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# National research infrastructure analysis

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# Summary

The analysis is based on the Latvian Research Infrastructure survey of 22 institutions (with 59 RI units and 410 significant equipment units) as well as five interviews with the management of seven research institutions.

In general, the Latvian research infrastructure is up to date and covers current research or service needs, it is moderately utilized, below 60% of capacity, and there are no significant capacity gaps. Mostly, the equipment by itself is not unique but unique are particular configurations or collections of instruments, as well as specialization of services, skills, and knowledge.

The quality and professionalization of RI management and maintenance significantly varies across institutions. At research institutes, in general, it is centralized, with established procedures and staff, while at universities it is highly decentralized, inconsistent, and insufficient.

Only one institution has implemented LIMS. Some institutions use different local systems to cover some of its functions. A lack of LIMS might impact the ability of potential external users to book RI services, and it impacts the quality of the monitoring and reporting.

Streamlining and improving RI management and maintenance is the utmost priority for developing high-quality services, improving efficiency, and increasing international competitiveness. Special attention should be paid to universities. Policies might include introducing requirements and best practices, funding for improving management and maintenance, and introducing LIMS.

Maintenance funding should be aimed at developing the "core" research infrastructure that provides world-class RI services and expertise to a broad range of researchers and businesses locally and internationally. It is not aimed at supporting the respective institution's research activities *per se*.

It should be appropriated to institutions that are well-maintained as RI service organizations – have professional RI management and maintenance unit, have implemented LIMS and quality management, have formal access to external users with easy booking, provide training, consulting, and support, have sufficient free capacity. Also, RI and services should be internationally competitive (significant scale, unique and competitive instruments or services).

There should be simple procedures for calculating and assigning maintenance funding. It might be based on the value of the specific research equipment and FTE of RI users, as well as might include indicators for foreign income and income from contracts, and fixed, significant maintenance costs.

Formally, almost all institutions provide access to infrastructure for external users. Usually, it is done through services provided or in collaborative projects. In reality, institutions do not see nor develop their infrastructure as a RI services platform. Rather, their missions and strategies are focused on their research agenda.

The external usage of the RI is low. 65% of instruments were used for external research below 5% of their capacity, and the next 25% at 5-10%. The numbers for business usage are even lower. Also, the number of external staff (e.g., visiting scholars or company employees) working at the premises is low, except for students.

Also, 68% of institutional income is from Latvian or foreign research grants. Income from Latvian business contracts is around 6% of institutional income, with the other 6% coming from domestic public contracts. Foreign income is rising, with 21% of institutional income coming from the EU framework programs and 19% from other foreign sources. However, non-grant and foreign income are highly concentrated in a few institutions.

Due to insufficient exposure to markets and insufficient market integration, and because of the small (*thin*) domestic market, strategic, top-down infrastructure development policy oriented towards domestic RIS3 goals can't be advised. Instead, RI development should focus on emphasizing the strategic advantages of competitive RIs (*"picking winners"*).

Furthermore, policies should aim at increasing the exposure of RIs to markets and fostering R&D collaboration between RIs and businesses. Namely, funding for initial (discovery) stages of the potential R&D projects, fostering the participation of RIs in "infrastructure networks" and consortiums, and supporting their participation in R&D infrastructure or services, or industrial fairs, rewarding institutions for establishing new collaborations.

Since there aren't pronounced capacity shortages, RI investments can focus on specific, ambitious policies, aim at strategic advantages of the institutions, and set a high bar for applicants.

Among investment priorities might be funding to replace instruments nearing end-of-life or uncompetitive (because multiple instruments near their end-of-life at the same time); to gradually develop capacity (expand RI services, broaden research agenda, or increase competitiveness); comprehensive projects for starting new strategic research or services (covering infrastructure, staff, research, running, and maintenance for 5 years); support the development of internationally competitive joint R&D initiatives between RIs and businesses; development of the shared research infrastructure, and support for merging RIs or developing joint RI platforms and services.

# Abbreviations

ESFRI – European Strategy Forum on Research Infrastructures

FORD – fields of research and development as defined in *"The Measurement of Scientific, Technological and Innovation Activities, Frascati Manual 2015"* (OECD, 2015)

FTE – full-time equivalents (of staff)

LIMS – Laboratory Information Management System

NZDIS – National Information System of The Scientific Activity

R&D – research and development

RI – research infrastructure

RIS3 – (Latvian) research and innovation strategy for smart specialization

STEM – science, technology, engineering, and mathematics

**Latvian research institutions participating in the analysis**

AREI – Institute of Agricultural Resources and Economics

BIOR – Scientific Institute of Food Safety, Animal Health and Environment "BIOR"

BMC – Latvian Biomedical Research and Study Center

CFI – Institute of Solid-State Physics of the University of Latvia

DI – Institute of Horticulture

DU – Daugavpils University

EDI – Institute of Electronics and Computer Science

KKI – Latvian State Institute of Wood Chemistry

LU – University of Latvia

LULFMI –Institute of Literature, Folklore, and Art of the University of Latvia

LUMII – Institute of Mathematics and Informatics of the University of Latvia

OSI – Latvian Institute of Organic Synthesis

SILAVA – Latvian State Forestry Institute "Silava"

RSU – Riga Stradins University

RTU – Riga Technical University

VEAVSRC – VSRC Radio telescope complex of the Ventspils University

# 1 Analysis of the Latvian research infrastructure

The analysis is based on the Latvian Research Infrastructure Survey and interviews with the management of research institutions.

The survey about Latvian research infrastructure was sent to all higher education and scientific institutions. It had two stages. First, general information about RIs and their composition was collected. Answers from 22 institutions were received, listing 59 RI units and 410 significant equipment units. The initial assessment of the "potential core RIs" was done and the smallest institutions (7 institutions, 15 RI units, 91 equipment units) were excluded from answering the remaining questions. In the second stage responses from 14 institutions, 44 RI units, and 319 equipment units were collected about utilization, income, costs and resources, results, and collaborations.

In addition, five interviews were conducted with the management of seven Latvian research institutions to understand better managerial motivations and decisions related to research infrastructure. To cover institutional differences, several research institutes and large universities were among the interviewees. In-deep interviews aimed to explore the following questions: How are decisions related to infrastructure planning and procurement made? How collaboration on RI use and access to it is organized for internal and external users? How is infrastructure utilization assessed and managed? How is infrastructure maintenance organized?

While responses provide sufficient information to evaluate the current situation and tendencies, several factors might impact their credibility and hinder the ability to construct quantitative indicators for policy (funding) tools. All data are self-reported, primarily based on employee estimations, and only in a few cases, institutions have (automatic, consistent, and detailed) records regarding, e.g., utilization, cost, or collaboration indicators.

Also, despite instructions and methodological help, we see differing understandings about defining a "research infrastructure unit". Some institutions reported one RI unit per institution, some split their infrastructure into several RI units by specialization. Further, definitions of "equipment units" differ. Some reported every single instrument, some – collections of related instruments. Finally, there are significant differences in reporting costs and results. Especially, institutions that split their RI into separate units had difficulty understanding how to split results and costs. Also, for research institutes, institutional results (income, publications, etc.) are related to research performed on their RI, and there is no unique accounting for RI-related results. Most of them just reported total institutional results.

## 1.1 The current state of the research infrastructure

In total, 410 “the most significant” equipment units or collections of related instruments were reported, with a reported total value of 134 million EUR. That covers more than 40% of all 1109 equipment units reported to NZDIS since in the survey multiple instruments were reported as sets.

Furthermore, 43 databases and collections were reported, including 22 digital resources in various fields, 15 biological sample collections, and four collections in humanities and arts. Most of these resources and collections are essential to support research activities or RI services of the respective institution. There are five significant “green infrastructure” objects, including greenhouses, or large research plantings and territories in forestry and agriculture.

**Novelty and uniqueness of the RI**

Overall, the Latvian research infrastructure is up to date. 44% of equipment units (156) are considered novel and more modern than at other institutions in the field, and 42% (148) are comparable to what other institutions use. 13% of equipment units (44) were considered “nearing the end of usability but still used in the field”, and only three (<1%) were considered obsolete.

Also, during interviews, research institution management admitted that the infrastructure is up to date and covers current research or service needs, and there aren’t significant capacity gaps. During the last funding calls, institutions aimed to fully cover current and anticipated research needs, and they largely succeeded in doing that.

The state of infrastructure doesn’t prevent it from being successful and competitive. 29 of 44 RIs explicitly answered “NO” to whether the state of infrastructure prevented them from receiving contracts or establishing collaborations, 10 didn’t provide answers, and five RIs (in three institutions) reported that contracts were lost due to lack of capacity or equipment, obsolete equipment, or lack of specific services or procedures.

The infrastructure is relatively unique for Latvia but can’t be considered unique in the broader region. 65% of equipment units were reported as unique for Latvia but only 30% – unique in the Baltic, and 10%– unique in Europe. However, RIs had difficulty assessing the uniqueness of their equipment, with 23% of equipment units missing this evaluation.

On the other hand, unique is the configuration or collection of instruments that fits the institution’s research activities and particular knowledge, skills, and experience (what is done with instruments). Even if some “duplication” of instruments can be observed, the institutions wouldn’t be able to provide the same research services. Moreover, instruments might have significantly different technical specifications while having similar names. Also, similar common appliances can be found in many institutions to support the daily activities of researchers. Pooling such instruments or organizing their shared use won't be efficient.

There are several filters during investment procedures to reduce "duplication". Internally, the management evaluates if other institutions could provide the respective services and if the purchase would be economically justified. Especially if the usage would be occasional and of low volume. Also, external evaluation and pressure to avoid duplication (by the ministry or funding institutions) motivate to double-check the availability of respective instruments and services before making investments.

Institutions have quite a good understanding of what instruments and competencies other research institutions possess and who can provide services.

**Utilization rates**

The infrastructure is not overloaded. 70% of equipment units are used below 60% of their potential (16% at 0-10% utilization, 12% at 10-20%, 15% at 20-40%, and 25% at 40-60%). At the same time, about half of the research infrastructures (17) reported some heavily used equipment units, above 80% of their capacity. In total, about 18% of the equipment is heavily used.

Management interviews support similar conclusions – the infrastructure utilization is average. There are no significant cases of underutilization nor significant shortages leading to long waiting times.

When asked how to increase utilization rates, common answers were increasing research funds and employing more scientists. Also, funding for lab technicians and engineers would increase utilization because researchers currently often do their jobs. In some cases, improvement of premises, auxiliary or related equipment is necessary. Novel equipment (especially, in a new research area) might be temporarily underutilized while competencies are developed or projects attracted.

However, the data about the utilization of the Latvian RI are not precise. Moreover, institutions have difficulties assessing them. 20% of the equipment had no utilization measures – neither based on specialist evaluations nor recorded by management systems. Even in cases where utilization rates were provided, only 36% of responses (or 25% of all equipment) in seven institutions were based on records, and the rest were staff estimates. Even in these seven institutions, only a part of the equipment (at varied proportions) was covered by the records. Furthermore, some institutions provided the same utilization rate for all equipment units, questioning credibility.

Institutions usually have rudimentary utilization logs at the labs or centers, primarily for maintenance needs and material management. Systematic logging is done for commercial services as required by state aid regulations. Also, when asked by funding institutions (e.g., the Ministry of Education) for particular equipment, it stops as soon as external requests end. There were responses that "reports might be prepared if asked," questioning credibility.

