INTERFACE

Report on the evaluation of the Mathematics Research Unit (RMATH) at the University of Luxembourg

Based on a peer review as commissioned by the Ministry of Higher Education and Research of Luxembourg

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COMPANY INFORMATION

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1 INTRODUCTION

The Ministry of Higher Education and Research (MESR) of Luxembourg mandated *Interface Policy Studies, Research, Consulting,* Switzerland, to organize and lead a research evaluation of the University of Luxembourg. Simultaneously, the Institutional Evaluation Programme (IEP) of the European University Association carried out an institutional evaluation of the University of Luxembourg. The results of the IEP evaluation are published in a separate report.

The research evaluation was conducted in 2016 and followed two earlier evaluations carried out in 2008 and 2012.

The University of Luxembourg has three Faculties with research units conducting research in different scientific disciplines. In addition, there are three interdisciplinary centres.[1] The evaluation focused on the research performance of the University research units and interdisciplinary centres. This report presents the evaluation of the Mathematics Research Unit (RMATH).

The observations and recommendations presented in this report are based on a peer review by the following three experts working in the research unit's research fields:

- Uwe Jannsen, professor of mathematics at the University of Regensburg, Germany
- Giovanni Felder, professor of mathematics at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), Switzerland
- Jan Obloj, professor of mathematics at the University of Oxford, United Kingdom

The peer review consisted of a self-assessment report written by the RMATH and a hearing at the research unit that took place in September 2016. The evaluation assessed the period 2012 to 2015. The hearing, which was organized and moderated by Interface, consisted of a self-presentation by the research unit, a group discussion of the self-assessment report, and several individual and group interviews. These included interviews with representatives of the management team, professors, PhD candidates,[2] and further members of the research staff. Based on the experts' assessments, the report was finalized by Ueli Haefeli and Olivier Dolder of Interface. The report has been approved by the experts.

The overall results of all unit evaluations are summarized in a synthesis report.[3] The synthesis report includes the findings of the interviews conducted with representatives of the management team at the University of Luxembourg.

1 The Interdisciplinary Centre for Contemporary and Digital History was established in 2016. It is not part of the evaluation, as the assessed period is 2012 to 2015.

2 The University of Luxembourg calls its PhD students 'PhD candidates'.

3 Rieder, Stefan et al. (2017): Evaluation of the University of Luxembourg, Interface Policy Studies, Research, Consulting, Lucerne.

The report is divided into two parts: The first part discusses the expert team's observations gathered during the evaluation process. The focus is on the input, the output, and the outcome/impact of the research unit:

- *Input* includes the preconditions for the research conducted, such as strategies, financial and human resources, infrastructure, organization, and quality assurance systems.
- *Output* includes the performance of the research unit, exemplified through research results and their dissemination.
- *Outcome and impact* refer to the medium- and long-term effects as well as the relevance of the output for science, society, economy, and politics.

The second part presents the expert team's recommendations for further development of existing strengths and overcoming observed weaknesses.

The evaluation team would like to thank everyone involved for preparing and implementing the hearing at the RMATH, for making the documentation available, and for participating in interviews.

2 RESULTS OF THE EVALUATION

2.1 OVERALL ASSESSMENT

The expert team is very impressed by the performance of this small research unit. The RMATH clearly punches above its weight. The research unit has produced a large number of publications of very high quality. It is well known and very visible in the international scientific community. The performance of the RMATH relies on the high quality of its professors, the large number of postdocs helping the professors co-run research and teaching, its success at obtaining grants from the Luxembourg National Research Fund (FNR), and the availability of the University internal project funding. Furthermore, there is an excellent team spirit within the research unit, and its members appear to be enthusiastic about the working conditions and atmosphere. In the future, the research unit will face challenges due to the FNR's decision to discontinue the AFR postdoc funding scheme[4] and due to other budgetary restrictions.

2.2 INPUT

Research strategy

The RMATH deals with a range of important topics in mathematics. Given its small size and considering the high quality and quantity of the research unit's research output, the experts assess the unit's strategy as very successful. Since its founding in 2003, the RMATH has managed to acquire core expertise in several fields while maintaining coherence between the different research groups. The RMATH presents itself as organized in five groups: Geometry and Mathematical Physics; Geometric and Harmonic Analysis; Probability Theory; Number Theory, Algebra and Computer Algebra; and Modelling. Three of the groups show strong and coherent performance. Two groups, namely, Algebra and Modelling, are relatively isolated and comparatively underdeveloped.

