ROLE AND VALUE OF USER BASE AROUND LARGE-SCALE RESEARCH FACILITIES

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Abstract. The paper summarises how research infrastructures depending on size, sector and the latest technical and organisational achievements develop their user base and what is the role of increased high quality user base for the development of research infrastructures.The aim of this study is further to analyse pre-conditions for the development of sustainable and long-term collaboration around existing or new large-scale research infrastructures, to assess catalysing mechanisms for the growth of local and transnational user base as an efficient new knowledge creation, commercialisation and innovation base around RIs. The research was conducted in seven steps: 1) clarification of definitions and understanding of terms and concepts; 2) analysis of common operational models and typologies of research infrastructure; 3) selection ofsectors in relevant areas of research infrastructure; 4) analysis of selected cases of research infrastructure objects in the Baltic Sea Region in three priority areas; 5) design of the performance metrix of research infrastructure; 6) validation of obtained conclusions by executing interviews with researchers and coordinators, and 7) aggregated analysis on factors determining demand and supply sides for large-scale research facilities with the aim to develop recommendations increasing the use of the facility.The last also includes elaborated analysis of the governance models for the research infrastructure. The research provides the indicator system and system-based algorithm for further deeper analysis for the large research facility operation, performance and increase of its capacity. The designed analytical approach allows to develop bundled recommendations for better fine-tuned policy measures to support operations of large scale facilities as sources of frontier science, new innovations and new knowledge concentration at national and local level.

Key words: large-scale research facility, research infrastructure, co-operation, talent attraction, scientific entrepreneurs.

Introduction

In Europe the role and importance of large-scale research infrastructures (RI) in many cases was driven by the European Strategy Forum on Research Infrastructures (ESFRI) placing in 2002 mega-infrastructures as the pan-European challenge for further development. The nation-wide innovation policies, with the aim to concentrate and consolidate resources allocated for further RI development, were strengthened by creation of efficient action plans and task forces, cross-border collaboration and strategic research specialisation. This process in the new member states was facilitated by creation of the European Regional Innovation support system (RIS, RITS and RITS + programs) followed by the Research and Innovation Strategies for Smart Specialised Regions (RIS3) [1].

The aim of this study is further to study pre-conditions for the development of sustainable and long-term collaboration around existing or new large-scale RI in the Baltic Sea Region (BSR), to assess catalysing mechanisms for the growth of RI user base as an efficient new knowledge creation, commercialisation and innovation tool around RIs. The research was conducted in seven steps (see also Fig. 1 for visualisation):

1. clarification of definitions and understanding of main concepts;
2. analysis of common operational models and typologies of large facilities;
3. selecting sectors in relevant areas of the RI;
4. analysis of selected cases of RI objects in the Baltic Sea Region in three priority areas;
5. design of the performance metrix of large facility;
6. validation of the obtained conclusions by executing interviews with researchers and coordinators,
7. aggregated analysis on factors determining demand and supply sides for large-scale research facilities with the aim to develop recommendations increasing the use of the facility. The last also includes elaborated analysis of the governance models for the research infrastructure.

In selecting conceptual approaches to the study, we followed to the methodology developed by ErkoAutio [2]. We combined different primary and secondary sources:

1. desk-based analysis of existing literature articles and reports;

2. existing data from large-scale facilities and/or organisation owning or managing them;
3. available reports from international, national organisations or local RIs; and
4. original data collection in the form of published case studies.

The secondary sources also included micro and meso documents more based on individual research facilities, their collaborative or user networks, data collections and intermediatory bodies themselves, as well as reviews sharing performance and socio-economic benefits.