Institutions don't analyze infrastructure utilization systematically. When making investment decisions, management uses "expert assessments" (e.g., obviously underutilized or overloaded).

Perhaps, the main rationale for not maintaining usage logs is that the infrastructure is underutilized, and there is no need for reserving or scheduling it. Therefore, keeping records is an extra activity without benefits for the researchers.

## 1.2 Research infrastructure by location, fields of R&D, and industries

The majority of RIs are based in Riga. There are 42 (71%) RI units in Riga at five higher education institutions and eight research institutes. In the regions, there are 17 RI units at six regional higher education institutions and three research institutes that are primarily related to agricultural & forestry research.

Most of the RI work in STEM and technical sciences. When asked to assign the FORD classification to their activities, 33 RIs reported working in Natural sciences, 10 in Biological sciences, and 8 in Computer and information sciences. Also, 32 RIs work in Engineering and Technology, 8 in Materials engineering, and 6 in Electrical and electronic engineering. A much smaller number of RIs (13) work in Medical and health sciences, 11 in Agricultural sciences, 8 in Humanities, and 4 in Social sciences.

RIs report covering all areas of the Latvian economy specialization. From the RIS3 perspective, most RIs work in "Biomedicine, medical technologies, pharmacy" (21 RIs), and in "Photonics, smart materials, technologies, and engineering systems" (20 RIs). Also, many RIs reported "Knowledge-intensive bioeconomy" (16) and "Information and communication technologies" (14) as their smart specialization areas. Fewer institutions are in Smart energy and mobility (9).

By the type of services provided (by CatRIS), the majority of RIs reported "Processing & analysis" as their main services (43 institutions) and "Access to physical and e-infrastructures" (33). Fewer institutions marked "Sharing and discovery" (26) or "Training and support" (25) as their main areas of activity.

Answers about specialization in FORD and RIS3 provide limited value for policy development. Each RI institution aims to demonstrate activity in a broad range of areas. Therefore, it is difficult to assess both the specialization of the particular RI and integration within the specific sector or field, as well as the capacity and competitiveness of the particular sector or field.

## 1.3 Management and maintenance of the research infrastructure

**Infrastructure management**

There are significant differences between research institutes and universities (higher education institutions) regarding the management and maintenance of the research infrastructure.

Research institutes are usually organized around the research infrastructure. Thus, the RI-related questions are strategic and of utmost importance for the upper management. Moreover, the institutes are of "manageable" size. Therefore, the executive level is directly involved in managing the research infrastructure. Infrastructure maintenance and management are centralized, with established procedures and staff. In general, the equipment is up and running, with some minor issues.

Universities, on the other hand, are large and diverse institutions, and infrastructure management and maintenance are highly decentralized – organized and performed by department (*fakultāte*), lab, or center management. At the university level, an indirect, policy-like approach to research infrastructure management can be observed – through formal requirements, procedures, and funding tools. This leads to inconsistent practices and overall subpar maintenance.

In all institutions, daily management and operational planning are done at sub-units, functional or specific to research sub-fields (*centers*, *platforms*, *groups*) at research institutes, departments, laboratories, or university research groups.

Only one institution uses centralized LIMS for comprehensive infrastructure management. Some institutions use different local systems (or paper journals) to cover some LIMS functions (booking, failures, usage records, etc.). The lack of LIMS might partially explain the difficulties for institutions to collect detailed utilization, cost, staff, or output measures during this analysis.

Institutions admit the usefulness of implementing LIMS as it helps organize maintenance and manage materials. Furthermore, it would be used for reserving and scheduling equipment usage and other infrastructure management needs. Implementing LIMS could improve monitoring and reporting capabilities as it allows easy generating utilization reports by projects, by units, and by funding types (e.g., commercial). It also contains a comprehensive equipment database and can be used to create public lists of available equipment and services.

On the other hand, institutions cite high investment costs and the complexity of the implementation to explain why they don't have LIMS. They emphasize the need to analyze institutional needs first and doubt if it will match the specific procedures and conditions of the institution. It is a long process as it involves changes in business processes and organizational culture. Moreover, low infrastructure utilization disincentivizes LIMS implementation since a low-hanging fruit – the ability to book busy instruments, is not relevant.

23 RIs have implemented a quality management system (14 RIs haven't). Of those, 16 have received certificates for their quality management. For 19, the quality management also covers procedures for providing RI services to external customers. Respondents admit that their RI management procedures aren't yet "up to the European level," noting insufficient RI management expertise and resources.

Implementing the LIMS and streamlining RI management won't be successful if it's not among the management's goals or if there isn't internal or external pressure to do that. The main drivers for streamlining and standardizing RI management and maintenance are a significant and rapid growth of the organization and research activity, as well as participation in international infrastructure networks. Networks help with technical assistance, peer reviews and external controls, best practices and standards, etc.

**Infrastructure maintenance and its costs**

Research institutes have well-established RI maintenance procedures. There are responsible persons at each center, lab, or group who follow equipment conditions and request maintenance or repairs, if necessary. Dedicated technicians and managers (or a special maintenance unit) at the institute or center level organize maintenance and repairs, or repair themselves when authorized support engineers are not required.

Mostly, institutes try to keep all instruments in running condition, and ready for use. If possible, under warranty coverage, insurance, or with service agreements. However, in some cases, resources are insufficient to keep everything in a running condition and with service agreements, nor is it always economically feasible. In such cases, the management prioritizes instrument repairs by their importance for the research processes. There were no reports about equipment downtimes that significantly influenced the research.

Universities have no centralized services or procedures for RI maintenance and repairs. Departments, centers, or labs arrange maintenance, warranties, insurance, service contracts, and repairs. At the university level, there are funding tools for covering repair costs, e.g., *"repair grants."* Universities report noticeable resource shortages for maintenance and the inability to cover all repair requests, leading to downtime. Furthermore, earlier, some equipment was purchased with no funding for installation, running, and maintenance, and is idling.

There are significant variations in reporting RI maintenance costs. It would be difficult to estimate precise costs and design funding tools with reasonable accuracy and minimum red tape.

Large research institutes reported a comparable number of staff working on maintenance tasks, roughly 23 FTE (16-29). However, "maintenance costs" had extreme variations, suggesting that institutions included different items. These costs do not correlate with asset values (2-15%), but rather with income (~7-11%). A significant part of maintenance costs is staff expenses (~60-80%). Repairs vary between 5% to 30% of maintenance costs and seem related to the type of infrastructure – smaller for digital infrastructure, and larger for lab equipment.

Institutions also note that existing research funding tools are not efficient for covering costs related to the development and maintenance of premises and auxiliary equipment (e.g., climate, air, water, gases, power, databases, etc.).

RI management name maintenance costs between 7-11% of the turnover, or 5-8% of assets. The most pressing need is to cover repair costs as they can't be funded from other funding sources. Further, it would allow expanding coverage of service agreements or insurance and keeping up auxiliary equipment. Also, funds are necessary for service technicians to free researchers from maintenance tasks and to exclude such expenses from project proposals (unexplainable staff costs and ambiguous responsibilities), as well as to devote resources to improving RI management and services for external RI users.

**Investment decisions**

In all interviewed institutions, *bottom-up* is the main approach to planning investments in infrastructure. Centers, labs, or departments submit lists of equipment they would need based on their research agenda, projects, state, utilization, and competitiveness of the existing equipment, or other (somewhat operational) considerations. Submissions are "vetted" by committees at different management levels. They analyze for duplication or similar equipment, benefits to other groups, and expected utilization v/s running and maintenance costs. Investment projects are matched with organizational development plans and research agendas.

*Top-down* decisions usually focus on the new strategic development of the infrastructure and the institution (e.g., significant expansion of capacity, "vertical integration" of services, or starting new research directions or services). None of the interviewed research institutions could name existing plans for strategic, large-scale investments in a completely novel research infrastructure or services.

The primary source for investments is EU-funded projects, therefore, shaping the development. Needs are assessed and infrastructure is developed "in batches" when the funding calls are open. Also, because this funding is fragmented, a significant part of the equipment becomes obsolete at the same time.

Institutions also use their own funds to develop RI infrastructure. They can afford to fund less expensive, more standard equipment, or provide "seed money" (internal grants) for new approaches or labs. Some smaller-scale purchases are made within research projects, usually satisfying the particular research group rather than following the strategic RI development.

## 1.4 Access to research infrastructure, use in R&D and business

All RIs, except three (in two institutions), reported open access to their equipment for external users, and almost all of them had formal procedures for infrastructure access. However, in almost all cases external specialists usually can't access instruments directly because training, experience, licensing, and *know-how* are needed to work with them. The usual form of "using RI" is through using services provided by the RI staff or collaborating on R&D projects.

Primarily, access to research equipment for both external and internal users is arranged through informal channels. Only one institution uses a formal reservation system to book RI equipment within the LIMS. Other institutions state that such reservation and scheduling are unnecessary as their RI capacity is sufficient for everyone to perform analysis within a reasonable time frame. Users directly agree with lab or center managers when they can use the equipment. Labs or centers might use some sort of local "reservation books".

The infrastructure is listed in catalogs, mostly field-specific databases or catalogs for consortiums or networks where RIs participate. However, the benefit from listings is marginal, because the equipment itself is not that unique, and potential users are interested in particular skills and competencies that are not easy to describe, emphasizing the importance of prior, personal contacts. Still, having a public list of equipment and services fosters collaboration with existing partners since they can look up what else might be available.

Few employees are involved in serving external customers. Only three institutions spent over 20 FTE annually on external services. For others, numbers are significantly lower; three institutions spent between 2-5 FTE, six – up to one, and two universities (summing of all their RIs) – around 9. Also, the number of *"employees (FTE) involved in strategic development, marketing and sales of the RI"* is low and varies significantly, suggesting that approaches to the strategic development of RI services are not formalized and vary between institutions.

In general, institutions do not see nor develop their infrastructure as a RI services platform. Instead, their missions and strategies are focused on their research agenda, and infrastructure is seen as a tool for fulfilling it.

### Research collaboration and participation in infrastructure networks

Collaborating on research projects is the most common way of letting other research institutions use the RI. Or researchers spend some time in other institutions. Also, semi-formal *"helping out each other"* is common when related costs aren't significant. The amount of *"plain"* RI services is minimal both work- and income-wise.

The actual use of the RI for external needs is low. For 65% of the equipment units, usage for needs of external research groups was below 5% of the capacity, and for the next 25% of the equipment units, the usage for such needs was between 5%-10% of their capacity. For serving business needs, the respective numbers are 73% below 5%, and the next 23% between 5%-10%.

Also, institutions don't use much of the other RIs' services. All institutions together in three years spent on external RI services ~65'000 EUR in Latvia and ~2000 EUR abroad. However, these numbers don't account for using external RI as a part of joint projects, which is the main form of utilizing capacities to other RIs. Funding tools sometimes restrict the use of external research services (only own or partner costs might be applicable).

RIs are comparably active at involving students in their work. Five institutions employed students from 30-133 FTE annually, and another five between 10-20. Numbers for other visitors are minuscule. Two institutions reported around 3.5 FTE annually of foreigners working at their premises, another two – between one and two, and four institutions – up to one. Also, the number of industrial researchers working at the RI is low, with only four institutions reporting 8, 3, 1, and 0.5 FTE, respectively.

