NWO Mathematics Cluster Evaluation

EVALUATION, CONCLUSIONS AND RECOMMENDATIONS

Netherlands Organisation for Scientific Research

NWO Mathematics Cluster Evaluation

EVALUATION, CONCLUSIONS AND RECOMMENDATIONS

DIAMANT

GQT

NDNS+

STAR
Stochastics - Theoretical and Applied Research

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PREFACE

It has been a great pleasure to chair the International Scientific Evaluation Board (ISEB), which had the difficult task of evaluating the Mathematics Clusters. This conclusion report underscores the importance and relevance of the clusters to the mathematics research landscape in the Netherlands. It is my pleasure to present the outcome of the evaluation in this report.

Two separate reports have been published for the evaluation of the Mathematics Clusters: (1) Self-evaluations submitted by the clusters, and (2) Conclusions and recommendations as outcomes of the evaluation. The latter report is organised as follows: the introduction provides the context in which the evaluation took place and the procedures followed. The next chapters include the ISEB findings on each Mathematics Cluster, addressing each criterion. Finally, we provide general conclusions and recommendations for the parties involved to contribute to the development of the Mathematics Clusters and therefore safeguard the future quality of mathematics research in the Netherlands.

On behalf of the ISEB, I would like to express my gratitude to the Mathematics Cluster members who presented their research to the ISEB and, in particular, the board members who worked hard to compile the data for the self-evaluation reports. The two evaluation days provided important information that enabled the ISEB to develop a broad range of findings and considerations for the future of the Mathematics Clusters. Finally I would like to thank the NWO-employees for their support.

Prof. Robert Tijdeman - Chair
International Scientific Evaluation Board (ISEB)

INTRODUCTION

Mathematics has become an essential tool in many sciences and in technology. As a country that depends on the quality of its science-based products, we must take care not to neglect a fundamental science such as mathematics. Strong international competition and the pressure put on staff due to the enormous increase in the number of mathematics students between 2010 and 2018, with no corresponding increase in staff members, has resulted in far from optimal conditions for mathematical research in the Netherlands. This particularly affects young mathematicians who, at a time that they have to broaden their scope and show that they are able to guide PhD students, are faced with a heavy teaching load and shortage of PhD students due to a lack of available research positions.

The mathematics community has combined its efforts to respond to these challenges in a way that is unique in the Netherlands and in mathematics elsewhere. In doing so, it has made use of the relatively short distances in the country. The Mathematics Clusters, established since 2005 by NWO, consist of strong groups from various universities and the NWO institute CWI. These groups cooperate with one another, and have helped establish Mastermath, which teaches mathematics courses to master's and PhD students at every Dutch university. Teacher selection is also largely the responsibility of the clusters. This increases the quality of teaching while decreasing the pressure on staff.

NWO must be praised for its support of the Mathematics Clusters between 2005 and 2018. It provided the means to organise cluster meetings and, most importantly, to hire PhD students, postdocs and promising researchers in tenure track positions. In 2010, an international visiting committee evaluated the clusters and concluded that all four were excellent, and one of them even exemplary. Their advice to continue the support was followed by NWO. The Ministry of Education, Culture and Science also provided funding in 2012.

It is likely that, in response to the sector plans, the Ministry of Education, Culture and Science will provide a considerable number of tenure track positions for permanent mathematics staff members in the near future. Eight years after the first evaluation in 2010, it is again time to evaluate the Mathematics Clusters to assess their quality and effectiveness. The overall aim of this evaluation is

to determine the future viability of the Mathematics Clusters. For this reason, NWO asked an international committee, the ISEB, to evaluate the clusters.

The ISEB consists of four members and one technical chair, supported by NWO representatives. Each ISEB member represents a cluster based on his or her expertise. A brief CV of each ISEB member is included in Appendix A of this report.

EVALUATION PROCEDURE

The Netherlands Organisation for Scientific Research (NWO) decided to establish an International Scientific Evaluation Board (ISEB) to evaluate the quality of the research activities of the Mathematics Clusters in the Netherlands. The aim of this is to reinforce the available knowledge and expertise and the existing collaboration. To ensure that the evaluation represents a fair and transparent assessment of the quality and relevance of publicly funded research, NWO developed the Terms of References (ToR), based on the Standard Evaluation Protocol (SEP) 2015–2021.

Aim

The overall aim of the evaluation is to examine the robustness of the Mathematics Clusters. The evaluation also identifies short-term and long-term goals, as listed below.

Short-term goals

- Conduct a retrospective (self)evaluation of (a) the efficiency of each cluster, and (b) the effectiveness of the cluster approach within the mathematics research community.
- With this in mind, ask the clusters to deliver a roadmap of their scientific activities and their future scientific and thematic focus. The roadmap reflects a long-term vision and comprises a comprehensive strategy plan that aims to enhance and strengthen the mathematics topics relevant to the cluster. In this roadmap, the cluster prioritises the research focus and the research capacities should resources become available in the near future. The roadmap can be considered a concise ten-year plan. As a start, the clusters will be asked to develop a scientific focus for an initial budget of 1M Euro for each cluster. This may require them to select scientific themes and staffing levels.

Long-term goals

On the condition that the outcome of the evaluation is positive, the following actions can be identified:

- Based on the submitted scientific and thematic focus for each cluster, a call for proposals may be developed in 2019. The ISEB should preferably be involved in the assessment in this granting scheme.
- Based on the roadmaps, funding may be provided for the organisation of the scientific activities in the clusters.

Criteria

The ISEB evaluated each Mathematics Cluster against the criteria listed in this section. The evaluation ensures a match between the qualitative assessment (text) and the quantitative assessment (assigned in scores 1–5+). Each criterion was given a score as follows: 1 = unsatisfactory; 2 = satisfactory; 3 = good; 4 = very good; 5 = excellent.

Scientific quality

- The ISEB evaluated the quality of the clusters' research and the contribution of this research to the body of scientific knowledge. This includes the scientific results of recent years, such as scientific publications, instruments and infrastructure developed by the cluster and funded research within the cluster.

Relevance to community

- The ISEB evaluated the quality, scale and relevance of contributions targeting specific groups and areas that the Mathematic Cluster has itself designated as target areas. Performance results were evaluated, such as facts and figures on research positions, funding, number of participants, and so on.

