often value such certifications and audits, audiences do not understand them, and these regulations do not incentivize communities' engagement. Since funders and users need to be involved to ensure a digital repository's reliability and to strengthen the sense of community, the TRUST principles were designed to facilitate their interaction and bring together stakeholders in judging the repository's reliability. TRUST stands for Transparency, Responsibility, User-focus, Sustainability, and Technology.

Furthermore, since KIs do not work in silos, interconnectivity and interoperability with multiple KIs are other essential dimensions when assessing them in relation to their technical pillar. Crucially, they need to connect with others within the ecosystem to increase their reach, impact, and, more importantly, to ensure their relevance over time. In this sense, noting how data flows within the digital repository and across other repositories is critical. Thus, the technical features that guarantee interoperability and interconnectivity with similar data also need to be identified. The data journey within a KI starts with collecting data from different data sources. Data is then validated to ensure its reliability. After being organised, the data is published in the KI and shared publicly.
We provide here some further guidance in assessing Pillar II (*Technical System*):
Principles

- Does the digital repository embed the FAIR and TRUST principles?
- Is the digital repository publicly accessible?
- Does the digital repository use standardised practices, protocols, and principles to ensure interoperability with similar platforms?

KIs' Ecosystem

- Do other similar and relevant repositories exist?
- How does this platform add value to the wider knowledge ecosystem?
- Does the digital repository contain technical features that guarantee its interoperability and interconnectivity with other relevant platforms?
- How does data flow within the repository? Does it cover the whole data journey, from data collection to data delivery?
- Does the repository provide space for relevant stakeholders to interact and encourage meaningful discussions?

Pillar III: Sustainability
A KI's long-term existence can only be guaranteed if parts of its resources focus on ensuring its operations are sustainable. Therefore, this third pillar of the analytical tool is concerned with the daily activities that guarantee the two other pillars function. For this reason, it assesses the efficiency of a KI's practices for data delivery and management, as well as the technical system's responsiveness to its communities' needs. Finally, monitoring and evaluation are needed to improve the KI's performance in all aspects and to ensure its survival.

We provide here some further guidance in assessing Pillar III (*Sustainability*):
Practices

- What is the best way to ensure that the digital repository can count on committed data providers for data collection?
- Does the digital repository have an effective and sustainable data curation process?
- Does the digital repository utilise a commonly accepted taxonomy that is familiar to users and consistent with other relevant repositories' taxonomies?
- Does the digital repository have a strategy to continuously revise and update the taxonomy, if necessary, to reflect recent changes and developments?

Responsiveness

- Does the digital repository have a data delivery strategy that targets different types of users and provides different data formats?
- Does the digital repository have a strategy in place to update data delivery based on users' input and feedback?
- Does the digital repository provide clear guidance on how to use the information available? Does it explain how to participate in the data collection process?
- Does the digital repository offer support materials to help users navigate it?

Monitoring & Evaluation

- Does the digital repository have a strategy in place for monitoring and evaluating its usefulness?
- Does the digital repository implement participatory tools that measure the platform's performance?

ii. Applying a theory of change framework

The theory of change (TOC) framework is a complementary step of the assessment tool that allows for a visual understanding of the pathway strategies for KI improvement. It is based on the assessment tool's diagnosis. This framework can be used for any level of intervention, such as a project, a program, a policy, a strategy, or an organisation. The assessment TOC can be applied when creating a new KI to identify its objectives and activities in advance to improve an existing KI and ensure it responds to emerging issues and decisions (Rogers 2014, 1).

Operationalizing the three pillars illustrates the key points considered when evaluating KIs. This analytical framework, combined with the TOC framework, creates an appropriate and coherent mixed methodology for diagnosing and developing pathway strategies to improve KIs. The TOC determines what activities to undertake to improve the KI. It identifies a desired long-term goal for the KI and then works backward to identify all the conditions necessary to achieve the desired outcome. These methods would allow KIs to sustain engagement with their communities, keep their data and data management principles (i.e., FAIR and TRUST principles) up to date, and to continue to be salient, credible, and legitimate digital KIs (Wilkinson et al. 2016, 4; Lin *et al.* 2020, 2; Cash et al. 2003, 4).