The most active participants in international networks and consortiums are CFI (4 networks), VEAVSRC and BMV (3), and OSI (2). Some institutions participate in one institution – LUMII, DU, RTU, and LU. The most *"popular"* networks or ESFRI consortiums among Latvian RI's are EATRIS-ERIC, BBMRI-ERIC, CLARIN-ERIC, and CERN. Participation in networks and consortiums does not increase infrastructure use *per se*. However, they are beneficial for establishing new contacts and for helping to implement the best practices for RI management or field-specific research activities.

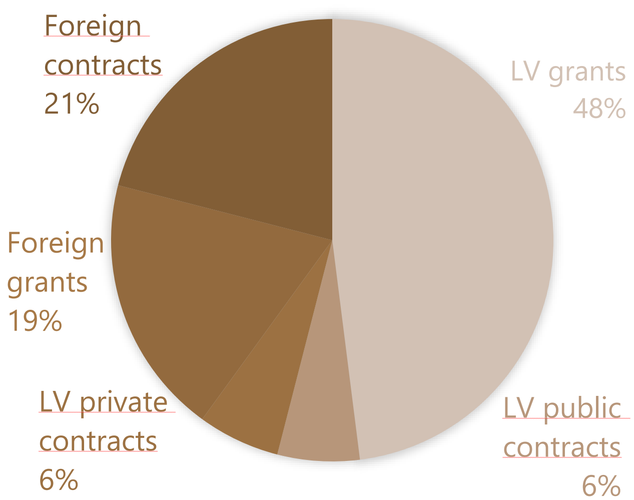
### Non-academic R&D collaboration

Formally, research infrastructures are actively involved in all smart specialization areas of the Latvian economy. In reality, of the reported annual institutional income of 57 million EUR, 67% is from Latvian or foreign research grants, only 6% from Latvian business contracts, and the other 6% from domestic public contracts (see Figure 1).

Moreover, 63% of all domestic public and private contracts income goes to three institutions. Another two institutions have a significant part (>10%) of their income from public domestic contracts. These examples are related to the high overall R&D activity in the particular sector or because they perform publicly funded functions.

Besides them, one institution reports 8% of their income from private contracts, two institutions around 6%, three from 3%-4%, and the rest between 0%-2%. Public contracts usually constitute only about 2% of institutional income. Low institutional income from domestic private contracts indicates a weak integration between RIs and economic actors.

*Figure 1. A proportion of income by source.*




Commercial usage restrictions for academic investments are named as obstacles to more active business use. Also, initial costs for understanding the needs of a business customer and creating the needed analysis are high. Furthermore, administrative and transactional overhead is significant for short-term (2-3 days) service projects. Thus, boutique "plain" infrastructure services don't cover costs. Institutions prefer to provide standardized analytical services or to collaborate with customers on larger R&D projects.

Latvian institutions are starting to focus on foreign sources, and they constitute 40% of income. However, these activities still are highly concentrated in a few institutions; TOP-three make 48% of EU framework income and 85% of other sources. Also, foreign R&D contracts are concentrated, with three institutions holding over 60% of them.

Overall, institutions demonstrate a strategic leaning towards domestic v/s foreign markets, as well as grants v/s contract funding by having varied proportions of the respective sources in their income.

Institutions do not know their potential partners or clients. Altogether, they could name 47 unique potential research collaborators in Latvia and 80 abroad, 68 unique potential clients in Latvia, and

33 abroad. Moreover, 1/3 of answers regarding potential Latvian or foreign clients were generic. The low numbers indicate a limited understanding of the potential market, insufficient foreign orientation, and a lack of competitive specialization at the global level of the RI and services.

## 1.5 "Core" research infrastructure

"Core" research infrastructure encompasses a wide range of facilities, technologies, and services with effective common governance, and provides world-class RI services and expertise in a specific field that are essential for supporting scientific research activities of a broad range of researchers across different disciplines both locally and internationally, as well serving R&D needs of companies and other organizations.

To be successful and internationally competitive, it has to be managed according to the best practices and provide high-quality RI services:

- has a separate RI maintenance and management unit with sufficient permanent employees who aren't students or researchers and aren't directly involved in research projects
- with its own annual budget, not directly funded from research projects (but its income can come from projects as deductions or internal fees)
- has implemented LIMS (with booking and usage accounting) and quality management systems
- open to external users, with formal access procedures, has a booking system that allows understanding the availability of necessary RI capacity or services and easily (remotely) schedule and reserve them
- has sufficient free capacity that can be allocated to external users
- provides users with necessary training, consulting, and support
- participates in international RI networks and is listed in the major EU-level RI & research services catalogs of the respective field.

Moreover, the infrastructure should be of significant size and *"interesting"* for the international scientific and R&D community. Our suggestion is that the "core RI" has above 1 million EUR in total value of significant, specific research instruments that each have a value above 100'000 EUR (excluding, e.g., desktop computers and other common hardware). It should have internationally unique or significant equipment or competencies, and internationally competitive specialization. Also large-scale, unique infrastructure, that can't be replaced (e.g., telescopes) can be considered as "core RI".

*The following suggestions regarding the potential "core" RIs are based solely on survey responses that might be inaccurate and incomplete. When applying for "core" RI status or RI maintenance* *funding, institutions might provide more detailed and accurate information, significantly impacting their classification.*

The majority of the Latvian institutions currently vaguely fit "core" RI requirements even if their instrument base is strong. Their weakest point is insufficiently developed management and maintenance. The strongest potential to be considered as a "core" institution is for CFI (all RIs), BIOR, OSI, and RTU HPC Center. Of smaller scale but still qualifies EDI, LUMII CLARIN-LV, and DI. Because of large-scale, nonreplaceable instruments, VEAVSRC and LU Astronomy and Space Geodesy Research Center fit "core" RI. Still, some of these institutions have to improve maintenance and management procedures to be considered competitive "core" RIs.

If RI management and maintenance are improved, some additional RTU RIs might qualify as "core".

The quality of answers has impacted the assessment of several RIs. Therefore, BMC is split into several RIs, each of them becoming less significant. KKI and SILAVA have weak responses regarding their management and access procedures, impacting their assessment.

LULFMI would qualify as "nationally significant RI" having collections that are important for Latvian culture and society. There is a potential to develop a strong "core" RI in humanities if LULFMI joins forces (common management of resources and services) with other collections of cultural artifacts (e.g., archives, museums, libraries).

Also, several other institutions could jointly form internationally competitive "core" RIs. In computing and data, a joint RI between BMC Bioinformatics Centre, EDI, LUMII Data and Cloud Computing Centre, and RTU HPC Center could be formed. In biotechnology, biosynthesis, and polymer science – between BMC Biotechnology Center, KKI, RSU Laboratory of Finished Dosage Forms, RTU Polymer Materials, and RTU Biosynthesis.

# 2 Recommendations

## 2.1 Maintenance and management

Establishing a modern RI management system (both LIMS & processes) is a prerequisite for further opening the RI and improving its international competitiveness, for efficient management of the RI and providing flexible, high-quality services, as well as for monitoring, evaluation, and designing targeted, cost-, resource- or result-based funding tools.

There should be a policy aimed at continuously streamlining and improving research infrastructure management and maintenance procedures. It might include both formal approaches, such as establishing criteria, practices, and requirements for high-quality infrastructure maintenance, as well as informal, such as a network and working groups for sharing "best practices" and jointly developing the requirements.

Improving RI management and maintenance at universities could be among RI policy priorities since respective processes at universities are noticeably weaker than at research institutes. It would include considerable centralization and professionalization of maintenance and management functions, e.g., by establishing professional maintenance units. In some cases, it would include centralization of research infrastructure, as well.

Implementing LIMS could be among RI policy priorities as it should improve RI management practices, as well as streamline RI booking procedures, and improve monitoring and reporting. The introduction should be gradual, at the same time streamlining RI management, and changing business processes and organizational culture.

Also, mandatory booking, utilization logging, and reporting requirements could be implemented gradually, focusing on the most expensive and unique instruments first. When reliable data can be collected from management systems of institutions, the functionality of the NZDIS can be reviewed, refocusing it from data gathering towards analytical functions.

There should be funding tools (e.g., investment projects) available for streamlining and improving maintenance and management, and for introducing LIMS (including both, solutions and organizational changes).

## 2.2 Access to infrastructure, use in R&D and business

At this moment, strategic, top-down infrastructure development policy oriented towards domestic RIS3 goals can't be advised. Research institutions have insufficient exposure to the domestic and foreign markets, leading to inadequate integration and incomplete information. Moreover, focusing on the domestic R&D market would restrict RI potential since the domestic market is small (*thin*), and often its needs, production capacity, human resources, managerial skills, and business strategies don't match RI specialization.

Instead, RI development should focus on emphasizing the strategic advantages of competitive RIs (*"picking winners"*) and furthering their international specialization and competitiveness, and supporting competitive R&D collaborations between RIs and businesses.

Development of contracted, collaborative R&D projects should be emphasized over providing boutique "plain" infrastructure services to businesses, as they better fit RI competencies and increase mutual understanding. Also, the development of specific, competitive standardized RI services could be supported.

Additional policies should be aimed at increasing the exposure of research institutions to markets and research collaborations. Especially, aimed at discovering foreign markets and collaborations, since it improves knowledge transfer and learning best practices. In addition to existing market discovery, collaboration fostering, and R&D support tools, the following policies could be introduced:

- funding for initial stages of the potential R&D projects – understanding client needs, designing the research, contracting, and other "soft" costs. Such funding tools should be simple with a small amount and low red tape, and reduce risks with some *skin in the game* for beneficiaries (co-funding, R&D project or contract as a result, etc.)
- fostering participation of RIs in "infrastructure networks" and consortiums as it improves RI management practices and opens collaboration opportunities. Also, supporting participation in R&D infrastructure or services, or industrial fairs
- to adjust incentives, performance-based funding might include rewards for institutions that establish new collaborations – obtain new paying clients or collaborators. To keep *skin in the game* for beneficiaries, tools might require, e.g., that clients pay for at least 20 hours of RI services.

Red tape on R&D collaborations should be reduced both externally (e.g., required by funding agencies) as well as internally (based on understandings, beliefs, and safeguards within the institution).

## 2.3 Maintenance funding

The goal of maintenance funding is to foster the development of a "core" research infrastructure that provides world-class RI services and expertise, and supports scientific research activities of a broad range of researchers both locally and internationally, as well as serves R&D needs of companies and other organizations. This funding is not aimed at supporting the respective institution's research activities *per se*.

Separate funding for RI maintenance might be a temporary tool incentivizing the development of high-quality RI services. After policy goals are achieved and sustainable funding for maintenance is established, this funding could be integrated into base funding or costs of research or R&D projects. Further, infrastructure investment calls might ask institutions to demonstrate sufficient means in their business plans to cover future maintenance costs of the new equipment.

Besides supporting "core" RI, there should be tools to support the development of management and maintenance for smaller-scale RIs at universities (higher education institutions), as separate tools or integrated into other policies for education or research.

Funding tools should account for the maintenance of premises and auxiliary equipment.

To foster the development of internationally competitive RIs, it is advised to appropriate the funding to the most competitive institutions instead of dispersing it to all.

Due to significant variations in reported indicators and the lack of objective source data for constructing or verifying them, it is not advised that RI policy (funding) tools are based solely on indicators due to questionable accuracy and the potential administrative burden. Also, tools should possess minimal red tape and collect minimum additional information from applicants.

