



Evaluation 2017 - 2022

NWO Institute CWI

Research institute for mathematics & computer science in the Netherlands

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www.academion.nl
info@academion.nl

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1. Foreword by the committee chair

It was a great pleasure to serve on this review committee for CWI, and a privilege to be its chair. Reviewing institutes can be a challenging task, but not in this case: We enjoyed reading the self-assessment report and had a productive and inspirational site visit. During our two and a half days at CWI, we held open and engaging conversations with leadership, researchers, support staff, PhD candidates, and postdocs, which allowed us to gain deeper insights into CWI's mission, future vision, and accomplishments in the review period. We would like to express our gratitude to CWI for their warm hospitality and excellent organization of the site visit and preparatory phase of the review. We would also like to thank Elian Bogers and Ella Bosch for their exceptional assistance during the review process. Overall, the visit was a very positive experience.

I'd like to offer in this foreword a few (personal) reflections.

I was particularly struck by the collegial and supportive environment at the institute. It appears that there is a culture of collaboration, with a focus on good mentorship and positive leadership. CWI is internationally recognized as a center of excellence in mathematical and computational research. We saw abundant evidence that this reputation is well-deserved. CWI has always been, and still is, a critical part of the Dutch research ecosystem and has a strong international position. Any organization at the leading edge of research must continually improve and re-invent itself. I was pleased to see and hear that the institute is willing and able to adapt. In the last few years, CWI has created a new and in-depth strategic plan including a SWOT analysis of the institute. That has helped in setting clear goals and foci. I believe that CWI's agility results from both pro-active leadership and the open-mindedness and strong foundational skills of its researchers.

In the report, we highlight several areas for improvement at the institute. We focused strongly on the goals of CWI as presented to us during this review: to be a collaborative center of research in the Netherlands; to contribute to university education in the country; to engage in ground-breaking research, with a strong focus on high-risk and high-gains projects; and to attract and cultivate exceptional talent, not just for CWI, but also for its research partners in the Netherlands.

To be successful as a collaborative center, CWI must further increase its visibility and recognition, particularly among the universities, and we discussed this with CWI's leadership. High-risk and high-gains research, essential for Dutch innovation and its leadership position in the world, requires bold visions and strong support, through unrestricted funding, by the Dutch government. Cutting base funding of CWI threatens this critical role of the institute. If CWI wants to be known as a center of talent acquisition and talent development, it must certainly become more gender diverse and tap into the talent that is provided by women, as well as other underrepresented minorities. Of course, diversity in gender and cultural and educational backgrounds is critical for many other reasons also, including equity and improved outcomes particularly in those areas of research in which diverse lenses and insights lead to reduced bias and fairer and more inclusive scientific approaches.

Again, thank you for inviting us to conduct this very interesting and thought-provoking review. We all hope that you will find the report useful, positive and constructive, as it was indeed intended.

Gefeliciteerd met jullie buitengewone prestaties,

Prof. [Emerita] Margot Gerritsen
Chair Peer Review Committee CWI

2. Procedure

2.1 Scope of the evaluation

This evaluation was carried out as part of the evaluation of the nine research institutes of the Dutch Research Council (NWO). NWO asked evaluation committees of external peers to perform an evaluation of its research institutes over the period 2017-2022. Quality assurance agency Academion acted as independent intermediary to safeguard the quality of assessment, providing secretaries for each of the site visit and helping the institutes and evaluation committees prepare and execute the site visits together with NWO-I, the institute organization of NWO.

The evaluations were carried out according to the Strategy Evaluation Protocol 2021-2027 (SEP), the protocol for research evaluations in the Netherlands, agreed upon by NWO, the Royal Netherlands Academy of Arts and Sciences (KNAW) and the Universities of the Netherlands (UNL). The committees were requested to carry out the evaluations according to a list of questions derived from the main assessment criteria of SEP (see appendix 1). The assessment was to include a backward-looking and a forward-looking component. The committees were asked to judge the performance of the institute based on the list of SEP questions and to offer its written conclusions as well as recommendations based on considerations and arguments. The main assessment criteria are:

- Research Quality;
- Societal Relevance;
- Viability.

During the evaluation of these criteria, the committees were asked to incorporate four specific aspects relating to how the institute organises and actually performs its research, its composition in terms of leadership and personnel, and how the institute is run on a daily basis. These aspects are:

- Open Science;
- PhD Policy and Training;
- Academic Culture;
- Human Resources Policy.

For more information on the SEP questions, see Appendix 1.

2.2 Composition of the committee

The committee for the evaluation of CWI was appointed by the Board of NWO, and consisted of the following members:

- Prof. [Emerita] (Margot) Gerritsen (chair), Energy Science and Engineering, Stanford University, and Executive Director of Women in Data Science Worldwide (WiDS)

- Prof. (Thomas) Vidick, Professor of computer science and applied mathematics, Weizmann Institute of Science
- Prof. (Michel) Goemans, Professor of mathematics, Massachusetts Institute of Technology
- Prof. dr. (Takayuki) Ito, Professor of computer science, Kyoto University
- Prof. dr. (Gustavo) Alonso, Professor of computer science, ETH Zurich
- Dr. Hugo Krawczyk, Senior Principal Scientist, Amazon Web Services

The committee was supported by Elian Bogers MSc (Odion Onderzoek), who acted as secretary on behalf of Academion. Dr. Ella Bosch was present during the site visit to support the committee on behalf of NWO-I.