Viability

- The ISEB evaluated the cluster's intended strategy for the years ahead and the extent to which it is capable of meeting its research and community targets during this period. It also considered the governance and leadership skills of the cluster's board. The evaluation of the roadmap is an essential part of this criterion.

Procedure

This section describes the preparation, implementation and expected outcome of the evaluation.

Preparation

The ISEB received the following documentation in preparation for the evaluation:

- A self-evaluation report from each Mathematics Cluster, including appendices such as a publication list, etc.
- A roadmap from each cluster including future plans presented as a strategic document that reflects on how the cluster will develop in the next ten years. This document also included a scientific prioritisation to be used for future calls for proposals.

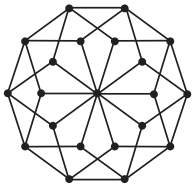
Implementation

The evaluation consisted of the following stages:

- At the first meeting (closed session) the ISEB discussed its first impressions and findings based on the documentation provided. This meeting was followed by a meeting in which the Dutch Mathematics Clusters presented themselves to the ISEB and their fellow researchers.
- In the interview session, the Mathematics Clusters gave an oral presentation on their self-evaluation and roadmaps. The ISEB had the opportunity to ask the Mathematics Clusters questions, for example concerning the provided documents. Each interview was followed by a closed session with the ISEB members to conclude their findings.
- After the interview session, a separate meeting was held with the ISEB, the cluster directors and a member of the NWO Science Domain Board to discuss the role of the Mathematics Clusters in general, nationally and internationally.
- The ISEB finally convened in a closed session to discuss its conclusions.

Expected outcome

Based on the final findings and conclusions, the ISEB provided a written assessment of each Mathematics Cluster, and of the Mathematics Clusters in general.



DIAMANT

EVALUATION OF **DIAMANT**

The DIAMANT Cluster unites a very dynamic and engaged community of researchers with a common emphasis on research topics with discrete and algorithmic content. In a small country like the Netherlands, this helps ensure the critical mass and diversity required to maintain a vibrant research community. However, using the cluster structure, DIAMANT has gone beyond this by encouraging and coordinating collaborations, and has therefore achieved remarkable interactions, from the highest levels of abstract mathematics to the forefront of applications that include direct interactions with other sciences, and the forefront of technological developments.

Scientific quality

The cluster aims to enhance the excellent research carried out by its members, and foster collaboration and exchange between pure and applied research with a remarkably broad yet coherent range of research topics. DIAMANT researchers are simultaneously at the forefront of important pure topics and of highly relevant applied topics.

At the purest and most abstract end of the spectrum of DIAMANT research, one may mention: The recent advances of Ben Moonen on the Tate and Mumford-Tate conjectures are worth mentioning. The senior level NWO TOP grant awarded to Moonen and Taelman (both DIAMANT researchers at the interface with GQT) received the senior level NWO TOP grant for their project on geometry and arithmetic beyond Shimura varieties. We should also mention The Princeton University Press book about on computational aspects of modular forms and their associated Galois representations by Couveignes and Edixhoven with contributions from a few other researchers, including Robin de Jong.

At the most applied end of the spectrum, there is the publication in *Nature* by DIAMANT researcher Joost Batenburg and co-authors on the 3D reconstruction of a complex crystalline nanoparticle at atomic resolution. Bodo Manthey and co-authors also published an article on the smoothed analysis of the k-means method. They show that if an arbitrary input data set is randomly perturbed, then the k-means method will run in expected polynomial time on that input set.

Leo van Iersel and a co-author have published a paper that identifies the networks that can be uniquely reconstructed from the set of networks obtained by deleting a single leaf. This work has important applications, among other,for example in evolutionary biology. Leo van Iersel was appointed on a DIAMANT- funded tenure track position in 2014.

Other highlights involving DIAMANT- funded positions include, one may mention the work of Daniel Dadush on algorithmic aspects of lattice problems with applications in cryptography, coding and optimisation, as well as his work that aims to explain the observed practical performance of fundamental algorithms, for which he recently obtained an ERC starting Starting gran. Sander Dahmen who developed algorithms and underlying theory to solve Diophantine problems.

Relevance to community

DIAMANT has 80 members at the associate professor level or higher, spanning practically every research institute in the Netherlands. The cluster encompasses a large community that includesa wide range from pure number theory and algebraic geometry, through cryptography, to operations research and logic. It is impressive that, despite this breadth and the presence of a core of very pure mathematics, the cluster managed to foster a sense of belonging, and even real interactions.

Key roles of the cluster include organising biannual meetings to educate all cluster members on all areas covered by the cluster, and fostering a sense of community, especially for PhD students and young researchers. The cluster also aims to make more PhD positions available for high-quality students and projects when none are available in member institutions. No fewer than 108 DIAMANT-associated PhD defences were held in the evaluation period. DIAMANT funded 24 positions between 2010 and 2018, 6 of which were tenure track positions. The cluster also plays an important role in running Mastermath, an excellent national master's programme that improves the efficiency and quality of master's degree programmes in mathematics at Dutch universities.

The cluster members have a truly impressive track record of obtaining funding for their research. They were awarded some 60 grants from NWO, including 16 Veni grants, 8 Vidi grants, and 4 Vici grants, as well as several large grants in the Zwaartekracht scheme with significant components related the themes of the cluster. The cluster has also obtained two Advanced, two Consolidator, and two Starting individual grants from the European Research Council, as well as a large number of FP7 and H2020 scheme grants.

DIAMANT saw significant growth in both internal interactions and successful interactions with the other clusters during this period, and currently has active interactions with all three of the other clusters. A particularly intense interaction took place with GQT in the area of algebraic geometry, which is now considered a common area of research and hiring for the two clusters. There are also important interactions with the STAR Cluster, mainly on the subject of algorithms involving stochastic aspects, and with the NDNS+ Cluster, mainly on the subject of optimisation.

Viability

DIAMANT has identified four main research themes for the period 2019-–2029, along with their as well as connections to national themes and their connections to the other clusters. They are well described in the self-evaluation report.
Although these plans are ambitious, they are well anchored in past performance and the current strengths of DIAMANT researchers. One concern however is the growing number of mathematics

students in the Netherlands and the corresponding increase in teaching load. The sector plan, which foresees significant investments in new tenure track lines, should help alleviate this problem and strengthen the very healthy current state of Dutch mathematics. A major remaining concern is the drain of talented students due to a lack of PhD stipends and postdoc positions. The DIAMANT Cluster therefore foresees using its funding for PhD and postdoc positions, rather than for basic cluster activities.