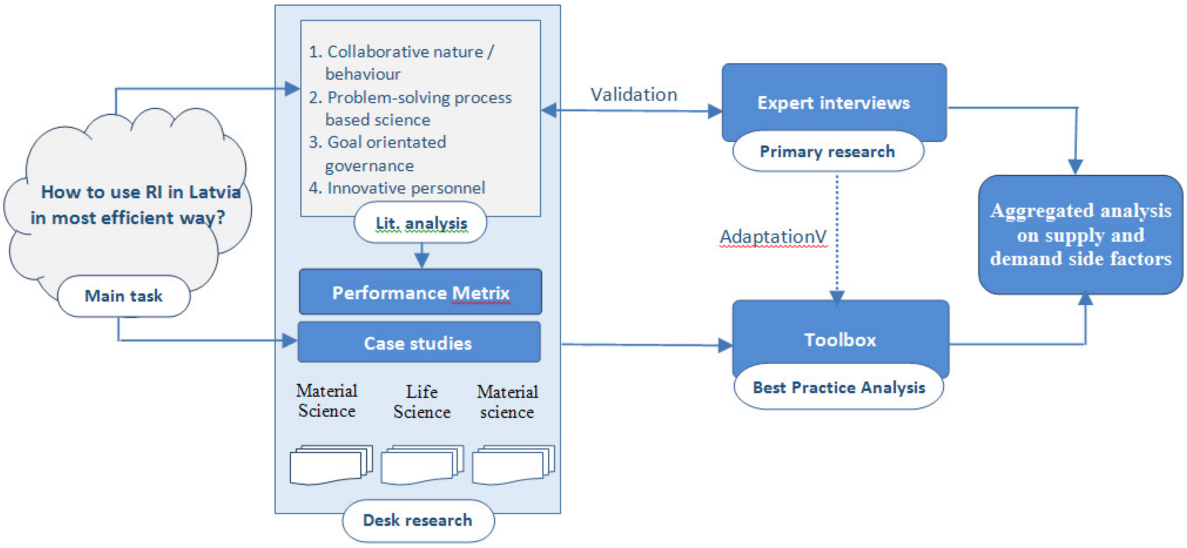

Fig. 1. **Visualization of overall research approach:** created by the authors

Methodology

Based on the analysis of the theory and previous research, the paper provides insight in the current state in the field. This is followed by an in-depth case study analysis of six different RIs, also discussions. The analysis is based on the results from the case study as well as primary research, namely, expert interviews and focus group discussions conducted with international and Latvian experts. The analysis at the core of this paper is structured in the following areas of research excellence:

- materials, photon, and neutron science.
- life sciences including biomedical research, biomedicine, diagnostics, and drug development.
- the welfare state.

As opposed to aggregative methods (which summarise well-specified data and stable concepts), we used the critical interpretive approach based on induction and interpretation to develop concepts and integrate them with theories. Based on that, an attempt to consolidate the observations creates a number of research questions, leading to the next stage of interpretation of the phenomena. This method is particularly useful in cases where synthesis is attempted in a theme where literature is sparse, fragmented, non-accumulative and lacking in theory and rigorous methods [2].

Terms and definitions

Almost all definitions of large-scale research infrastructures arise from initiative of technologically complex and high-cost equipment and infrastructure essential to carry out frontier research with cutting-edge technologies and advancing our understanding of the world. E.g. the EU defines as **“RIs that** are “facilities, resources and services used by the science community to conduct research and foster innovation. They include major scientific equipment, resources, such as collections, archives or scientific data, e-infrastructures, such as data and computing systems, and communication networks.

For the purposes of this research ESFRI definition will be used, namely:facilities, resources or services of a unique nature that have been identified by European research communities to conduct top-level activities in all fields. RI includes the associated human resources and covers major equipment or sets of instruments, in addition to knowledge containing resources, such as collections, archives and data banks [3;4].

Typology of research infrastructure

After the assessment of the main existing definitions, we have to address different research infrastructures that can be divided in several different categories [5;6]. However, for the purpose of the current research we divide them in severalaggregated blocks:

University based RI: is linked to a specific university and utilised for both research, as well as educational purposes. Regular large-scale equipment in universities, if the investment exceeds k€200 (for universities) or 100 thousand EUR [5;7]. The university-based infrastructure can be divided in smaller Campuses for specialised research.Next block is industry based RICorporate large-scale research facilities that can be found in a case of strategic large-partnerships that have a significant role in scientific development and operate significant RI [8]. RI can also be organised as a separate research institute. Universities also might have separate specialised RI at science institutes specialising in a particular field or undertake multi-disciplinary research [7]. Research institutes also can be separated from universities as well as industries and act as independent RI, e.g. particle accelerators, telescopes etc. [6;7].

