

## Environment template (REF5)

<b>Institution:</b> Queen's University Belfast
<b>Unit of Assessment:</b> 10 (Mathematical Sciences)
<p><b>a. Overview</b> The Mathematical Sciences UoA at Queen's University Belfast (QUB) is part of the School of Mathematics and Physics, and is the only research unit in Mathematics in Northern Ireland. There are seven research centres within the School, of which two are represented in this return, namely the <i>Centre for Statistical Science and Operational Research (CenSSOR)</i> and the <i>Pure Mathematics Research Centre (PMRC)</i>.</p> <p>CenSSOR was established in 2005 with the initial employment of three research-active staff. It currently has one professor and two lecturers (one on probation) in Statistics and one lecturer in Operational Research. Two more posts are due to be filled imminently, one of which is externally funded. Due to its relatively recent formation, there was insufficient critical mass for its return to UoA 22 in RAE 2008. Instead, two of its staff members were included as part of UoA 6, <i>Epidemiology and Public Health</i>.</p> <p>The PMRC has undergone a large turnover in staff during the last decade due to retirements, with only two staff members in common between the RAE2001 and 2008 returns. Two lectureship appointments have been made recently and the new staff members commenced employment in 2013. The Centre is now in a period of consolidation, with the previous round of appointees settling in to full membership of the unit and taking over substantive management roles both in research and teaching.</p> <p><b>b. Research strategy</b> The strategy in CenSSOR is centred around the further advancement of multidisciplinary research with emphasis on applications in the public sector, and more specifically within healthcare, and traffic and infrastructure modelling. Research interests include <i>Survival Analysis, Bayesian Modelling, Data Mining, Markov Modelling, Stochastic Models</i> and <i>Longitudinal Data Analysis</i>. Further recruitment of one academic staff member and two new postdoctoral researchers will be linked with the movement of finance and health analytics companies into Northern Ireland and is a consequence of the research conducted in collaboration with the <i>Cumberland Initiative</i>. The second new academic post is funded by the ESRC with the aim of promoting quantitative modelling and research in sociology.</p> <p>At the heart of the research strategy of PMRC is the further development of its well-established <i>Functional Analysis</i> group, and the consolidation of its newer group in <i>Algebraic Topology</i>. Building on their pre-RAE2008 achievements, in the assessed period PMRC staff members have started new collaborative links with leading experts and have extended their existing expertise to new subareas, such as <i>Abstract Harmonic Analysis, Linear Preservers</i> and <i>Stable Homotopy Theory</i>. The immediate strategic aims of the PMRC have two key points: firstly, deepening its current expertise in <i>Functional Analysis</i> and widening its scope into fields of applications such as <i>Quantum Information Theory</i> and the <i>Theory of Locally Compact Quantum Groups</i> and, secondly, enhancing its research power in <i>Algebraic Topology</i>, specifically in <i>Abstract and Toric Homotopy Theory</i>, with the view of expanding its research expertise into <i>Functor Calculus</i>. During the assessed period, both CenSSOR and PMRC have, in accordance with the corporate research strategy, built up an even stronger international profile. Among their immediate aims is to enhance further their national research links and UK-based collaborative network.</p> <p>In both centres, the achievement of the highlighted goals is facilitated by an intensive programme</p>

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of seminars, colloquium talks and research visits. Research students are expected to be active participants in these events, which give them the opportunity of discussing their own and other researchers' work as well as broadening their education. In CenSSOR, there is a seminar programme of around ten talks per year. Furthermore, QUB has a *Research Forum for Statistics and Operational Research*, which receives annual financial support of £2.5K from central funds. It brings together researchers from across QUB and supports the broader user community. In the last year alone, the Forum has hosted eminent speakers such as Professors Sir David Cox and Jeff Griffiths. One of the CenSSOR staff is a member of the *Special Interest Group in Connected Health* established by QUB to bring together 45 academics across the University working in the connected health area. The multidisciplinary nature of the group makes it a useful vehicle for collaboration that facilitates workshops, health hack events and conferences at QUB. One of the CenSSOR members is Chair of the *Royal Statistical Society Northern Ireland Local Group*, which often hosts talks by international visitors at QUB. In PMRC, there is a weekly *Pure Mathematics Colloquium*, with talks (intended to be accessible to all academic staff and postgraduate students) delivered by visiting speakers as well as by our own staff and research students. In the past academic year, 25 talks were held in this series. It has featured speakers of the highest international standing such as Professors Paul Baum (Penn State), Vern Paulsen (Houston) and Andreas Winter (Barcelona). Various groups within the PMRC also hold weekly research seminars, two being conducted in the areas of *Operator Algebras* and *Regular Operators*.