The Netherlands enjoys international renown in the general area of logic and the foundations of mathematics, thanks to such international figures such as Brouwer, Beth, de Bruijn, Heyting, and more recently Barendregt, Moerdijk and van Benthem. This area fits in naturally with the subjects covered by the DIAMANT Cluster. It used to have a higher profile in the DIAMANT and GQT community and we hope that the clusters will not let this nationally strong subject fall between the cracks of the clusters. One saving grace for logic is the interdisciplinary Institute for Logic, Language and Computation at the University of Amsterdam, and it would be a pity to lose the high level of mathematical logic for which the Netherlands is known.

The presence of institute representatives in addition to the current cluster board ensures a close relationship with each of the other clusters. Robin de Jong acts as research manager and organiser of the DIAMANT symposia. This structure seems to function very well. A large part of its strength is that it relies on the involvement of excellent researchers. On the other hand, this is very time consuming. Both the self-evaluation and the presentation to the board were very well prepared and reflected the depth of thought and impressive level of perspective behind the plans and the structure of the cluster.

Conclusions and recommendations for the DIAMANT Cluster

The DIAMANT Cluster produces excellent research both in pure mathematics and applications, and has fostered a remarkable amount and level of interactions between pure and applied areas. The DIAMANT Cluster is deeply relevant and very important to its community and, given adequate and stable funding, there is no reason to question its long-term viability.

We recommend that the cluster organisation, hiring policy and activities continue in the same successful manner as in the past. In particular, the symposia, which expose pure and applied mathematicians to each other's work and foster a strong sense of community, also among the young researchers of the cluster, are very important and should continue. We encourage the cluster to continue in its plans to serve as a vehicle for the conception of large projects with partners outside mathematics. We also encourage it to continue the current trend of interaction, internally and with the other clusters. In particular, the cluster should look for opportunities to reverse the recent decline in the representation of logic and foundations within the clusters, especially the DIAMANT Cluster.

The overall evaluation of this cluster is excellent.

GQT

EVALUATION OF **GQT**

The GQT Cluster was established as the Fellowship of Geometry and Quantum Theory in 2004, and had as its main goal to study the mathematics of theoretical physics, and string theory in particular. It became the GQT Cluster in 2006, gradually broadening its scope of research themes in algebraic geometry, geometric analysis, category theory and integrable systems, often but not always with a connection to physics.

Scientific quality

The research topics covered by the GQT Cluster range from every aspect of geometry, a key area of fundamental mathematics, to every aspect of quantum theory, a key area of theoretical physics. Although each of the research areas of the GQT Cluster is still strongly connected to and motivated by physics, with regular publications in physics journals, purely mathematical research in different areas of geometry is also strong in the GQT Cluster.

The research output of the GQT Cluster between 2010 and 2018 was excellent. This led to numerous articles in top journals such as *Annals of Mathematics*, *Acta Mathematica*, *Inventiones Mathematica*, the *Duke Mathematical Journal* and the *Journal of the European Mathematical Society*. Members of the GQT Cluster were awarded the Spinoza prize (Moerdijk in 2012), an ERC Advanced grant (Opdam in 2010) and two Vici grants (Shadrin in 2012 and Crainic in 2013), as well as numerous other awards and national and international grants.

Some of the highlights of the GQT Cluster's research are truly impressive. For example, Moonen made important progress on the Tate conjecture and the Mumford-Tate conjecture in algebraic geometry. Ioan Marcut proved a striking rigidity theorem for Poisson manifolds, saying that all deformations are necessarily trivial, while Crainic and Fernandes gave a new proof of Conn's linearisation theorem. Opdam made a key contribution to the Langlands programme in his work on the representation theory of affine Hecke algebras. Furthermore, Stokman established explicit asymptotic expansions of quantum spherical functions.

Several of the key members of the GQT Cluster are among the main research leaders in their field worldwide. The scientific quality of the members of the GQT Cluster is its main asset.

Relevance to community

For research in fundamental mathematics and theoretical physics to advance, two needs must be met: a critical mass of high-level researchers at different career stages, and a framework in which these researchers are exposed to a broad range of topics, fostering collaboration and offering ideas for applications outside their own expertise.

The GQT Cluster fulfils both needs. The funding allows them to hire researchers at PhD, postdoc and tenure track level and to organise workshops, conferences and seminar series. The GQT Cluster unifies all research groups in geometry and quantum theory in the Netherlands. Often, these individual research groups are too small to create an active research environment on their own. The GQT Cluster manages to build a community of researchers, which has a tremendously positive effect on the broadening of each researcher's scope and intellectual environment.

In this type of fundamental research, it is important to continuously adapt the themes to current needs and opportunities. The recent tenure track hirings in the GQT Cluster demonstrate such a flexibility, with two joint hirings with the NDNS+ Cluster (in spectral geometry/ergodic theory and in topological data analysis), one joint hiring with the STAR Cluster (in probability theory with connections to theoretical physics) and one joint hiring with the DIAMANT Cluster (in algebraic geometry). Over the years, the list of research topics in the four main themes of the GQT Cluster has changed in a natural and organic manner. Compared to the other clusters, these four themes cover a less broad range of research expertise, which necessarily limits the capabilities of the GQT Cluster to respond to bigger project calls or to make a bridge to applied mathematics.

The GQT Cluster plays an exemplary role in the training of young researchers. Twice a year, all PhD students, postdocs and advanced master's students of the GQT Cluster come together for one week to attend the GQT Graduate School and Colloquium. These are key events for community building and for enhancing the exposure of young researchers to a broad range of research results.

Viability

The GQT Cluster conducts almost entirely *blue sky* and *curiosity-driven* research in pure mathematics and theoretical physics. In the long run, this type of research is just as important as more applicable or applied research. Nevertheless, funding for this type of fundamental research is more difficult to obtain. The GQT Cluster is therefore essential for maintaining the viability of pure mathematics and theoretical physics research in the Netherlands.

Algebraic geometry (one of the key areas of GQT) and number theory and arithmetic geometry (one of the key areas of DIAMANT) are increasingly becoming a single area of mathematics with continuously interacts with each other. This evolution is seen worldwide. It is therefore very good that the GQT and DIAMANT Clusters propose to treat this area of mathematics as a joint endeavour.

