Institution: University of Sussex

Unit of Assessment: 10 (Mathematics)

1. Context

The Department of Mathematics is part of the School of Mathematical and Physical Sciences and is currently organised into three groups: Analysis and PDEs (partial differential equations), including Financial Mathematics; Mathematics Applied to Biology; Numerical Analysis and Scientific Computing. In addition, Probability and Statistics is a related research area that we are building, and recent appointments in this area strengthen and consolidate our expertise in this field, with the intention of establishing a new group.

The current research leading most directly to non-academic impact stems from two of these areas, Mathematical Biology, and Probability and Statistics. In these areas we have developed real-life-driven mathematical models of disease transmission (for both animal and human pathogens) and of immune-system dynamics – specifically malaria, dengue and meningococcal infections – and have carried out meta-data analysis of the outcome of heart surgery. These areas of impact are complemented by strong research-based outreach and media involvement based on Probability and Statistics, and quantitative-analysis contributions to the banking and financial sector, notably risk modelling in banking and hedge-fund optimisation.

Research in Mathematics has the potential to have an impact on a wide range of beneficiaries in the health, business and financial sectors, as well as be of relevance to the general public. Research from Sussex in the REF period has had an impact on the following specific beneficiaries:

- Medical practitioners and patients undergoing heart surgery, where statistical analysis of real-life data by the current members of the growing Probability and Statistics group has contributed to the shaping of medical-practice guidelines and the improvement of patient-health outcomes.
- People and communities in developing countries, where epidemiological modelling by the Mathematics Applied to Biology group contributed to the development of mitigating policies for meningococcal infections in sub-Saharan Africa.
- Businesses involving digital marketing and their clients, where mathematical optimisation has led to an improved performance and better profits.
- Those in the UK and abroad concerned about the use or misuse of probability and statistics in widespread sport-betting, lottery and games involving probability.

2. The Unit's Approach to Impact:

The Department's approach is based on the strategic vision of the University, which prioritises knowledge exchange and the translation of research to the benefit of society and businesses. Below we outline the Department's four approaches to achieving these goals:

2.1. *Making non-academic connections*. A wide exposure is essential to identify and exploit opportunities to generate socio-economic impact. The department has successfully engaged with businesses and the community on multiple levels:

- We encourage consultancy projects to build relationships for impact. Members of the Department have engaged in consultancy projects with small and medium-sized businesses. This has allowed them to apply research results to real-life problems and to showcase the relevance and impact of their research beyond academia. Successful consultancy projects include collaborations with the Digital Marketing Sector (see Impact case study) and with the Banking and Finance sector on modelling risk and optimisation problems arising in the context of complex financial products. Mathematical models contributed to developing a better understanding of risk by interested financial companies, including hedge-fund manager International Asset Management, and management consultants Corporate Governance Consultancy. These projects were initiated by the University's Research and Enterprise Office, which hosts events to

connect researchers and business.

- Public engagement with research is driven through participation in relevant events. Members of the Department have participated in fairs and festivals such as Brighton Science Festival (Haigh and Kiss) and the Hay-on-Wye Festival, where activities showcase the research highlights of the Department. They also give public lectures put on by organisations such as the Royal Statistical and the London Mathematical Societies. The Department has a dedicated Outreach Officer who regularly gives talks in local schools and colleges, and organises on-campus outreach activities to bring the Department's research to a wider audience.

2.2. *Promoting interdisciplinary research to support impact*. Interdisciplinary research is key to our impact approach as it allows the Department, firstly, to formulate research questions with the end-users and real-life problems in mind and, secondly, to demonstrate the power of mathematical approaches/techniques in tackling challenges arising in areas/sectors other than Mathematics. This, in turn, contributes to the knowledge economy and generates impact. To facilitate such research, the University of Sussex has defined six interdisciplinary Research Themes, with Environment and Health, Digital and Social Media and Mind and Brain the most relevant for Mathematics. The Department has fully contributed to the development of these themes – particularly Environment and Health – with on-going collaborations with the Brighton and Sussex Medical School on 'predictive models for aneurism cure: mathematical modelling of arterial plaque haemodynamic interactions', and 'shape-optimisation algorithms to improve the processing of echogram data', together with 'human behaviour and risk perception in epidemic models'. The Department is now leading the development of a new interdisciplinary University Research Centre in Scientific Computing and Numerical Modelling.

2.3. *The strategic appointments of faculty members*. It has been a priority to appoint impact-ready faculty. This is reflected in several members having a proven track record of impact-generating research. These include:

- Kiss working on livestock-disease transmission models with output informing foot-and-mouth disease and avian-influenza preparedness and control policy in the UK;
- Giesl developing bio-mechanical data-driven modelling of the musculo-skeletal system, with impact on the early diagnosis and prevention of lower-back pain; and
- Blyuss working on mathematical models of immunological interactions for dengue fever.

