Institution: Queen Mary University of London (QMUL)

Unit of Assessment: B10 Mathematical Sciences

a. Context

The School of Mathematical Sciences is committed to delivering high-quality research, and to maximising its reach and influence. As part of this, a key priority is to provide an environment conducive to impact on the economy and our society. Our School strategy objectives related to impact are aimed at improving our external relationships to ensure we reach out to business, policy makers and young people through our outreach activities. We also have a set of internal impact objectives, such as placements, innovation funding and sharing good practice, to ensure that our environment is conducive to impact and individuals/groups are supported in their impact activities.

b. Approach to impact

We are committed to ensuring an environment conducive to impact through long-term sustainable funding streams, encouraging interdisciplinary working and building partnerships with research users. This section summarises our impact initiatives.

ImpactQM: The School's allocation from the £2.9M Queen Mary EPSRC Knowledge Transfer account was mainly used to support 3-month periods of industrial contact time for academics, kick-starting collaborations with industry (IBM, inuTech, Shell). The scheme links early career researchers with industry partners, allowing them to work on projects which transfer Queen Mary's leading-edge research into business. In the School, this programme enabled Bandtlow to share his expertise with InuTech, an SME working with engineers to design vibrational prediction techniques. Walters was supported to work with IBM to validate the mathematical insights to explain behaviour of scale free networks with a view towards optimal database design. The programme also supported collaboration with Shell discussed at length in the Economical Experiments for the Fuel Efficiency Industry case study.

Bridging the Gaps: Bridging the Gaps is an EPSRC-funded project set up to facilitate multidisciplinary capacity building across Queen Mary. This funding has been used by the School to conduct *statistical physical analysis of the dynamics of foraging bumblebees,* a project led by Klages which has had interdisciplinary interest, particularly from ecologists. The funding has also been used to develop an interdisciplinary project with the School of Electronic Engineering and Computer Science titled *Personalised Research Dashboard* led by Tokarchuk and Grossman, which aims to provide a dynamic self-updating environment in which researchers get the most up-to-date highly-specialised information. This project has led to an EPSRC First Grant Proposal on *Social and Temporal Recommendation*, supported by BT and Last.FM.

Investing in our researchers: Sabbaticals and secondments are a vital tool for supporting impactful research. The School actively supports sabbaticals and secondments to encourage collaboration. The relevance for impact is taken into account when sabbaticals are awarded to research staff. For example, three Queen Mary Mathematicians (Bullett, Stark and Walters) have taken year-long secondments at Heilbronn Institute for Mathematical Research (HIMR) to work for GCHQ. All members of staff are supported to develop research proposals which have impact as an integral part.

Outreach: The School has a long-standing tradition in outreach activities and widening participation. The School allocates resources including a 0.5 FTE dedicated Recruitment and Outreach Manager. We have delivered a range of outreach activities. Exemplar initiatives which draw on research conducted are summarised below:

- ***Goldsmiths' Teachers' Course***: Each summer since 2008 we have hosted a summer school. Lecturers cover their own area of research and update secondary school teachers on the latest developments in mathematics. Typically 12 members of staff contribute. As examples Soicher has delivered presentations on Latin Squares research and Harris has delivered presentations on traffic-flow and gas-network research. Since the introduction of this course, the number of schools we have engaged with has increased by 50% (from 160 in 2007/08 to 240 in 2010/11).
- ***Pure Mathematics Taster Day***: organised annually since 2009, this event has been attended by over 200 A-level mathematics students. It focusses on Ramsey Theory accessed through the exploration and importance of patterns leading into probability. Students are introduced to the excitement of research-level mathematics and encouraged to explore the different concepts leading up towards works such as I. Leader, P.A. Russell and M. Walters, 'Transitive Sets in

Euclidean Ramsey Theory' *Journal of Combinatorial Theory* Series A, Volume 119, Issue 2, February 2012, pages 382-396.

- ***Academic staff contribute to events***. Notably Harris delivered a talk 'From Applied Maths to Transport Modelling' inspired by her research in this area as part of a summer school for A-level students on energy and the environment.
- ***Engagement with the wider public*** is an important element in generating impact including the stimulation of public interest in mathematics. Our academics also impact in the media including national TV (Cameron, 2010 and Majid, 2009) and Spanish CNN (Lopez, 2010). Focussing on impact tied to specific research, Cameron gave an invited series of public LMS Forder lectures in New Zealand in 2008, with an audience of 150. Matt Parker, a stand-up comedian and mathematician employed part-time by the School, has stimulated public interest in mathematics through his work. He has disseminated short videos on YouTube about how mathematics can be applied in real-life situations (one of the videos has had over 700,000 views – November 2013).

c. Strategy and plans

Impact is a key part of our School's research strategy and is driven by four areas including: research groups, nurturing an impact culture, partnerships with industry, and partnerships with policy makers.

Nurturing an impact culture: We are committed to encouraging our researchers to recognise, disseminate and celebrate the impact (and potential impact) of their research.

