Open Science at a time of the COVID-19 pandemic: a new opportunity to improve emergency response

Hanna Shmagun
Korea Institute of Science and Technology Information (KISTI), University of Science and Technology (UST)
hanna.shmagun@gmail.com

Charles Oppenheim
Robert Gordon University
c.oppenheim@rgu.ac.uk

Jangsup Shim
Korea Advanced Institute of Science and Technology (KAIST)
sjshl1iit@gmail.com

Kwang-Nam Choi
Korea Institute of Science and Technology Information (KISTI)
knchoi@kisti.re.kr

Jaesoo Kim
Korea Institute of Science and Technology Information (KISTI),
jaesoo@kisti.re.kr

Abstract

The ongoing COVID-19 pandemic has become a major milestone encouraging a change from traditional scholarly communication practices and policies in favour of greater openness, sharing, and reuse. Interviews with South Korean and Australian experts has helped to highlight the factors that either enable or limit the impact of Open Science during a public health emergency, such as the COVID-19 outbreak. The paper categorised such factors as: contextual and external; institutional and regulatory; resource-based; individual and motivational, and supplemented this categorisation with the interviewees' quotes to illustrate specific cases and examples. The institutional and regulatory factors are perceived as the most important ones by interviewees.

1. Introduction

The current coronavirus pandemic has revealed the vital importance of Open Science (OS) for effective emergency preparedness and response, according to international and national institutions [1]. Numerous OS initiatives and projects have emerged in the wake of the COVID-19 pandemics. These are challenging traditional science to become more open, global, collaborative, and closer to society.

For example, many large publishers have positively responded to the Open Access call [2] by providing free of charge access to some of their coronavirus-related publications for as long as the pandemic lasts. UNESCO has called on governments to reinforce scientific cooperation and integrate OS into their strategies to fight against the COVID-19 [1]. There have also been many initiatives related to opening up existing research data, such as virus genome sequences and protein structures, and offering access to data analysis tools [3,4]. Preprints have become a norm to report on the ongoing research results [5]. In comparison to previous major infectious diseases outbreaks, the scientific response to COVID-19 is unprecedented in terms of the speed of production and the scope of dissemination of scientific evidence [5-7].

However, despite the fact that the COVID-19 pandemic has highlighted the importance of OS, it has also highlighted the insufficient capacities of national scholarly communication systems to rapidly and effectively respond in times of emergency. Even the developed countries, which had already had pre-pandemic commitment to OS development, have shown the lack of comprehensive and consistent OS policies, inadequacy of cross-sectoral coordination mechanisms, and insufficiency of current incentive structures for researchers to pursue greater openness and collaboration [8]. Many initiatives launched during the current pandemic, such as open access to coronavirus-related publications, seem to be a temporary response to the crisis rather than the start of more sustainable structural changes in research culture [9]. International academic publishers are expected to return to their traditional subscription-based business model as soon as the pandemic is over, and much of the valuable scientific evidence related to infectious and other diseases, natural disasters and environmental problems will still be kept closed behind paywalls.

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The aim of this paper is to identify factors that are viewed by South Korean and Australian experts as enablers or barriers to OS practices in public health emergencies. We will address both pandemic-specific and broader relevant OS factors in the country-specific context.

2. Literature review

OS is a broad umbrella notion encompassing various practices aiming to remove barriers to knowledge creation and dissemination by maximising openness at each stage of the research life cycle thanks to the networking benefits of Information and Communication Technologies (ICT). This notion is applied to any field of knowledge, including science, social science and humanities. The best known OS practices are open access to scientific publications, open research data sharing, and open collaboration within and beyond research communities [10]. A distinctive feature of OS is reuse and sharing of scientific information viewed as OS data. These include the vigorously verified information at any phase of scientific enquiry that are findable, accessible, interoperable, reusable both by machines and by people (e.g., pre-registration plans, research data, papers, patents, research reports).