**Selection criteria**

To qualify for maintenance funding, institutions have to conform to criteria for well-maintained "core" RI (as listed in Chapter 1.5):

- has a separate RI maintenance and management unit with sufficient permanent employees (and more than one FTE) who aren't students or researchers and aren't directly involved in research projects
- this unit has to have its own annual budget instead of being directly funded from research projects (but its income can come from research projects as deductions or internal fees)
- has implemented LIMS and quality management, consistent accounting for usage, staff, costs
- open to external users, with formal access procedures, has a booking system that allows understanding the availability of necessary RI capacity or services and easily (remotely) schedule and reserve them

- has sufficient free capacity that can be allocated to external users (utilized below 70-80%)
- provides users with necessary training, consulting, and support
- participates in international RI networks and is listed in the major EU-level RI & research services catalogs of the respective field.

*These criteria as well as other management and maintenance requirements can be introduced gradually allowing institutions to catch up with them, and they should be supplemented with other tools (investments) allowing institutions to improve their management and maintenance.*

Further, the infrastructure itself should be of significant size and *"interesting"* for the international scientific and R&D community:

- above 1 million EUR in total value of significant, specific research instruments that each have a value above 100'000 EUR (excluding, e.g., desktop computers and other common hardware)
- or large-scale, unique infrastructure, that can't be replaced (e.g., telescopes)
- or "nationally significant RI" having collections that are important for Latvian culture and society
- having developed internationally unique or significant competencies, and internationally competitive specialization.

Furthermore, RIs can receive a higher assessment, if:

- there is a designated staff for RI strategy and service development
- there is a development strategy and business plan for RI (separate from the research agenda)
- infrastructure and its services are unique in Europe
- the quality management system is certified
- has a Seal of Excellence
- a significant proportion of equipment is covered by service agreements
- a significant amount of income is from abroad or contracts in Latvia. This indicator should be used as pass/fail and not proportional to the respective income (e.g., >5% of income from EU frameworks, >5% from foreign contracts, >5% from contracts in Latvia).

*(Any of these indicators can be used as additional selection criteria for "core" RI)*

### Calculating maintenance funding

Funding to selected "core" RIs should be appropriated by formulas based on simple indicators because calculating real maintenance costs would introduce a significant administrative burden with limited accuracy and credibility. The amount could be calculated using:

- total asset value of the specific research equipment (excluding premises, auxiliary equipment, and common hardware) * $k_1$
- RI users in FTE * $k_2$

Additionally, if the following RI costs and revenues can be credibly assessed, the calculation might include:

- foreign income and income from contracts in Latvia * $k_3$
- fixed, significant maintenance costs (e.g., electrical power) * $k_4$

The funding could be designated to cover specific maintenance costs, asking institutions to submit them. If institutions have submitted a request to cover a specific amount, then the assigned funding shouldn't exceed it.

**Procedures for granting maintenance funding**

1. "Core" research institutions apply for maintenance funding and submit all data necessary for evaluation of their eligibility as well as for calculating the funding.
2. Experts assess if the RI corresponds to "core" criteria (e.g., quality of management and maintenance, uniqueness and competitiveness of instruments, competencies, and services). Submitted data might be audited if necessary.
   *A committee of experts, representatives from society, and policymakers assesses if the infrastructure is "nationally significant RI".*
3. The expert-ranked list of "core" RIs is submitted to the committee of experts, representatives from society, and policymakers for assigning priorities.
4. The committee of experts and policymakers makes a decision to assign the funding for the next 2-3 years, rolling.

## 2.4 Investment priorities and procedures

There aren't pronounced capacity shortages – infrastructure is up-to-date and moderately utilized. Therefore, further investments can focus on specific, ambitious policies and set a high bar for applicants.

**Investment priorities**

Infrastructure investments should focus on the quality of research and business plans of individual institutions since there aren't pronounced capacity shortages and strategic, *top-down* RIS3-based development is not feasible.

The following investment priorities might be considered:

- replacing instruments nearing end-of-life or uncompetitive. In such cases, the applicant should justify its utilization, need for future operations, and improvements in competitiveness. This kind of investment is necessary because multiple instruments near their end-of-life at the same time because prior investments were fragmented, in "batches"
- gradual capacity development both regarding the expansion of infrastructure services (horizontal or vertical), broadening research agenda, or increasing competitiveness. These investments should be based on current organizational strategies and research agendas. The applicant should justify intended usage and need, high-quality research or services, soundness and feasibility of business and research plans
- starting new strategic research or service development projects, including a radical increase in competitiveness. In such cases investment projects should be comprehensive, covering infrastructure, staff, research, running, and maintenance costs for 5 years
- *supporting the development of internationally competitive joint R&D initiatives between research institutions (RIs) and businesses (R&D services or industrial research platforms). The respective investment tools should be developed by the policymakers in the economic development*
- development of the shared research infrastructure. Evaluation as for the gradual development or for new initiatives, respectively
- support for merging RIs or developing joint RI platforms and services.

Investments should provide funding also for the development of premises and auxiliary equipment.

**Procedures for investment calls**

Procedures for awarding investment funding should contain separate evaluations for application quality and for investment priorities. Moreover, separate evaluations should be for research and for the business plan.

1. first, separate committees of international experts evaluate the quality and feasibility of research and the business plan:

- quality of the research – quality of the application, quality of research and feasibility of the research agenda, quality of the team, etc.
- feasibility of the RI's business plan related to investments

Applications are ranked by quality, and only those above the threshold are considered for funding.

2. second, a committee of representatives from R&D-intensive economics, internationally competitive science, and policymakers decides on priorities for projects, based on national or societal needs, goals, and policies.

## 2.5 Latvian RI strategic roadmap

Following approaches of other countries, National RI roadmaps are not *top-down* strategic policies for infrastructure development. Rather, they are collections of internationally competitive infrastructures that inform about the overall direction for developing national science. They serve as tools for internationally promoting national science as well as guidelines for education and economic policies.

National strategic research infrastructure roadmaps are built *bottom-up*, based on competitive development and investment proposals prepared by research institutions. The *bottom-up* approach ensures higher feasibility of proposals as well as comprehensive competitiveness of the respective RIs, including human resources and competencies, experience, as well as cohesion with broader scientific and education systems, and businesses.

Institutions submit internationally competitive proposals to be included in the National RI Roadmap. Experts and representatives evaluate the quality and competitiveness of proposals, and national priorities to decide which ones should be included.

Inclusion in the roadmap doesn't guarantee investment or maintenance funds. During the regular investment calls, projects from the roadmap might get some priority or have some shortcuts in evaluation procedures since the proposals are already evaluated earlier. However, the final priorities of projects are evaluated together with all other submissions in the call to reassess their current importance.

To maintain consistency of the national RI and science policies, part of experts and representatives who decide on infrastructure calls also participate in developing the national strategic infrastructure roadmap (and *vice versa*).

# Appendices

Appended *Summary of the survey of Latvian RIs*, *Summary of interviews with RI management*, and *Other country examples of funding research infrastructure* are intermediate draft documents that could provide some additional in-deep details (mostly, technical), which might be useful for specialists when drafting the respective RI policies.

## A1 Summary of the survey of Latvian RIs

The survey about Latvian Research Infrastructure (RI) was sent out to all higher education and scientific institutions. It consisted of questions regarding the composition of the RI (equipment, premises, databases, etc.), utilization, income, costs and resources, results, and collaborations.

The survey had two stages. First, we collected general information about RIs and their composition. We received answers from 22 organizations, listing 59 RI units and 410 significant equipment units. Then, we made the initial assessment of the potential “core RIs”, and excluded the smallest institutions (7 organizations, 15 RI units, 91 equipment units) from answering the remaining questions. Thus, we have responses from 44 RI units in 14 organizations, and 319 equipment units about utilization, income, costs and resources, results, and collaborations.

While responses provide sufficient information to evaluate the situation and tendencies, several factors might impact their credibility and hinder the ability to construct quantitative indicators for policy (funding) tools. All data are self-reported, mostly based on employee estimations, and only in a few cases institutions do have (automatic, consistent, and detailed) records regarding, e.g., utilization, cost, or collaboration indicators.

Also, despite instructions and methodological help, we see differing understandings about:

- what is a “Research infrastructure unit”? Some organizations reported one RI unit per organization, some split their infrastructure into several RI units by specialization
- what is an “Equipment unit”? Some organizations reported every single instrument, some reported collections of related instruments
- what costs and results to report? Especially, organizations that split their RI into separate units had difficulty to understand how to split results and costs. Moreover, for research institutes institutional results (income, publications, etc.) are related to research performed on their RI, and there is no special accounting for RI-related results. The majority of them just reported total institutional results.

**Research infrastructure by geography, FOS, RIS3, and CatRIS**

*(based on answers from all 59 RI units in 22 organizations)*

The majority of RI is based in Riga. There are 42 (71%) RI units in Riga at 5 higher education institutions and 8 research institutes. In the regions are 17 RI units at 6 regional higher education institutions and 3 institutes, mostly related to agricultural & forestry research.

Most of the RI are related to STEM and technical sciences (by FOS). 33 RIs reported that they work in Natural sciences, of them 10 in Biological sciences, and 8 in Computer and information sciences. Also, 32 RIs work in Engineering and Technology, of them 8 in Materials engineering and 6 in Electrical and electronic engineering. A much smaller number of RIs (13) work in Medical and health sciences, 11 in Agricultural sciences, 8 in Humanities, and 4 in Social sciences.

RIs report covering all areas of the Latvian economy specialization (by RIS3). The majority of RIs work in Biomedicine, medical technologies, pharmacy (21 RIs) and in Photonics, smart materials, technologies, and engineering systems (20 RIs). Also, many RIs reported Knowledge-intensive bioeconomy (16) and Information and communication technologies (14) as their smart specialization areas. Much fewer organizations are in Smart energy and mobility (9).

By the type of services provided (by CatRIS), the majority of RIs reported Processing & analysis as their services (43 organizations), and Access to physical and e-infrastructures (33). Fewer organizations marked Sharing and discovery (26) or Training and support (25) as their areas of activity.

**Equipment – novelty, uniqueness, utilization**

*(novelty and uniqueness based on answers from all 59 RI units in 22 organizations,*
*utilization – on answers of the potential "core RIs" – 44 RI units in 14 organizations)*

In total 410 "the most significant" equipment units or collections of related instruments were reported, with a reported total value of 134 million EUR. That covers ~40% of all 1050 equipment units reported to NZDIS.

Overall, the Latvian research infrastructure is up to date. 156 equipment units (44% of valid answers) were evaluated as "more modern than the majority of other institutions in their field have". Further, 148 (42%) were rated as "the same as the majority of other institutions use". Only 44 (13%) equipment units were considered "nearing the end of usability but still used in the field", and only 3 (<1%) were considered obsolete.

The infrastructure is relatively unique for Latvia, but can't be considered unique in the broader region. From valid answers, 65% of equipment units were reported as unique for Latvia. However, only 30% of the equipment was considered unique in the Baltics, and only 10% – unique in Europe.

However, RIs have difficulty assessing the uniqueness of their equipment, with 23% of equipment units missing this evaluation.

Based on valid responses from the potential "core RIs" (319 equipment units), the overall utilization of the equipment is moderate, with 70% of equipment units used below 60% of their potential (16% at 0-10% utilization, 12% at 10-20%, 15% at 20-40%, and 25% at 40-60%). About half of the research infrastructures (17) reported some heavily used equipment units (utilization above 80%), in total, about 18% of the equipment is heavily used.