Physically all the above-mentioned types of infrastructure can be located in one place or distributed. In the first case, the administrative and physical unit is located in one place. In the second case it is a network of geographically distributed instruments or collections located in different geographical places, which operate (in real time) as a single-machine, e.g. LOFAR stations increase instrument's resolutions more than any single facility could achieve [6;9]. To ensure and facilitate access to different types of RI national nodes are being developed as an access point or operative node of wider network of spatially distributed facilities [10]. To conduct research in remote places mobile facilities can be utilised. This involves vehicles, vessels or satellites specially designed for scientific research [11].

Latest ICT development has facilitated the growth of virtual facilities and e-infrastructure. Virtual facilities provide scientists with remote access to the research instruments or large data sets over the Internet or communications network. E.g. distributed large-scale equipment pools, databases, archives, libraries, object based collections of natural, cultural objects with open access to them etc. [7]. E-infrastructure, in turn, is a more complex structure and represents high performance communication networks and computer grids, e.g. PRACE, EGI or EUDAT in Europe, and XSEDE in the USA. Some see this "fourth paradigm" of data-intensive science – beyond observation, theory and simulation [6;12;13].

As a separate type of RI Social research infrastructures should be mentioned. They are defined as a type of RI which is relevant to the humanities and social sciences, based on human networks of very high scientific value. Social RIs frequently evolve in natural sciences as a by-product to the large-scale facilities to encourage disciplinary and interdisciplinary collaboration[6].

Besides the above described typologies there are two subcategories to be mentioned. Often large-scale RIs are of national importance or **National facilities.** The targets of national infrastructure objects usually are to maintain, contribute or develop the nation's research excellence or to meet the upcoming challenges in particular field of science or group of society [14]. The model of **International facilities** represents large-scale facilities founded by several countries or international organisations. Firstly, this group represents large facilities established by major international agreements and are managed by founder-country's created international organisation or operator with shared strategic plan [15].

Identified development of science and large-scale research facilities

Many research facilities exist for scientific purposes only. Economic and social impacts are generated indirectly and are not properly assessed. For the other facilities the impact on economy and society is stated in their mission. For example, national reference laboratories, blood sample banks and biobanks are designed to support public health and do scientific research as a supporting activity [16]. In such cases, the wider societal impacts are embedded in the facility's design. The performed literature analysis allowed group all main types of RIs with their needs and operation characteristics around four main challenges identified that RIs are facing today, namely:

- from academic freedom to well managed research collaboration;
- from new knowledge creation to new problem-solving competence;
- change to high competition requires new governance techniques;
- technical growth embeddedness asks for formation of next generation personnel.

Challenge 1: From investigator-driven to research collaboration driven science

Historically scientific facilities ought to be placed in already functional technological localities, containing many well-educated people with diverse skills, living in a culturally rich environment [17]. At conventional lab facilities usually a lab leader, individual scientist - lone genius determines the research plan, including use of available equipment.

Introduction ofinternational multi-partner collaborative governance of research helps attract additional resources [15]. An extremely homogeneous and conservative researchers' community with complicated peer-review mechanisms can be extremely resistant to any innovation of scientists and limits scientific progress within particular boundaries of the current community. Real and more rapid scientific progress occurs, when new and more flexible science paradigm towards existing evidence of technological ecosystem emerges and drives the activities of the scientific community [15]. The large-scale Science facilities have implied the shift from investigator-driven research towards more planned and guided collaborative research. Science policy is more and more based on top priority science topics, stemming from state-of-the art observations and theory performed on collaborative bases and involving large-scale Ris [18].

The opportunity to use large-scale research infrastructure objects determines the level of openness to scientific community and can be characterised by three main stages of operation cycle: using the equipment, submitting samples or placing orders to be investigated and an opportunity to expand equipment limits by integrating new functions at existing equipment [19]. Procedure for call for proposals after evaluation of submissions provides transnational access. The ease of virtual access (online services) of large-scale RIs offers better preconditions to attract external users. However, also they play a more important role both in quantitative and qualitative terms[6].