Previous studies have examined the factors influencing scientists' information sharing and/or reuse behaviour in general [11] or within particular disciplines – for example, in health and life sciences [12], food science and technology [13], and astrophysics [14]. A widely cited study (co)-authored by Y. Kim argues that these factors can be categorised into four broad groups: (1) *institutional factors*, including funding agency's policy; (2) *resource factors*, including data repositories; (3) *individual factors*, including researchers' perceived efforts, benefits, and risks; and (4) *other organisational and environmental factors* [15].

However, only a few peer-reviewed studies, including position papers, have examined the emerging phenomenon of open scholarly communication in a public health emergency context [16-19]. There have also been a few studies and opinion pieces on the topic commissioned by international organisations. For example, in response to the previous SARS, MERS-CoV, Ebola and Zika outbreaks, the Wellcome Trust commissioned a study about policies, practices, and infrastructure supporting pathogens data sharing in public health emergencies [20]. Elsewhere, the Research Data Alliance (RDA) COVID-19 Working Group recently produced an initial set of guidelines for data sharing in the current pandemic with a focus on Omics[1], Clinical Medicine, Epidemiology, and Social Sciences data [21]. The OECD's opinion piece "Why Open Science is critical to combatting COVID-19" presents some enablers and barriers of OS in the crisis [22]. One of the major deficiencies of such studies is a rather narrow focus on sharing research data within Biomedical Sciences and a lack of recommendations for the development of comprehensive national OS strategies.

We believe our research offers fresh insights for organisations dedicated to planning or improving national OS strategies in a more systematic and focused way. We highlight the importance of including the emergency-specific mechanisms of effective communication of multiple information resources across different research domains into national OS strategies. In addition, our case study-based approach reveals certain cross-country differences in the field.

3. Research approach and design

We used a case study strategy, conducting semi-structured interviews with South Korean (primarily) and Australian experts (Table 1). These countries have demonstrated a significant progress in adopting OS practices in the pre-pandemic period [23].

Using a purposive (expert/judgmental) sampling technique [24], a sample of fourteen people was formed to include researchers and practitioners from Biomedical and Health Sciences, S&T policy, OS/Open Access areas, as well as those involved in scientific information service design and provision. The majority of interviewees (nine from fourteen) have research or job responsibilities related to COVID-19 or similar public health emergencies. Almost all (twelve of fourteen) interviewees have OS data reuse experience, and nine interviewees said to have OS data sharing experience.

Table 1. The profiles of interviewees

N	Institution	Job title	PhD	Gender	Experience in the field at the interview
1	Korean Bioinformation Center (KOBIC)	Senior researcher	+	M	1 ~ 5 years
2	Korea Institute of Science and Technology Information (KISTI)	Principal researcher	+	M	over 20 years
3	Korea Research Institute of Chemical Technology (KRICT)	Principal researcher	+	M	over 20 years
4	Korea Institute of Science and Technology (KIST) / Biomedical Research Institute	Researcher	currently enrolled	F	1 ~ 5 years
5	Korea Institute of Science and Technology Information (KISTI)	Principal researcher	+	M	6 ~ 10 years
6	Chungnam National University	Professor	+	M	11 ~ 15 years

[1] Omics data is high-throughput data from cell and molecular biology.

7	Korea Institute of Science and Technology Information (KISTI)	Principal researcher	+	M	16 ~ 20 years
8	Science and Technology Policy Institute (STEPI, Korea)	Research fellow	+	F	6 ~ 10 years
9	Korea Institute of Science and Technology (KIST) / Biomedical Research Institute	Researcher	currently enrolled	F	1 ~ 5 years
10	Korea Institute of Science and Technology Information (KISTI), Korea Research Institute of Chemical Technology (KRICT)	Principal researcher	+	M	16 ~ 20 years
11	Republic of Korea Navy Marine Corps (Medical service)	Military doctor	-	M	1 ~ 5 years
12	The Australian Research Data Commons (ARDC)	Senior research data specialist	+	F	11 ~ 15 years
13	Cytrax Consulting (Australia), RDA	Principal consultant (Cytrax Consulting), co-chair of interest groups (RDA)	-	M	1 ~ 5 years
14	the Australasian Open Access Strategy Group (AOASG)	Senior manager	+	F	16 ~ 20 years