Mostly, the equipment is used for internal research activities of the organization. For 65% of the equipment units, usage for needs of external research groups was below 5% of the capacity, and for the next 25% of the equipment units the usage for such needs was between 5%-10% of their capacity. For serving business needs, the respective numbers are 73% below 5%, and the next 23% between 5%-10%.

As main restrictions to more active and broader usage of the equipment were mentioned:

- access for external users to the infrastructure is through services provided by the staff because only designated specialists with specific training and certification can operate the equipment;
- equipment is intended for very narrow or specific use, for specific goals, or specific materials;
- some equipment is new and in the testing stage, or needs a repair;
- to reach the maximum utilization, improvement of premises, auxiliary or related equipment is necessary, or more funding to cover staff expenses or electrical power costs (for digital infrastructure);
- commercial use is limited by EU funding restrictions (below 20%);
- copyright laws restrict access to some resources in the digital infrastructure.

It must be noted that the reported utilization rates of equipment should be taken with a grain of salt because institutions have difficulties assessing them. Around 20% of equipment institutions didn't have any utilization measures – neither based on specialist evaluations nor recorded by management systems. Moreover, in cases where the overall utilization rate was provided, only 65% of them had also estimates about the usage for external clients.

In cases where equipment utilization rates were provided, only 36% of responses (or 25% of all equipment) in 7 organizations were based on records by the equipment management systems (or LIMS), and the rest were staff estimates. Even in these 7 organizations, only a part of the equipment (at varied proportions) was covered by the records.

Furthermore, reporting utilization rates was complicated by a varied understanding of the "research equipment unit". Some organizations reported complete labs, or even premises as one unit, and later were unable to assess its utilization accurately. Related, also measure "usage as hours per year" was not informative as it was reported up to value "9000" (likely summing up the usage of all equipment in the lab). Finally, some organizations provided the same utilization rate for all of their equipment, questioning credibility.

**Costs and staff**

*(based on answers of the potential "core RIs" – 44 RI units in 14 organizations)*

There are significant variations in reporting RI maintenance costs. Therefore, it will be difficult to estimate the costs precisely and design related funding tools with reasonable accuracy and minimum red tape.

Institutions have varied understandings about what would be the costs of "empty" infrastructure both regarding human resources involved and financial expenses. Sometimes they included all staff in responses. Moreover, 60% of institutions reported staff and costs as "estimates" rather than based on records. Also, if institutions reported having multiple RI units, often they have the same staff maintaining all of them, and institutions aren't able to split costs between RI units. Finally, if reported numbers were linked to funding tools, we might encounter strategic answers.

Large research institutes reported a similar number of staff working on maintenance tasks, roughly 23 FTE (16-29). However, reported estimates of "maintenance costs" had extreme variations from ~140'000 EUR to ~1'200'000 EUR per year, suggesting that organizations included different cost items in them. These costs don't seem to be related to the reported values of their most significant assets (2-15%), but rather to their income (~7-11%). A significant part of maintenance costs is staff expenses (~60-80%). Expenses on repairs have a notable variation between 5% to 30% (which seems related to the type of infrastructure – smaller for digital infrastructure, larger for lab equipment).

**Income and contracts, by type**

*(based on answers of the potential "core RIs" – 44 RI units in 14 organizations)*

44 RI units in 14 organizations altogether reported income of 57 million EUR, the TOP5 accounting for 70% of income (14.5, 8.7, 6.5, 5.5, and 4m EUR). Of this amount, 29 million EUR were domestic (Latvian) grants. 11 m EUR was foreign income, and 12 m EUR was EU framework funding. Much smaller income is from domestic public (~3.42 m EUR) and private contracts (~3.35 m EUR).

However, over 50% of all domestic public and private contract income goes to two organizations. Respectively, this income comprises 31% and 58% of income for these organizations. Also, the same two organizations have 33% of all current R&D contracts (by count). The favorable results could be explained by the high overall R&D activity in the sector where these organizations work, also, because they perform state-procured monitoring, analytical, or research activities.

*Table 1. A proportion of assets, income, and contracts by each research institution*

| Institution | Assets | Income | Income, contracts LV | Income, foreign | R&D contracts, LV | R&D contracts, foreign |
|---|---|---|---|---|---|---|
| AREI | 0.9% | 0.1% | 0.7% | 0.0% | 0.2% | 0.0% |
| BIOR | 3.0% | 6.6% | 17.2% | 11.3% | 6.9% | 1.3% |
| BMC | 7.1% | 9.7% | 12.4% | 3.1% | 2.8% | 15.3% |
| CFI | 15.9% | 15.4% | 8.0% | 23.6% | 17.2% | 6.4% |
| DI | 4.0% | 0.0% | 0.4% | 1.0% | 8.6% | 1.9% |
| EDI | 2.5% | 6.5% | 4.4% | 6.4% | 8.0% | 12.9% |
| KKI | 1.9% | 11.4% | 5.8% | 4.7% | 4.3% | 6.4% |
| LULFMI | 4.8% | 2.0% | 1.7% | 0.9% | 7.8% | 4.4% |
| LUMII | 2.1% | 0.0% | 0.0% | 0.3% | 2.4% | 2.5% |
| OSI | 27.7% | 25.5% | 6.2% | 27.3% | 2.2% | 31.8% |
| SILAVA | 4.7% | 7.0% | 33.4% | 5.5% | 25.0% | 5.7% |
| DU | 6.0% | 3.0% | 0.5% | 0.2% | 1.5% | 0.0% |
| RSU | 6.8% | 3.2% | 3.2% | 4.6% | 4.1% | 1.9% |
| RTU | 7.6% | 7.3% | 0.4% | 6.5% | 5.8% | 3.8% |
| VEAVSRC | 3.2% | 1.0% | 4.0% | 0.7% | 0.2% | 0.6% |
| LU | 2.0% | 1.3% | 1.5% | 3.8% | 3.0% | 5.1% |

Another three organizations also receive a significant part (>10%) of their income from public domestic contracts, presumably, because there are dedicated public R&D funding schemes and programs in their sector. In other cases, public contracts constitute only about 2% of organizational income.

Overall, institutional income from domestic private contracts is low, indicating a weak integration between RIs and economic actors. One organization reports 33% from private contracts and one – 8%, two organizations around 6%, three from 3%-4%, and the rest between 0%-2%. Also, when measured by the number of domestic contracts we see that three organizations hold over 50% of them. Further, 95% of all IP is registered by 4 organizations, and only 2 RIs reported at least one spin-off in the last three years.

Latvian organizations are starting to focus on foreign income, and those who are active there, demonstrate significant progress. However, just a few organizations do that. Thus, 81% of all foreign income is generated by 6 organizations. In European frameworks, 7 organizations make 82% of income. Regarding other foreign sources, 85% of all income is generated by only 3 organizations (37%, 30%, 18%). For three organizations, foreign income provides more than half of their income; for the other two, around 40%, and for the next three, around 30%. Also, foreign R&D contracts are concentrated with three organizations holding over 60% of them. For two, foreign R&D contracts are significantly more than local ones.

The state of infrastructure doesn't prevent it from being successful at competing for foreign or contract funds, or within the EU framework. 29 of 44 RIs explicitly answered "NO" to the question if the state of infrastructure prevented them from receiving contracts or establishing collaborations. 5 RIs (3 organizations) reported that there were contracts lost due to lack of capacity or equipment, obsolete equipment, or lack of specific services or procedures. The remaining 10 RIs didn't provide an answer.

Overall, organizations demonstrate a strategic leaning towards domestic or foreign markets, grants or contract funding by having varied proportions of the respective sources in their income.

**External access to RI and collaboration**

*(based on answers of the potential "core RIs" – 44 RI units in 14 organizations)*

To understand if RIs are managed as infrastructure services organizations, we included a measure about "how many employees (FTE) are involved in strategic development, marketing and sales of the RI". Reported numbers don't correlate with income, assets, or other key measures, suggesting that approaches to the strategic development of infrastructure are not formalized and vary between organizations.

All RIs, except three (in 2 organizations), reported open access to their equipment. Also, almost all RIs, except seven (in 5 organizations), reported having formal procedures for infrastructure access. However, almost all RIs reported that external specialists usually can't access instruments directly, but will use services provided by the RI staff or will collaborate on projects.

23 RIs have implemented a quality management system (14 RIs haven't). Of those, 16 have received certificates for their QM, and for 19, the quality management covers also procedures for providing RI services to external customers.

Numbers for actual collaborations have the potential to grow. Only three organizations spent more than 20 FTE/annually on services for external customers. For others, numbers are significantly lower, three organizations spent between 2-5 FTE, six – up to 1, and two universities (sum of all their RIs) around 9.

RIs are comparably active at involving students in their work. Five organizations employed students from 30-133 FTE/annually, and another five between 10-20.

Numbers for other types of collaborations are minuscule. Thus, only two organizations reported around 3.5 FTE/annually of foreigners working at their premises, another two – between 1 and 2, and four organizations reported up to 1. Also, the number of industrial researchers working at the RI is low, with only four organizations reporting 8, 3, 1, and 0.5 FTE respectively.

Also, usage of RI services in other institutions is minimal. All organizations together in three years spent on external services ~65'000 EUR in Latvia and ~2000 EUR abroad. Those numbers don't account for using external RI as a part of joint projects, which is the main form of collaboration if there is a need to use the capacity of other RIs.

To promote their services and capacities, RIs are listed in catalogs. 23 of them are listed in Latvian catalogs, and 14 –in foreign catalogs. Often, these are sector-specific databases and catalogs for consortiums or networks where RIs participate.

The most "popular" among Latvian RI's are the following networks or ESFRI consortiums:

- EATRIS-ERIC, where participate BMC, OSI, and RSU,
- BBMRI-ERIC, where participate BMC and RSU,
- CLARIN-ERIC, where participate LULFMI and LUMII,
- CERN, where participate CFI and VEAVSRC.

*(it would be interesting to evaluate if those "Latvian groups" in consortiums collaborate among themselves or with other partners (risk of "ethnic enclave economies")).*

The most active participants in international networks and consortiums are:

- CFI: Synchrotron facilities (including Desy, MAX-4, EXFEL), ESS, EURATOM, CERN
- VEAVSRC: ILT (LOFAR), EVN (European VLBI Network), CERN
- BMC: Instruct-ERIC, EATRIS-ERIC, CLARIN-ERIC
- OSI: EU-OPENSCREEN, EATRIS-ERIC

Other organizations reported participating in one network or consortium:

- LUMII: PRACE
- DU: ELTER (ESFRI 2018)
- RTU: ALBA Synchrotron
- LU: EPOS

The numbers are low for named unique potential research collaborators abroad and for unique potential clients in Latvia or abroad. Organizations together named 47 unique potential research collaborators in Latvia and 80 abroad, 68 unique potential clients in Latvia and 33 abroad.

Moreover, when thinking about specific potential research collaborations in Latvia or abroad, organizations can name specific partners. However, when thinking about potential clients in Latvia or abroad, in 1/3 of cases organizations named only general categories instead of specific partners.

The low numbers might indicate a limited understanding of the local and foreign markets as well as a weak foreign orientation and an insufficient specialization at the global level of the RI and services.