Human and financial resources, infrastructure, and equipment

The research unit's current personnel structure with 10 professors, 18 PhD candidates, and a large body of 26 postdocs (at the end of 2015) is quite unusual but reflects the funding opportunities (for postdocs) that the research unit had (see section 2.3). The research unit has been successful at exploiting these opportunities while creating and maintaining a well-functioning framework. However, this situation is not sustainable in general, and especially since the FNR has discontinued the AFR postdoc funding scheme that was the main source of grants for postdocs at the RMATH. The expert team appreciates the research unit's awareness of this problem.

The research unit's staff seems to be satisfied, and this results in excellent team spirit. The experts nevertheless identified a shortcoming: The teaching load is not uniformly

[4] The AFR Postdoc programme was an individual funding scheme for postdocs, running from 2008 to 2016 (see <www.fnr.lu>).

distributed among PhD candidates, and quite a large number of teaching hours are assigned to *vacataires* (i.e. instructors with temporary contracts).

In the experts' view, the financial situation of the RMATH is good. Nevertheless, the experts learned that the research unit has concerns regarding future travel budgets. It should be noted that an adequate travel budget is important for a mathematics unit, since personal interactions and discussions with international colleagues are crucial for mathematical research. The experts therefore point out that the budget for travel expenses should be increased, if the number of staff members increases.

The research unit was in a comfortable situation regarding infrastructure during the period under evaluation. The RMATH will move shortly to the new Campus Belval, and the experts learned that some members of the research unit are either uninformed or worried about the upcoming move. One major concern is that there will be no blackboards in the new rooms: The availability of blackboards or whiteboards is crucial for the mathematicians' research and teaching activities. The experts feel that it is important to keep everyone fully informed and engaged regarding such important changes.

Organization

The RMATH has quite an informal management structure that has worked smoothly during the past years. But the experts are unsure as to what will happen after the imminent retirement of the current head of the research unit, who has been able to manage this high degree of informality very well. The informal structure could cause difficulties for a future head and will not make taking over leadership of the research unit any easier.

External research collaborations and service provision

In the experts' view, the collaboration activities with other universities are impressive. For example, the research unit set up formal collaboration agreements with universities in Poland and Russia. In addition, the research unit made efforts to engage with other partners, e.g. the Luxembourg Business Association (FEDIL).

Quality assurance system

The RMATH assures its quality by publishing in peer-reviewed journals and by applying for external funding. This is adequate, in the opinion of the experts. They do not see a need for a specific quality assurance system within the research unit itself.

The research unit's professors supervise their PhD students well. Nevertheless, the experts are of the opinion that a more formal system of supervision would help to guarantee quality in the future. A system of this kind will possibly be put in place in the framework of the new doctoral school.

2.3 OUTPUT

The RMATH has excellent research output und is well known in the international scientific community. The members of the research unit published a number of papers in a variety of high-ranked international journals. The members have been very active in organizing and participating in international conferences, workshops, and meetings. The research unit therefore has high international visibility. Considering the small size and the young age of the research unit, the experts rate its scientific track record as even more impressive. However, there are some differences in quality within the research unit (see below).

The research unit's current personnel structure, with nearly three times more postdocs than professors, is quite unusual compared with other institutes of mathematics (see section 2.2 above). However, it shows that the research unit made the best use of available resources, which the experts greatly appreciate. The RMATH was very successful in acquiring external competitive funding: It obtained several AFR postdoc, OPEN,[5] and INTER grants[6] and was recently awarded a PRIDE block grant[7] for PhD positions. In addition, the research unit was successful in acquiring University internal competitive funding, i.e. for internal research projects (IRP). In the future, external funding opportunities will become scarcer due to the FNR's decision to stop the AFR postdoc funding scheme,[8] and the financial situation will change due to other budgetary restrictions (see section 2.5 below).

To further describe the research unit's research output, the experts chose to follow the RMATH's classification of five main research directions:

- The Geometry and Mathematical Physics group as well as the Geometric and Harmonic Analysis group are investigating interrelated questions of geometry and algebra with a strong connection with physics. They have an excellent research record in the theory of infinite dimensional Lie algebras, deformation and Toeplitz quantization, Kähler geometry, Lorentzian geometry, and Teichmüller theory. Their recent works on deformation quantization, in particular on the classification of universal quantizations of Lie bialgebras and the Grothendieck-Teichmüller group, are among the most interesting recent developments in this area.
- The Probability Theory group, driven by three professors and their groups, is energetic and produces excellent outputs. The professors cover a wide range of topics while at the same time having common interests and connecting with other researchers at the RMATH by combining probability with analysis and geometry.

5 The OPEN programme of the FNR provides funding for a limited number of high quality research projects in areas that are currently not covered by the thematic CORE programme. CORE is the central programme of the FNR; the objective of CORE is to strengthen the scientific quality of Luxembourg's public research in the country's priority research domains (see <www.fnr.lu>).

