

# Ten Years of NATCOR

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## 1 Introduction

The *National Taught Course Centre in Operational Research* (NATCOR) is one of six *Taught Course Centres* (TCCs) for doctoral students in the mathematical sciences, established in 2006 and initially funded by the *Engineering and Physical Sciences Research Council* (EPSRC). The original EPSRC pump-priming grant covered the period 2006–2011, and the follow-on grant covered 2011–2016. This report covers the main activities and developments during those ten years, and then concludes with some remarks about future prospects.

## 2 Origins

In 2004, the EPSRC, in conjunction with the Council for Mathematical Sciences, conducted a review of mathematics in the UK [1]. The EPSRC also conducted a separate review of *Operational Research* (OR), in conjunction with the Economic and Social Research Council and the UK OR Society [2]. Although the outcomes of both reviews were very positive, some concern was expressed about the relative lack of breadth and depth in doctoral studies in the UK compared to overseas (especially the US). In an attempt to address this, the EPSRC issued a call in early 2006 for pump-priming funding to aid the creation of several TCCs in the mathematical sciences.

The original NATCOR grant proposal to the EPSRC was submitted by a consortium of six groups (Department of Mathematical Sciences, Brunel; School of Mathematics, Cardiff; Department of Management Science, Lancaster; School of Computer Science, Nottingham; School of Mathematics, Southampton; Warwick Business School), with Lancaster taking the lead.

Key objectives expressed in the original proposal were:

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- “To establish a national centre to develop and deliver taught course provision in OR”;
- “To develop a syllabus at the level... of courses... at leading US institutions, yet with a technical focus which reflects UK research strengths”;
- “To make the above provision available to (an average of) 30 EPSRC-funded students annually and to up to 40 other UK-based students”;
- “To deliver (i) models for the development and delivery of provision and associated support functions, (ii) a committed team of collaborating providers, and (iii) adequate income streams to guarantee sustainability beyond the funding period”.

The application, which had the strong support of the UK OR Society and the Smith Institute for Industrial Mathematics, was successful. A grant of £241K was awarded, aimed at covering a five-year period from October 2006 to September 2011.

For reference, the other five TCCs created at the same time were:

- The *Academy for PhD Training in Statistics* (APTS)
- The *London Taught Course Centre for PhD Students in the Mathematical Sciences* (LTCC)
- The *Mathematics Access Grid for Instruction and Collaboration* (MAGIC)
- The *Scottish Mathematical Sciences Training Centre* (SMSTC)
- The “Oxford-led” Mathematical Sciences TCC.

### 3 The First Five Years (2006-2011)

#### 3.1 Preparation (2006-7)

The first year was devoted to preparatory work, including the establishment of management and administrative support structures, the building of a website (<http://www.natcor.ac.uk>), and the development of courses, including the appointment of course coordinators, discussion of potential contributors and development of draft syllabi.

It was decided that the main NATCOR administrator would be based in Lancaster. Oversight of NATCOR would be provided by:

- The *executive committee* (EC), chaired by the NATCOR director, with delegates from the members of the consortium.
- The *external advisory board*, chaired by the president of the Government OR Service, with delegates from both public and private sector, along with student representatives.

- The *international advisors*, initially consisting of Professors David Ryan (Auckland), Erwin Pesch (Siegen) and Pat Jacobs (NPS, Monterey).
- The *TCC committee*, consisting of the directors of the six TCCs and an EPSRC representative.

As for the courses themselves, it was decided to repeat every two years a suite of five week-long residential courses (similar in spirit to “Spring” and “Summer” Schools), in the following topics:

1. *Heuristics and Approximation Algorithms*;
2. *Convex Optimisation*;
3. *Combinatorial Optimisation*;
4. *Stochastic Modelling*;
5. *Simulation*.

This would mean running three courses one year and two the next. In the latter year, there would also be a conference, called the *Student Conference in Operational Research* (SCOR).

The choice of a residential course model in part reflected a belief in its effectiveness in fully engaging participants and in part stemmed from an aim to build a larger and more strongly connected community of PhD students in OR, to the longer term benefit of UK research in the subject. The choice of a two-year delivery cycle for the five courses was dictated by a practical concern to have a sufficiently large student population (i.e., of first and second year PhD students) to guarantee viability of each course.

### 3.2 First cycle (2008–09)

The five residential courses mentioned above were delivered for the first time. The first three were delivered in 2008 in Nottingham, Brunel and Southampton, respectively. The last two were delivered in 2009 at Lancaster and Warwick, respectively. Each course included lectures (from academics and guest speakers from industry), case studies and workshops.

The courses were attended by doctoral students from all over the UK, with the number of students ranging between 65 and 80. Including the universities which had a representation on the NATCOR EC, students from more than 30 UK universities attended one or more courses.