2.3 Independence

Before the site visit all members of the committee signed the NWO Code of Conduct, by means of which they declared that their assessment would be free of bias and without regard to personal interest, and that they had no personal, professional or managerial involvement with the institute or its research programmes. It was concluded that the committee had no conflicts of interest. The NWO-I coordinator present during the site visit did not take part in the evaluation, but provided the committee with background information and context on the position of the NWO institute upon request.

2.4 Data provided to the committee

The committee received the self-evaluation report from the institute, including all the information required by the SEP.

The committee also received the following documents:

- SEP 2021-2027;
- Terms of Reference;
- CWI Strategic plan 2022-2027;
- CWI Diversity Plan 2021-2025;
- NWO Strategy 2023-2026;
- Additional data on employee surveys;
- Additional data on personnel, support staff, and base funding of NWO institutes.

2.5 Procedures followed by the committee

The committee proceeded according to the SEP 2021-2027. The secretary instructed the committee chair on her role in the evaluation. In its first meeting on 21 September 2023, the committee was briefed by the secretary on research evaluations according to the SEP 2021-2027, and by the NWO-I coordinator on the Dutch research landscape and position of the NWO institute therein.

Prior to the site visit, all committee members independently formulated a preliminary evaluation based on the written information that was provided before the site visit. During its preparatory meeting on 26 October, the committee discussed the preliminary evaluations and identified questions to be raised during the site visit. It agreed upon procedural matters and aspects of the evaluation. CWI and NWO welcomed the committee the

evening of 1 November. The site visit took place 2 and 3 November (see the schedule in Appendix 2). After the interviews the committee discussed its findings and comments in order to allow the chair to present the preliminary findings and to provide the secretary with argumentation to draft a first version of the evaluation report. The final evaluation is based on both the documentation provided by CWI and the information gathered during the interviews with representatives of the institute during the site visit.

The draft report by the committee was presented to CWI for factual corrections and comments. In close consultation with the chair and other committee members, the comments received were reviewed to draft the final report. The final report was approved by the Board of NWO on 23 February 2024.

3. Evaluation of CWI 2017-2022

3.1 About CWI

Centrum Wiskunde & Informatica (CWI) is the Dutch research institute for mathematics & computer science, founded in 1946. Since 2018, CWI is part of the Institutes Organisation (NWO-I) of the Dutch Research Council, NWO. CWI conducts pioneering research in mathematics and computer science and transfers new knowledge to society and industry. The institute focuses on four focus areas of fundamental research: (1) Algorithms, (2) Data and Intelligent Systems, (3) Cryptography and Security, and (4) Quantum Computing. Research draws its inspiration from fundamental questions in mathematics and computer science but is also motivated by major societal challenges in a wide range of fields, for example energy, health care, climate, communication, mobility, and security.

CWI is an internationally oriented institute with scientists from approximately 27 countries. The institutes staff consists of 211 employees (in 2023), including 164 scientific staff, 45 support staff, and 2 visiting fellows. The scientific staff consists of 56 research staff (tenure track included), 32 postdocs, 76 PhD candidates, 4 scientific programmers, and 4 scientific project members. Scientific staff is organized into fifteen research groups. The research groups are in line with the four research focus areas.

Following the retirement of the previous director Jos Baeten in 2020, Ton de Kok took office as the new director of CWI. The CWI Management Team consists of the director, the institute manager, and four senior researchers, who each represent three or four research groups. CWI relies on basic funding from NWO: covering fixed costs, i.e. tenured staff and support (and amounting to 60% of CWI's annual budget). The remaining 40% of budget comes from external sources and consists primarily of competitive research programmes, including competitive project funding from NWO, national and European programmes, and from public-private partnerships.

3.2 Mission, vision and strategy

Mission and vision

CWI aims to conduct pioneering research in mathematics and computer science, generate new knowledge in these fields, and convey it to society at large and to industry in particular. CWI strives to advance the scientific foundations of the digital society and to support the national mathematics and computer science communities in the Netherlands. CWI is a connector for these communities, a breeding ground for talent, and a place of scientific interaction.

Strategy

CWI's strategy for the evaluation period initially consisted of seven research themes, and aimed to increase basic funding, personal grants and public-private partnerships to support the development of these themes (CWI's Strategic Plan 2017-2022). However, during the evaluation period, plans had to be modified. In 2020, the NWO Executive Board commissioned a survey focusing on the role and position of CWI, in the context of national developments in mathematics and computer science. Observations and recommendations of the survey were the starting point of a reflection process for the CWI directorate and management team. Later that year, CWI

started to build their strategy explicitly on two pillars that were the main recommendations of the survey: CWI performing a more explicit role as a national centre and focusing more sharply in choosing research topics.

To align with the needs of science and society, four focus areas of fundamental research are determined in CWI's strategic plan 2022-2027. The four focus areas are the basis for steering all research investments, in refocusing research staff, and in creating new connections between researchers with different expertise:

- 1) Algorithms: The digitalization of society and the omnipresence of computers bring new challenges and opportunities for algorithms;
- 2) Data and Intelligent Systems: The growth of data and increasingly complex processes require advances in data management and intelligent autonomous systems;
- 3) Cryptography and Security: The more society digitalizes, the more important it becomes to guarantee the security and privacy of all digital information and its processing;
- 4) Quantum Computing: The development of quantum computer hardware simultaneously requires the development of quantum computing algorithms and software.