The questions for interviews were based on a systematic literature review followed by coding of the selected literature using NVivo 12 Plus software [25]. The PRISMA protocol [26] was used for identification, screening, and inclusion/exclusion of literature from Web of Science and SCOPUS databases. We used a combination of search terms including *open science* AND *factors*; *open science* AND *enablers*; *open science* AND *barriers*; *scholarly communication* AND *epidemics*; *open science* AND *public health emergency*; *epidemics* AND *open research* AND *open access*; *open science* AND *data sharing* AND *COVID-19*. We also searched for in-text cited references, studies published by international organisations (including OECD and the Wellcome Trust), relevant papers published by the target interviewees, COVID-19 Special Issue publications (e.g., The Asia-Pacific Journal: Japan Focus, Special Issue "Pandemic Asia" [27]). We finally selected 93 papers for NVivo qualitative analysis.

NVivo analysis of the selected literature was based on a hybrid approach of deductive and inductive coding. Using a deductive coding approach, we created four categories known as 'nodes' pointing at the factors that affect OS practices, according to Kim's typology noted above (contextual or external factors, institutional and regulatory factors, resource factors, individual and motivational factors). Afterwards, the application of an open, axial, and selective coding of the selected literature has allowed for building a hierarchy of sub-factors ('child nodes'), which formed the basis for formulating the interview questions.

The interviews were conducted in May 2020 (Korean experts) and in September 2020 (Australian experts) using various methods (face-to-face interviews, telephone interviews, Zoom interviews, and email) as appropriate. All interviews were transcribed and analysed in NVivo following the same coding procedure as had been used for the literature review analysis. As a result, additional nodes were added to the taxonomy of factors, while some initially established nodes were revised.

4. Results

This study defined a set of factors affecting OS practices in public health emergencies, such as the COVID-19 crisis. Factors first identified from the literature review and then tested/supplemented by interviews, were placed into four groups. These were *contextual or external factors* (political and socio-economic context, including public health emergency circumstances); *institutional and regulatory factors* (regulatory regime and leadership; interdisciplinary and cross-sector partnerships; and research communities' norms); *resource factors* (ICT infrastructure, financial and human resources); and *individual and motivational factors* (perceived personal efforts; perceived risk of negative consequences; perceived benefits; multiple dimensions of trust related to OS practices). The overview of all factors is summarised in Table 2.

Table 2. Taxonomy of factors affecting Open Science practices during the COVID-19 crisis

Group of factors	**Factors:** ● **enablers,** ◈ **barriers,** ★ **context-specific**	**Key point**	**Essential quotes**
1. contextual or external	● Emergency experience	Emergencies force to develop the national capacities for rapid and effective cross-sector collaboration and coordination, including open communication among scholars.	"By the time we came to COVID, we had some lessons learned from the bushfire disasters, which highlighted the need for rapid collaboration and data sharing." (AU) "Some countries are beginning to realise that pandemic has made it absolutely critical that they have a national approach to OS. That has happened in Malaysia, for example." (AU)