Challenge 2: From new knowledge creation to finding new solutions

The output from the basic research depends on the investigator-driven research, while the targeted research – on developed or identified solutions [15]. If the earlier role of science was embedded as an efficient generator of new ideas facilitating incremental or radical innovations, discoveries and new knowledge, then in the 21st century science should be viewed as a platform of interdisciplinary frontier research targeted to feed a globally competitive economy, that can be beneficial for the society [8].The shift to more targeted both basic and applied or industrial research was caused by growing costs, introduction of Technology Readiness Level criteria, required consolidation of efforts and lack of technically and commercially thinking academics [18].

The large-scale research facilities require new creative and innovative solutions for data and novel ICT systems. The system should be integrated with other systems and allow intensive data mining, retrieval of meta- or processed data, parallel and cloud computing, including high speed data streaming and other complicated procedures. ICT frontier resources consuming system represents combined efforts of engineers, scientists, technically and geographically distributed programmers from many institutions, but integrated and exploited as one joint machine[6]. The solution-focused philosophy includes also transfer of solution-based knowledge to the industry. The importance of the Technology Readiness Level of designed elements of large RIs starts to prevail in technical requirements [18].

Challenge 3: New ways of governance

The planning of costs for any RI includes design, construction, commissioning, operation and de-commissioning expenses as a crucial aspect for sustainability [20].

In several occasions, e.g. the OECD report outlines difficulties of properly account contingencies and quite large operating costs. Typically, 10% of total construction costs annually. The “free, open, merit-based access” for external, non-affiliated to facility users, applied in many countries and for international level facilities, requires that operating costs consider external access expenditures at the planning stage [20]. The hosting institutions cannot always cover all operating costs and considerable modernisation costs, which arise during the lifetime of the research facilities. Long-term commitment for institutional funding will provide stability, sustainability and will influence the entire scientific system in a country [7].

It is important to review the received innovation potential associated with the big-science experiments, and also, the best approaches to nurture and exploit this potential [2]. Since the large-scale RI is a very costly endeavour, it is very important to develop appropriate and efficient governance models. Crucial aspect here is the utilization rate and contribution to the coverage of the fixed costs.

Based upon a peer review selection process, the ESFRI roadmap identified a set of 48 new pan-European RIs or major upgrades to existing ones, corresponding to the needs of European research communities in the next 10 to 20 years.Transnational access to research facilities is a goal in all FP funding programmes – since FP2 till FP8. FP8 added four relevant objectives important for further large-scale facility use [21]:

- support to Regional Partner Facilities in synergy with DG REGIO actions;
- supported operation phase of new RIs;
- fostered innovation potential of RIs;
- strengthened human capital of RI.

Shift to project based approach. The funding agencies usually provide financing for planned specific and measurable results. Such results researchers have to reach within limited time, personnel and with the highest quality (excellence). Goals can be reached introducing project and risk management based techniques and involving partner (user) consortia in the decision-making process, transfer the administration from academics to project managers, introducing of ICT in management, as well as shift from in-house approach to open science paradigm in management. An interaction between the involved scientists is playing a more increasing role and ICT can be seen as a tool to facilitate this interaction.

Challenge 4: Formation of the next generation scientists, experimental engineers and managers

Modern large-scale research infrastructure require continuous technical upgrade and scientific and engineering proof of new concepts generated, access to multidisciplinary knowledge and experimental curiosity [22]. Use of frontier instruments drives science and inventions in applied science to provide knowledge-based problem-solutions, pieces and components for practical science that should drive technological development of next generation instruments [23]. Technoscience as a concept was introduced to emphasize that practitioners or engineers (inventors) maintain and deploy their scope of knowledge that is not always embedded in science-generated knowledge [23].

The new agents of change are employed at large facilities and surrounding labs as”Scientific entrepreneurs”, who show opportunism, some risk-taking and the ability to purposefully enrol and coordinate resources [23]. The specialisation and division of labour occur not only locally in some institute, but also nationally and more and more internationally. Maintenance and technical standards of technically very advanced instruments and infrastructure [23] lead to the dissolving of sharp boundaries between the professional identities like “instrument builder”, “experimentalist” and “scientist” [2, p. 106]. Managers are similar to CEOs and have enabling role to assemble policy framework together with external users and in-house activities in one stream [2, p. 285].