According to the committee, the institute has created a unique and strong value-proposition. CWI has an ambitious strategy focusing on the intersection of mathematics and computer science, guided by four focus areas of fundamental research. The committee welcomes the development of the four focus areas that are well-chosen and help position CWI strongly in the Dutch and international research landscape. They are aligned with societal technological needs, especially given the ever-increasing relevance and impact of statistics, analytics, machine learning, and artificial intelligence. CWI has shown agility in responding to rapidly changing research and societal landscapes, expectations, and financial conditions.

National role

CWI aims to strengthen its role in the national mathematics and computer science communities in three ways: (1) as a collaborative centre for research and cooperation, (2) as a strong contributor to academic teaching (CWI researchers spend on average ten percent of their working time on educational activities), and (3) as a talent attractor and developer.

The committee finds the goals to strengthen its national role and establish stronger links with universities particularly well thought out, ambitious, and critical for its long-term success. Collaborations with universities can take place through many different activities and at many different levels, including: academic course instruction; sabbatical exchanges; student internship programs; co-advising of graduate students; research collaborations, particularly around scientific challenges with societal impact; joint grant proposals; CWI-organized conferences and workshops that facilitate idea-sharing and inspire national collaborations; and joint outreach programs. A further strengthening of CWI's role as national center for collaboration and innovation is highly critical for its long-term stability and success. Universities and peer research institutions must be amongst CWI's strongest supporters, and government organizations, particularly NWO, must understand and see the critical role that CWI plays.

During the site visit, the committee sensed some unease around this topic. CWI has taken steps to better understand how the institute and its national role as center of collaboration and innovation are regarded by peer institutes and universities. However, the committee expects that the institute could do more to strengthen its position. Are expectations met? What gaps or shortcomings do partners see? The committee encourages CWI to actively talk to universities (e.g., through more frequent consultations) to help better align collaborations, to improve existing programming and expand future programming, and to raise the profile of CWI amongst its

partners. The committee recognizes that clear communication, expectation management, close collaborations, and mutual trust are fundamental pillars supporting CWI's important goal to take its leading role in the national mathematics and computer science communities, and receive due recognition.

3.3 Research Quality

In order to assess the research quality conducted at CWI, the committee considered the research output of the institute in terms of research papers and books, grants, software and standards, collaborations, editorship and scientific meeting organization, academic and societal recognitions, and societal impact (see also chapter 3.4). Research metrics and indicators, as well as narrative case studies, were provided to the committee in CWI's self-evaluation report, and additional information was presented during the site visit.

The committee is impressed by the institute's excellent and outstanding research quality, especially given its relatively small size. CWI provides an excellent example of how research at the intersection of mathematics and computer science can lead to exceptional, innovative, and impactful research results. The institute has a strong reputation internationally across all four focus areas, especially at the intersection of mathematics and computer science. Both at institute and individual level, CWI is involved in many relevant national and international networks (e.g., IFIP, SIAM and IACR) and collaborations (e.g., with French Inria). Former graduates are now professors at some of the best universities in the world (e.g., Harvard), are worldwide leaders in the area, or are involved in successful start-ups or companies (e.g., Snowflake).

Senior CWI researchers are also strongly connected to Dutch universities. They typically hold part-time professorships at Dutch universities. The committee sees several advantages for senior staff, including access to resources, diverse perspectives, teaching activities, and the creation of synergy between CWI and partner institutions.

In the research focus area of Data and Intelligent Systems, CWI is considered one of the best places for database architecture, system design, and overall optimization, and researchers in these groups are highly sought-after and highly-regarded leaders in these areas. They are particularly well-known worldwide in the area of databases (e.g., MonetDB and DuckDB) with several open source systems widely used and amply cited in the literature. Several start-ups were created on the base of CWI research and/or were founded by CWI research staff.

The research focus area Cryptography and Security at CWI continues its decades-long tradition of excellence and leadership. The research covers some of the most significant areas in the discipline including those that are academically challenging, industrially relevant, and have major potential societal impacts. The researchers are leaders in their respective areas such as secure multi-party computation, post-quantum cryptography, cryptanalysis, and physical systems security. Some recent highlights include work on design and analysis of cryptography for the post-quantum area (when quantum computers become strong enough to break current public-key cryptosystems), including contribution to the design of NIST encryption standards in this area; state of the art contributions to privacy preserving computations and new cryptographic primitives; and security of cyber-physical systems, in particular geared to the protection of large-scale computing infrastructures.

CWI researchers demonstrate a strong leadership in the area of Quantum Computing, an area which has long been, and continues to be, a major strength of the institute. Traditionally focused on quantum complexity theory and quantum cryptography, CWI's range of expertise has broadened to encompass quantum algorithms as well

as (relatively) near-term applications of quantum computers. Some of CWI's strongest recent results in this area lie in the development of new algorithmic techniques for quantum computers, and the study of their limitations. This direction is strengthened by a close interaction between researchers from different groups at CWI, leading to productive cross-fertilization. While the number of permanent researchers in quantum computing at CWI does not seem to have substantially grown over the years, the impact of the institute in this area has considerably grown. In addition to the core strength of the institute, this can be attributed to a wide range of partnerships with university groups, building on the CWI-UvA research center QuSoft and the launch of a national Quantum Software Consortium. The participation of CWI researchers in these broader research initiatives have also led to a development of the institute's contributions to technology and society. Thanks to its long tradition and these more recent developments CWI is uniquely positioned to have a major impact in the future shaping of quantum technologies and their impact on society.