Group of factors	Factors: ● enablers, ◈ barriers, ★ context-specific	Key point	Essential quotes
	● Political openness	In general, political openness and democracy are assumed to create more space for OS. However, it depends on country characteristics and circumstances. In a public health emergency, even democratic countries can employ some authoritarian tools to rapidly respond to the emergency.	"Authoritarian countries can still have OS.", "For example, Singapore is more like authoritarian state, but it has good OS practices…Even China adopted open research data declaration last year." (AU)
	● Globalisation	Science diplomacy is a factor that can push many countries to develop OS policy.	"OS is a global idea, trend and we are trying to follow it as other countries do." (KR)
	● Government-citizen collaboration	Citizens' trust in and support for government policy positively affect rapid scholarly communication and cross-sector collaboration in an emergency.	"Korean people are very collaborative with government, especially in any crisis." (KR)
	◈ Socio-political conflicts	Any international or internal socio-political conflict is a limiting factor for effective scholarly communication during an emergency.	"The conflict between the US and China over COVID-19 slows down the global cooperation process, which can also challenge OS practices." (KR)
	◈ Digital divide	A problem of digital divide should be considered while developing OS policies in both developed and developing countries.	"Research should be carried out and disseminated in both ways (offline and online). We cannot totally replace traditional science by OS. It is only a supplement to a traditional scholarly communication, otherwise the minority groups, such as senior researchers or the disabled, can be discriminated." (KR)
	★ Level of economic development	Developing countries with low-resource settings have an investment demand for more basic necessities to improve people's standard of living and cannot afford additional investment in scientific infrastructure and services.	"In developing countries, there is usually a low status of science and there is a general opinion that scientists live off the state's generosity by not producing qualitative outcomes." (KR)
2. institutional and regulatory factors	● National OS policy leadership and coordination	It should be a national OS plan/strategy through which diverse interests and policies are reviewed, adjusted and improved in a coordinated way.	"One of our biggest problem in Australia is that we don't have a national approach/ strategy for OS." (AU) "Korea has a strong Open Government Data policy…but we don't have a well-developed, coherent OS policy, such as in the European Union." (KR)
	★ Flexibility/rigor of regulations in regard to opening up scientific evidence	Legally binding instruments and enforcement mechanisms (e.g., DMP) imposed by government research funders can promote OS practices, especially in an emergency. However, overregulation can be a burden and demotivation for scientists to carry out government-funded research.	"Research data sharing is encouraged but not explicitly mandated yet." (AU) "Making research data open, reusable, findable requires a lots of efforts. Researchers are already busy. If you make data sharing mandatory, should researchers shift the other 10-20% of their duties to research data management or do you have a new workforce to help researchers to do that? I don't think it should be strictly mandatory." (AU)

Group of factors	Factors: ● enablers, ◈ barriers, ★ context-specific	Key point	Essential quotes
	● Fast tracks for procedures involved in a research life cycle (i.e. data production, sharing of preliminary findings, data and final results publishing)	The important requirement for scholarly communication in an emergency situation is to share scientific evidence as soon as possible.	"Local Korean journals and research communities have not been ready enough for expedited peer-reviewed publication, though some domestic preprint services have been newly developed." (KR)
	● Measures to ensure quality control, legal and ethical compliance	The establishment of a National Research Ethics Committee is important. This body can provide peer-review of the critical scientific evidence, make a decision on OS practices while striking the right balance between collective interests (public health) and individual interests (privacy, IPR), etc.	"The urgency of getting information for the sake of public health interest may have greater priority than privacy concerns." (KR) "You cannot just say that there is no privacy rights because we are in a pandemic" (AU)
	● Systematic policy of OS incentives for researchers	The incentives are especially needed to motivate scholars to share their research data, since the process to prepare research data for reuse requires lots of efforts and time.	"I think it is a huge problem. A systematic approach to develop different kinds of incentives, general and emergency-specific, is needed." (KR)
	● Interdisciplinary and cross-sector partnerships (e.g., government, research institutes, hospitals, industry)	It is important to have a mediator (organisation) to foster emergency-related partnerships. It can be done through funding models, coordination, building skills, providing facilities and data linkage, dissemination of projects outcomes.	"The more interaction patterns between multiple actors are developed – the greater the demand in society for some open data hubs." (KR) "For example, the Australian Centre for Disease Preparedness, run by the CSIRO, and the Population Health Research Network perform similar functions," (AU)