Facilities create a learning and mobility environment where scientists, users and industry interact in maintenance, operation, development, construction, and use. The mobility is one of the solutions for providing highly competent scientists. Growing number of staff transfers, dual career partnerships and transfer of social security between RIs are some aspects that enhance the competence development and facilitate the growth of the user base [6].

Table 1

Main indicators for overcoming the challenges

No	Indicator	No	Indicator	No	Indicator
1.1.	Strategy of openness.	2.3.	Level of technical development	3.5.	Consolidation replacement effect
1.2.	Level of used facility by external users	2.4.	Move of novel ICT systems	3.6.	Global networking value
1.3.	Structured openness.	2.5.	Existence of strong technical standard	4.1.	Experimental engineers
1.4.	Focus on quality science	2.6.	Level of innovation ecosystem quality	4.2.	Role of facility's scientists as intermediators with external users
1.5.	Embedded science excellence	3.1.	National user consortia	4.3.	Role of facility managers
1.6.	Support to users	3.2.	Targeted financing program	4.4.	Learning environment
2.1.	Level of guided technical development	3.3.	Shift from academic freedom to planned science process	4.5.	Balanced and sustainable science
2.2.	Ability to attract funding	3.4.	Level of e-infrastructure development	4.6.	Readiness for new competencies

Note: No first digit gives No. of Challenge, the second – No of particular indicator.

Design of RIs performance evaluation metrix

Each system and its quality might be characterised and its elements compared using an evaluation Metrix developed for such purpose. When it comes to the analysis of exploitation of large-scale research facilities and virtual collections, the understanding of factors influencing the use of facility obtain primary importance. For each challenge we have defined six indicators (see Table 1).

Now we may develop balanced Metrix consisting of 24 different factors combined in four main groups or levels.This will be a subject for further analysis based on 6 case studies conducted on the international arena.Such analysis will provide the necessary insight in the presence of the above-mentioned parameters and indicators, and also their influence on the user base development.

Good practice among selected research infrastructures

Firstly, the focus of the case study analysis was international RIs, which are attractive to scientists due to more opportunities, access to advanced knowledge, and knowledge spillovers, in different European countries. Secondly, the cases were chosen based on different types of RIs (single RI and distributed RI) in order to assess the similarities and differences predetermined by the type of RI. Thirdly, the scope of the networks related to the leading institution of the RI was considered when choosing a case, because networks are considered critical in cooperation. Finally, the cases were chosen based on the cooperation of the leading institute of the RI with institutes of other BSR countries. During the research, there were 2 case studies conducted in each of the fields of scientific excellence (life science, materials science and welfare state):

1. Biobanking and Biomolecular Research Infrastructure (BBMRI-ERIC): http://www.bbmri-eric.eu/.
2. European infrastructure for translational medicine (EATRIS): https://eatris.eu/.
3. European X-Ray Free-Electron Laser Facility (XFEL) https://www.xfel.eu/.
4. SOLARIS National Synchrotron Radiation Centre http://www.synchrotron.uj.edu.pl/en_GB/
5. Integrating RI for European expertise on Inclusive Growth from data to policy (InGRID) http://www.inclusivegrowth.eu/.
6. Survey of Health, Ageing, and Retirement in Europe (SHARE-ERIC) http://www.share-project.org/.

The authors selected the case studies in order to provide broader insight into the different practices in operations and in particular in the different strategies to attract talent and increase the user base. The analysis was conducted on the following main blocks: structural attributes, human resources, financial resources, services and outreach activities.

Structural attributes are very different in all analysed cases; however, we have identified several aspects that can be seen as common. First of all, the structures are to large extent determined by logical links between networks and their members. These links are defined by common research interests, knowledge gravity aspects etc. This implies that no matter if the structure is being physically built or virtually developed, the interests and supply –demand conditions play a significant role how the infrastructure is being developed. Second, the structures are built taking into account the user consortia needs and built-in network conditions, meaning that the existing networks and defined network expansion goals to large extent determine the developed structures.