Current strategic investment by the University into the Department has been used to make appointments to strengthen and grow the existing expertise into a new research group in Probability and Statistics, including Stochastic Analysis. This acknowledges the strong potential of this branch of Mathematics to generate interdisciplinary collaborations and thereby translate research into beneficial practical outcomes.

2.4. *Supporting and promoting impact*. The Department recognises and supports individuals and groups with innovative, novel research ideas, which are likely to lead to the generation of impact. In such cases, individuals or groups benefit from reduced teaching and administrative loads – e.g. faculty recently benefited from this scheme in the context of securing research funding from EPSRC on cell motility and migration and on incorporating human behaviour in epidemic models, and from the Royal Society on processing echogram data to allow faculty to develop links with non-academic contacts and potential beneficiaries, including clinical laboratories and clinicians. Higher Education Innovation Funding is allocated directly to faculty by the School to provide seed-corn funding to support their initiatives.

3. Strategy and Plans for Supporting Impact:

We will continue our strategy to ensure that high-quality research evolves hand-in-hand with the translation of research results into practical applications for the benefit of businesses and communities. We will maintain the four approaches outlined in Section 2 and intend to build capacity and resources to achieve impact in these additional six ways:

3.1 The management team is structured to support impact. The Head of School, the Director of

Research and Knowledge Exchange and the Head of the Department (HoD) are responsible for the delivery of the University's vision and research impact. We operate a Research Strategy Group composed of the HoD and research-group leaders. This group is now responsible for implementing the Knowledge Exchange and Impact strategy, tailored to address subject-specific needs.

3.2. We will diversify our portfolio of funders by actively supporting faculty at all stages in the funding process through the Department's Research Strategy Group. Engaging with funders who typically do not prioritise Mathematics will increase the number of projects where core research combines with applications and broadens our exposure to new contacts and impact-generating opportunities. This is a new initiative with some initial successful examples of funding from SEEDA (the former Regional Development Agency) and the British Council. Funders will also include business partners such as the engine optimisation company Ricardo, with whom we are working.

3.3. The Department benefits from a recently appointed (July 2013) School-level Industry Liaison team that is responsible for strengthening communication between academics, research funders, industry and non-academic partners. The role will include advice, guidance, facilitation and follow-up of collaborations. This activity is further supported by the appointment of a Research Impact Officer who is part of the central University research-support team and is responsible for developing and promulgating methods of embedding communication and translation into research across all departments.

3.4. The School has introduced a research-based impact peer-review and audit, starting in October 2013 – reviewing progress against 'Pathways-to-Impact' statements. Taking place annually, this will assess different impact-facilitating approaches and allow the formalisation and dissemination of best practice or the adjustment of strategy, as necessary.

3.5. We will involve potential end-users at the planning stages of research, to better align our activities with their needs. For existing consultancy projects – especially with the financial sector – we will actively explore ways of enhancing the direct penetration of cutting-edge mathematical research into service or consultancy provision.

3.6. We aim to strengthen and formalise outreach activity that emerges from our research. We have recently started an internal campaign of collecting research-based outreach talks (http://www.sussex.ac.uk/maths/outreach/talks). We are also in the process of strengthening and diversifying this portfolio with a series of fully planned outreach sessions for schools and colleges and by offering a clear set of activities from which schools can choose.

4. Relationship to case studies

The impact case studies in mathematics are:

- The mathematical modelling of meningococcal meningitis and implications for the control of meningitis in sub-Saharan Africa – the result of a strategic appointment.
- Increasing profit and improving performance through the integration of online digital-marketing data into bidding decisions – the result of a strategic appointment.
- The statistical analysis of heart-surgery data influences practice guidelines and choice of procedures.

Two of the Impact Case Studies (Kiss and Blyuss) are a direct result of strategic appointments (Section 2.3) that took into account their previous impact track records. Both have worked on mathematical modelling problems in epidemiology, with applications to livestock diseases, malaria and dengue. Kiss's work included problems in the digital industry, kick-started during meetings with the Research and Enterprise Office to match scientific expertise to real-life problems (Section 2.1).

The impact case study on heart-valve operations stems from the applied branches of Probability and Statistics (Section 2.2). Robinson has built up significant expertise in the rigorous statistical analysis of data from the outcome of heart operations – transplants, coronary-artery bypass and grafts and aortic-valve operations – and has active collaborations with physicians at hospitals in the UK and Germany.