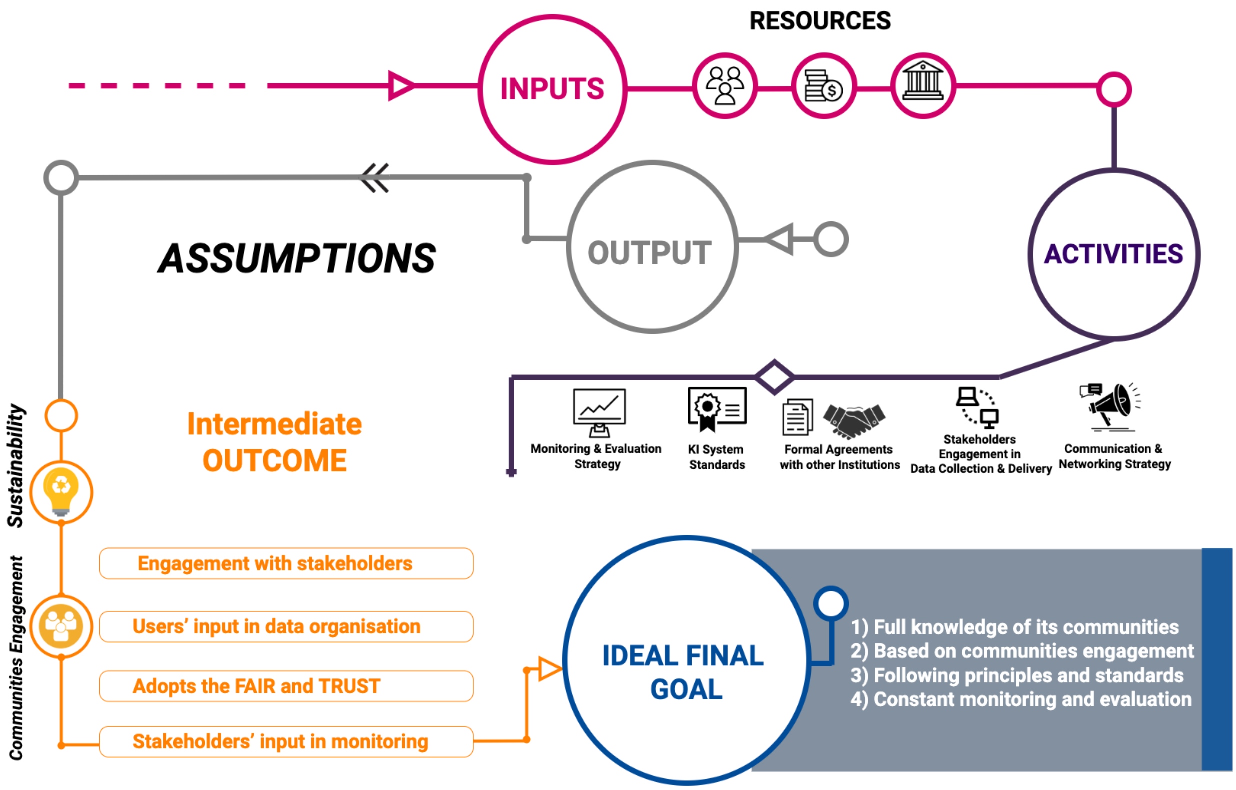

Figure 1: KI pathway proposal, including the intermediate steps, activities, and resources comprising the assumptions and preconditions underpinning the path.