Student feedback was encouraging, with average scores of around 3.5 on a scale of 5. The students particularly appreciated the opportunities that NATCOR provides for networking with both academics and fellow students. Another highlight singled out was the case studies on the Stochastic Modelling and Combinatorial Optimisation courses.

One issue that quickly became apparent was the wide range of student backgrounds and abilities. Some complained that the courses were too easy, some that they were too difficult. The EC decided (with strong encouragement from the external advisory board) not to drop the level of mathematics. This has remained the position of the committee ever since.

The Lancaster course was immediately followed by the 1st SCOR. It ran smoothly and, again, students appreciated the opportunity to network.

### 3.3 Second cycle (2010–11)

At the start of this cycle, representatives of four more universities (Edinburgh, Kent, Salford and Strathclyde) were added to the EC. By this time, completion of the NATCOR suite of courses had become the norm for doctoral students specialising in OR in the UK. A small number of students from overseas universities also started attending the courses.

The five core residential courses mentioned in Subsection 3.1 were delivered for a second time, at the same venues. Attendance was a little higher than before. The EC was also pleased to see that student feedback was better than before, with average scores of around 4.2 on a scale of 5. This was partly due to improved accommodation and catering, but also due to some minor changes in course content. Two innovations that were particularly well received by the students were:

- The inclusion of more industrial case study material in all five courses.
- The inclusion of a talk by former student Cheryl Voake, entitled “Life after NATCOR”, in which she discussed the impact that NATCOR had had on her PhD and her subsequent career.

Voake also wrote a (highly positive) article for *MSOR Connections* [4].

The 2nd SCOR was held in 2010, immediately after the Heuristics course. In addition, following feedback from academics and students, two *one-day* courses were held:

- *Data Envelopment Analysis* (DEA);
- *System Dynamics* (SD).

The DEA course ran in 2010, immediately after the Convex Optimization course. It was reasonably well attended (16 students), and the student feedback was very positive. The SD course ran in 2011, immediately after the Simulation course. Attendance was good (26 students) and feedback was again very positive.

In August 2010, the EPSRC completed a review of all six mathematical sciences TCCs [3]. The two residential TCCs (NATCOR and APTS) were particularly commended for management, value for money, and value to students.

## 4 The Next Five Years (2011-2016)

### 4.1 The second EPSRC grant (2011)

In 2011, the EPSRC issued a call for applications for follow-on funding for the Mathematical Sciences TCCs. The NATCOR consortium (now involving ten universities) submitted an application, which was again successful. The grant covered another five-year period (2011-2016), but involved less money than before (£150K as opposed to £241K). Moreover, the EPSRC advised that no further funding for TCCs would be made available in future, i.e., that the TCCs would have to become self-sustaining in the long term.

Immediately following the awarding of the 2nd grant, Professor Kevin Glazebrook handed over the directorship of NATCOR to his colleague, Professor Adam Letchford. Also, representatives of two more universities (Loughborough and Oxford) were added to the EC.

### 4.2 Two initiatives (2011-12)

The first thing that the new director did was to implement two promises made in the second grant application: the establishment of a more rigorous assessment process, and a comprehensive review of course content.

The new assessment regime was agreed in November 2011. Towards the end of each NATCOR course, all students would be required to undergo a (relatively light) summative assessment exercise. A mark or grade would then be computed for each student, and departments could then request to see the assignment, marking scheme and/or results for their students. Departments could also request to be sent a slightly more demanding and/or time-consuming summative assessment exercise, along with its marking scheme. The exact nature of the assessment(s) were to be decided by individual course providers.

The content review was started in November 2011 and completed in September 2012. Two sub-committees were formed: Professor Jeff Griffiths (Cardiff) led the review of the Stochastic Modelling and Simulation courses, and Dr Paresh Date (Brunel) led the review of the other three courses. Meanwhile, the director contacted the EC, external advisory board, international advisors, and supervisors of NATCOR alumni, for comments and suggestions. In addition, the NATCOR administrator conducted a survey of career destinations of alumni.

The main conclusion from the exercise was that the existing structure, with five one-week courses over a two-year cycle, together with occasional one-day courses on specialist subjects, was working very well. We did however receive a few suggestions for potential additional courses. Topics suggested included the Analytic Hierarchy Process, Business Analytics/Data Mining, Forecasting/Time Series Analysis, Game Theory, and various advanced optimisation techniques.