**Recommendations**

- establishing a modern RI management system (both LIMS & processes) is a prerequisite for further opening the RI and improving its international competitiveness, for efficient management of the RI and providing flexible, high-quality services, as well as for monitoring, evaluation, and designing targeted, cost-, resource- or result-based funding tools
- due to significant variations in reporting indicators and the lack of objective source data for constructing or verifying them (e.g., operations data from the LIMS), it is not advised that RI policy (funding) tools are based solely on indicators due to the questionable accuracy and the potential administrative burden
- there aren't pronounced capacity shortages – infrastructure is up-to-date and moderately loaded. Therefore, further investments can focus on specific, ambitious policies, and set a high bar for recipients
- the main access to the RI is through research projects or R&D contracts. Due to the specifics of the RI and its services, we can't expect a huge increase in "plain" RI access or "plain" RI services. Rather, new collaborations on research projects or solving R&D problems should be fostered
- collaboration with domestic clients outside academia remains weak. The low number of named potential clients indicates an incomplete understanding of the market. Policy tools aimed at establishing new collaborations are suggested:
  - activity-based – funding the client discovery process and initial (design) stages of the potential R&D projects
  - results-based – rewarding an increase in new paying clients (e.g. bought >20h)
  - reducing red tape (both internally and externally enforced)
- foreign collaborations and income are on the rise but only a small number of RIs focus on them. An ambitious target could be 80% of collaborations and income abroad, similar to the export share in the GDP. Participating in international networks and establishing new foreign collaborations are essential for learning RI management and current practices, understanding market needs, and developing (regional) specialization of the RI. Policy tools for establishing

international collaborations might include (in addition to similar tools as for local collaboration):
    - activity-based – participation in RI networks
    - activity-based – participation in infrastructure, R&D service, and industrial fairs
    - results based – new foreign collaborators and paying clients

- strategic investments in RI specialization couldn't be suggested before institutions improve the exposure to the market and international landscape, understand better the global and local market needs, and improve the product-market fit (having feasible business plans as an indicator)

- based on the state of the infrastructure, the following investment approaches could be suggested:
    - replacing or upgrading equipment nearing the end of life or becoming uncompetitive. Must justify the current utilization, the need for future activities, and improvement in the RI competitiveness
    - gradual improvements or expansions, based on the existing institutional strategies and research agendas. Must justify the current utilization, the feasibility of the business plan and the research agenda
    - development of new research capacities. Should be funded as comprehensive development projects, including staff and research costs for, e.g., five years.

# A2 Summary of interviews with RI management

As required by the Technical Specification of the Consulting Agreement, and following the methodology agreed by Consultants and the Ministry of Education, five interviews were conducted with the management of Latvian research institutions to understand better managerial motivations and decisions related to research infrastructure.

In-deep interviews aimed to explore the following questions: How decisions related to infrastructure planning and procurement are made? How collaboration on RI use and access to it is organized for internal and external users? How infrastructure load is assessed and managed? And how infrastructure maintenance is organized?

To cover institutional differences, several research institutes and large universities were among the interviewees.

**Principal differences between research institutes and universities regarding RI management**

Research institutes are usually organized around the research infrastructure. Thus, the RI-related questions are strategic and of utmost importance for the upper management. Moreover, the institutes are of "manageable" size, thus the executive level is directly involved in managing the research infrastructure.

Universities, on the other hand, are large and diverse institutions. The direct management of RI is done at the departmental level (Latvian – fakultātēs). At the university level, an indirect, policy-like approach to research infrastructure management can be observed – through formal requirements, procedures, and funding tools.

In all institutions, daily management and operational planning are done at the level of sub-units, functional or specific to research sub-fields ("centers", "platforms", "groups") at research institutes; departments, laboratories, or research groups at universities.

Growth (e.g., the revenue of some institutions has grown 3 times) and participation in international networks are the main drivers for streamlining and standardizing RI management processes and improvements in RI access, reservation, usage reporting, maintenance, and quality management. Networks help with TA, peer reviews and external controls, standards for processes, etc. Respondents admit that their RI management procedures aren't yet "up to the European level", noting insufficient RI management expertise and resources.

**The general state of the RI and priorities for the development**

Priorities for infrastructure development are related to the current condition of the RI. The majority of respondents replied that the existing RI corresponds to necessities and is comparable to what their partners and similar organizations use. Infrastructure and equipment satisfy current research needs. There are no significant capacity gaps – "everyone can get their analysis done within a reasonable time". Also, there are no obvious, strategically significant functionality gaps.

The main concern is the aging of the equipment, both technically and functionally. A significant part of equipment nears the condition when it might become economically unfeasible to maintain or repair. Also, to stay competitive and current, institutions might need to upgrade equipment to be able to perform a wider range of analyses or at a better quality.

Therefore, the main RI development priorities are:

- to replace technically aged equipment, evaluated by its technical condition, costs and feasibility of maintenance and repairs, and if the unit is essential for the functioning of the research institution;
- to replace or upgrade functionally obsolete equipment, evaluated by its technical condition, comparing its functionality to one available in similar or competing institutions, and following the plans for developing the research program, or research capacity;
- to gradually develop the research infrastructure, following the gradual development path of a research program or research capacity. Gradual development follows the advancements in the field (new methods, research questions, etc.), expanding the research program, developing services and capacities that are related to the existing ones (i.e., integrating the full "research & development value chain"), matching capacity and functionality to similar or competing institutions.

None of interviewed research institutions had plans for strategic, large-scale investments in a completely novel research infrastructure, unrelated to the replacement or gradual development described above. As respondents noted, such projects can't be just infrastructure investments. The strategic projects for developing new areas should include sufficient resources for both, infrastructure, attracting specialists and developing competencies, and supporting the research group until it becomes competitive (up to five years).

Institutions also note that existing research funding tools are not efficient for covering costs related to the development and maintenance of premises and auxiliary equipment (e.g., climate, air, water, gases, power, databases, etc.).

**Duplication of the RI**

The majority of the RI is not unique per se. Unique is the particular collection of instruments that fits the research activities of the institution, as well as the particular knowledge, skills, and experience. Even if there might be observed a formal "duplication" of instruments, very likely that the institutions wouldn't be able to perform the same research activities. Moreover, while having similar names, instruments might have significantly different technical specifications. Also, the respective equipment might be already fully loaded.

Also, similar common appliances can be found in many institutions to support the daily activities of researchers. It won't be feasible to pool these instruments or organize their shared use.

On the other hand, before procuring new equipment, the management evaluates if, alternatively, respective services could be done by other institutions and if the purchase would be economically justified. Especially, if the usage would be occasional and of low volume. Also, external pressure (ministry, funding sources) to avoid duplication helps.

Institutions have quite a good understanding of what instruments and competencies other research institutions possess, and who could provide particular services.

**Planning and procuring the RI**

In all interviewed institutions bottom-up process is a significant part of planning investments in infrastructure. Infrastructure centers, departments, laboratories, or research groups submit lists of equipment they would need based on their research agenda, current or planned projects, condition of the existing equipment, its capabilities compared to competitors, utilization rates, or other (rather operational) considerations.

"Vetting committees" exist at all institutions at different managerial levels to evaluate the submitted lists. They analyze for a duplication of the requested equipment or if similar is available within the organization. Also, if other groups also would benefit from purchasing the particular equipment.

Expected utilization rates are weighted against expected running and maintenance costs, and if it could be possible, instead, to use similar equipment or research services in the region. Infrastructure investment projects are matched with organizational development plans and research agendas.

Top-down decisions usually focus on the new strategic development of the infrastructure and the organization, e.g., strategic expansion of research capacities to integrate the full "research value chain", or to support the planned expansion of research areas or research services, or to significantly improve competitiveness (to excel in some areas).

The major funding source for research infrastructure development is EU-funded investment projects, and they shape this development. Thus, infrastructure development needs at the institutional level are analyzed and packed into projects "in batches" – when the funding calls are open.

During the last funding calls, the main strategic approach for institutions was to fully cover with infrastructure the current research needs and those anticipated in the medium term, and they largely succeeded in doing that. However, because of this fragmentation of funding, a significant part of the equipment becomes technically and functionally obsolete at the same time.

Also, institutions use their own funds to develop RI infrastructure. Usually, they can afford to fund less expensive, more common equipment, also "seed money" (internal grants) for new approaches or labs, and some strategic investments.

Some equipment is purchased within research projects. This kind of investment is of a smaller scale, usually focusing on the needs of a specific research group, rather than the strategic RI development. Managerial approval of these purchases focuses on basic checks – duplication, anticipated maintenance costs v/s expected load.

**Access to the RI and collaborations**

Mostly, access to research equipment is managed through informal channels both for external and internal users.

Only one institution uses a formal reservation system to allocate RI equipment and schedule its use, within the Laboratory Information Management System (LIMS). They note higher predictability as the main benefit – researchers can be sure that equipment will be available exactly when they need it within their projects. Especially useful the reservation system is for unique, more expensive units rather than for common lab instruments (though, researchers like to reserve them as well).

Other institutions position that such reservation and scheduling are not necessary as their RI capacity is sufficient for everyone to perform analysis within a reasonable time frame. Users within the institution often just agree with lab or center managers when they could use the equipment or they use some internal system to inform about their needs. Lab or center managers might use some sort of "reservation books". Also, labs have good coverage of the often-used lab instruments, and researchers can perform their common analytical needs themselves.

External users also most often gain "access" through informal prior contacts. The most common way of letting other research institutions use the RI is by collaborating on research projects. Or researchers spend some time in other institutions. Also, semi-formal "helping out each other" is common when related costs aren't significant. The amount of "pure" RI use for a fee is minimal both work- and income-wise.

Institutions themselves use external RI services when they need a specific analysis or services but do not possess the necessary equipment or competencies. Funding tools sometimes restrict the use of external research services (only own or partner costs might be applicable).

The most common form of "using the RI" rather is receiving respective analytical services which are performed by the staff working on the particular equipment. It is because people who haven't undergone the necessary training and received "a license" often aren't allowed to operate the equipment. Also, occasional users often don't have the necessary know-how to do the work efficiently, even if they have the appropriate training.

Providing custom analytical services for businesses is expensive and uncompetitive since significant expenses are related to understanding customer needs and designing the analytical methods and protocols suitable for them since customers often don't have a sufficient understanding of it. Additional service personnel would be necessary to provide quality services to businesses.

Also, for short-term (2-3 days) service projects administrative and transactional overhead is significant. Organizations mention that state aid regulations also influence the competitiveness of services.

Successful and profitable collaboration with businesses are cases when standardized analytical services are provided. It could be specialized sub-units that focus on providing pre-defined/standardized analytical services to businesses and organizations. Or providing regular analytical services to regular customers, designed once and repeated regularly. Alternatively, custom services could be organized as R&D projects aimed to understand and solve customers' problems rather than just providing "pure" RI services.

The benefit of listing the infrastructure in catalogs is marginal since often the equipment itself is not that unique, rather the specific collection of instruments as well as specific skills, knowledge, and experience regarding doing particular research activities has value, also, because prior, informal, personal contacts play an important role in collaborations or arranging use of research services.

On the other hand, having a public list of available equipment and research services fosters collaboration with existing partners since they can look up what other services or instruments might be available. A comprehensive institutional web page with available services and equipment could have a similar value.

Participation in formal "infrastructure networks" and consortiums does not increase infrastructure use and sharing per se. They are very beneficial for establishing new contacts and collaborations, as well as for helping to implement the best practices for RI management or doing field-specific research activities. That later leads to increased RI use and sharing it.