Human resources are the second block. The attraction and development of skilled and talented scientists and employees is explicitly stated priority in all the analysed cases. A lot of efforts are spent to eliminate the impact of a physical distance and financial limitations to attract the highly qualified human resources, e.g. there is support for application development, training provided to use the infrastructure, virtual access opportunities etc. However, there are also some thresholds identified that are supposed to achieve two goals: ensure that taxpayers' money is properly spend for the benefit of the EU and second is the knowledge and capability verification before the access to the infrastructure is granted. In the first case the threshold is set in form of limit for non-EU citizens to participate and in the second it is the demand to have a certain scientific degree, namely, in some cases only PhD students are eligible to apply to work within the network or facility.

Financial resources – the role is to provide the necessary financial resources, but also to motivate. Financial support is provided for development of the infrastructure and operation. Also sometimes used to cover the real costs of operations. Budgets are very different in terms of size but similar in terms of sources, so the EU governmental and municipal budgets are prevailing. Here we can observe that larger proportion of the EU funding has a positive impact on openness and attraction of external talent. At the same time the EU funding brings some negative effects as well. During the focus group discussions it was stated that the EU support usually is project based and those projects are usually short term. This creates significant uncertainty for scientists and their future employment perspectives.

Services and benefits. Here a very wide range of components can be found. E.g. data, materials and samples, access (use) to equipment to conduct experiments or tests, coordination of knowledge exchange, access to computing power, funding application support, industry access, and technical assistance. This also includes training of users (scientists) and training in data processing and interpretation of the results. The provided services are also extensively used as a tool to attract scientists that could bring an added value to the particular research field. This creates some risks for smaller countries and infrastructures, since they are less attractive for scientists compared to large infrastructures providing very wide services and benefits.

Outputs and outreach in all cases can be described as significant. First to be mentioned are publications developed as the results of research conducted within the research infrastructure. Demand to publish and ensure that the research results are publicly available is a common approach from the larger institutes, especially in case of significant funding from the EU. External access to the results and data is provided thus allowing faster and more efficient dissemination of the research results.

In addition to the international case studies an extensive primary research was conducted in Latvia. For each of the fields of scientific excellence working groups consisting of international and local experts were created in order to assess a number of topics: e.g. financing and costs of RI, the importance of retaining scientists, scientific cooperation, topics of joint interest for future multilateral research collaboration, etc. During the final working group discussion the participants agreed to a set of issues that have to be addressed, namely, insufficient funding for RI, insufficient cooperation in certain science domains, the value of long-term strategies, and lack of qualified research personnel in certain science domains.

During the interviews the importance of transparency and openness in RI access policies, the lack of funding for new and maintenance of existing RI, the importance of training new scientists and RI personnel, and cooperation development were discussed. The interviewed experts' insights mostly overlapped with the conclusions from the working group seminars.

Analysis and discussion

Initially the case studies were selected in different areas of science, presuming that there might be some significant differences between the areas. However, the case studies as well as the working group discussions did not identify any significant differences in how the challenges and new trends are perceived and how they influence the strategies deployed to attract scientists and increase the user base. Infrastructures in all areas and of different size are affected by the increasing role of collaboration. The only minor difference here could be observed in the area of welfare state research that is less dependent on the distance to the researchers and scientists. The picture becomes different, if some particular equipment is needed to conduct the research. In this case, more effort is needed to attract the user base and ensure their ability to conduct experiments and other measurements. The shift to more solution-based research shows the opposite picture. In general Material and Life sciences are more oriented towards finding new technical solutions. The welfare state is still more focused on generating new knowledge leaving the solutions and decisions to the administrative managers. Thus, also the user base and in particular ability to attract and employ new talent is more in an institution's strategic focus for Material and Life sciences. New ways of governance and project-based work were closely related to the financing model of the RI that includes both the size of the funding and type, e.g. the EU supported projects or national base funding. Smaller and not so wealthy countries are facing more challenges to ensure operational sustainability. This is relevant also for governance models that are oftentimes tailored depending on the demands from the supporting institution. This to large extent limits the operational freedom and ability to attract talent and increase the quality and capacity of the user base. The formation of the next generation scientists is the last and most relevant challenge to be addressed and discussed. This challenge was recognized as important from all primary and secondary sources. The current scientific development has been accelerating during the last decade and has become more dynamic, and is changing faster. This is also relevant for the user base that has become more global, but also more dynamic in terms of mobility. This can be explained by more openness between the EU countries as well as political support for exchange and mobility, e.g. H2020, ERASMUS and other programs demand sufficient cross border partnerships for the eligibility to obtain the financial support. The comfort zone for younger generation of scientists is much more global, so they can easier search and pursue different opportunities depending on their scientific interests. Increased networking and mobility, on the one hand, and more increasing knowledge gravity create substantial challenges for smaller infrastructures that face difficulties to attract and retain the new generation of scientists. However, there are some solutions deployed, namely, offering niche services for scientists, operating as subcontractors and national nodes for larger institutes etc. In other words smaller RI seek their innovative ways to ensure sustainability of human capital, which tends to drain to larger and more financially strong infrastructures.