Group of factors	Factors: ● enablers, ◈ barriers, ★ context-specific	Key point	Essential quotes
	★ Research communities' norms	Some disciplines have a stronger OS culture: for example, Astronomy, Earth Science, High-Energy Physics, Biomedical Science (Genomics). The maturity of discipline, long history of international scientific collaboration, research with less sensitive information determine the OS culture.	"OS more comes from research communities of practice, which push government policies." (AU) "Sometimes there are disciplines doing better than others, because they have to collaborate by sharing results globally." (AU)
3. resource factors	● Interoperability of ICT infrastructure	Interoperable data exchange between heterogeneous scientific and cross-sector systems is very important.	"Interoperability is really a big issue. We are not doing terribly well yet. What we need are data exchange standards implemented by data infrastructure providers beforehand." (AU)
	● Operational Readiness Levels (ORL) of data	A classification framework of the quality/trustworthiness of all content on OS platforms for rapid data-driven decision making should be established. The ORL framework, developed by the Disaster Lifecycle Cluster at the Earth Science Information Partners community, can serve as a reference model.	"Operational readiness of data is something that's absolutely critical and that is missing in lots of infrastructures globally. We have lots of data, but we don't have the mechanisms to make it operationally useful in a real-life scenario." (AU)

Group of factors	Factors: ● enablers, ◈ barriers, ★ context-specific	Key point	Essential quotes
	● Automatic regulatory compliance embedded in scientific information services	For example, it can be applied to check if the research grant applicant submitted DMP in a proper form, if the user of CC-BY licensed content properly attributed the author, if research data/outcome being uploaded to a system do not contain any privacy-sensitive information. Blockchain and intelligent software agents can support this.	"To make this possible, the interoperability and linkage of data are important…I think lots of things we are doing today can be automated. But at the current stage, when machines cannot teach themselves to learn, you need hard-coded rules and standards for compliance procedures." (AU)
	● Financial resources	The government should provide rapid funding for prioritised areas of research and relevant OS infrastructure.	"The government pretty quickly put some extra money to fund pandemic-related research. To fund OS infrastructure – there is no something I have seen to put forward in the pandemic." (AU) "In this pandemic we had to use our own, very limited budget to rapidly launch a data service related to the outbreak ... There is a complicated procedure, money cannot easily flows from the government to public research institutes." (KR)
	● Open Science education	Research institutes, data service providers and other agencies should assist researchers in data sharing, data management, and data reuse practices.	"Korean researchers have the ICT skills to use generic information systems and web services, but the problem is that researchers do not know much about OS services: where to upload my data, where to access other researchers' data and why I should do it…" (KR) "We should educate people how to search for scientific content and how to judge its quality." (AU)
	● Expert groups for rapid peer-review of research data/outcomes	The emergency-related information sharing should be preceded by a solid fact-checking and scientific peer-review process, but performed at high speed. There is a need to employ additional experts during an emergency.	"The real challenge is not enough people to do rapid peer-review… Proper structured reporting of research evidence (paper, data) is also important for this." (AU)
	● Professionals creating and delivering the evidence-based popular science content	The government should provide commercial opportunities for alternative organisations and professionals, such as science journalists, who are much more capable to create popular science content and communicate it to the public.	"In order that ordinary people pay attention to scientific information, understand it, and benefit from its use in daily life, such information should be really interesting and easy to understand. It can be, for example, infographics, summary of research findings in a story-writing style, Q&A interviews with researchers." (KR)
4. individual and motivational factors	◈ Perceived personal efforts, concerns, risk of negative consequences	Researchers' perceived concerns: concern about compliance with personal data protection law; concern of being "scooped"; fear to lose reputation because of the revealed mistakes, etc.	"Researchers want to exploit maximum use of dataset they have generated. It prevails in the Humanity sector. There is an academic competition. If you make your dataset publicly available, you give away your competitive advantage. Because you can ask different research questions using the same dataset and publish different papers. Some researchers who collected good data during their early career can use it for the entire academic life." (AU)

