Institution: University of Portsmouth

Unit of Assessment: 10 Mathematical Sciences

a. Context

Research in the Department of Mathematics is focussed on 2 groups: the Logistics & Operational Research Group (LORG) and the Nonlinear & Complex Systems Group (NCSG). Our impact so far has resulted from the LORG, with a focus on e*conomic impacts, impacts on public policy and services, impacts on health and, more recently, impacts on the environment.* Beneficiaries include:

- public-sector organisations, including hospitals, the MoD, and Port Authorities,
- commercial organisations for whom logistics is crucial to success, including multinationals (especially in defence-related industries), and local companies and consultancies.

b. Approach to impact

The work of the Logistics and Operational Research Group (LORG) is focussed on mathematical aspects of Operational Research (OR) with strengths including the theory underlying multi-objective optimisation, polynomial optimisation, and combinatorial optimisation. Fundamental research in these areas underpins contributions to impact spanning 20 years in the areas of healthcare, finance, logistics, and (recently) renewable energy. User groups in these areas face the challenges of managing complex flows of resources in accordance with conflicting objectives, performance targets, and constraints, in the face of changing environments and fluctuating levels of demand. They look to the work of the LORG for techniques to analyse and understand the complex inter-dependencies of their business. When applying the underlying theory, researchers work directly with users to build accurate bespoke models that enable them to plan robust operations across various potential scenarios and to restructure operations to optimise performance against multiple competing objectives. Early impact arose through a variety of channels, including supervisions of international PhD students established with industrial partners. Work in the areas of healthcare and finance provides the basis for the Impact Case Studies (REF3b: UOP10HEALTHCARE and UOP10INVESTMENT), and led to a movement towards combining mathematical advance with decision-maker liaison to produce both new OR theory and impact. These early successes bred the confidence to engage with users from a variety of sectors.

Reach and Significance: Current work by the LORG on Offshore Wind Energy has high national and European significance. The need to achieve targets of 20% of energy from renewable sources is imperative. Our joint 2OM project has excellent reach within the Channel Interreg zone (Southern UK and Northern France) and is supported by the following industrials: WPD, Areva, Alstrom, Dieppe Meca Energies, STX, Acte, Port of Dieppe, Port of Ramsgate, and Marine South East. These organisations are looking to the decision support tools, supply chain research, and life cycle research that are the deliverables of the 2OM project, to predict future trends and reduce their costs by achieving logistics efficiencies. **This potentially impacts on every UK household:** part of the cost of our energy bills goes to subsidise offshore wind power. The project also aims to provide free decision support tools to help SMEs engage in the offshore wind sector. In 2013, the group helped to found LEANWIND, a 10 million Euro EU FP7 project with 31 partners that will have significant reach on a European scale. Our role is to develop cost-minimisation and logistical-optimisation algorithms across all parts of the offshore wind supply chain. This will involve close liaisons, including funded visits, with the industrial partners which include: Acciona Infraestructuras, Maersk, Vasco Gallega Sociedad de Cartera, EDP Inovacao SA, Iberdrola Renovables Energia SA, Port of Ostend, B9 Energy O&M Ltd and the industry body EWEA (European Wind Energy Association).

Specific elements of our approach to impact and examples of the outcomes are as follows:

We assign "pump-priming" funds for staff travel to exploratory meetings and international project preparation events, *before* relationships are established (and where outcomes are necessarily uncertain). Since 2008, this strategy has led to many engagements with companies and public-sector bodies, securing the position of the LORG in large networks of stakeholder partnerships and Europe-wide grant consortia, including:

- LOGMAN (Logistics & Manufacturing Trends and Sustainable Transport), with AustriaTech, SYKE Finnish Environment Institute, and others, *in which we investigated logistics and manufacturing supply chains to determine their Carbon footprints.*
- SEABILLA (Sea Border surveillance) with Alenia Aeronautica, BAE System, Selex, Thales,

Telespazio, EADS Defence & Security, and others, *in which we developed multi-criteria algorithms for routing of UAVs over the Mediterranean Sea and English Channel.*
- 2OM (Offshore wind energy) with a consortium of universities led by University of Le Havre, with CRiTT, AREVA, Port of Ramsgate, Marine South East, and others.
- LEANWIND (Logistic Efficiencies And Naval architecture for Wind Installations with Novel Developments) with a network of 31 partners.