The four main research themes of the GQT Cluster have done much to bring together mathematicians in the Netherlands with similar research interests and to create a community with sufficient critical mass to perform high-level research. The precise delineation of these themes should however remain flexible.

Conclusions and recommendations for the GQT Cluster

The GQT Cluster conducts research at the highest international level. The GQT Cluster provides a lively and active research environment, fostering collaborations between different areas of mathematics and theoretical physics and exposing young researchers to a broad range of research themes.

The cluster organisation, hiring policy and activities should continue in the same successful manner as in the past. The training activities for young researchers, including workshops and conferences, are particularly important and should be continued.

The GQT Cluster expects to be able to hire 12 tenure track researchers in the coming years through the sector plans. It is questionable whether their proposed a priori distribution of three tenure track researchers in each of the four research themes of the cluster is the optimal way to go. The extra hirings through the sector plans could be an ideal opportunity for the GQT Cluster to further broaden its scope within mathematics and theoretical physics, and also towards applications.

The overall evaluation of this cluster is excellent.

NDNS+

EVALUATION OF **NDNS+**

The NDNS+ Cluster focuses on non-linear patterns in the broadest sense, including all aspects of non-linear dynamics in non-linear systems and their applications in the sciences and beyond, in industry and society. This virtual infrastructure can be regarded as an umbrella for all mathematics that aims to understand dynamical systems, both ordinary differential equations and partial differential equations, and their numerical approximations together with their applications beyond mathematics.

Scientific quality

The scientific roots of this cluster are in the groups created in the 1980s around Takens, Peletier and Eckhaus in these directions. Over the years, these groups expanded, and they now cover a wide range of methods and techniques in non-linear dynamics with an applied analysis twist. These groups have mastered the use of the classical applied mathematics cycle of modelling, analysis, numerical methods and simulations, with applications now ranging from mathematical biology to data science. The scientific grounds of this cluster are cemented on a large community of over 90 research members across all Dutch universities.

During the evaluation period 2010–2018, the research produced was excellent. The cluster had a fantastic publication output in all sub-areas of interest: bifurcation and chaos, multiple scales, scientific computing, variational methods, patterns and waves, and stochastic dynamics. The cluster published in top journals in theoretical aspects of these topics, such as *Annals of Mathematics*, *Communications in Mathematical Physics*, the *SIAM Journal of Mathematical Analysis*, and the *Journal of Differential Equations*, as well as in applied and numerical approaches: *Physical Review Letters*, *Journal of Computational Physics*, and the *SIAM Journal of Scientific Computing*. Remarkably for this type of research, the cluster was also able to publish in large audience avenues such as *Nature* and *Science*, two of the most prestigious journals across all sciences, demonstrating the connections with other scientific areas.

There is a new board and the director recently changed in early 2018. The new director, Stephan van Gils, and the other new members of the board represent the different research directions inside the cluster and the connection with more applied research areas.

The funding obtained by the cluster in competitive calls of the NWO is quite significant, with four Vici, seven Vidi and three Veni grants during the span of this period, plus many other grant types. The funding through grants from EU H2020 programmes was also quite remarkable.

The benefit that this cluster provides for the Dutch mathematical community, both from the teaching and research viewpoints, is key for the industrial and technological underpinning of mathematical sciences. It benefits the whole of the mathematical community, making the master's and PhD students more competitive in the job market outside academia due to the applied nature of their acquired research and training skills, and hence attracting better undergraduate students into mathematical studies.

Relevance to community

The main expenditures of the cluster were on hiring, which had a tremendous impact on the community in terms of PhDs (10) and tenure track positions (7). Considering the scale of this community of mathematicians in a small country like the Netherlands, this is a great success. The cluster was able to identify research areas in need and attract great young scientists such as Cristoph Brune (inverse problems, clustering, image processing) and others through strategic hiring.

The cluster was able to maintain a good level of activity in cohort building events such as PhD days and the different cluster meetings in which networking was the main objective. Workshops and mini symposia in the Dutch Mathematical Congress allowed the cluster to showcase its main achievements and interact with other clusters in the community.

The cluster demonstrated a healthy interaction with other clusters, in particular the STAR cluster, due to their clear shared classical research interests in dynamical systems with random components and data science for future directions. They also interacted with DIAMANT in optimisation, based on their shared expertise in applications in image processing and tomography.

Finally, the cluster has made a large effort to organise research-focused activities with other scientific areas. For instance, Roeland Merks is pushing the boundaries of cellular automata models with applications in cancer growth and angiogenesis in the life sciences. Several applied analysis groups have focused their research into modelling tissues and cell networks at different levels, with excellent scientific contributions – for example in *Science* concerning glucose metabolism in yeast. The scientific computing group also made a great contribution during this period, with applications in aerodynamics and tomography in microscopy images. Their collaboration with Photonic Systems Groups in large research projects, where cutting-edge numerical analysis tools are being used, is quite remarkable. In summary, the cluster provides an excellent service to the scientific community at large.

Viability

The cluster's roadmap was considerably revamped compared with the previous period, reflecting changes in the research landscape worldwide. While the scientific directions in the previous period were structured classically according to mathematical discipline, the new scientific directions include the theoretical and computational underpinnings of dynamical systems in general in the first two items of the roadmap. This basic, core research is essential to nurture future generations of scientists in this field and to provide them with the basic skills and background they need. Moreover, it allows them to expand into applications in science and society in general with the next two directions of interest, namely Dynamical Systems and Data and Emergence. Both of these are hot topics of research internationally.

The interaction with STAR in the Data Science direction is already well structured, using techniques of variational calculus and dynamical systems on graphs and unstructured data is one of the challenges of this generation of mathematicians. Complementing these with statistical approaches will produce some important research outcomes and interesting mathematical problems. Emergence and self-organisation in dynamical systems has attracted many scientists in the last years, due to its importance in the life and social sciences. Understanding consensus/synchrony is crucial in a variety of applications, ranging from opinion formation in sociology to computational neuroscience.

Conclusions and recommendations for the NDNS+ Cluster

The research performed by the NDNS+ Cluster is cutting edge in applied mathematics. The training provided for young researchers and postdocs in the modelling, numerics, analysis and simulation skills needed for this research is outstanding.