Group of factors	Factors: ● enablers, ◈ barriers, ★ context-specific	Key point	Essential quotes
	● Perceived benefits	Researchers' perceived benefits: publication of articles and research datasets in high-level journals; citation; reputation building; OS practices as part of performance metrics in the evaluation process; inclusion of OS activities in the researcher's working hours; promotion opportunities; increased chances to get research funds; feedback from a scientific community for research improvement, etc.	"I am not altruist by nature. For me, motivation to share my data would be promotion, building reputation in my field…" (KR)
	● Trust in OS	Dimensions of OS trust: trust in science and scientists; trust in data service provider (institution); trust in data platform (service); trust in data quality; trust in research community with Open Science experience; trust in reciprocal action.	"Researcher's reliance on OS experiences within a research community is the most important issue. If you share, the others will share with you." (AU)

As part of the interviews, we asked the respondents to rank the four identified groups of factors using a 1-4 scale ("1" is the most important and "4" is the least important group of factors). The results are presented in Table 3.

Table 3. Ranking data of factors affecting Opens Science practices

Interviewees	Contextual/ external factors	Institutional/ regulatory factors	Resource factors	Individual/ motivational factors
N 1	1	2	4	3
N 2	3	1	2	4
N 3	1	3	2	4
N 4	1	1	1	1
N 5	4	1	3	2
N 6	1	4	2	3
N 7	4	1	3	2
N 8	2	3	4	1
N 9	4	1	3	2
N 10	2	1	3	4
N 11	2	1	3	4
N 12	3	1	4	2
N 13	4	2	3	1
N 14	2	3	4	1
Value	34	25	41	34
Average rank	**2.4 (II)**	**1.8 (I)**	**2.9 (III)**	**2.4 (II)**

The *institutional and regulatory factors* were named as the most important group. Two other groups comprising *individual and motivational factors* and *contextual or external factors* were ranked second. Finally, *resource factors* were perceived by interviewees as the least important group of factors. "I believe if you have a relevant policy and individual willingness, you can find resources for OS. But if policy-makers and researchers are against it, resources will not be allocated and used," said an interviewee. It should be noted that one of the interviewees assigned the same degree of importance to all the identified factor groups not being able to discriminate between them and arguing that OS is dependent on different combinations of all factors. Some respondents argued that the COVID-19 pandemic significantly increases the impact of contextual/external factors on OS development.

5. Discussion and conclusions

In this study, we have identified diverse factors influencing attitudes to OS data sharing and reuse practices in public health emergencies, such as the current COVID-19 pandemic. We have divided these factors into four broad groups (contextual or external, institutional and regulatory, resource, individual and motivational factors), classified them as enablers, barriers, or context-specific factors, and presented the key results in a table format. Each factor is accompanied with real-life examples provided by relevant interviewee responses. In addition, we gave a score to each of the four groups of factors based on its priority to the experts who we interviewed.

The institutional and regulatory factors, such as laws, pressures by funding agencies and journal publishers, legally-binding partnerships, research communities' norms, are perceived as primary factors which can significantly foster or hamper OS practices. Although OS practices are technically feasible with the advanced ICT, multiple legal and ethical impediments, particularly related to research data sharing, still continue to exist [28]. For example, among the gaps are ambiguity about protection of research data as intellectual property, a lack of policies to make OS practices a part of performance metrics in the research evaluation process. The OS practices in a public health emergency situation require also additional policies to put in place – such as expedited procedures for development, evaluation, and dissemination of scientific evidence, with embedded quality control and protection of researchers and human research subjects' interests.