6 The INTER Programme is the FNR's main funding instrument to foster international collaboration (see <www.fnr.lu>).

7 PRIDE is the programme of the FNR for funding doctoral research in Luxembourg. Under this programme, a block of PhD grants is awarded to a consortium of excellent researchers grouped around a coherent research and training programme (see <www.fnr.lu>).

8 The AFR Postdoc programme was an individual funding scheme for postdocs; it ran from 2008 to 2016 (see <www.fnr.lu>).

The three aspects are interwoven particularly in their work on stochastic differential geometry, with a recent focus on heat equation on manifolds with time-dependent metric and important earlier contributions on sub-Riemannian diffusions yielding a geometric theory of curvature-dimension inequalities and understanding of lower Ricci curvature bounds through functional inequalities. The professors and groups are recognized internationally for their work combining Stein's method and the stochastic calculus of variations, which is called the Malliavin-Stein approach. These include central limit theorems for random variables in Wiener chaos, known as the fourth moment theorem, which they recently extended to non-commutative settings, geometric results on Poisson spaces, and Stein-type extensions of the log-Sobolev and Talagrand inequalities. They remain leading experts in this exciting and increasingly important approach to probabilistic approximations, limit theorems, functional inequalities, and other topics.

- The Number Theory, Algebra and Computer Algebra group consists of two professors. One of the professors has carried out very interesting and successful work on the topic of the famous correspondence suggested by J.-P. Serre between modular forms and Galois representations and further generalizations between automorphic forms and Galois representations. This can be used, for one, to realize particular Galois groups over number fields (the so-called inverse Galois problem); for another, using modular forms modulo prime powers, one asks for the properties of these Galois representations, for example their local behaviour. The explicit constructions are also carried out numerically, which provides the bridge to computer algebra. The output is impressive, and there are many contacts with other groups internationally in this field. The second professor works in Modelling and Decision Theory and links with his colleague because of the algebraic flavour and the computational aspects of his work. In particular, he has made important contributions to the theory of functional equations.
- The Modelling group is in an exploratory phase. It is closely linked with the probability group, in terms of both persons and research. The group's recent interests include the problem of compressed sensing. Importantly, the group has established contacts with industry (through FEDIL) that could be developed further in parallel to the group itself.

2.4 OUTCOME AND IMPACT

The RMATH has very strong scholars who have had significant impact on the international scientific community. Further, the expert group gives a positive rating to the research unit's outreach activities: During the evaluation period, the University invested in good relationships with Luxembourg grammar schools and their mathematics teachers (e.g. advanced training for mathematics teachers). The research unit hence shows a large potential to influence future school curricula. The upcoming professorship in didactics can continue the efforts relating to the schools. The experts are of the opinion that it is important that the research unit maintain these efforts. Moreover, the RMATH should try to raise awareness that the University of Luxembourg offers excellent education in mathematics.

2.5 STRATEGY FOR THE FUTURE

The research unit is very active and creative in establishing links and collaborations across the University (e.g. in the domain of computational science or financial mathematics) and with industry. However, to enable collaborations, the research unit needs to (a) sustain existing expertise and efforts, and (b) bring in much needed new expertise. The experts are of the opinion that the RMATH's future strategy should rely on the preservation of core expertise on the one hand, and on innovation and collaboration on the other.

The experts appreciate that the RMATH is aware of its future challenges and has ideas on how to develop further. In general, the RMATH has a good strategy for the future. Nevertheless, the experts express some concern, because the research unit does not yet have convincing measures to meet all of its challenges. The experts team points out the following strategic matters:

- *Creation of intermediate positions*: The expert group shares the research unit's opinion that the postdoctoral positions have to be maintained somehow. Especially for a mathematics unit, intermediate positions between PhD candidate and professor are crucial. Whereas other disciplines need equipment to conduct experiments, mathematics needs postdocs, senior lecturers, and assistant professors to conduct research. The experts are aware that replacing the postdoctoral researchers will be challenging, given that the FNR has stopped awarding AFR postdoc grants. They see potential in developing the current structural postdoctoral position system further towards a two-tier structure, with junior postdoctoral positions and more advanced positions. In addition, the expert team points out that alternative funding opportunities, such as on the European level, should be explored.
- *New professorships to strengthen existing research groups and to make them sustainable:* In the experts' view, the research unit's plan to enhance its scope by filling the two missing professorships in Algebra and Modelling is adequate and important. The RMATH will thereby reach critical mass in these two research domains and will be able to maintain its scientific quality. To keep scientific quality up, the core expertise of the RMATH has to be fostered, and the positions in these areas of core expertise should be preserved.
- *New professorship to develop computational sciences:* The experts support the RMATH's plans to align their development with the new focus on computational sciences and see a need for at least one additional professorship in this domain. A computational sciences professor could bring in the much-needed expertise in statistics.
- *Application for EU research projects:* The RMATH is currently preparing two proposals for European Research Council (ERC) grants. This is highly appreciated by the expert team. For one, the acquisition of an ERC grant would be additional proof of the RMATH's scientific quality. For another, it would function as a very important source of income, since as mentioned above, recent changes have adversely affected the funding environment for mathematics.