The basic activities run by the cluster in terms of workshops and networking events for PhD students and postdocs should continue as they are. The same recommendation is given for the training activities. The cluster has had a tremendous impact on mathematics in the Netherlands and there is no reason to change the basic structure.

The cluster clearly has the scientific strength to move towards the new proposed research directions, but this needs an energetic steer of the community, in particular by the director of the cluster in close collaboration with the board. Moreover, a clear strategic hiring plan in these areas is needed.

The overall evaluation of this cluster is excellent.

STAR
Stochastics - Theoretical
and Applied Research

EVALUATION OF **STAR**

The STAR Cluster is the meeting point for Dutch academics active in probability, statistics and stochastic operations research. This enormous field is very important across science, industry and society, and STAR plays a leading national and international role in its development and application.

Scientific quality

The subjects spanned by the STAR Cluster constitute an area of current scientific endeavour of great breadth and significance, namely the description and analysis of systems in the presence of uncertainty. STAR approaches this area across three coordinated fronts: probability, statistics and operations research in the presence of randomness. These three topics have distinctive features that share a common language and fundamental methodology. Each is strengthened in the presence of the other two, and their conjunction forms a coherent and successful programme. This is evidenced by the large number of substantial achievements, the prominence of the scientists involved, and the level of connections with target groups, including industry.

STAR may appear to be a late developer in the cluster world, but it was in effect an early prototype with the far-sighted creation in 1997 of the research institute Eurandom, with funds provided by NWO and TU/e (the NWO funding was discontinued in 2007). Eurandom now operates a workshop programme and a visitor programme, while undertaking a coordinating role within STAR. It has international visibility and impact, consolidated by transnational agreements. The two Eurandom programmes contribute important and useful functions within the organisational structure of STAR.

The cluster has ten nodes (nine Dutch universities plus CWI) and is managed by a Scientific Board, currently comprising Richard Boucherie (UT), Eric Cator (RU), Remco van der Hofstad (TU/e + Eurandom), Geurt Jongbloed (TUD), Marie-Colette van Lieshout (CWI + UT) and Evgeny Verbitskiy (UL + RUG). The cluster currently has approximately 112 active researchers, and 39 first-time appointments were made in the reporting period 2010–2018 (of whom 11 were female). Members of the cluster have supervised more than 170 PhD theses and supported over 60 international conferences. Membership of the cluster is extended to all scientists active in stochastic mathematics. Members have earned recognition and prominence internationally through their work and their awards, and have jointly attracted extensive funding from Dutch and international sources.

Members of STAR work primarily within stochastic mathematics, in other words in the areas of probability, statistics and stochastic operations research. While probability theory is their common language, these areas have distinctive connections to such topics as mathematical physics, finance, network theory, data description and analysis, and biomathematics. It is a special feature of STAR that its members have retained a close and productive sense of community across the potential differences of this rich scientific vein.

Scientific highlights include the development of Bayesian non-parametric statistics, inverse problems, statistics for stochastic processes, and statistical learning. Numerous significant topics in statistical mechanics have been studied, including the theory of metastability, random polymers, percolation, random graphs and networks, and self-organised criticality. Another main theme is statistics and modelling in the life sciences, particularly allied to topics in genomics and epidemiology, as well as the analysis of data relevant to diagnosis and patient care. Stochastic networks and communication networks have received special attention for their theory as well as their applications, including healthcare. Research in finance and econometrics is now less prominent than in earlier years, reflecting a trend seen in other international centres.

Relevance to community

The data provided by the cluster is overwhelmingly positive, and there is clear evidence that the cluster's work benefits the target communities, including academia (national and international) and industry. One of STAR's main achievements is the creation and maintenance of a strong community across stochastic mathematics. Through its coordinating role, the cluster provides an excellent environment for the intellectual development of younger researchers, and it supports strong communication between researchers in related areas.

Viability

The STAR researchers were invited to express their opinions on the most important directions for stochastic research today and tomorrow. Based on their replies, we can identify the emerging themes as centred around data, networks and dynamics.

Data science is a particularly visible and topical area of research worldwide (also in the Netherlands), and will rightly be a major feature in the next phase of STAR. The five nominated sub-areas are Bayesian non-parametrics, data assimilation, statistical learning, geometry and data, and computational statistics.

Network theory will continue to be developed. The relevant sub-areas are Markov decision theory, queueing theory, random networks, network functionality, and network algorithms. Stochastic dynamics will be studied in such contexts as statistical mechanics, climate and traffic models, and physiological systems. The key challenge is to marry deterministic dynamical laws with stochastic fluctuations. Special topics include stochastic differential equations, flows, inverse problems, random processes, and dynamical systems.

The above projects are very important to pure and applied research, both in the Netherlands and beyond. The cluster is well positioned to deliver excellent achievements in these areas. Its management processes are well adapted to the science and to the community, and there is an excellent balance between vision, ambition and reality.

Conclusions and recommendations for the STAR Cluster

Overall, this is a broad, ambitious, and important programme with a healthy balance of risk and potential gain. STAR researchers are well placed to make important contributions in many important areas. There will be numerous opportunities for interactions with the other clusters, especially DIAMANT (in the area of algorithms) and NDNS+ (for dynamical systems). It is vital for the future of Dutch science that the cluster be adequately supported in the continuation and development of its role. Funds to cover administrative support would be a very useful and productive investment in its future.

The overall evaluation of this cluster is excellent.

GENERAL CONCLUSIONS

The ISEB considers the clusters to be an effective way of organising mathematical research in the Netherlands. Together, they cover almost all active research mathematicians in the country, with key areas that are strongly represented in the Netherlands. They therefore form units that improve internal interaction and external visibility. The clusters form platforms from which mathematicians can successfully compete to participate in large consortia such as Networks and QSC (Quantum Software Consortium).

The ISEB has observed that the clusters play a crucial role in building communities of young researchers, for example by offering them high quality training through seminars, workshops and summer schools. The clusters organise two- to five-day conferences a few times a year where senior and junior researchers can meet in an international setting. Most PhD students and postdocs in a cluster participate in these conferences and attend a broad spectrum of lectures. The quality of this training is exemplary and should be continued.

The clusters also enable the organisation of Mastermath, a unique national collection of courses for master's and PhD students at a higher level and with a broader range than can be offered by any university in the Netherlands. This provides opportunities for students from different universities to meet each other and for already overloaded staff to spend more time on research, as the classes are much larger than at the individual universities. The clusters therefore play an important role in dealing with the tremendous increase in the number of mathematics master's students in the Netherlands without a corresponding increase in the number of staff.