The research focus area Algorithms is considered CWI's fourth strong scientific pillar. The committee is particularly impressed with the nicely vertically integrated structure: fundamental research is done on the theoretical foundation (for example on integer programming) and at the same time such techniques are applied to societal problems (for example in logistics). CWI is internationally visible through high-impact publications, editorships in major international journals, prestigious awards and grants, and through playing a leading role in the organization of international workshops, conferences, and semester programmes at premier international research institutes.

In general, the scientific leadership of CWI is evident in many ways; in the frequent publication of highly relevant articles in excellent journals, as well as conference papers and software tools, and in the attraction of a large number of prestigious grants, both nationally and in the EU.

Despite these very positive impressions, the committee believes that CWI has the potential to position itself more strongly, both nationally and internationally. CWI needs to more effectively showcase its strengths and increase its visibility. The committee believes CWI's strategic efforts in terms of branding, marketing, and visibility within and outside the Netherlands are too limited. For example, nominations for recognitions and grant initiatives are initiated by the research groups themselves (bottom-up approach). A strategic promotion/elevation strategy for CWI researchers and their impact should be developed. Such a strategy can also be used to elevate underrepresented minorities, which aids in retention as well as hiring.

3.4 Societal Relevance

CWI's mission includes transferring knowledge and expertise to create value for society and industry. To achieve this, they follow a three-pronged approach:

- 1) Direct research collaborations and partnerships with industry partners and public institutions,
- 2) The creation of research-based spin-off companies, and
- 3) The development of (prototype) software tools.

The committee is impressed by CWI's large societal impact, particularly given its relatively small size. Given the fundamental high-risk, high-gain nature, its contributions to society are often long-term, via the well-established process of fundamental research acting as the foundation of more applied research. The balance between fundamental and applied research is maintained through long-term research strategy commitments, for example in data systems, quantum computing, cryptography and security machine learning, and neuromorphic

computing. At the same time, researchers are encouraged to collaborate with societal partners and look for societal impact opportunities.

The institute spans the whole spectrum, from fundamental research all the way to open access tools (e.g., 2-IMMERSE), (prototype) software tools and products (e.g., further development of Rascal meta-programming language and Genetic optimization software GOMEA), standards (e.g., contributed to W3C, ITU, MPEG and VPEG), and spin-offs (e.g., DuckDB). Long-term fundamental research and software development have the potential to impact a wide range of areas. The committee believes that the institute's focus on fundamental research is incredibly important in creating long-term societal impact, and this must be maintained.

An effective way to transfer knowledge and expertise to society and industry is by spinning off research-based startups. CWI's spin-offs have been very successful. Many startups still exist or have met their exit strategy (e.g. buyouts) as planned. CWI strongly supports researchers who intend to found a startup, and it has both an effective spin-off policy and spin-off incubator. During the evaluation period, five new spin-off companies have been founded. The committee learned that the main motives for spin-off creation at CWI are job creation, societal impact, and supporting entrepreneurship, and to a lesser extent revenue sharing.

CWI collaborates with governments, companies and societal organizations to develop solutions in a wide range of fields, from energy, health care, climate, communication, mobility to security. Collaborations vary from publicly funded research projects to contract research with industry and/or public institutions. The committee is positive about the strong connections with government and industry, and finds that the institute is strongly embedded in the Dutch research community. Successful examples are the Cultural AI Lab and the AI, Media & Democracy Lab. The committee is particularly impressed by the jointly established (with UvA) world's first quantum software research centre, QuSoft. It is a great example of being a leading house, catalyst, and meeting place for all academic research in the region in the field of quantum computing.

During the evaluation period, CWI has received a steady amount of funding through partnership research. In total, 23 PhD candidates and 18 postdocs have been financed by direct partnerships with industry and public institutions. Furthermore, 125 companies and non-profit parties outside academia have been involved in CWI-projects funded by NWO, the EU, and other grants and projects. These findings clearly show extended connections with the large ecosystem around CWI.

Open Science

CWI attaches great value to promote open access, open data, and open software. Open source software, reuse, and collaboration are embedded in the work processes of individual researchers. Researchers that the committee met during the site visit indicated that they feel encouraged and motivated to open up their work to the public, although some tension was experienced related to (excessive) publishing fees. Open science and open access are strongly supported by the leadership team and form a key part of the institute's strategy. CWI is a strong contributor to open science with many research data, software, tools, and outcomes made available publicly, and where possible with stakeholder engagement. CWI establishes itself as a research institute that produces open-access tools and artifacts that are incredibly valuable to the research community and highly influential in industry. The committee especially applauds its contribution to open domain software.

3.5 Viability

According to the committee, CWI has an excellent and ambitious strategy focusing on the intersection of mathematics and computer science, while being guided by four focus areas of fundamental research and strengthening its national role, as described in section 3.2 of this report. The committee is confident in the institute's ability to implement its ambitious strategic plan and accompanying strategic roadmap. The committee discussed some threats in terms of viability, which are elaborated in this section of the report.