Image description: White background. The image starts with an arrow following a medium pink circle, “Inputs”, after is a title “Resources” and below three small circles with small icons: people, money, and institutions. Next is a medium purple circle, “Activities,” followed by five icons describing activities as “Communication and Network Strategy,” “Stakeholders Engagement in Data Collection and Delivery,” “Formal Agreements with other institutions,” “KI System Standards,” and “Monitoring/Evaluation Strategy.” In the middle of the image is a medium grey circle that describes “Outputs.” Following is an arrow, pointing to the first output, “Assumptions.” The assumption is “Intermediate Outcome.” The two intermediate outcomes are “Communities Engagement” and “Sustainability.” The “Communities Engagement” section’s four headings are “Engagement with stakeholders,” “User’s input in data organisation,” “Adopts the FAIR and TRUST principles,” and “Stakeholders’ input while monitoring.” The final section of the figure is the “Ideal Final Goal,” and its four headings are Full knowledge of its communities, Based on community engagement, Following principles and standards, and Constant monitoring and evaluation.

V. Case study: The assessment tool and theory of change for GO-SPIN

The assessment tool and TOC were applied to evaluate UNESCO’s Global Observatory for Science, Technology, and Innovation Policy (GO-SPIN) platform to develop and recommend actions for its improvement. GO-SPIN aims to close the knowledge gap related to STI capacities to address the SDGs through an open platform. Launched in 2012 by UNESCO, it is a methodological tool to map countries’ STI landscapes and analyse national STI policies and their implementation. It focuses on developing countries and least developed countries (LDCs).

The tool’s three pillars assessed both the current and ideal situations for the platform with inputs from interviews with experts and the platform’s users. Using the TOC methodology, developed through a qualitative backcasting analysis, we identified a pathway for GO-SPIN to advance from its current situation towards an ideal one. The actions identified in the pathway then constituted the recommended next steps for GO-SPIN, as discussed below.

Subsequently, we sought to proceed from understanding the system’s behaviour to building possible pathways. For this, the research draws from the TOC strategic approach (Center for Theory of Change, 2020). Using the assessment tool built in the previous stage, it first identified a desired final goal for GO-SPIN and then evaluated its current situation. Starting from the final goal’s framing allowed us to develop the ideal scenario without current practices influencing or constraining us. The ideal goal was built based on best practices found within the literature, as well as the stakeholders’ needs and expectations identified through the interviews and surveys. The current situation was assessed using feedback from the platform’s users and internal experts. Once we mapped the desired ending and starting points for GO-SPIN, the analysis consisted of identifying the “missing middle” stage (backcasting) that would allow GO-SPIN to get from the current situation to the desired one (Rogers 2014, 3). This analytic process included defining intermediate outcomes and laying out the actions and enabling conditions needed to reach the final goal (Star and Ruhleder 1996, 132).

The following information summarises the UNESCO GO-SPIN current situation and ideal outcome along the three pillars. It provides an example of how the assessment tool might be applied and its potential results.

i. Communities

Current situation

The platform has defined users (developing countries), but their profiles or needs have no further characterization. In terms of engagement with stakeholders, the platform has no long-term engagement with data providers, low visibility, and no communication strategy. We observed a lack of alliances with key structures both in and out of the UN system, which makes it an isolated initiative with low institutional prioritisation and limited institutional ownership.

Ideal outcome

The platform has complete knowledge about stakeholders, targeted users, and is clear about its objective and scope. The platform has participatory methodologies for data collection and delivery, communication, and diffusion activities, as well as interaction and cooperation with local and international institutions.

ii. Technical system

Current situation

Interviewed and surveyed participants highlighted the platform for providing salient cross-comparative data on developing countries. However, they felt the platform was not user-friendly and provided low practical information and use. The most common criticisms included the interface design, the underlying system's high complexity, the low amount of information on many countries, and the lack of explanations for most of the platform's tools. This is possibly because the platform was developed with limited resources and time. In light of the TRUST principles, GO-SPIN ensures some transparency since all the information is publicly accessible and is only uploaded once it has been peer-reviewed and curated. Nevertheless, some survey respondents and participants mentioned that they struggled to obtain meta-data and to identify the information's origin. A severe lack of human resources reduced the project's capacity to meaningfully engage in labour-intensive data curation processes, weakening the responsibility principle within the TRUST framework.