**Utilization rates of the RI**

In most cases, the infrastructure load rate is adequate/average. There are no significant cases of underutilization nor significant shortages leading to long waiting times. Novel equipment (especially, in a new research area) might be temporarily underutilized while competencies are developed or projects attracted.

Exceptions are some equipment at universities that were purchased earlier from project funds but didn't have installation, running, and maintenance costs covered, leading to the idling of the instruments. Such situations aren't allowed anymore.

Additional scientists and research funding would be necessary to increase infrastructure utilization rates. Also, funding for lab technicians and engineers would increase utilization because researchers currently often do their job.

Only one institution uses centralized LIMS for logging infrastructure use. The same system is used for reserving and scheduling equipment use (as mentioned above), for infrastructure maintenance, managing materials, and other infrastructure management needs. LIMS allows easy generating utilization reports by projects, by units, and by funding types (e.g., commercial). It also contains a comprehensive equipment database and can be used to create public lists of available equipment and services.

They admit that LIMS implementation had to be gradual. LIMS increases the workload of researchers and technicians since they have to log their activities. So, in the beginning, it was used to reserve unique, the most expensive equipment units with the highest utilization rates. Gradually, employees understood the benefits of having equipment in the LIMS (availability predictability, easier maintenance, and reporting) and agreed to expand its coverage. Also, in parallel, the general standardization and improvement of RI usage and maintenance procedures was done because of rapidly increasing research activity. These steps also helped to change culture and attitudes.

Other institutions report that they have some equipment utilization logs at the labs or centers, mostly for maintenance needs and material management. There are no special procedures for analyzing infrastructure load or preparing statistics at the institutional level. When making decisions on infrastructure investments, management rather uses "expert assessments" regarding infrastructure load (e.g., obviously underutilized or overloaded).

Perhaps, the main rationale for not maintaining usage logs is that the infrastructure is not fully loaded and there is no need for reserving or scheduling equipment use. Therefore, logging is considered an extra activity without benefits for the researchers themselves.

Institutions do more systematic logging and statistics if funding institutions (e.g., the Ministry of Education) request that. Usually regarding particular equipment units funded from specific calls. However, as soon as external requests end, the logging stops. There were some responses that "reports might be prepared if asked", questioning their credibility.

Also, systematic utilization logs are done for commercial services or supporting businesses as that is required by state aid regulations.

Organizations admit that it might be useful to implement LIMS that could also help organize material management and maintenance. However, they haven't decided on implementing it, citing high investment costs, the need to analyze organizational needs first, doubts if it will match the specific procedures and needs of the institution, and the complexity of the implementation. Implementation of the LIMS and streamlining of RI management won't be successful if it's not among the goals of the management or there is no internal pressure to do that.

**Maintenance and repairs of the RI**

Research institutes have well-established RI maintenance procedures. There are responsible persons at each "center", "lab", or "group" that follow equipment condition and request maintenance or repairs, if necessary. Dedicated technicians and managers (or a special maintenance unit) at the institute or center level organize maintenance and repairs or repair themselves when authorized support engineers are not required.

Mostly, institutes try to keep all instruments in running condition, ready for use. If possible, under warranty coverage, insurance, or with service agreements. However, in some cases, funding and resources are not sufficient to keep everything in a running condition and with service agreements, nor it is always economically feasible. In such cases, the management prioritizes instrument repairs by their importance for the research processes. There were no reports about equipment downtimes significantly influencing the research.

At universities, there are no centralized services or procedures for RI maintenance and repairs. Maintenance, warranties, insurance, service contracts, and repairs are arranged by departments, centers, or labs themselves. At the university level, there are funding tools for covering repair costs, e.g., "repair grants". Universities do report noticeable resource shortages for maintenance and the inability to cover all repair requests, leading to downtime.

Institutions note that RI repair costs are not applicable under the existing research funding tools. Moreover, if maintenance costs (e.g. staff) are included in projects, that reduces the competitiveness of proposals (unexplainable HR costs) and complicates reporting. Also, funding maintenance staff from projects creates ambiguity if they should work for project needs or institutional needs.

Institutions also cover maintenance costs from "internal reserves" or "resources for development". At the same time, institutions respond that they see "research base funding" as resources for development. Also, maintenance and technical servicing tasks are often done by researchers or lab technicians themselves, therefore, using their time inefficiently.

According to respondents, the annual funding in the range of 5-8% of the RI asset value would be sufficient to cover both repair and maintenance costs, including parts (their stock to reduce downtimes), HR, and service agreements, premises and auxiliary equipment, and to support technological processes that are independent of research activities. Institutions stressed that such a funding tool should have minimal red tape, or be based on simple indicators (e.g., asset values).

With maintenance costs covered, institutions will be able to free researchers' time, devote resources to improve RI management, and improve support (assistance & services) for external RI users.

**Main conclusions and recommendations**

- there might be separate funding tools aimed at various needs: a) replacement of technically aged equipment, b) upgrading aged or purchasing new equipment to upgrade or expand research capacity, c) longer-term, comprehensive projects (infrastructure + HR + research) for developing completely new research areas or capacities;
- there should be funding tools for infrastructure maintenance or repair costs. It could be a special maintenance support tool or such costs could be applicable within existing tools (study funding, research or R&D grants, etc.);
- development and maintenance of premises and auxiliary equipment should be included in funding tools;
- an expert opinion is necessary when evaluating "duplication" cases to understand if instruments indeed are similar and if the particular research services can be provided by other institutions, taking into account their collection of instruments, skills, and competencies. It should be applied to cases when the equipment is obviously underutilized. A minimum value threshold should apply since many common lab instruments are similar;
- implementation of LIMS could be among RI policy priorities as it might improve RI management practices, the accuracy of RI utilization reports, and the availability of equipment catalogs. Some funding is necessary to cover LIMS purchase and implementation costs. Also, the mandatory utilization logging and reporting could be implemented gradually, first,

focusing on the most expensive and unique instruments. Implementing LIMS should be done together with streamlining RI management;

- publishing equipment lists in online catalogs and market spaces has limited value since the majority of collaborations and service uses are arranged through existing personal channels. On the other hand, if LIMS is implemented and equipment lists are maintained, listing equipment could help to expand existing collaborations;
- participation in "infrastructure networks" and consortiums should be encouraged as it improves RI management practices and opens collaboration opportunities;
- improving RI management and maintenance at universities could be among RI policy priorities since respective processes at universities are noticeably weaker than at research institutes;
- designing and providing comprehensive "RI services for everyone" is not feasible. Rather institutions could: a) developed specific, competitive standardized services or b) develop collaborations with businesses through R&D projects.

# A3 Other country examples of funding research infrastructure

For comparative analysis of RI funding approaches, we selected countries that are relatively well-performing in science and innovations, have relatively small population size, and are geographically located similar to Latvia. Among Baltic countries, Estonia ranks well in the number of publications and research excellence. Yet, it still has a relatively low citation count and the number of patent applications that serve as guiding KPIs when evaluating research and innovation systems.

*Table 1. R&D outputs of the selected EU countries*

| | Articles published per 1mil. pop. (2018) | Place in the world by citations (count) (2022) | Patent applications (WIPO 2022) |
|---|---|---|---|
| Latvia | 732 | 84th (3078) | 108 |
| Estonia | 1070 | 72nd (5764) | 26 |
| Finland | 1922 | 34th (33655) | 1662 |
| Sweden | 2009 | 20th (67290) | 2196 |
| The Netherlands | 1762 | 14th (97734) | 3470 |

We chose Sweden, Finland, and Netherlands to analyze their RI funding since they have good performance in science and innovations (see Table 1.) and at the same time are comparable to Latvia regarding availability of natural resources and geographical location (impacting the economic structure), and relatively smaller population (impacting broadness of science and complexity of its governance).

Selected countries have proven that their research systems (including funding approaches) can be competitive internationally. They provide insight into successful approaches that Latvia might use to further RI maintenance and management funding.

### Approach to funding research infrastructure in Sweden

Sweden's main body for research infrastructure evaluation and funding is the Swedish Research Council (SRC). They provide analysis, evaluation, mapping, and advice on future research policy questions to the Ministry of Education and Research.

The process of investments in Research Infrastructure and the development of the national research infrastructure a bottom-up process that begins with institutions expressing their plans and needs that are later evaluated by an international panel. All evaluated applications are listed in the National Roadmap, where they are categorized as “A1 ready for a call”, “A2 funding currently not prioritized by the Swedish Research Council", and "A3 not ready for a call". Annual grant calls are open to the first category, "A1 ready for a call".

Which of the RI are moved to the A1 or A2 category of the Roadmap is an internal SRC decision. Often those in the A3 lack the argumentation for future business plans or are viewed as not competitive enough from a global perspective.

Among supported A1 projects are both the development of particular RIs as well as projects for 1) merging RI, 2) aligning RIs with international standards to make them comparable internationally and increase collaboration, or 3) opening access and sharing infrastructure, or moving the equipment to increase the utilization rate.

Swedish Research Council (SRC) announces annual calls for grants on specific topics or within a specific area of interest for research infrastructures. The applicants listed in the national RI roadmap have some priority.

To receive SRC funds, the research infrastructure needs to meet four selection criteria: 1) to be of national interest, 2) to be openly accessible to research, 3) have a long-term funding plan, and 4) the common organization with a higher education institution.

After submission of applications, an international panel reviews each one based on scientific, organizational, and technical criteria. The international panel is made up of international experts from various science fields and can evaluate applications from a larger, global perspective. The evaluation of the international panel is considered by the SRC when making final funding decisions.

Once the strategy and annual goals of the RI development has been established, the applications are assessed according to their scientific relevance, strategic and national relevance, and other aspects considered[1]:

- **national interest** – to what extent does the infrastructure fulfils, or has the potential in the future to fulfill the SRC criteria for research infrastructure of national interest
- **ethical considerations**, where applicable
- **scientific impact** – does the application satisfies type of call, provides state-of-the-art capabilities for advancing research. Does RI have a sufficiently broad and sustainable scientific user base or potential comparing to similar infrastructures in other countries. Are there cost-efficient alternatives that would satisfy the same need

[1] See https://www.vr.se/english/applying-for-funding/calls/2022-10-25-grant-for-research-infrastructure-of-national-interest.html

- **socio-economic impact** – the assessment of the RI's ability to provide benefits outside academic research (commercial use or societal benefit), including the UN global sustainable development goals and national innovation and economic impact
- **implementation, leadership, and organization** – feasibility of the proposal, adequacy of the organizational structure, appropriate and cost-efficient management structure; possessing necessary competencies in terms of scientific and strategic aspects and management; having relevant partners; both funding and personnel at an appropriate level and sufficiently secured; potential risks assessed; relevant collaborations with other infrastructures described
- **consortium** – is the suggested form of consortium appropriate to fulfill the needs; in case of a consortium, are all organizations relevant for the infrastructure
- **e-infrastructure** – appropriate data policy and data management plans; does the technical solution provide access, analysis, active data storage, and data management; sufficient support for users in terms of software, development of user-specific tools, and database solutions; readiness to sustain the growing need for e-infrastructure; when applicable, has the infrastructure consulted and coordinated with other infrastructures to ensure that necessary e-infrastructure is available for users
- **prioritization between functionalities or components** – which components are central or highly relevant; can components be identified as relevant or less relevant; is the budget of each component reasonable and cost-effective in terms of personnel, equipment etc.?