CWI is primarily funded by NWO: basic funding comprises roughly 60% of the total budget. The remaining 40% of funding is based on external grants from various sources and funding bodies. Base funding and external funding have been mostly steady over the past years. In 2021, the NWO Board announced a reduction in basic funding for all institutes starting in 2022, with an additional structural cut for CWI, totalling 820,000 euro in 2024. The committee considers these budget cuts significant, unwelcome, and unwise, as they put undue pressure on the institute. CWI can only fulfil its mission as national centre of collaboration and innovation and top research institute if support for the institute is stable and sufficient. The type of research done at CWI and the national role it plays require a substantial base funding. Cutting this base funding simply imperils CWI's mission and the committee recommends in the strongest terms that the additional structural budget cut be reversed. In general, the budget of CWI is insufficient to remain internationally competitive in a rapidly evolving and expanding scientific field. The committee urges NWO to align its expectations and requirements with adequate funding and support.

The committee is impressed with the institute's outstanding accomplishments and its overall research quality, given its relatively small budget, especially compared to international research universities and institutes. The expectation that CWI takes a leading role in the Dutch research landscape, establishes stronger links with universities, collaborates on scientific challenges with societal impact, and maintains the institute's outstanding level of research excellence is realistic only provided CWI is given adequate funds.

In the following paragraphs, the committee makes several recommendations regarding additional funding opportunities, but, as CWI is a public institution, the committee wishes again to highlight the importance of sufficient and stable basic funding for CWI to fulfill its leading role and the high expectations placed upon it, and stresses that these alternative funding opportunities should be seen as supplementary, not as replacement funds.

The current budget squeeze forces the institute to cut costs, primarily by strategically using staff mobility and retirements. The committee recommends that leadership investigates possibilities to attract alternative funding sources to increase investments in staff and support. These may include the establishment of part-time funded positions or sabbaticals, and the formation of industrial affiliate programs. The committee also advises to rethink, where/if possible, the financial model associated with spin-offs and consider if higher economic returns could be made feasible. In other words, it encourages CWI to not sell off its IP too cheaply. The committee was very pleased to learn about the initiative to host sabbaticals at CWI and encourages the institute to move forward to bring people in from the outside. Hosting sabbaticals and creating part-time funded positions do not only reduce pressure on base funding, it also strongly connects CWI with (inter)national institutions and leads to additional insights and innovation.

Another threat is increased competition in the computational sciences from national and international research universities and institutes. Recent increased funding investments in computational sciences, both at Dutch universities and international research institutions lead to fierce competition in scientific leadership and talent attraction. This will lead to increased competition in scientific leadership and talent attraction. In this context, the committee emphasizes the importance of startup packages to attract talented new staff, and branding and marketing activities to increase national and international visibility. The committee recommends that CWI regularly re-assesses its national and international position in this increasingly competitive and fast-changing field. CWI's management team should understand its stakeholders and their expectations. It should understand the mission and the strategic plans of its top competitors. It should understand which are its highest potential collaborators, both nationally and internationally. This will also serve as valuable input to further develop the strategy to strengthen the institute's national role.

Human Resources policy

An important aspect of CWI's national role is attracting and fostering talent. CWI has a tenure track (TT) system and a phased career path for talented young researchers. The committee observed that CWI helps boost the academic careers of many of its staff. It has been with great interest to learn that CWI is exploring various TT-trajectories lengths, including the possibility of shortening the trajectory from 5 to 3 years for candidates who have completed a postdoc position. The committee expects that flexible TT-trajectories will support CWI's role to attract, develop, and retain talent.

Today's research is an international endeavour and highly competitive. Given the flexible model, high research autonomy, and focus on research (low teaching obligations), CWI is in a position to attract talent from all over the world. However, due to recent budget cuts, CWI is obliged to primarily use staff mobility and retirements to bring on new hires. CWI has no to limited resources available for growth and cannot consistently afford startup packages for TT. Strategic hiring decisions will be made based on needs in specific focus areas and diversity goals. The committee regrets the current hiring situation and stresses the importance of funding for opportunity hires and for equitable support of new hires.

The committee applauds that CWI has an established reward and promotion system that recognizes not only standard research metrics, like number of publications or grants, but also takes into account societal impact, contributions to open science, and other contributions to CWI's strategic goals. During the site visit, researchers at all levels (PhD, postdocs, and TT) expressed being aware of their evaluation and promotion criteria and felt supported in their professional development. Overall, researchers experience a supportive and encouraging leadership and effective support systems (i.e., grant writing support, professional development activities) but a formal mentoring system at all levels seems to be lacking. The formal mentorship programme for TT no longer exists. The committee recommends to put consistent mentoring programs in place at all levels. The mentoring system could be focused on detailed advice and feedback, transparency in and guidance through evaluation cycles, grant and manuscript writing support, professional development, and can also discuss and support broader challenges and opportunities (e.g., social cohesion, wellbeing, communication).

In the Strategic Plan 2022-2027, there is a stronger emphasis for staff to move to universities than before. It is outlined that after a research period of 10 to 15 years at CWI, many researchers move on to a university to become a full or associate professor. CWI considers this outflow a success as it contributes to talent development and creates room for new staff and research directions. During the site visit, it became apparent that this was not communicated clearly nor sufficiently to staff. Some staff members were uncertain about the

possible implications for their careers and for the institute (e.g., specific expertise leaving CWI). The committee recommends clear and transparent communication regarding career paths and departures.

