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National research infrastructure analysis

Latvian RI strategic roadmap and recommendations

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Latvian RI strategic roadmap and recommendations

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.

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.

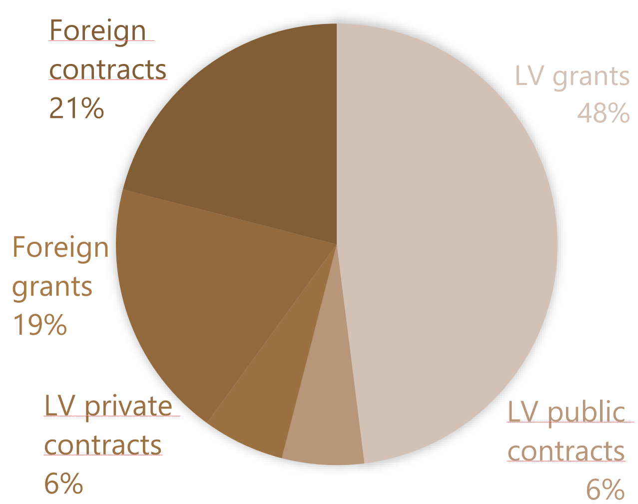
Non-academic R&D collaboration

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

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*).

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).

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).