The national interest is further defined through the following criteria:

- enables research of the highest scientific quality
- are openly accessible primarily to researchers but also to the business sector, the public sector, and other relevant actors. When access is limited, prioritization of criteria shall primarily be based on scientific excellence
- creates clear national added value
- have long-term plans for the scientific operations and their development
- take long-term responsibility for management and control, funding, competence accumulation, and development of the operation
- contribute to societal development, e.g., enables research that addresses societal challenges.

Proposals for new areas of research that are prioritized within the calls. However, applications for new and existing RIs should be joined in a single submission[2].

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[2] See https://www.vr.se/english/just-now/news/news-archive/2022-10-13-these-can-now-apply-for-grants-to-research-infrastructure-2023.html

The assessment of applications is done by the International Panel Experts and the Council for Research Infrastructure (RFI) involving the e-infrastructure committee and three advisory groups of experts (professors, directors, researchers) in different scientific fields: Group A for databases and infrastructure for analysis and materials for humanities, medicine and social sciences, Group B for observatories and measuring platforms for astronomy, the climate, the environment and earth sciences, and Group C for high-tech laboratories for physics, and chemistry, as well as materials, engineering and life sciences.

The evaluation of application has two stages:

1) an initial review of applications and sending out supplementary questions to the applicant. SRC usually inquires about the applicant's budgetary items and reviews the application, after which a written statement is released to the advisory group on the applications and their scientific value.

2) in the second stage, the advisory group collects reviews form the SRC, international panels, and e-committees, and uses them to prioritize applications. After the prioritization, the dialogue with the chosen applicants and their administrative bodies begins regarding project content and follow-up of the infrastructure operation. Based on the dialogue, the SRC makes the final decision, deciding on the amount of funding, and special terms and conditions for the infrastructures to receive the grant.

**Approach to funding research infrastructure in Finland**

Finnish Research Infrastructure Committee (FRIC) altogether has a chair and vice chair, a permanent expert, and 15 members that are university rectors, research center CEOs or Directors General, members from the Research Council of Finland as well as the ministerial representatives from the Ministry of Economic Affairs and Employment, Ministry of Social Affairs and Health, Ministry of Health and the Environment, and the Ministry of Education and Culture.

FRIC monitors and develops Finnish and international research infrastructure activities, submits proposals to the Academy Board on long-term RI plans, selects projects to be funded, and monitors them.

Funding awarded by FRIC are meant to upgrade and construct research infrastructure, not to maintain it or fund research (Strategy for National Research Infrastructures In Finland 2020-2030, Academy of Finland).

FRIC announces grant calls annually. Depending on the needs of the Research Infrastructure, they can be targeted at specific groups of RIs. E.g., within the Recovery and Resilience Plan 2022, the grant call was announced for the local research infrastructures to support closer collaboration between RIs and regional R&D&I actors. The objective was to fund upgrades to existing or currently under-construction infrastructure to support their greater resilience in the digital landscape (for digitalization, automation, sustainability, etc.).

Similar to that of Sweden, selection and evaluation critical include the significance of research (high added value), cooperation and impact for regional specialization and business regeneration, ownership (a clear division of the rights, obligations, and roles of the owners), sufficient expertise and know-how within the existing RI, services and users (clearly described access procedures for different types of users), digital platforms and data (supports digitalization and big data), emphasis on responsibility and green transition, clearly outlined long-term funding plans for the maintenance and development of services (sustainable business plan for at least five years), and evaluated and assessed risk management (see Picture 1.)

*Figure 1. A general overview of the criteria and objectives of the grants to Research Infrastructure*

| 6. Criteria of the decision-making process in the RM procedure | | |
|---|---|---|
| **Eligibility criteria** | **Evaluation criteria** | **Feasibility criteria** |
| A RI must:<br>• provide potential for world-class research and scientific breakthroughs,<br>• be of broad national interest and enhance the international impact,<br>• have a long-term plan for scientific goals, maintenance, financing and utilisation,<br>• be used by several research groups/users for high-quality research,<br>• be open and easily accessible to researchers, industry and other actors,<br>• have a plan for access to and preservation of collected data and/or materials,<br>• be extensive enough so that individual groups cannot manage them on their own,<br>• introduce new cutting-edge technology (if relevant. | For RI which are in operation or designing or implementation phase[4]:<br>1. Scientific quality and potential<br>2. Open access and utilisation<br>3. Relevance to the strategies of host institutions<br>4. National and international relevance<br>5. Feasibility and Sustainability<br>(for detailed information see link to document[5]) | The feasibility of the project is assessed on the basis of the technical, institutional (e.g. form of ownership, terms of use or membership) and personnel requirements during the whole life cycle of the RI: Planning costs<br>Investment costs:<br>• Construction/Building (incl. manpower)<br>• Acquisition of real estate<br>• Special technical equipment<br>• Supply/construction of devices and equipment<br>Operating costs:<br>• Personnel costs (e.g. operation, maintenance, user support)<br>• Material costs (incl. membership fees or other payment of contributions to organisations)<br>• Costs of running the premises (rent, electricity)<br>• Other noteworthy investments (replacement purchases) required to keep the research<br>• infrastructure and equipment on an adequate level, reflecting the state-of-the-art<br>Decommissioning costs:<br>• Costs of closing down the business and conservation of the resources developed |

At least two expert panels review applications. After reviews, panel members hold a joint meeting on the application and their assessments, and agree to release a joint statement on the application rating.

Not necessarily that reviewers are international experts. They can be nationals that are chosen considering possible conflict of interest with the applicants. Conflicts of interest are considered both at personal and professional (past three years) levels, e.g., if have applied for the same funding instrument; has collaborated with the applicant; is in managerial, subordinate, or instructor position with the applicant, etc.

FRIC makes the final funding decision.

**Approach to funding research infrastructure in the Netherlands**

Similar to Finland and Sweden, the Netherlands has a Dutch Research Council (NWO[3]) that provides grants for funding high-risk research and covering up to 75% of costs for setting up new RI. NWO is a part of the Dutch government. It has an executive board and supervisory board, and the presidents are appointed by the Ministry of Education, Culture and Science.

Applicants for Research Infrastructure calls are encouraged to develop international platforms and research consortia. Often projects have a long-term funding plan for up to five years, but the Research Infrastructure must be used longer. Grant calls for research infrastructure are announced annually. Grants cover costs for scientific equipment and databases, personnel for the infrastructure setup, and international memberships.

The latest call from 2023 considers large-scale infrastructure investments that follow the outlined National Roadmap. The National Roadmap includes and prioritizes RIs that significantly contribute to innovation and help solve major social issues related to the environment, climate, health, and civilization. For evaluating economic and scientific significance a permanent *Strategic Conference Permanent Committee on National Institutes (PCNI) about infrastructure*[4] has been established.

To apply for grants, the RI has to be listed in the National Roadmap and Strategy (closed calls). The listed institutions can apply individually or in consortiums.

[3] See https://www.nwo.nl/en/supervisory-board-of-nwo
[4] See https://www.nwo-i.nl/en/artikel/strategische-conferentie-permanente-commissie-nationale-instituten-pcni-over-infrastructuur/

Applications must justify:

1. Relevance of RI:
    - relevance to the national research strategy (National Roadmap)
    - relevance to international strategies (e.g., Sustainable Development Goals)
    - current scientific breakthrough that motivates the development of RI or an expected scientific breakthrough
    - consortiums
2. Impact and added value:
    - available capacity v/s required capacity by users for the RI
    - has a clear access policy that enables access for different types of users
    - list of services provided to scientific users and their impact on its users
    - impact on other scientific fields
    - socio-economic impact
    - importance of generated data (how data is generated and made available to benefit the science, society, and economy)
3. Organizational and financial aspects:
    - decision-making structure
    - plan for education and training of users
    - strategies for procurement, IP, and commercial activities
    - key performance indications, milestones, and deliverables of the RI
    - detailed plan of financial feasibility and sustainability after the end of the RI grant (sources of income, commercial use, expected capacity and utilization, running costs, dismantling costs) and how this commitment is guaranteed

If there are more applications than the total amount of grant available, the application assessment begins with pre-selection by four criteria (scientific quality, impact, organizational and financial aspects, technical aspects).

In the next stage two external experts are assigned for an application. Each expert can review only one application per year and is not paid, their identity is confidential. Expert submits a review to the NWO and forwards the report and comments to the applicant, who can appeal it. If NWO is satisfied with the review, the process is followed by an interview and a site visit.

The selection committee consisting of volunteering senior researchers assigns scores to all applications. NWO, follows their ranking and funds projects until the budget is exhausted. NWO may follow a fair distribution of funds between science fields instead of strictly following the ranking.

**Highlights of approaches to funding research infrastructure in other countries**

- Germany has strict rules for awarding RI grants. RIs are required to provide a long-term business plan that guarantees operation costs at least 10 years after the development phase.
- RI grants are often aimed at developing new or upgrading existing RIs. Specific tools for funding maintenance are not common. Institutions are required to secure themselves the funding for running and maintenances of the RI, and justify it in their business plans. Sources might include research funding, institutional base funding, education funding and other income from national or regional budgets as well as income from R&D contracts.
- There is a need for long-term business plans of research infrastructures to ensure the sustainability for RI investments.
- ESFRI criteria for evaluation of RI investments can be used as they cover most of important aspects and foster internationally unified approach.

*Figure 2. ESFRI criteria for evaluation of RI investments*

| Objective | KPIs |
|---|---|
| **Enabling scientific excellence** | 1. Number of user requests for access<br>2. Number of users served<br>3. Number of publications<br>4. Percentage of top (10%) cited publications |
| **Delivery of education and training** | 5. Number of master and PhD students using the RI<br>6. Training of people who are not RI staff |
| **Enhancing collaboration in Europe** | 7. Number of members of the RI from ESFRI countries<br>8. Share of users and publications per ESFRI member country |
| **Facilitating economic activities** | 9. Share of users associated with industry and publications with industry<br>10. Income from commercial activities and the number of entities paying for service |
| **Outreach to the public** | 11. Engagement achieved by direct contact<br>12. Outreach through media<br>13. Outreach via the RI's own web and social media |
| **Optimising data use** | 14. Number of publicly available data sets used externally |
| **Provision of scientific advice** | 15. Participation by RIs in policy related activities<br>16. Citations in policy related publications |
| **Facilitating international co-operation** | 17. Share of users and publications per non-ESFRI member country<br>18. International trainees<br>19. Number of members of the RI from non-ESFRI countries |
| **Optimising management** | 20. Revenues<br>21. Extent of resources made available |

- When assessing the required RI capacity v/s available, all users have to be taken into account (consortiums, higher education institutions, etc.).
- Insufficient responsiveness of the research system to non-researchers is a common phenomenon, leading to limited socio-economic impact. Also, research infrastructures underperform when there is a mismatch between 1) the research activities as well as number and areas of degrees provided by universities, and 2) regional societal needs (see Estonia's RI Peer Review, 2020). There should be policies aiming to minimize the mismatch and foster mutual learning.
- Establishing a centralized body (e.g., National Research Council) tasked with developing a system-wide strategic planning for significant research infrastructure helps to improve international competitiveness of the national RI.

# A4 Latvian RI database

*The Latvian RI database is attached to the Analysis as a separate MS Excel file.*