### 4.3 Third cycle (2012–13)

All of the courses in the second cycle (i.e., the five core courses and the two one-day workshops mentioned in Subsection 3.3) were repeated in the third cycle. There were however some significant changes, made in response to the content review mentioned above:

- Improved software was made available in the *Heuristics* course. Instead of using spreadsheets, students could use “HeuristicLab”, developed by the Heuristic and Evolutionary Algorithms Laboratory in Hagenberg, Austria.
- In an attempt to address the range of student backgrounds and needs, the *Convex Optimisation* course started offering two parallel streams, one emphasizing theory, the other applications. (Students spent the first two days together, and then decided which stream to follow.)
- In the *Combinatorial Optimisation* course, the material on classical network optimisation problems was shortened, to make room for a lecture on Bender’s decomposition and its applications.
- A rather different way of addressing the mixed-ability issue was explored in the *Stochastic Modelling* course: Professor John Quigley (Strathclyde) kindly provided a series of short on-line videos to help students get up to speed on various topics.
- In the *Simulation* course, the advanced statistical content was reduced a little, to allow more time for students to conduct model building. (The course also moved from Warwick to Loughborough.)

These changes all seemed to be well received. Indeed, attendance remained buoyant and feedback remained positive.

Another key development in this period is that the EC increased the degree to which it promoted NATCOR amongst academics and students from disciplines other than OR. This was done not only by contacting specific individuals, but also by posting regular announcements to popular subject-specific mailing lists (such as `dmanet`, `opt-net` and `allstat`). The effects were soon noticed: we started to receive students from very diverse backgrounds, including not only OR but also mathematics, statistics, applied probability, computer science, engineering and even business studies.

One other minor development is that the oversight of SCOR was handed over from NATCOR to the UK OR Society. The ultimate goal was to make SCOR self-sustaining. The 3rd SCOR was held in April 2012 in Nottingham and was well attended.

#### 4.4 Fourth cycle (2014–15)

To a large extent, the fourth cycle was simply a repeat of the third cycle. There were however two new developments:

- The European Association of OR Societies, EURO, made a statement concerning the desirability of more doctoral-level training courses in OR across Europe. After some discussion with the NATCOR director, EURO kindly agreed to fund around ten “bursaries” each year. Each bursary pays for one European student to attend a week-long NATCOR course, including travel and subsistence. EURO holds a competition each year for the bursaries.
- The *Convex Optimisation* course moved from Brunel to Edinburgh. The new course coordinator in Edinburgh, Dr Julian Hall, combined the NATCOR course with a series of talks by an eminent guest speaker, Professor Stephen Boyd from Stanford. This initiative led to increased demand, with over 80 students attending the course.

As a result of both of these initiatives, we started seeing an increase in the number of students from mainland Europe. We also began to allow post-docs and junior lecturers to attend our courses, subject to the agreement of the director.

Feedback from the courses remained very good, with average scores of around 4.3 out of 5.

#### 4.5 Start of fifth cycle (2016)

As usual, we ran the following two courses in 2016:

- *Heuristics and Approximation Algorithms* (April 2016, Nottingham);
- *Convex Optimisation* (June 2016, Edinburgh).

On the other hand, the EC decided not to hold the DEA workshop for a fourth time in 2016. In its place, as an experiment, NATCOR provided two new “half-week” courses:

- *Systems Dynamics* (May 2016, Warwick);
- *Forecasting and Predictive Analytics* (September 2016, Lancaster).

The new Lancaster course was a great success, with high attendance (41 students) and very positive feedback (average scores above 4.0 on everything except accommodation). The experience with the Warwick course was more mixed, with only 18 students attending and average scores around 3.5.

It is likely that we will hold both of the new courses again in 2018, though possibly with some changes, both to the content and the accommodation.

## 5 Summary and Prospects

On balance, it is fair to say that NATCOR has been a success, with buoyant attendance and positive student feedback, together with the endorsement of the EPSRC, the UK OR Society, the Smith Institute, EURO, eminent academics and the external advisory board. While the names of the five core NATCOR courses have remained the same, the courses themselves have evolved over time in response to feedback from the EPSRC, the Advisory Board, the lecturers, the students and their supervisors. Moreover, the new half-week course in Forecasting and Predictive Analytics proved to be very popular. We therefore strongly believe that NATCOR remains entirely fit for purpose and extremely relevant to doctoral training in OR and related areas.

The key challenge faced by NATCOR (and the other TCCs), now that EPSRC funding has ended, is to become financially self-sustaining. Over the past ten years, NATCOR has accrued a very healthy surplus of around £100K, but it must be borne in mind that this has to cover not only the administrator's future salary, but also future expenses for the EC and Advisory Board. To address this issue, NATCOR has recently increased its registration and accommodation fees. The EC is currently discussing other possible ways of addressing the issue, which may include strategies for increasing demand and/or attracting sponsorship from relevant sources.

## References

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