Between 2010 and 2018, the clusters received NWO funding for temporary and tenure track positions to bridge the gap between students and tenured staff in a period when the universities had very little resources themselves to do so. The clusters carefully assigned single positions to groups where they were most needed and organised international recruitment to attract the best candidates. The recent development of the sector plan means that there does not seem to be a need to assign tenure track positions to the clusters in the next four years, but the urgency to assign PhD and postdoc positions to the clusters remains unchanged. Such positions are not only essential for the development of young talent, but also for the staff members who need younger colleagues with more research time as collaborator.

The clusters extended their domains in the period 2010–2018, so that almost all active researchers are now a member of at least one cluster. Every cluster also collaborates with the other clusters to some extent. DIAMANT and GQT even have algebraic geometry in common, although the emphasis differs. The ISEB notes that there are no walls between the clusters, but open borders. It is considered exemplary that some NWO-funded postdocs and tenure track positions have been assigned to combinations of two clusters.

The universities should note that, while NWO's primary focus is research development, the universities should focus on talent development. The lack of talent-based PhD studentships paid by the universities ultimately leads to a brain drain from the Netherlands. Bright, talented mathematics students are typically confronted with the following situation under the current scheme: during their second master's year they want to apply for a PhD studentship. At that stage, a typical mathematics research group in the Netherlands will be unable to guarantee a PhD studentship because the supervisor first has to apply to one of the calls. The student will therefore apply abroad (often in Belgium, Germany or the UK), and accept a PhD studentship there.

At several universities in the Netherlands, one of the conditions for getting tenure after a tenure track period is to obtain competitive funding for a PhD student. It is good practice to encourage a tenure track assistant professor to supervise at least one PhD student. The university should provide the funding for such a PhD position. Imposing as a necessary condition that the tenure track assistant professor obtain competitive funding for such a PhD position creates all kinds of perverse effects. It puts pressure on the tenure track researcher, and it encourages the tenure track researcher to make a safe choice of research project, often directly in line with his or her past research. This is not the type of high-risk, high-gain research that is needed in mathematics. This tenure track criterion encourages the mathematics community in the Netherlands to tweak the funding scheme for PhD students in such a way that the funding can go to the tenure track researchers. Generally speaking, in a good tenure track system, the only requirement should be that a tenure track researcher continues to perform at least as well as he or she did in the past. Introducing highly-random conditions, including the award of grants and the acceptance of articles in specifically-named top journals, will not lead to better performance by the tenure track researcher. It might even lead the tenure track researcher to continue to apply to universities outside the Netherlands.

The committee observed good cooperation between the different clusters. This cooperation is more important than the (also necessary) competition. Although some clusters favour the equal distribution of funding, it should not be automatically assumed that each cluster will receive the same amount of support from NWO.

We were impressed by the level of cooperation between the clusters and with other disciplines, even in a theoretical cluster like DIAMANT. It is important that researchers in other disciplines are aware of mathematical knowledge that may be useful to them. However, the cooperation with these research groups seems to be mainly due to individual actions, and the clusters could play a more active role in this process.

The committee noticed that the clusters are trying to increase the number of women in their staff. Nevertheless, the proportion of female staff is still low compared with other countries. More female staff can encourage other young women to choose a scientific career in mathematics. We therefore urge the clusters to stimulate diversity and inclusion in mathematical research.

Each cluster organises its meetings in a way that meets the needs of its members. The ISEB believes this is best facilitated by having available a fixed annual sum for a number of years, with no further conditions. Every cluster has applied for support for administration. However, the ISEB believes it is better to support the cluster chairs so that they can properly fulfil their tasks. This can be done by acknowledging the responsibilities of the chair and decreasing the teaching duties. Administration is the responsibility of the universities.

Mathematics differs fundamentally from the experimental sciences and lacks the unifying effect of a large experimental infrastructure or direct practical goals. Nevertheless, mathematics, as the underlying language common to large parts of science, and as an abstract setting where

connections between the most unlikely subjects may be found, is vital for a sophisticated and successful science programme and more generally for a modern high-tech society. The cluster structure in itself and the (few) young researchers in the form of PhD students and postdocs requested by the clusters form the infrastructure that ensures the health and integrity of mathematics in the Netherlands. It is therefore vital to the future of Dutch science that support for the Mathematics Clusters be adequate and stable over time.

We recommend providing adequate, stable funding for the unique and very successful mathematics clusters infrastructure created by the Dutch mathematical community.

GENERAL RECOMMENDATIONS

To NWO

- Create an annual call for PhD positions open to all members of the four clusters. Ask the clusters to make a motivated ranking of these proposals. This ranking should then be validated by an independent NWO panel.
- Create an annual call for postdoc positions open to any PhD holder in mathematics who wants to work in one of the four clusters. Ask the clusters to make a motivated ranking of these proposals. This ranking should then be validated by an independent NWO panel.
- The clusters represent the research infrastructure of mathematics in the Netherlands, in much the same way as telescopes form the infrastructure for astronomers, or accelerators for particle physicists. Given this comparison, it is obvious that a *stable funding* for creating research positions in this infrastructure is essential. This means that the clusters should have a horizon of at least five years of stable funding and autonomy in how to spend the funding. This will allow the clusters to prioritise so that, ultimately, the funding is spent much more efficiently, compared to a situation in which the clusters have to respond to short-term funding calls.
- The cluster funding for organising workshops and conferences, inviting guests, and so on should be 'without conditions', to be spent freely by the clusters. It is recommended to secure the funding for the activities by adopting this as structural funding.
- If, as is expected, 20% of the sector plan funding goes into the *tweede geldstroom* (competitive research funding), and is invested in mathematics via NWO, the clusters should have a significant role in deciding how this extra funding for mathematics research is allocated.

To the universities

- Universities should provide funding for a limited number of PhD positions in mathematics that can be awarded to the most talented students who want to pursue a PhD in mathematics.
- The only requirement made of a tenure track researcher given a permanent position after the probationary period should be that he/she continues to perform at least as well as in the past.
- Universities are encouraged to reduce the other duties (teaching, administration) of the chairpersons of the four clusters so that they can spend more time on strengthening ties within the cluster, between the clusters and with research groups that apply mathematics.