- *Development of mathematical finances:* The research unit has a successful master's degree programme in mathematical finance, and it has explored collaborations and development in this domain via student internships in industry. The RMATH has also established first contacts with FEDIL. There is room for additional collaboration, for example on the PhD level: The FNR offers PhD grants for research projects carried out in collaboration with a company in Luxembourg (AFR-PPP[9]). However, the experts are sceptical about intensification of the development in the area of mathematical finance, because this will involve considerable effort and is outside the main research focus of the RMATH. Since the department is small, the experts fear that there are not enough resources for successful development of a mathematical finance strand.

In general, it is important that the RMATH not diversify its activities too much at once. The maintenance of core expertise is crucial for the research unit in order to maintain its excellence in teaching and research.

9 See <www.fnr.lu>.

3 SUMMARY AND RECOMMENDATIONS

3.1 SUMMARY

The RMATH has excellent research output, and it is well known and visible in the international scientific community. It has been very successful in acquiring external competitive funding. Taking the small size and the age of the unit into account, the performance of the unit is even more impressive. Members of the research unit published many high quality articles in a variety of important, international peer-reviewed journals. However, differences in quality within the research unit remain. The research unit's members were very active in organizing and participating in international conferences, workshops, and meetings. The collaboration activities with other universities are commendable. Furthermore, there is excellent team spirit within the RMATH, and the staff members are extremely satisfied.

The current personnel structure, with a very high number of postdocs, is quite unusual but reflects the skill and success of the research unit in acquiring funding. Even though the research unit has a quite informal management structure, it works very well. The financial and infrastructure situation of the RMATH is good, but there are concerns about future infrastructure (a lack of blackboards/whiteboards) at the new location of the research unit.

The research unit will face challenges primarily due to the FNR's decision to discontinue the AFR postdoc funding scheme (the main source of grants for postdocs at the RMATH) but also due to other budgetary restrictions.

3.2 RECOMMENDATIONS

Based on the observations stated above, the expert team formulates the following recommendations for the research unit, the University, and the MESR.

Recommendation 1: Maintain the scientific quality and team spirit

The research unit performs very well. The experts encourage the research unit to continue conducting excellent research. The RMATH shows an excellent working culture, which is something that is much easier to destroy than to build. Therefore, the experts recommend taking care of this exceptional team spirit.

Recommendation 2: Retain core competences

Retirements of a number of senior staff are coming up in the near future. The expert team recommends replacing these researchers with new hires in their respective broad fields. The RMATH will only be able to develop further if the core competences in mathematics are preserved.

Recommendation 3: Award new professorships to the Algebra and Modelling groups

In order to maintain the scientific quality and preserve the sustainable momentum in the existing and relatively isolated Algebra and Modelling groups, the research unit should be reinforced with an additional professorship in each of the two groups.

Recommendation 4: Invest in development of computational sciences

The research unit has a number of ideas for development aligned with the new focus on computational sciences, and this should be supported by the University. The experts believe that there is a need for at least one additional professorship in this domain. A computational sciences professor could bring in the much-needed expertise in statistics.

Recommendation 5: Offer funding opportunities to mathematics

Mathematics is neither a national research priority nor a University research priority, and recent changes have adversely affected the funding environment for mathematics: The AFR postdoc funding scheme was discontinued, and the University's IRP budgets are being decreased. New funding opportunities should be created to sustain the dynamic research environment in mathematics. At the same time, the research unit should continue its efforts to secure European research funding.

Recommendation 6: Create opportunities to hire intermediate level staff

The current structure, with a very large body of postdocs, should be replaced gradually with a two-tier structure, with postdoctoral researchers (junior) and intermediate positions (e.g. junior professor, research fellow) that could take on more responsibility in teaching and supervision. This would lead to a better-balanced research environment.

Recommendation 7: Introduce more formal structures and prepare for the succession of the research unit head

Currently, the organization of the research unit works very well. However, the current modus operandi will be challenged by a change in the head of the research unit and the planned growth of the unit. Therefore, the expert team recommends holding regular research unit meetings that include representatives of the postdocs and PhD candidates. This will in particular ensure that the selection of the new head is transparent and consensual.