In addition to the intensive seminar programmes, both units host research visitors: since the start of 2008, the PMRC has received 50 visits by 35 researchers, including two who each stayed for a period of nine months, another for six months and a third who made three visits totalling five months. Over the same period, CenSSOR, where the culture is to use conference attendance as an opportunity for collaboration, received three long-term visitors. Compared to their position at RAE2008, both units have thus substantially increased their collaborative networks.

**c. People**

**i. Staffing strategy and staff development** Staffing in CenSSOR and PMRC is directly linked to their research strategies. Thus, one of the staff members of CenSSOR appointed within the REF period works within *Longitudinal Data Analysis*, which allows for a link between the interests of two established members of the group, while the other one covers a critical lack of expertise in *Operational Research*. In PMRC, one of the two new appointees strengthens the *Functional Analysis* group, adding the *Theory of Linear Preservers* to its research portfolio and, at the same time, providing a crucial expertise in *Abstract Harmonic Analysis*. The other new staff member provides critical mass for the viability of the *Algebraic Topology* group, adding an expert in *Model Categories* with substantial experience in *Equivariant Homotopy Theory*, an area providing exciting new results in general algebraic topology.

Newly-appointed staff are given a probationary period of three years. In collaboration with a mentor, the probationer agrees a development programme. His/her progress is monitored regularly and is annually reviewed by a School Committee chaired by the Head of School and including the Director of the relevant Research Centre. The Committee conducts a Confirmation in Post process at the end of the probationary period. While staff members are not permitted to act as first supervisors for PhD students during their probationary period, they are encouraged to act as second supervisors to gain experience in the supervisory process. Probationers are expected to successfully complete the *QUB Postgraduate Certificate in Higher Education Teaching* and to attend a course on PhD supervision. Whilst on probation, teaching loads of staff members are

reduced and they are not allocated major administrative duties. New appointees are entitled to a start-up package of up to £12K to help develop their research. Several have also received support of up to £5K from the *QUB Promising Researchers Fund*.

An annual appraisal process (which includes 6-monthly reviews) is conducted by the Director of the relevant Research Centre for all staff who pass probation. Apart from encouraging staff to reflect on all aspects of their careers, the appraisal process feeds into their future plans in terms of promotion and serves as an avenue for research assessment and management.

Staff members are encouraged to apply for sabbatical leave. Invaluable in this, in view of the small staff numbers in both units, has been the provision of teaching assistance by the School through hiring a temporary assistant to cover the teaching duties of the staff on leave. During the current REF period, five academic staff members have each been granted a one semester sabbatical leave. We also endeavour, where possible, to organise teaching commitments to allow staff to have semesters free from major teaching duties. All staff members have access to the extensive programme of courses of the *QUB Staff Development and Training Unit*, and are eligible to apply for a number of university schemes aimed for provision of support for conference attendance and other research activities, from which two PMRC staff members have already benefitted.

Research staff are normally given a six month probationary period, with the project supervisor acting as mentor. The Confirmation in Post is again undertaken by a School Committee involving the relevant Director of Research. Research staff are normally supported by externally-funded research contracts. During the REF period, CenSSOR and PMRC have had a total of seven PDRAs, two of whom are conducting collaborative research with the health analytics company Aridhia. QUB actively supports the Concordat for Training Research Staff and provides training aimed specifically at them. Where possible the Research Centres, in conjunction with the cognate Teaching Departments, contribute by allowing researchers to gain lecturing experience under the supervision of an experienced member of staff.

Cairns, a member of CenSSOR, was originally an RCUK-funded Academic Fellow. Upon completion of her five-year fellowship, she successfully passed through probation and is now on the QUB permanent lecturing staff. Barnes, a current member of PMRC, initially joined the centre while being the Principal Investigator of a three-year EPSRC Postdoctoral Fellowship.

The majority of staff appointments in recent years have been international. This has contributed to the preservation of natural collaborative links with research centres in Germany, Greece, Russia and Taiwan, as well as to a high degree of cultural diversity. The School is fully committed to promoting equal opportunities and to creating and sustaining an environment that celebrates staff and student diversity. All staff have successfully undergone diversity training through a centrally administered QUB training course. Female staff members are entitled to maternity leave and additional support upon their return, e.g. Cairns has taken such leave twice during the REF period. As of September 2013, the School is one of only two Mathematics *Silver Athena SWAN Award* holders in the whole of the UK and is a supporter of both the IOP's *Project JUNO* and the LMS's *Good Practice Scheme*. The Director of CenSSOR is the leader the School's Athena SWAN Self Assessment team leading the School in its recent submission and previously when awarded a *Bronze Athena SWAN Award*.