To the clusters

- Pay attention to cooperation with the other clusters and with related groups in other disciplines. Continue to create momentum for collaboration by organising activities for the relevant clusters and its members.
- Strengthen research in the area of logic and foundations of mathematics.

To all parties involved

Encourage the representation of women and other minorities in the staff.

APPENDICES

A. International Scientific Evaluation Board (ISEB)

Prof. Robert Tijdeman - chair

Prof. Tijdeman studied mathematics at the University of Amsterdam and defended his PhD thesis in 1969. He spent the academic years 1968/69 at the Mathematics Institute of the Hungarian Academy of Sciences in Budapest and 1970/71 at the Institute of Advanced Study in Princeton, U.S.A. He was a reader at Leiden University from 1971 to 1975 and professor from 1975 until his retirement in 2008. His special interests are number theory (e.g. Diophantine equations) and discrete mathematics (e.g. discrete tomography). He was an invited speaker at the International Congress of Mathematicians in 1978. He was president of the Dutch Mathematical Society from 1984 to 1986 and served as chairman of visiting committees in 1989, 2007 and 2014. He was elected as member of the Royal Netherlands Academy of Arts and Sciences in 1987 and received an honorary doctorate from the University of Debrecen in 1999.

Prof. Mai Gehrke

Prof. Gehrke is affiliated to the Université Côte d'Azur and is a Senior Research Director in Theoretical Computer Science at the Centre National de la Recherche Scientifique (CNRS). She previously held the chair in Algebra and Logic at Radboud University in the Netherlands and a full professorship in mathematics at New Mexico State University in the United States. She holds an MS and a PhD in mathematics from the University of Houston. She is an editor of *Mathematical Logic Quarterly* and the *Houston Journal of Mathematics*. She is co-founder of the TACL conference series and has served on numerous scientific committees such as the CoNRS (Fr), DIAMANT Cluster (NL), Lorentz Center (NL), NWO Vidi (NL) and NSF interdisciplinary (US), as well as numerous programme committees. She was awarded an ERC Advanced grant on Duality in Formal Languages and Logic in 2015. Her main contributions are in Stone duality theory, and in particular in the Jónsson-Tarski theory of canonical extensions, which focuses on duality for additional operations. More recently, she has been working on duality theoretic extensions of the profinite algebraic tools of automata theory and their application in complexity theory.
Source: https://simons.berkeley.edu/people/mai-gehrke

Prof. José Antonio Carillo de la Plata

Prof. Carrillo currently holds a chair in Applied and Numerical Analysis at Imperial College London, to which he was appointed in October 2012. He was ICREA Research Professor at the Universitat Autònoma de Barcelona during the period 2003–2012. He held assistant and associate professor positions at the Universidad de Granada, where he also did his PhD. He served as chair of the Applied Mathematics Committee of the European Mathematical Society 2014–2017 and chair of the 2018 Year of Mathematical Biology. He is currently the Program Director of the SIAM activity group in Analysis of PDE. His research field is Partial Differential Equations (PDEs). His expertise comprises long-time asymptotics, qualitative properties and numerical schemes for non-linear diffusion, hydrodynamic and kinetic equations in the modelling of the collective behaviour of many-body systems such as rarefied gases, granular media, charge particle transport in semiconductors, or cell movement by chemotaxis. He was recognised with the SEMA prize (2003) and the GAMM Richard Von-Mises prize (2006) for young researchers. Further, he is also a recipient of a Wolfson

Research Merit Award by the Royal Society 2012–2017 and the 2016 SACA award for best PhD supervision at Imperial College London. He was elected a member of the European Academy of Sciences, Section Mathematics, in 2018.
Source: https://www.imperial.ac.uk/people/carrillo

Prof. dr. Geoffrey Grimmett

Prof. Grimmett was educated at Oxford University before moving in 1976 to Bristol University for his first tenured post. After 16 wonderful years in Bristol, he moved in 1992 to the Statistical Laboratory of Cambridge University as professor of Mathematical Statistics. He served as the 17th Master of Downing College from 2013 to 2018.
His principal scientific interests are probability theory and statistical mechanics, and especially the mathematical theory of disordered physical systems. In addition to numerous research articles, he has written three research books entitled Percolation (1999), The Random-Cluster Model (2006), and Probability on Graphs (2010), and he has co-authored two successful textbooks on probability and random processes at the undergraduate and postgraduate levels.
Source: http://www.dow.cam.ac.uk/people/professor-geoffrey-grimmett

Prof. dr. Stefaan Vaes

Prof. Vaes obtained his PhD at KU Leuven in 2001. From 2001 to 2006, he was affiliated with the Institute of Mathematics of Jussieu in Paris, first as postdoctoral researcher and then as research associate of the Centre National de la Recherche Scientifique (CNRS). In 2005, he held the Peccot chair at the Collège de France. In 2006, he returned to KU Leuven, where he is currently full professor and head of the Analysis section. He was awarded an ERC Starting grant in 2008 and an ERC Consolidator grant in 2014. Prof. Vaes' research focuses on operator algebras and their connections to group theory and ergodic theory. He was an invited speaker at the International Congress of Mathematicians in 2010. In 2015, he was awarded the Francqui Prize and in the spring of 2017, he was a Rothschild Fellow at the Newton Institute in Cambridge. Prof. Vaes is editor of several journals. In particular, he is one of the editors-in-chief of the Journal of Functional Analysis and one of the coordinating editors of the Transactions and Memoirs of the American Mathematical Society.