Diversity

The committee learned that promoting diversity, and in particular gender diversity, has been high on CWI's priority lists over the past years. In the last review cycle, the evaluation committee asked the institute to develop more and stronger initiatives to attract women researchers. It strongly encouraged the institute to support and cultivate women leadership. CWI committed itself to taking concrete measures to reach these targets. The committee likes the diversity policies and practices put in place, including the establishment of a Diversity, Equity and Inclusion (DEI) team, the implementation of the Gender Equality Plan (GEP), and continual effort to improve recruitment and selection processes. The committee was pleased to learn about actions taken by the institute (e.g., Constance van Eeden Fellowship, inclusive marketing, communication and selection practices, and actively reaching out to female talent to fill six tenure track positions), as well as by individuals (e.g., a proactive search for female talent for vacancies). However, the DEI team did not undertake all actions as specified in the CWI Diversity Plan. In the interviews with CWI staff, it was mentioned that the gender balance and academic culture related to it changed for the better over the past years: staff commented that the institute is "walking the talk more than before".

The committee appreciates all these efforts and developments. However, gender diversity targets have not been met and there is little to no improvement since the last review. Of particular concern is the persistent underrepresentation of women in leadership: out of 15 research group leaders, only two are women, and there are no women members in the management team. The committee wonders if international (female) talent recruitment initiatives are sufficiently aligned with international hiring cycles. Typically, hiring in the USA and many leading international research institutions happens at well-defined times of the year. Looking for candidates within this cycle (between November and March) might be beneficial in finding talent as most applicants are focused on the international hiring cycle. CWI is also encouraged to actively recognize and reward activities related to promoting diversity, including reimbursement of hours participating in the DEI team, rewarding participation in selection committees, and other activities either promoting diversity or bringing in the female perspective. The committee also encourages the institute to (continue to) look for active support systems, including women support networks, information packages, evaluation guidelines, and clear expectations considering diversity-related activities, and to take advantage of women's organization (such as Women in Analytics, Women in Data, Women in Data Science Worldwide, Women in Big Data, Women in AI) in recruiting.

Increasing gender diversity, at all levels and certainly in leadership, must be a top priority for CWI in this upcoming review period.

Academic Culture

CWI's management philosophy is to give research groups a relatively high degree of research autonomy. Effort is clearly put into involving all staff and allowing for a fair and open academic culture. In the interviews, academic staff confirmed the level of academic freedom, where researchers are free to develop own research ideas and directions, and pursue opportunities for collaboration and funding with institutional support. Staff seemed also well-informed about the role and function of persons of trust. The good atmosphere is also reflected in the high number of researchers willing to stay at CWI and the many examples of researchers returning after periods of

research elsewhere. The committee was interested to learn about the regular surveys held on work climate and employee perception around openness, safety, and inclusion.

The previous evaluation committee recommended to be aware of good and efficient communication between the different layers of the institute. Even though CWI has taken actions, the committee feels there is still room for improvement. As of now, staff is too dependent on informal communication lines about grants applications, CWI's financial situation and budgets, mentoring, hiring procedures, and specific expectations related to career development. For some staff members, this creates unnecessary uncertainties. The committee recommends the management team to be pro-active, transparent, and open towards all levels of staff in the organization. In addition, the committee advises the management team to improve internal communication and transparency about decision-making processes considering accepting (opportunity) hires.

PhD Policy and Training

From 2017-2022, 60 PhD candidates completed their thesis at CWI. In general, PhD candidates have two PhD supervisors, a daily and second supervisor. One of these must have promotion rights at the university where the student is matriculated. In the first three months of their employment, each CWI PhD candidate, in cooperation with his or her supervisor, formulates a personal programme for education and supervision. The agreements in the personal programme are the basis for the annual evaluation interview between the PhD candidate, daily supervisor, and the group leader. All PhD candidates go through a “go-no-go” decision within 18 months of their employment.

During the site visit, the committee met with a diverse group of PhD candidates (diverse in terms of nationality, research expertise, affiliated university, and stage of their PhD trajectory). During interviews, the talented PhD candidates expressed satisfaction with their program, supervision, professional and societal engagements, and the considerable degree of academic autonomy they enjoyed. Relationships with supervisors were described as strong and supportive, and expectations were overall clear. PhD candidates expressed they had sufficient opportunities and allocated time for professional development, including attending and presenting at conferences and taking courses. Being associated with both CWI and a university was described as the best of both worlds. Even though the committee did not hear this directly, it could imagine that the degree of academic freedom and development options could be overwhelming to some students. Keeping track of PhD candidates' satisfaction, progression, and needs during their PhD trajectory, and (mental) wellbeing seems vital.

4. Executive summary

4.1 Conclusion

CWI has an excellent and ambitious strategic plan. CWI's research sits at the intersection of mathematics and computer science, and it has formulated four research focus areas. CWI's goal to strengthen its national role is three-fold: (1) as a collaborative centre for research and cooperation, (2) as a contributor to academic teaching, and (3) as a talent attractor and developer. A further strengthening of CWI's role as national center for collaboration and innovation is well thought out, ambitious, and highly critical for its long-term stability and success. CWI is characterised by high levels of academic freedom and frequent generation of bottom-up initiatives in an open academic culture. CWI distinguishes itself by its strong ability to work across the spectrum, from long-term fundamental research to open access tools, open domain (prototype) software tools and products, standards, and spin-offs. CWI shows scientific top leadership in many ways; CWI's research is of exceptionally high quality with strong societal relevance, and it is well-connected through collaborations with national and international institutions, societal partners, and industry.