Ideal Outcome
The platform fully implements and monitors the FAIR and TRUST principles. It is accessible to users, establishes formal relations with related platforms to ensure interconnectivity and interoperability, has regular information flow, and encourages users' interaction outside the platform.

iii. Sustainability
Current situation
Interviewees internal to GO-SPIN raised the issue that methodology about organising data was not developed in a participatory way. Furthermore, the methodology seems stagnant since its creation. The delay in developing a manual that lists standards for collecting information about the platform has affected how well the methodology for organising the GO-SPIN data is understood, and thus negatively impacted standardising and updating data. The latter has also affected countries' engagement, which in return showed little commitment. In practice, data collection has relied on the GO-SPIN team alone. Furthermore, even when data presented in the platform might be relevant, it may not be salient for certain users (e.g., non-governmental organisations, researchers) since data is presented in one standard format. The absence of support from users' behaviour while navigating the platform worsens this issue. Finally, the platform only utilises Google Analytics to monitor usage statistics. No other strategy seems to exist for engaging with stakeholders and users to obtain feedback and inputs.

Ideal Outcome
The platform uses a taxonomy familiar to users and consistent with those that other repositories use. It collects data from comprehensive data sources, utilises users' inputs to target data delivery and data organisation, provides more and better tools for users, and has an integral monitoring and evaluation strategy that focuses on operational aspects' effectiveness and the platform's long-term goal.

VI. Discussion
Recent international actions such as the UN 2030 Agenda for Sustainable Development or crises such as the COVID-19 pandemic have shown the need for strengthening KIs that enable sharing science policy-related information, leading to evidence-based policy making. Through our review of the current state of the field, we have identified the need to develop an assessment tool to evaluate existing and future KIs related to STI policy. From a socio-technical standpoint, establishing this assessment as a standard evaluation tool is an important first step towards improving international STI policy cooperation. In particular, such a tool could help strengthen existing international efforts reflected in the Addis Ababa Action Agenda and the post-2015 Development Agenda Outcome (Walsh, Murphy, and Horan 2020, 4) that call for an online platform as an information gateway on existing STI initiatives, mechanisms, and programs within and beyond the UN (Walsh, Murphy, and Horan 2020, 6).

The assessment tool was intrinsically linked to the GO-SPIN platform since it was developed with this particular KI in mind and then applied as a case study. Understanding this platform involved a detailed analytical process that included a thorough review of the literature regarding KIs, as well as repositories related to science policy and knowledge management. This was combined with the more practical approach of mapping different procedures that STI repositories use in an attempt to close the gap between academic conceptualizations and on the ground practices.

Importantly, developing this assessment tool is a novel contribution to the field of KIs. The tool's innovative approach lies in that it integrates different concepts and bodies of knowledge. While siloed in different debates and disciplines, these concepts and bodies of knowledge are indeed highly interconnected and address similar phenomena - one from a theoretical standpoint (KIs) and one from a practical standpoint (NGRs). The assessment tool was therefore developed by combining these theoretical and practical perspectives. This approach will be much needed in the future in order to refine KIs.

Using GO-SPIN as a case study, we have shown the assessment tool's usefulness in evaluating a KI based on the tool's different pillars, which aim to ensure that KIs are sustainable over time. Moreover, the assessment tool combined with the TOC proved useful in diagnosing the current state of affairs and proposing eventual pathway strategies to improve a KI. This mixed-method approach could allow KI curators and evaluators to pinpoint the main opportunities for improvement. In turn, KIs would thus offer continued support and engagement with their communities, apply relevant data management principles (i.e., FAIR and TRUST), and enable KIs to be salient, credible, and legitimate (Cash et al. 2003, 4).

With regards to KIs' future particularly pertaining to science policy related information, our research suggests that a need exists for similar existing KIs to interoperate. However, some issues related to the STI policy landscape go beyond the assessment tool's possibilities and need to be taken into account in future iterations of the tool. For example, more attention needs to be paid to the conflicting political agendas of the various organisations that build and operate these KIs. These might hinder the interoperability of KIs pertaining to STI-related information and may very well prevent them from strengthening and improving. Indeed, as the case study revealed, competition issues between GO-SPIN and similar STI platforms are a reality that need to be reflected upon particularly from a social dimension to find institutional solutions. This could constitute an important first step to allow for desired interoperability. Finally, in an international development context with scarce resources and high stakes, the assessment tool can become an important instrument, allowing for launching KIs that are dynamic, inclusive, relevant, and sustainable over time.