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**ii. Research students** Both CenSSOR and PMRC receive awards from Northern Ireland's *Department for Employment and Learning* (DEL), which are administered by QUB, allocated to Schools and thereafter distributed to Research Centres. Typically the Centres obtain one or two awards per year, in line with its staff complement. The PMRC currently has five PhD students, one of which EPSRC funded. CenSSOR currently has seven externally funded students, three of whom are supported by *Northern Ireland's Strategic Investment Board*. Two more students, funded by the *Centre of Excellence in Public Health*, started in September 2013. In addition, CenSSOR has a partnership with Milano-Bicocca University to jointly fund a studentship, and its staff are involved in the supervision of external PhD students. CenSSOR and PMRC advertise studentships nationally. Both units have experienced a recent upsurge of funded overseas applications.

Postgraduate students are assigned a supervision team, consisting of a principal supervisor and a second supervisor, who undertakes responsibility for the student's participation in skills training courses as well as acting as a back-up supervisor. Progress is monitored annually by a committee on which the supervisor representation must be a minority. The PhD project undergoes a feasibility review after three months of the commencement of the degree, followed by a rigorous progress assessment towards the end of the first year, where the committee decides if a student should proceed to study for a PhD, transfer to an MPhil or withdraw. Both Research Centres are of fairly small size, and hence contacts between research students and academics tend to be frequent and rather informal; this allows for any problems that students may encounter to be quickly noticed and dealt with by staff. Students in CenSSOR are linked to an external collaborator, usually from a local company or a government body, acting as an external advisor to the student, giving valuable insight into industry/services and often providing external data to be used as part of the research.

At the start of their PhD studies, students attend a QUB induction event and take short courses, such as *LaTeX* and others, relevant to their Research Centre. They are required to participate in the Centres' seminar programmes and to give talks at them. In 2012, the School initiated a *PhD forum*, chaired by Moutari from CenSSOR, and a *Postdoctoral Research Forum* chaired by another member of the School. These have the capacity to facilitate short technical courses as requested by School's PhD and PDRA community. Research students have access to the QUB *Postgraduate Researcher Development Programme*, linked directly to the national *Researcher Development Programme*, and aimed at enhancing their research and transferable skills.

In common with similar centres at many other HEIs, the PMRC has found that PhD students' general mathematical education is in need of improvement, even though its PhD entry requirement has included a 1<sup>st</sup>-Class Honours MSci (or equivalent) since 2002. Depending on the complement of our student cohort, we run a series of short lecture courses, each consisting of approximately eight hours of lectures, on topics of general importance. These have proved invaluable in expanding our students' mathematical education. Visitors often interact with students either informally or by giving research talks at an appropriate level. In particular, we have several ERASMUS links which support visits by staff who have contributed to this programme.

In both Centres, research students are mandated to attend national and international conferences and give talks at them, with funding provided either from the Centres or from the centrally allocated £700 per annum bursary. When beneficial, students have undertaken longer research visits: in 2010-2011 two students from the PMRC visited Athens for a total of six months; one from CenSSOR has recently returned from the first of three two month trips at *Milano-Bicocca University*, while another spent six months at Ohio State University under a US-UK Fulbright

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Scholarship. The success of the supervision and training practices within the unit is demonstrated by the PhD completion rate which for the REF period stands at over 90%.

All PhD students are given the opportunity, after in-house training, to undertake assignment marking and conduct tutorials, while a small number are invited to deliver selected undergraduate lectures. These activities provide valuable experience for a possible future academic career.

To complement the student's subject specific research training, QUB has endorsed a *Research Development Framework* and has created a simplified *Personal Development Planner* for students' use. As part of this initiative, QUB operates a comprehensive generic skills training and development programme, in which we have been active participants, and which includes support for student-led initiatives, an annual poster competition and graduate schools.