A further strengthening of CWI's role as national center for collaboration and innovation is highly critical for its long-term stability and success. Universities and peer research institutions must be amongst CWI's strongest supporters, and government organizations, particularly NWO, must understand and see the critical role that CWI plays. CWI's strategic efforts in terms of branding, marketing, and visibility within and outside the Netherlands are too limited. The committee believes that CWI has the potential to position itself more strongly, both nationally and internationally.

To continue in its leading national and international position, CWI must maintain its strong fundamental basis, its strong academic culture, and its good relationships and collaborations with academic colleagues, societal partners, and industry. The focus on fundamental research is an incredibly important foundation for creating long-term societal impact. The expectation that CWI takes a leading role in the Dutch research landscape, establishes stronger links with universities, collaborates on scientific challenges with societal impact, and maintains the institute's outstanding level of research excellence is realistic only provided CWI is given adequate funds. To keep the institute viable in a fast-changing and highly competitive environment, CWI needs forward-looking and pro-active leadership that explores strategic opportunities, and actively assesses and strongly defines CWI's position and role in the Dutch research landscape, as well as internationally. Increased competition in scientific leadership and talent attraction increases the importance of startup packages to attract talented new staff, and branding and marketing activities to increase national and international visibility.

4.2 Recommendations

- Be continuously aware of good and efficient communication between the different layers of the institute. The management team needs to be pro-active, transparent, and open towards all levels of staff in the organization.
- Put consistent mentoring programs in place at all levels.
- Continue efforts of keeping track of PhD candidates' satisfaction, progression, and needs during their PhD trajectory, and (mental) wellbeing.

- Investigate possibilities to attract additional funding sources to increase investments in staff and support (i.e., funding for opportunity hires and equitable support of new hires). These may include the establishment of part-time funded positions or sabbaticals, and the formation of industrial affiliate programs. Rethink, where/if possible, the financial model associated with spin-offs and consider if higher economic returns could be made feasible.
- Assess CWI's international position in its increasingly competitive and fast-changing field. Regularly re-assess CWI's national position and continue to talk actively to universities (i.e., through periodic consultations) to help better align collaborations, to improve existing programming and expand future programming, and to raise the profile of CWI amongst its partners.
- Effectively showcase strengths and increase visibility. A strategic promotion/elevation strategy for CWI researchers and their impact should be developed. Such a strategy can also be used to elevate underrepresented minorities, which aids in retention as well as hiring.
- Continue efforts and proactive actions regarding (gender) diversity. Gender diversity, at all levels and certainly in leadership must be a top priority in the upcoming review period.

Appendix 1: SEP Questions Evaluation NWO institutes

The 3 main criteria:

1. Research quality:

- How does the assessment committee assess the scientific quality of the institute, in light of its own aims and strategy? Central in this assessment are the contributions to the body of scientific knowledge. The assessment committee is asked to reflect on the quality and scientific relevance of the research. Finally, the academic reputation and leadership within the field is assessed. Looking ahead into the future, which recommendations can the committee give to the institute regarding their research quality?
- How does the committee assess the institute's place in the national and/or international research landscape? Is the institute a frontrunner or a follower in its field? Does the committee see untapped opportunities?

2. Societal relevance:

- How does the committee assess the societal relevance in terms of impact, public engagement and uptake of the institute's research in economic, social, cultural, educational or any other terms that may be relevant? The assessment committee is asked to reflect on societal relevance by assessing an institute's accomplishments in light of its own aims and strategy. Looking ahead into the future, which recommendations does the committee have for the institute regarding its societal relevance?

3. Viability:

- How does the committee assess the extent to which the goals for the coming six-year period remain scientifically and societally relevant? It is also asked to assess whether its aims and strategy as well as the foresight of its leadership and its overall management are optimal to attain these goals. Finally, the assessment committee is asked to assess whether the plans and resources are adequate to implement their strategic plan. The assessment committee is also asked to reflect on the viability of the institute in relation to the expected developments in the field and societal developments as well as on the wider institutional context of the institute.
- How does the committee assess the way the institute fulfills their national role and does the committee have any recommendations regarding this?¹
- How does the committee assess the way the institute contributes to the vision on 'Dutch research in 2030' as is written down in the NWO Strategy 2023-2027 and does the committee have any recommendations?

¹ With respect to the reports from the PCNI, the portfolio committee and (where relevant) the exploration reports.

In addition, there are also 4 important aspects contributing to the success of the institute:

4.1 Open Science

The assessment committee is asked to consider to which extent the institute opens up its work to other researchers and societal stakeholders in the context of its strategy and policy. Furthermore, the committee is asked to consider whether the institute reuses data where possible; how it stores the research data according to the FAIR principles; how it makes its research data, methods and materials available; and when publications are available through open access. The committee is specifically asked to give the institute and NWO-I recommendations on their Open Access and FAIR data and software policy. The assessment committee is asked to reflect on the current policies, and the practices with regards to the open availability of the publications, research data and methods and assess them in light of NWO's high ambitions (e.g. is the institute a frontrunner in its field with regard to Open Access and FAIR data and software?).

4.2 PhD policy and Training

- The assessment committee is asked to consider the supervision and instruction of PhD candidates. Furthermore, the committee is asked to consider whether the quality assurance system is functioning properly. The committee is asked for recommendations on how to enhance the supervision and education of PhDs (together with the universities), also in light of the three main criteria.