Toolbox for facilitation of collaboration

This chapter is focused on the aggregated analyses of the case studies with some comparison with the results of literature analysis, primary research and the developed metrix. This includes thorough analysis and assessment of the webpages for each of the infrastructures, statutes, annual reports and developed strategies etc. This information was searched for all the cases, however, for some of them the information was missing or was insufficient. This was considered as a clear indication on flaws in the collaboration strategy, since the extensive and sufficient information about all the aspects of co-operation is a necessary pre-condition for success. The analysis was conducted according to the theoretical insights provided in the previous chapter on metrix. The theoretical framework in that chapter is more extensive and contains higher level of detail. However, the analysis in accordance with the complete theoretical framework was not possible due to the lack of publicly available data and information.

The chosen areas of excellence are rather different in terms of the type of operation; however, the conducted analyses revealed that the selected cases are rather similar in terms of the tools and approaches used to facilitate the use of infrastructure as well as local and international co-operation. In the following paragraphs the most important tools for enhanced collaboration are identified and described.

Openness is the first criteria observed in all selected cases: the information about the project and infrastructure is available on websites in number of languages and English is default language for all the analysed cases. However, the fact that information is available does not mean that it is sufficient and appropriate to attract the interest and co-operation partners. It is important that the available information is structured and provided in a way that creates a clear and realistic perception of the expected rules for collaboration. Equally important it is to ensure that the provided information is accurate and attractive describing all the opportunities provided for scientists.

Strategy of openness is the next criterion. Even though the selected cases can be considered as fairly open, the openness as such is not a sustainable facilitator of co-operation. It is important to develop a clear strategy for openness and this is supported by both theoretical findings and from the case analysis. Such a strategy outlines the short and medium-term activities aimed at promotion of the infrastructure and research collaboration. The vital component of the strategy is focus on the international collaboration both within as well as outside the EU. If such a strategy is developed, it should also be publicly available to ensure that the possible co-operation partners can gain the information about the current state as well as future development of the principles and strategy of openness.

Transparency is important both for attraction of the scientists and co-operation partners as well as to ensure that the projects accepted for development are of high academic and scientific value. Clear and transparent criteria for selection of projects facilitate the inflow of applications from all over the world. The appropriateness and quality of the projects are prioritized compared to the country of origin, e.g. the fact that researchers come from the EU does not provide them with additional points in the application procedure.

The support measures for applicants can be described as significant and extensive. This includes support during the application process as well as during the use of the infrastructure. Support measures include detailed guidelines for application preparation and submission. The use of the infrastructure often is also provided with additional support measures, e.g. courses and other support for knowledge that is necessary to work with the infrastructure.

Financing aspects: the large-scale infrastructure usually is being developed with the extensive financial support from the government and/or the European Union. This includes financing for development as well as operation of the infrastructure. The large cost of the development and operation incline the expectation that the use of the infrastructure will be expensive, and charges will be applied to all researchers that are using it. This is true to some extent, since membership fees are applied for participating universities and/or countries. However, the fees usually are not applied for individual scientists. Even more in some cases the financial support is provided for scientists in order to attract them and make their stay more comfortable.