**d. Income, infrastructure and facilities** Both CenSSOR and the PMRC are located in the new, purpose-built £3.3M David Bates Building (DBB) which has state-of-the-art lecturing and seminar facilities. All staff and research students have their own computers, as well as full access to library, interlibrary loan, Internet, printing, photocopying and scanning facilities. The McClay Library, which opened in 2007, is adjacent to the DBB giving speedier access to books and journals that are not available electronically. A small on-site library is hosted at PMRC, containing essential titles in a variety of mathematical disciplines, available for long-term use to PMRC members and students. The entire computing inventory of the PMRC was renewed when it moved to the DBB in 2007 and machines for staff and postgraduate student use were replaced by a new generation at Easter 2012. All staff and postgraduates have laptop computers, and two Dell R210 II servers were obtained recently, primarily for teaching purposes but research usage is also expected. CenSSOR has a pair of Dell R410 servers where it runs SAS, Matlab and R for teaching and research purposes, and is currently using SODA (SAS On Demand Access) for teaching purposes with the eventual prospect of research use through cloud technology.

Both CenSSOR and PMRC receive annual funding allocations from QUB, typically £7K to each Research Centre in non-pay and £4K to each in equipment. In addition, QUB operates an incentive scheme whereby a fraction of the Investigator funding on fEC grants is returned to the relevant Investigators as a non-pay allocation.

CenSSOR's external research funding is focussed on healthcare aspects of its work, with major funds coming *via* a £5M UKCRC Centre of Excellence (CoE) award shared among 20 collaborators coming to an end in 2013. The co-investigators have successfully managed to secure funding of £3M for the next phase of the CoE. CenSSOR has also received confirmation of funding as a participant in a £3M grant with the external company Aridhia, £2M of which comes from *Invest Northern Ireland*, and past grants such as the £129K RCUK Academic Fellowship that funded Cairns, in addition to several others that provided by various health agencies. It is anticipated that this funding pattern continue and be extended through applications of newly-appointed staff members. In April 2012, CenSSOR was awarded a research grant by the *Strategic Investment Board* to work on the Police Operations Decision Support System and has since had further funding to work on Strategic Infrastructure Planning Models (SIPM) for N. Ireland.

PMRC's research funding has built on its success during the RAE2008 period that included Todorov's EPSRC First Grant of £113K, which continued into 2009. Hazrat (who has now left) followed on his First Grant in the RAE 2008 period with a £33K standard EPSRC grant, whilst

Hüttemann obtained a £125K EPSRC First Grant in 2010. Barnes, one of the two new members of PMRC, held a three year £220K EPSRC Postdoctoral Fellowship until August 2013, while Todorov was recently awarded a £32K EPSRC standard grant. PMRC staff members have been extensively supported by a variety of schemes of the London Mathematical Society, and two Royal Society International Exchanges grants have complemented their funding portfolio. The Centre plans to build further on its past record in attracting EPSRC funding, to continue being active in LMS and Royal Society schemes and to explore EU funding opportunities.

**e. Collaboration or contribution to the discipline or research base** In both CenSSOR and PMRC, international research collaborations are highly intensive: during the REF period, members of PMRC have maintained international collaborative links with 43 researchers from Europe, North America, Asia and Africa and have published joint papers with 28 of them, while members of CenSSOR have maintained active collaborations with 30 researchers from abroad, and with 20 more researchers nationally. Examples of currently active collaborations of PMRC members include those with Pere Ara (Barcelona), Junko Inoue (Tottori), Jean Ludwig (Metz), Vern Paulsen (Houston), Stefan Schwede (Bonn), Victor Shulman (Vologda) and Andreas Winter (Barcelona). In CenSSOR, apart from academic collaborators, staff maintain active links with other parties such as industry and the public sector, including health services, police and the *Department for Employment and Learning*. Support for these collaborations comes from a variety of sources, with the QUB start-up packages being important for members of staff at an early career stage, whilst those with more experience relying on external income such as Royal Society and LMS grants. The Research Centres provide partial support for their visitors through their QUB non-pay allocation. Staff have also obtained funding from foreign research councils; in particular, during her tenure before joining QUB, Lin was continuously supported by the *Taiwanese National Science Council* and has secured a year-long research grant through a highly competitive scheme of the Council (an equivalent to an EPSRC Fellowship), while Mathieu has obtained funding from the *Spanish Ministry of Education* to support a sabbatical visit.

As further examples, one member of CenSSOR visits the Università degli Studi di Milano-Bicocca on a regular basis and this has resulted in securing funding from Milano-Bicocca University to co-support a PhD studentship with QUB. A visit of Todorov to Vern Paulsen in Houston, supported by QUB, led to him securing a Royal Society grant and the aforementioned EPSRC grant, which started in November 2013. The latter collaboration is unique in its interdisciplinary nature, linking the PMRC expertise in *Operator Algebras* to current problems in *Zero-error Quantum Information*. An evidence for the valued expertise at CenSSOR and PMRC is the fact that their members have acted as external examiners for eight PhD and one MPhil theses within the REF period, as well as external appointments, such as Lin's Visiting Professorship at the University of Metz (2009-2010).