We publicise the expertise of the group, culminating in visits to companies to discuss our research. Relationships are founded via close liaison with our institutional Research & Innovation Services (RIS), by careful selection of placements for postgraduate students, and via the growing reputation of the group in specific areas. The group organises workshops with industrial practitioners, including DASIG (2011) and a Southern OR Group sponsored workshop for the Offshore Wind Sector (Portsmouth, 2013) and members of the group serve on committees of major conferences, including the MOPGP series (8th International conference, Portsmouth 2008).

We maintain existing relationships via regular meetings and work directly with partners to capitalise on these relationships for sources of future impact: Via a liaison with our Press Office, the publicity generated by the existing 2OM project led to initial contact with a current LEANWIND lead partner. We utilise the University's *Research & Innovation Services (RIS)* and *Institute of Industrial Research (IIR)* – which has an enviable record of industrial and commercial experience – as conduits to engage with users. This led to regular meetings between the LORG and non-academic partners to develop bespoke mathematical algorithms, decision support systems, and decision-making advice, including:

- CADRE (Congestion Avoidance Dynamic Routing Engine) funded by South East England Development Agency (SEEDA), with Comsine (lead partner), Hampshire County Council, Smartcom Software, Transport Research Laboratory (TRL), and ViaMichelin.
- IMAS (Cost-Effective Inventory Management in the Armed Services through Improved ABC Optimisation) funded by Centre for Defence Enterprise (MoD), with Polaris Consulting Ltd.
- EEMS (Embedded Energy Management System) funded through the Technology Strategy Board's Emerging Technologies - Energy Efficient Computing competition, with Xyratex.

We provide expertise to our colleagues, underpinning interdisciplinary research, by developing the underlying algorithms that can test their hypotheses and provide scientifically justifiable decision support: a recent (2013) Container Port project, with collaborators (Asteris and Collins) from the Department of Economics, has led to a meeting with officials from the UK Government Department for Transport to discuss the implications of our work.

We support newly-appointed staff to participate and interact fully with end-users on existing projects, and we support them to develop their own interactions with end-users: New staff have engaged with the existing renewable energy projects (2OM, LEANWIND) and we recently appointed a Faculty-funded Postdoctoral Research Assistant to work with a new staff member (Song) on a new project with Optrak, on packing and routing algorithms.

We forge links with potential user-groups via carefully selected MSc placements and via non-academic CPD activities: Based on our research expertise, we run an *MSc in Supportability Engineering* and associated *Continuing Professional Development (CPD)* courses with partner organisation *Logistics Support Analysts (LSA)* and we provide specialist CPD training to non-academics from the Ministry of Defence and many large defence contractors including BAE Systems, Rolls Royce, Babcock, Honeywell, General Dynamics, Thales, and Selex.

We carefully select and send MSc students to work in companies on placements, both with partners already established and those that are tentative, with 7 placements in 2010-2013, including at: Stork Blowmolding & Bottling Machinery Ltd. For "Cost effective maintenance decision support system for machine breakdown", Datum Electronics Ltd. for "Order promising decision support system", and STS Defence for "Simulation for STS Defence manufacturing processes". Placements are brokered with the aid of the Institute of Industrial Research. Projects involve regular meetings to collect primary data, present results of analysis, and discuss progress with the company. *These placements foster contacts that help to publicise the expertise of LORG and to maintain and strengthen links with other non-academic partners:* initiation of the Stork partnership (above) led to the host company becoming a direct partner with LORG in a successful Technology Strategy Board bid (brokered via the IIR). **The department hosts one-year visiting lecturerships and annual Summer Internships** (recently lecturers from China, and Interns from City University Hong Kong).