B. Programme evaluation 13 & 14 December 2018

Meeting Evaluation Mathematics Clusters

Thursday, 13 December 2018, Muntgebouw Utrecht

Chair of the day: Rob Tijdeman

Programme		
13:30	**Registration**	
14:00	Opening by NWO Auditorium	Introduction Christiane Klöditz, Head Mathematics & Computer Science, NWO
14:15	Introduction ISEB Auditorium	Introduction of ISEB and their mission Rob Tijdeman, Chair
14:30	Highlights cluster Auditorium	Pitches by successful researchers
14:30	DIAMANT	Peter Bruin, Leiden University Leo van Iersel, Delft University of Technology
15:15	STAR	Joost Batenburg, Centrum Wiskunde en Informatica Julia Komjathy, Eindhoven University of Technology Arnoud den Boer, University of Amsterdam Johannes Schmidt-Hieber, University of Twente
16:00	**Break**	
16:45	Continuation – Highlights cluster Auditorium	Pitches by successful researchers
16:45	GQT	Ben Moonen, Radboud University Martijn Kool, Utrecht University Jasper Stokman, University of Amsterdam
17:30	NDNS+	Christoph Brune, University of Twente Hermen Jan Hupkes, Leiden University Mark Peletier, Eindhoven University of Technology
18:30	**Start networking dinner**	
20:00	**End of meeting**	

Programme Evaluation Mathematics Clusters

Friday, 14 December 2018, Muntgebouw Utrecht

Programme		
08:30	**Coffee and tea**	
09:00	Opening by chair	
09:05	Introduction evaluation process by NWO	
09:15	Cluster: DIAMANT Handelskamer 5	Prime referee: Mai Gehrke Board representatives: Frits Spieksma, Marc Stevens and Bart de Smit Available time: 75 minutes in total*
10:30	**Break**	
10:45	Cluster: GQT Handelskamer 5	Prime referee: Stefaan Vaes Board representatives: Gil Cavalcanti, Erik Koelink, Hessel Posthuma and Carel Faber Available time: 75 minutes in total*
12:00	**Lunch ISEB**	
12:45	Cluster: STAR Handelskamer 5	Prime referee: Geoffrey Grimmett Board representatives: Richard Boucherie, Remco van der Hofstad, Geurt Jongbloed and Evgeny Verbitsky Available time: 75 minutes in total*
14:00	**Break**	
14:15	Cluster: NDNS+ Handelskamer 5	Prime referee: José Antonio Carrillo de la Plata Board representatives: Bob de Rink, Jason Frank and Stephan van Gils Available time: 75 minutes in total*
15:30	**Break**	
15:45	Round table discussion	Attendees: 1. Rob Tijdeman (chair), ISEB 2. José Antonio Carrillo de la Plata, ISEB 3. Mai Gehrke, ISEB 4. Geoffrey Grimmett, ISEB 5. Stefaan Vaes, ISEB 6. Bart de Smit, DIAMANT 7. Carel Faber, GQT 8. Stephan van Gils, NDNS+ 9. Evgeny Verbitskiy, STAR 10. Jan Bouwe van den Berg, Mathematics Scientific advisory board 11. Onno Boxma, Mathematics Council 12. Arjen Doelman, NWO Science Domain board 13. Bas Zwaan, NWO Science Domain board 14. Christiane Klöditz, NWO Head Mathematics and Computer Science 15. Petra de Bont, NWO 16. Rosemarie van der Veen-Oei, NWO Separate agenda is distributed.
17:00	Conclusions and preparations report	ISEB only
18:00	**Closure**	

* Available time: 75 minutes in total

- 5 min – briefing + inventory questions to be raised (committee only)
- 15 min – short presentation (including 2 or 3 cluster board representatives)
- 45 min – discussion (committee and cluster board representatives)
- 10 min – debriefing (committee only)

C. Abbreviations

AI	Artificial Intelligence
aio	PhD student (Assistent in opleiding)
AMaMef	Advanced Mathematical Methods in Finance
CWI	Center for mathematics and computer science (Centrum voor Wiskunde en Informatica)
DIAMANT	Mathematics Cluster: Discrete, Interactive and Algorithmic Mathematics, Algebra and Number Theory
ECM	European Congress of Mathematics
ENW	NWO Domain Science (former: Exacte Wetenschappen)
ESF	European Science Foundation
EURANDOM	European research institute for the study of randomness
EZK	Ministry of Economic Affairs and Climate Policy
FELab	Financial Engineering Laboratory
fte	Full-time equivalent
GPU	Graphics processing unit
GQT	Mathematics Cluster: The fellowship of Geometry & Quantum Theory
HGL	Professor (hoogleraar)
IAS	Institute for Advanced Study
ICM	International Congress of Mathematicians
KWF	Dutch Cancer Society (Koningin Wilhelmina Fonds voor de Nederlandse Kankerbestrijding)
LEI	Leiden University
LUMC	Leiden University Medical Center
Mastermath	Dutch organisation for master's education in mathematics
MCMC	Markov chain Monte Carlo
NDNS+	Mathematics Cluster: Non-linear Dynamics of Natural Systems
NMC	Dutch Mathematical Congress
NWA	National Research Science Agenda
NWO	Netherlands Organisation for Scientific Research (NWO)
OCW	Ministry of Education, Culture and Science
PI	Principal Investigator
PWN	National Platform Mathematics (Platform Wiskunde Nederland)
RU	Radboud University
RUG	University of Groningen
SEP	Standard Evaluation Protocol
STAR	Mathematics Cluster: Stochastics - Theoretical and Applied Research
STW	NWO Domain Applied and Engineering Sciences (former: Stichting voor de Technische Wetenschappen)
TNO	Netherlands Organisation for applied scientific research
TT	Tenure track
TU/e	Eindhoven University of Technology
TUD	Delft University of Technology
UD	Assistant Professor (universitair docent)
UHD	Associate Professor (universitair hoofddocent)
UT	University of Twente
UU	Utrecht University
UvA	University of Amsterdam
UvT	Tilburg University
Veni	NWO-Innovational Research Incentives Scheme (vernieuwingsimpuls) programme for young researchers just after their PhD with a maximum of 3 years
Vici	NWO-Innovational Research Incentives Scheme (vernieuwingsimpuls) programme for senior researchers with a maximum of 15 years after their PhD
Vidi	NWO-Innovational Research Incentives Scheme (vernieuwingsimpuls) programme for young researchers with a maximum of 8 years after their PhD
VU	VU University (in Amsterdam)
WUR	Wageningen UR (University & Research centre)

There are two separate reports published for the evaluation of the Mathematics Clusters: (1) Self-evaluations submitted by the clusters, and (2) Conclusions and recommendations as outcomes of the evaluation. This report contains the outcome of the evaluation and is composed by the International Scientific Evaluation Board (ISEB).

From 2005 until 2018, NWO, the Ministry of Education, Culture and Science, and the Ministry of Economic Affairs and Climate Policy have provided a total of 23.5 million euros in funding to strengthen the research and activities within the Mathematics Clusters. The universities and CWI partly matched this amount. The amount of matching provided in the period 2010-2018 is stated in the self-evaluation reports of the Mathematics Clusters.

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