Virtually all research activities undertaken by CenSSOR are interdisciplinary in nature. The creation of the *Analytics Institute* is an integral part of its plans for further engagement with users. Examples of the kind of work that has been undertaken go back to *A Study of the Effectiveness and Cost Effectiveness of Public Access Defibrillation in Urban and Rural Populations in Northern Ireland*, which was awarded £552K by the Research and Development Office of the Department of Health. One of the most recent of note is the aforementioned UKCRC Centre of Excellence award of £5M with a further phase of funding of £3M starting in 2013, to 20 collaborators, including one from CenSSOR, for a multi-partner centre focussing on nutrition and physical activity. In between, there have been several other healthcare-related and public sector projects as well as one on *Understanding the Determinants of Further Education College Demand and Flow in Northern*

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Ireland, awarded £51K by the Strategic Investment Board. All of these activities are driven by the requirements of users and the whole emphasis of CenSSOR's research is towards user needs.

There is very active participation in the wider academic community from members of both CenSSOR and PMRC. Marshall was President of the *Irish Statistical Association* (2010-2012) and is a member of the *RSS Council*. She has acted as a reviewer for major grant applications for *ERC*, *NIHR*, research councils in Italy and Romania, as well as for the *Ministry for Health* in Singapore and as an EPSRC panel member. Marshall was also an executive committee member of the *International Biometrics Society* (2008-2011). CenSSOR staff have been expert members of various advisory boards, including the *Statistics Advisory Committee*, *SAS Academic Advisory Board* (which includes being appointed a SAS honorary fellow), the *Census Advisory Group*, the *Northern Ireland Statistics Research Agency* and the *Northern Ireland Longitudinal Study Research Approvals Group*. Several members of CenSSOR and PMRC have acted as grant reviewers for the EPSRC, while Mathieu (PMRC) has acted in that capacity for the *NSERC* of Canada and the *Israel Science Foundation*. Both Mathieu and Wickstead have served on the *Irish Mathematical Society* Committee, with Mathieu currently being its President, while Wickstead has also been Honorary Treasurer of *Heads of Departments of Mathematical Sciences* until April 2013. Mathieu was also recently elected to membership of the *Royal Irish Academy*.

Since January 2008, CenSSOR staff have organised two conferences at QUB and have been involved in the organisation of eight other conferences or workshops. PMRC staff, over the same period, have organised nine international conferences at QUB in various areas including *Operator Theory*, *Algebra Combinatorics and Dynamics*, *Toric Methods in Homotopy Theory* and *General Topology*, funding for all of which was secured externally. They were members of the organising committee of ten conferences held elsewhere. In the same period, PMRC staff gave a total of 49 invited lectures at international conferences. CenSSOR staff delivered 12 seminars in UK and other universities which include the University of Nice-Sophia Antipolis (France), RWTH Aachen University (Germany), IFFSTAR-GRETIA (Paris) and *Milano-Bicocca University (Italy)*, whilst PMRC staff gave 73 external seminars in universities both in the UK and abroad, with two members delivering a total of four mini-courses for young researchers: in Chios and Samos (Greece) and in Chengdu (China).

Staff members are dedicated to providing editorial support to publishing, with Marshall on the editorial board of the *Health Systems Journal* and the *Italian Statistics Journal* and a member of the *RSS Series A and Significance* editorial board. Mathieu is the editor of *Mathematical Proceedings of the Royal Irish Academy*, and holds editorial positions with *Extracta Mathematica* and the *Journal of Mathematical Analysis and Applications*. He was also the editor of the *Irish Mathematical Society Bulletin* until January 2011. Shkarin is a member of the editorial board of the *Journal of Function Spaces and Applications*, Todorov is a member of the editorial board of *Serdica Mathematical Journal*, while Wickstead – of the editorial board of the journal *Positivity*, which he helped found in 1997. Since the start of 2008, PMRC staff have refereed over 185 articles in 68 different journals, including publications of the *American Mathematical Society* and *London Mathematical Society* as well as *Advances in Mathematics*, *Journal of Algebra*, *Journal of Functional Analysis*, *Journal of Mathematical Analysis and its Applications*, *Mathematische Annalen*, *Positivity*, *Quarterly Journal of Mathematics Oxford*, and *Studia Mathematica*. CenSSOR staff refereed 75 articles for 25 different journals. In the same period, PMRC staff also wrote 45 reviews for *Mathematical Reviews* and 64 reviews for *Zentralblatt MATH*.