According to the responses of experts from South Korea and Australia, both countries have not still developed a comprehensive national strategy and regulatory regime for OS. This was perceived by the interviewees to be a significant obstacle to effective scholarly communication in both emergency and non-emergency situations. However, the pre-pandemic continuous commitment of both countries towards OS development, as a component of emergency preparedness, has positively affected their responses to COVID-19. South Korea has learned some lessons from the Severe Acute Respiratory Syndrome (SARS-CoV) and the Middle East Respiratory Syndrome (MERS-CoV) outbreaks, while Australia has realised the importance of scientific information sharing and cross-sector collaboration being familiar with the devastation of natural hazards, such as bushfires. Thus, by the time the COVID-19 pandemic hit, both these ICT-advanced countries had already had some basic infrastructure for OS. In particular, the Korea Institute of Science and Technology Information/KISTI (in Korea) and the Australian Research Data Commons/ARDC (in Australia) have had a key role in constructing such infrastructure and providing relevant data services. Nevertheless, a national ICT infrastructure for OS was perceived by interviewees from both countries as not properly developed yet. In particular, the issue of interoperability was pointed out.

Based on our results, we found that South Korea adheres to a rather top-down approach to OS, while the Australian approach to OS is largely dependent on bottom-up forces. In Korea, the government sector, including the Ministry of Science and ICT and the subordinate KISTI, has a leadership role in promoting OS policies and maintaining ICT infrastructure for OS data services. In Australia, different research communities and interest groups drive the adoption of OS policies and practices [29]. Their activities are coordinated by ARDC (limited company), which is the main OS data service provider in Australia.

The overall findings of this study show that multiple processes, including normative structures and basic infrastructure, should be systematically prepared before a crisis hits. A national scholarly communication system based on OS principles cannot be built overnight in sudden crisis situations, even though some tools, such as crowdsourced data collections, can be hastily provided.

We are aware of the limitations of the study: the small sample of interviews, biased towards researchers from South Korea, and the qualitative nature of research limit generalisation of the findings; the approach to rank the groups of factors is inevitably simplistic. Nevertheless, we hope that our study contributes to the OS theory and does provide insights for policy-makers about what are perceived are the key factors of OS practices in public health emergencies.

As part of the next phase of the research, we are interviewing experts from other countries and from more diverse fields, including government research funders, R&D managers, data service providers, and publishers. The results from all these interviews will be used as inputs for a structured questionnaire, which will targeted at multiple stakeholders in South Korea. We also will develop a conceptual model of an ideal national OS Ecosystem with the capacity to respond in public health emergencies. The design of the conceptual model will draw on Ostrom's Institutional Analysis and Development (IAD) analytical framework [30]. The conceptual model will be built as a practicable analytical tool for science and technology managers and researchers alike to incorporate OS-based multidisciplinary communication into all stages of research planning and implementation. It will also be able to serve as a conceptual instrument to assess and recommend improvements to national OS policies and practices. A preliminary model of such an OS Ecosystem is presented in Figure 1 and is a result of some of our previous research [31].

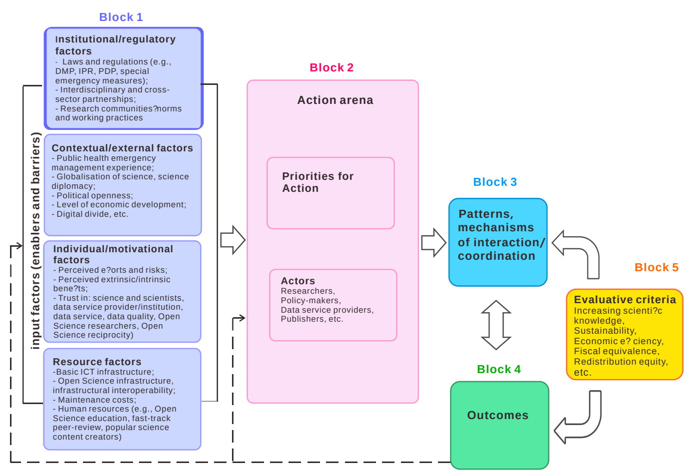

Figure 1. A preliminary conceptual model of Open Science Ecosystem (adapted from Ostrom's IAD Framework)

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