4.3 Academic Culture

- *Openness, (social) safety and diversity & inclusivity:* The assessment committee is asked to consider the openness, (social) safety and diversity & inclusivity of the research environment. The assessment committee is also asked to evaluate the actions and plans for the future of the institute with regards to (social) safety, diversity & inclusivity.
- *Research integrity:* The assessment committee is asked to consider the institutes policy on research integrity as well as the way the institute facilitates the relevant actions and requirements formulated in the Netherlands Code of Conduct for Research Integrity. For both themes: Looking ahead into the future, which recommendations does the committee have for the institute regarding their academic culture, also in light of the three main criteria?

4.4 Human Resources policy

- *Talent Management:* The assessment committee is asked to consider the institute's policies on talent selection and development in relation to its aims and strategy. More specifically, it is asked to evaluate the institute's recruitment policies, opportunities for training and development, coaching and mentoring, as well as career perspectives for researchers and research support staff in different phases of their career. An important aspect of this is the (inter)national cultural change regarding recognition and rewarding in academia that NWO-I is implementing. What are the institute's plans to further the desired cultural change and which recommendations does the committee have for the institute and NWO-I?

Appendix 2: Programme of the site visit

1 November (Location: Hotel in Amsterdam)

- 18.00 – 18.30 NWO and CWI welcome the panel
- 18.30 – 20.15 Dinner at hotel

2 November (Location: CWI)

- 9.00 – 10.00 Management team (MT)
- 10.00 – 10.15 Closed session panel
- 10.15 – 11.00 Policy 1: Impact and international role
- 11.00 – 11.30 Coffee + visit FleX-ray Lab
- 11.30 – 12.15 Policy 2: Talent management
- 12.15 – 13.00 PhD candidates
- 13.00 – 13.45 Lunch: panel with PhD candidates and Postdocs
- 13.45 – 14.30 Postdocs
- 14.30 – 15.00 TT
- 15.00 – 15.30 Tenured staff
- 15.30 – 16.00 Drinks/snacks + visit Immersive Media Lab
- 16.00 – 16.45 Algorithms
- 16.45 – 17.30 Cryptology and Security
- 17.30 – 18.15 Management team (MT)

3 November (Location: CWI)

- 8.15 – 9.00 Closed session panel
- 9.00 – 9.45 Quantum Computing
- 9.45 – 10.30 Data and Intelligent Systems
- 10.30 – 10.45 Coffee break
- 10.45 – 11.30 Policy 3: Open Science, Security, Social safety, Academic culture, DEI
- 11.30 – 12.00 CWI Fellow
- 12.00 – 12.30 CWI Diversity/Equity/Inclusion Team
- 12.30 – 13.00 Female (research) staff
- 13.00 – 13.30 Lunch
- 13.30 – 14.15 Provisional: additional questions to subgroups
- 14.15 – 16.00 Internal deliberation of the committee
- 16.00 – 16.15 Tea break
- 16.15 – 17.00 Discussion of preliminary results with MT
- 17.00 – 17.15 Presentation of preliminary results of the site visit to CWI
- 17.15 – 18.15 Drinks

Appendix 3: Quantitative data

Quantitative data on the institute's composition and funding, as described in SEP Appendix E, Tables E2, E3 and E4:

Research staff

	2017	2018	2019	2020	2021	2022
Scientific staff (incl TT)	56	56	56	57	52	48
Postdocs	41	44	40	41	34	32
Scientific programmers	7	7	6	6	7	4
PhD candidates	67	74	77	75	86	76
Scientific project members	2	2	3	3	6	4
Total research staff	173	183	182	182	185	164
Support staff	41	45	49	47	45	45
Visiting fellows (ERCIM)	1	1	3	0	0	2
Total staff	215	229	234	229	230	211

Funding

Absolute figures are in million Euro

	2017	2018	2019	2020	2021	2022
Direct funding	11,3 59%	11,6 59%	12,0 56%	12,2 59%	12,6 59%	12,9 60%
Research grants national competition	4,0 21%	3,5 18%	4,9 23%	4,1 20%	4,4 21%	4,5 21%
Research grants European competition	1,7 9%	2,2 11%	2,2 10%	2,4 11%	2,3 11%	1,7 8%
Partnerships research (industry, public institutions)	2,1 11%	2,3 11%	2,2 10%	2,0 10%	2,0 9%	2,1 10%
Other	0,0 0%	0,0 0%	0,0 0%	0,1 0%	0,0 0%	0,4 2%
Total funding	19,0	19,6	21,3	20,8	21,3	21,5

PhD candidates

Starting year	Enrolment			Success rates, graduated					
	male	female	Total (M+F)	<= Y4	<=Y5	<=Y6	<=Y7	Not yet finished	Dis-continued
2014	11	2	13	6 46.2%	3 23.1%	0 0.0%	0 0.0%	2 15.4%	2 15.4%
2015	21	2	23	16 69.6%	1 4.3%	1 4.3%	1 4.3%	1 4.3%	3 13.0%
2016	17	5	22	7 31.8%	5 22.7%	3 13.6%		6 27.3%	1 4.5%
2017	16	4	20	9 45.0%	1 5.0%			8 40.0%	2 10.0%
2018	16	3	19	7 36.8%	0 0.0%			10 52.6%	2 10.5%
Total	81	16	97	45 46.4%	10 10.3%	4 4.1%	1 1.0%	27 27.8%	10 10.3%
Total graduated <=Y7				60 61.9%					