- The Centre for Discrete Mathematics (CDM) is our flagship Centre for engaging with external partners. Building on our previous success, the CDM will act as an umbrella to foster impact from mathematical studies of discrete structures. The CDM is an important external face for the School and we have started working in partnership with our colleagues in Electronic Engineering and Computer Sciences, and Life Sciences to identify jointly funded research opportunities. Building upon the successful interdisciplinary seminars series, the CDM will host termly impact sharing seminars where all staff will be invited to contribute examples of how their research could be utilised in non-academic contexts and invite feedback from other researchers. Colleagues from other disciplines will be invited to attend these seminars to encourage cross-fertilisation from other disciplines and sharing of best practice.
- For some of our grant applications we are required to produce impact pathways to demonstrate how our research could be utilised by stakeholders outside of our HEI. We have adopted this good practice and are now producing impact pathways for all of our research (whether required by the funder of not) to help nurture a culture of impact within the School. Researchers are encouraged to share these pathways with peers in other disciplines to encourage innovative ideas and impact potential. Researchers will be advised on how to gain evidence of impact and our recently appointed Research and Enterprise Manager will also support with this process.
- We will be working with our colleagues in other faculties to disseminate our research to a broader audience. This will include a series of public lectures and non-academic partners will be invited to attend – we will be actively encouraging our industry partners to attend and will work closely with Queen Mary's Business Development Office to build these relationships.

Partnerships with industry and policy makers: We have a number of sustained relationships with industry partners (IBM, inuTech and Shell) and policy makers (HM Treasury, GCHQ, European Commission) that have proved mutually beneficial. We are now in a position to build upon these partnerships and expand our portfolio.

- The School is keen to encourage staff to take placements within industrial settings as this is a successful way to embed our research amongst possible users. We will aim to support at least one placement per academic year. The aim of these placements is to generate collaborative research proposals. We are also keen to promote the benefits of EPSRC Industrial CASE as a mechanism to build relationships with non-academic partners.
- We will continue to engage with Queen Mary initiatives. The Innovation Fund supports researchers to overcome the bottlenecks that often delay research having an economic or social impact. Proof of Concept and QTech Accelerator funds support researchers to achieve commercial viability. We will aim to identify at least two projects per year suitable for such funding, potentially leading to commercial success and taking our research to new audiences.

- We have identified the pharmaceutical industry as a key sector for collaboration and plan to run a networking campaign to build and embed our contacts in this area. The School has a strong track record in experimental design which can be utilised in clinical trials and currently have a jointly funded PhD student with Novartis and have been in dialogue with Lilly Pharmaceuticals about our experimental design research. We are also in dialogue with AstraZeneca regarding the application of our particle packing research.
- Tech City is a cluster of technology businesses in east London, with which the School are ideally placed geographically to engage. We have identified the possibility of fast tracking the commercialisation of software emerging from our statistical research and plan to engage Tech City businesses as our software develops.
- Elements of our current research will be informing policy and have socio-economic and environmental impacts. We have relationships with policy makers built-in to these research projects from the start to help ensure that impacts are embedded. For example, our current EPSRC-funded research into Multi-Event Modelling could lead to enhanced flood resilience. This project builds upon Beck's work in the areas of complex systems, stochastic processes, dynamical systems and spatio-temporal chaos. Beck is leading the research which will employ super-statistical techniques for analysis of historical time series (primarily daily rainfall, extreme sea level and waves) with the aim of specifying stochastic models that reproduce the higher-order statistics of the underlying stochastic processes at multi-timescales. The results will be used to either develop new simulation tools or to improve existing ones. Our partners, the Environment Agency, Scottish Environmental Protection Agency and DEFRA will gain improved understanding of long-term processes of erosion and changes in flood risk and the implications for design and asset management on both coasts and rivers.

d. Relationship to case studies

i. Research groups and partnerships to harvest impact

As described above, we are keen to encourage our researchers to engage with external partners when there is a complementary fit with their academic research. This worked particularly well with regards to the ***Informing policy and mitigating risk – modelling infrastructure networks*** case study which built upon our School's ongoing work into infrastructure networks. We have a research group dedicated to this area, the Real World Networks (RWnets) group which brings together expertise in statistical mechanics and complex systems.

The Heilbronn Institute is a collaboration between academia and GCHQ based at Bristol University. Three Queen Mary mathematicians (Bullett, Stark and Walters) have taken year-long secondments at HIMR with the full encouragement and support of the School. These collaborations drew upon our expertise in Combinatorics, Algebra, Statistical Mechanics and Dynamical Systems, and Design of Experiments. All of these were productive and one, which is detailed in our ***classified case study***, has had a significant impact.

ii. Complementing our diverse research interests

Our approach allows researchers to make the most of their expertise in Algebra (pure mathematics), Statistical Mechanics and Dynamical Systems (applied mathematics), and Design of Experiments (statistics). This expertise underpins our impact cases, most notably with regard to our activities on infrastructure networks based on our expertise in statistical mechanics and complex systems (***Informing policy and mitigating risk***) and our collaboration with inuTech (***Spectral theory to improve the accuracy of vibrational energy predictions***) with substantial industrial and technological relevance which benefits from our research expertise in Dynamical Systems. Our partnership with the Heilbronn Institute has led to our classified case study regarding impact on defence and security.

iii. Making use of Queen Mary funding initiatives to kick-start impact

We have utilised the ImpactQM funding source to enable Bandtlow to share his expertise with InuTech which led to the impact described in the ***Spectral theory to improve the accuracy of vibrational energy predictions*** case. ImpactQM also kick-started parts of Gilmour's activities as described in the ***Economical Experiments for the Fuel Efficiency Industry*** case. Data mining for the European gas network (***Informing policy and mitigating risk***) was also funded by ImpactQM.