Project base approach is evolving as a new way of operation. From the literature review follows that the science is experiencing the shift in focus from the general knowledge development to solutions and more planned and managed scientific work in finding the solutions. This implies the focus on goals of the project necessary resources and planned timeline. Such a way of organizing the scientific work ensures more result and solution orientation as well as more predictable resource need and allocation. Also, from the perspective of scientists, such approach is more favourable, since the rules for use of the facility and important milestones are clearly defined and can be used for progress assessment at any time.

Promotion also is an important tool for facilitation of more extensive use of infrastructure and increase of the user base. This includes information spreading about the opportunities provided at the facility. Also, scientific publications play an important role in promotional package of the facility. In the analysed cases it can be observed that publications are being developed as well as promoted intensively in order to raise the interest and attract skilled and knowledgeable scientists.

Project support, e.g. Horizon 2020 currently is the main EU instrument for supporting of science and research. All the analysed institutes are having H2020 applications high on the priority list. This is relevant for both development of the own H2020 applications as well as supporting other scientists in this respect. This inclines that the toolbox suggested for other scientific infrastructures should include support for and/or within H2020 projects. This support then can be further broken down in smaller details, e.g. help in preparation of application, support for understanding the philosophy of H2020, financial support for some part of development of H2020 projects etc.

ICT and E-infrastructure play ever-increasing role in the operation of infrastructure. The analysed cases to large extent offer remote access and use of the infrastructure. This means a significant cost saving and increase of the use of the infrastructure, as less need for travel and physical space is needed. The intensity of use in turn is achieved through shorter lead times and better opportunities for multiuse of the infrastructure. ICT infrastructure is crucial in many areas of our lives and especially in science. Modern research cannot be operational and competitive without a sufficient computing power, fast broadband, modern communication and videoconferencing tools etc. Thus, in order to facilitate the co-operation and use of infrastructure the facility holders need to update and upgrade the ICT system regularly to ensure it is up to date and operational. This is relevant for specialized as well as general ICT infrastructure that is operational at the facility.

Conclusions

First, we should conclude that the development of the research infrastructure and efficient use to large extent depend on support from the government, the European Union and other external funders.

The second conclusion is related to the context. No matter which tools are involved in the facilitation of use of infrastructure, it is important to adjust them to the specific context and user needs. This includes the ecosystem present in the country, institutions involved directly or indirectly etc.

The third conclusion is related to the gravity of the knowledge. The larger agglomeration of scientists is more attractive for other scientists. This is evidenced also by efforts made by the scientific institutions in creation of wide and knowledge intensive networks. This brings many benefits to the institutions, namely, wider access to the new solutions developed and scientific competence possessed.

The fourth conclusion is about the increasing use of ICT and e- infrastructure that allows efficient and fast use remotely. Developed ICT infrastructure will positively influence knowledge gravity: opportunities to interact with the best scientists in the field without the need to travel somewhere.

The fifth conclusion is related to the general operational principles for scientists and scientific institutions. Business principles, more orientation on results and efficient use of resources, project-based work are only few examples on how the scientific work is changing in order to sustain the competitiveness of European researchers.

The last conclusion is about accelerating importance of co-operation synergies and development of critical mass. This to large extent can be achieved through the technical solutions, like ICT etc., but that is not the only influencing factor. The willingness and readiness of the scientists to co-operate and co-create is increasing, thus providing us with reason to expect even more new and innovative scientific projects and solutions that are developed through productive and efficient co-operation.

In addition to the impact of the R&D output from the infrastructure, there are several financial economic impacts to the locality where large-scale scientific facilities or scientific employers are located. These impacts occur through the budget of the employer being spent in the surrounding or wider area to the site. Budgets are spent on wages, equipment, overheads etc. in the area. Maintenance and upkeep of the facilities and equipment constitute a significant amount that is spent on local basis. A summary of the literature analysis provides us with the main outcomes:

- Economic benefits are also provided due to the economies of scale achieved by the large RI.
- Benefits to the local economy come from the skills gained by the staff that works at the facility and also include economic activity generated by visiting staff and users.
- The most direct way in which large facilities have impact on the host nation is through different channels of collaboration with the national science base. The host of a large scientific facility gains scientific prestige and leadership and the ability to raise the profile of a particular science area.

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