VII. Research limitations and future work

We acknowledge that the assessment tool presented in this paper is an ad-hoc fusion and adaptation of other frameworks and theories. Through interviews and surveys, the assessment tool was supplemented with information based on a diverse pool of experts' insights. The authors hope that this is a useful first step in the field of KI research and that it will be expanded further. The qualitative approach taken here, though suited to provide in-depth information, is not meant to be considered as a representative sample of STI policy experts. Further discussions within wider communities of experts will be needed to expand on and validate the instrument.

Some critical deficiencies in terms of the fairness of representation of the study must also be considered. For example, relevant literature in languages other than English or Spanish was excluded. In addition, despite efforts to ensure equity, a gap persisted with underrepresentation of women, non-binary people, and those with disabilities. Furthermore, experts from all identified STI data platforms were not interviewed due to lack of response. Because of this, insights into details on those platforms' practices were not gathered.

Appendix: List of the thirty digital sample platforms analysed.

Online repository	Repository type	Institution/NGO
Go Spin	Observatory /platform	UNESCO
SAGA UNESCO	Project with platform	UNESCO
Innovation Policy Platform (IPP)	Platform (Closed)	OECD- World Bank

STIP Compass	Database/platform	OECD - European commission
Eurostat	Statistical database	European Commission
Research and Innovation Observatory – Horizon 2020 Policy Support Facility	Observatory R&I Policy	European Commission
CyT-DES	Platform	CEPAL - (ECLAC) - ECOSOC UN
African Science Technology and Innovation Indicators (ASTII)	Platform	African Union Development Agency (AUDA-NEPAD)
Knowledge Platform on Science, Technology & Innovation Policies for Sustainable Development – ARTNET	Platform	UNESCAP - ECOSOC UN
SDG Gateway	Statistical database	Statics division UNESCAP - ECOSOC UN
UN TFM	Platform (demo)	United Nations Interagency Task Team on Science
Smart Specialisation (S3) Platform	Platform	European Commission
African Open Science Platform initiative (AOSP)	Platform - (Pilot Project closing 2019)	South African Department of Science and Technology (DST)
United Nations Economic and Social Commission for Western Asia (UNESCWA)	Network platform	UNESCWA - ECOSOC UN
The Network for Science and Technology Indicators –Ibero-American and Inter-American (RICYT)	Network platform	Organization of American States (OAS) (Spanish: Organización de Estados Americanos OEA)
Research Infrastructure for Science and Innovation Policy Studies (RISIS2) RISIS CORE FACILITY	Platform (Project 4 years)	European Commission
Development Data Group	Statistical database	World Bank
Databank: ECA	Databank	UNECA - ECOSOC
United Nations Economic Commission for Europe	Statistical database	UNECE- ECOSOC
IST-Africa	Repository	European Framework Programme

AOSTI- African Observatory for STI	Observatory (closed)	African Union
Knowledge Repository ECA	Repository	UNECA - ECOSOC
SIPER – Science and Innovation Policy Evaluation Repository University of Manchester	University Repository	University of Manchester
Knoema	Private Data Bank	Private
Basel Convention Regional Center for Training & Technology Transfer for the Arab States in Egypt (BCRC-Egypt)	Centre's repository	Basel convention UN program
European Open Science Cloud (EOSC)	Cloud for research data	European Commission
Asian and Pacific Centre for Transfer of Technology- APCTT	Library (undergoing a design revamp)	ESCAP - ECOSOC UN
Observatorio de Ciencia Innovación y Tecnología	National Observatory	National Pedagogic University (Spanish: Universidad Pedagógica Nacional) of Colombia
RI2.0 (Digital Repository of the National Commission for Scientific and Technological Research – CONICYT) - National Research and Development Agency	National repository	Government of Chile (Spanish: Gobierno de Chile)
INGSA - International Network for Government Science Advice	Collaborative platform	International Science Council

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