c. Strategy and plans

Experience of collaboration with research users directly informs our strategy. Past successes and clear demand for our expertise has led us to identify OR and Logistics as growth areas, with impact a central aspect. Current demand is particularly high in renewable energy. **In 2014-2020, we aim:**

- **To maintain and enhance our fundamental research expertise:** we aim to appoint 4 new, permanent, full-time, staff in 2014-2017, with at least 2 in OR. We will target investment to grow numbers of PhD students, Postdoctoral staff, and staff research sabbaticals.
- **To maintain and grow cross-disciplinary applications of OR,** in the University and beyond: Strategic investment (2012-2013) launched the ORIBUS Research Network to develop and apply OR to build innovative business processes. Further (HEIF) funds have been invested (2013) to set-up a cross-faculty Operational Research Centre. In 2014-2020, this virtual centre will bring together OR researchers spanning fundamental mathematics to business applications, to provide a focus for collaboration and impact-generation.
- **To capitalise on the expertise of newly-appointed staff** in the Nonlinear & Complex Systems Group, by supporting them to develop cross-faculty and external interdisciplinary contacts contributing to impact-generation. Recent appointments have been targeted at developing future collaborations with practitioners in Earth and Environmental Sciences (Burridge), Biological Chemistry (Banaji, Hennig), and Aerospace Engineering (Waters).
- **To maintain existing relationships and establish new ones** through our growing network of contacts, by funding regular meetings and engaging in tighter integration with RIS and IIR.
- **To expand involvement in the formation of research grant consortia,** via continued investment of "Pump-priming" funds for exploratory meetings with potential partners.
- **To foster collaborations, by allocating funds to support long-stay research visits** from staff at existing and prospective academic and non-academic partners.
- **To carefully select and send MSc students to work in companies on placements,** with partners already established and those that are tentative: With the IIR, we have now secured additional industrial placements for students on our MSc *Logistics and Supply Chain Management,* to assist considerably in the sustainability of our end-user interactions, including a "Future Food" Technology Strategy Board project with Stork and a project with the Crown Estate on Offshore Wind. Both will provide valuable future contacts for impact.
- **To monitor impact activity** via the OR Centre, and continuing quarterly reports by the departmental Research Coordinator to the Faculty Research & Innovation Committee.
- **To engage in industry Open Days and visits** from national and international companies, brokered by RIS & IIR: e.g., in 2013 staff gave presentations to IBM to explore collaboration.
- **To form further engagements through international PhD students:** We secured (2013) *a collaboration involving 8 companies in the lucrative Thai Silk Industry* (Kampo, Shinawatra, Classic Model, PNL, Watchara, Chattong, Chalieo, and Paothong) and the University of Technology Thanyaburi, for LORG to supervise a PhD student. The companies will host 2-3 visits each for primary data collection (interviews and factory tours) to develop OR models of inventory management (using existing suppliers as case studies) and analyse the constraints that restrict expansion of Thailand's silk industry, supporting the policy decisions of the Thai government. LORG members will engage fully to act as a catalyst to generate future impact.

d. Relationship to case studies

The case study *UOP10HEALTHCARE* (involving hospitals in the UK and China) began when the University of Portsmouth, recognised locally as a centre for OR expertise, was approached by the Portsmouth Hospitals NHS Trust as their Medical Assessment Unit (MAU) was a new concept in UK patient flow management at that time. This led to the development of in-depth OR models that in turn led to innovations in goal programming, sensitivity analysis, and mixed modelling methodologies. The case study *UOP10INVESTMENT* (investment portfolio selection) came about via dissemination of our work in journals and at conferences, together with the growing reputation of the group, reaching the attention of an Advisor to the Sovereign Wealth Fund of Kuwait and subsequent construction of a set of goal programmes for multi-objective portfolio optimisation.