



The Royal Academy
of Engineering

The Assessment of Research Quality in Engineering Disciplines

A recommendation to the
Higher Education Funding Council for England
for adoption in the
Research Assessment Exercise 2008





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Index

1. Background	3
2. Proposed Methodology	4
3. Appropriate Evidence for Assessment	7
4. Conclusions	10
Annex 1	11
Annex 2	12

1. Background

Engineering research involves the acquisition of new knowledge and its application (together with existing knowledge) in creating novel artefacts - devices, structures, procedures and processes. Engineering depends on technology transfer and hence the evaluation of the quality of academic engineering research requires, *inter alia*, consideration of the interface between original thought and its application. Engineering research is becoming more complex in that it is increasingly inter- and multi-disciplinary. Innovative engineering is often the output of a team of people each with skills and vision in disparate areas of engineering and science. This in turn brings added complexity to the assessment of individual excellence when the output is team dependent.

It is recommended that evidence of performance in both aspects of engineering research (knowledge acquisition and its application) should be used to evaluate research performed by University departments. The determination of the quality of the first element, referred to here *Mode 1* research, is adequately addressed by the well-established procedures adopted and refined by the Higher Education Funding Councils in earlier Research Assessment Exercises. The use of peer review for *Mode 1* research is fully supported, but there is a need for better and more appropriate assessment of *Mode 2* research, the application element. It is the *combination* of these two elements that differentiates engineering (and applied) research from purely knowledge-seeking scientific research. There is a need to recognise the significant impact on society through enhanced wealth-creation and quality of life which excellent applied or *Mode 2* research brings. Engineering research imposes an obligation on departments to collaborate with the user communities (e.g. industry, health, defence), and hence the extent and the quality of these relationships and the corresponding research outputs should be used in the assessment.

The requirement is for a methodology that reveals the quality and value of research and its impact on the "outside world". This must ultimately be tied to specific evidence of detailed work and its impact. The following recommendation, prepared by a Working Group of Royal Academy of Engineering Fellows drawn from academia and industry (Annex 2), seeks to secure a uniform assessment of research quality and esteem across all engineering disciplines but it is believed to be applicable to applied research in non-engineering disciplines. The guidelines and methodology proposed have been developed from the approach outlined in The Academy's report "Measuring Excellence in Engineering Research" (January 2000), the guidelines used in the Electrical Engineering assessment panels in the 1997 and 2001 exercises, and the outline given in RAE 2008 paper "Initial Decisions by the UK Funding Bodies" (February 2004). The former document identified the five characteristics of Research Excellence as *Mode 1* and *Mode 2* Research, Strategy, Scholarship and, Vitality and Sustainability. The latter document proposes that Assessment Panels should produce a "quality profile" for each Unit of Assessment (which for the purposes of this document essentially refers to a university department) and that the process should assess research outputs rather than individual researchers. "Quality" is to be distinguished by one of five "star" ratings (0* to 4*) and the overall departmental profile is to be quoted to the nearest 5%, with an additional statement identifying the percentage of staff submitted for assessment. This is a finer gradation than in previous RAE exercises and demands considerable thought to ensure that the results will be credible whilst avoiding excessive burdens on both departments and panels.

This paper brings together the principles of The Royal Academy of Engineering publication with the requirements of the HEFCE publication. The objectives of this paper are therefore to:

- Propose a methodology to enable a research assessment quality profile to be constructed for an engineering department;
- Ensure that the assessed qualities of both *Mode 1* and *Mode 2* research contribute to the profile;
- Outline the evidence required for the research assessment, whilst minimising the load imposed on institutions by the new "profile" requirement.

2. Proposed Methodology

2.1 Overall Approach

The methodology which follows is not uniquely applicable to the assessment of research in engineering disciplines but is relevant to all applied research. The assessment methodology proposed should be considered as a guideline, open for development before application, rather than be seen as prescriptive.

In arriving at a methodology for assessing both Mode 1 and Mode 2 research, a number of ways of measuring each mode and then combining the two results were considered. However, this led to an overlap in data analysis as, in practice, rarely does either Mode exist in isolation. It is true nevertheless that Mode 1 research is normally performed by individuals whilst Mode 2 research is more likely to be the result of the same individuals working as part of a group. In line with the requirements established by HEFCE, the following proposed methodology does not lead to an overall assessment of individuals. Instead, an initial departmental profile will be achieved by the moderated summation of the various components originating from individual, group and departmental outputs. (The groups would normally be part of a single Engineering Department but the methodology could be applied across departmental boundaries as might be necessary for interdisciplinary research.)

Individual contribution

This concerns the assessment of published research by individuals on the basis of their *publications* (Section 3.1 below), for which there exist well established methods within previous RAE for the assessment of its quality.

Group contribution

The next important indicator of the quality is the esteem (Section 3.2 below) in which the research group is held. This may be assessed by considering the recognition of the individuals by their peers and is manifested in national or international honours, awards and invitations to participate in activities drawing on the individual's skills and achievements.

High quality departmental and group outputs are often closely aligned with a high level of impact in the community of interest, and manifested for example by enhancements of wealth creation and quality of life. To achieve success in this type of research, significant relationships have to exist between the parties involved. This in turn is reflected in the level of *funding* (Section 3.3 below) and its duration. However, the true value of research in the longer term is only realised when it has measurable *impact* (Section 3.4 below) on the community it serves as indicated by embodiment in a product, process or standard for example. A further indicator of the quality of the research output is therefore its verifiable practical impact, methodologies for which are proposed later.

Departmental contribution

In addition to the above, the Head of Department will be required to make a submission related to Strategy, Scholarship and Vitality & Sustainability as outlined in Section 3.5. This information will be used to underpin or moderate as appropriate the *Initial* departmental profile resulting from the individual and group inputs to give the *Final* departmental profile.

It therefore follows that information should be supplied by each HEFCE identified Unit of Assessment addressing the individual, the research group and the department.

2.2 The Assessment Process

The fundamental requirement is for each declared researcher to be associated with one and only one research group per initial star rating assessment and to submit four examples of research output under the "Publications" category. (Where an individual works in more than one group this should be highlighted in the departmental submission). For each publication and for each of the research categories "Esteem", "Funding" and "Impact", the assessment panel will award a rating of "International" (I), "National" (N) or "Unrated" (U). The assessment of submissions under the "Esteem", "Funding" and "Impact" categories will result in a single rating per category, and this will be considered together with the ratings allocated to the publications of all members of the research group.

The ratings for each single "Publication" together with the best two of the remaining three ratings are then combined to yield an initial star rating using Table 1 below:

Table 1

Rating	4*	3*	3*	2*	2*	1*	1*
Publications	I	I	N	N	U	N	U
Other two of three	I,N	2N	2I	2N	I,N	N,U	2N

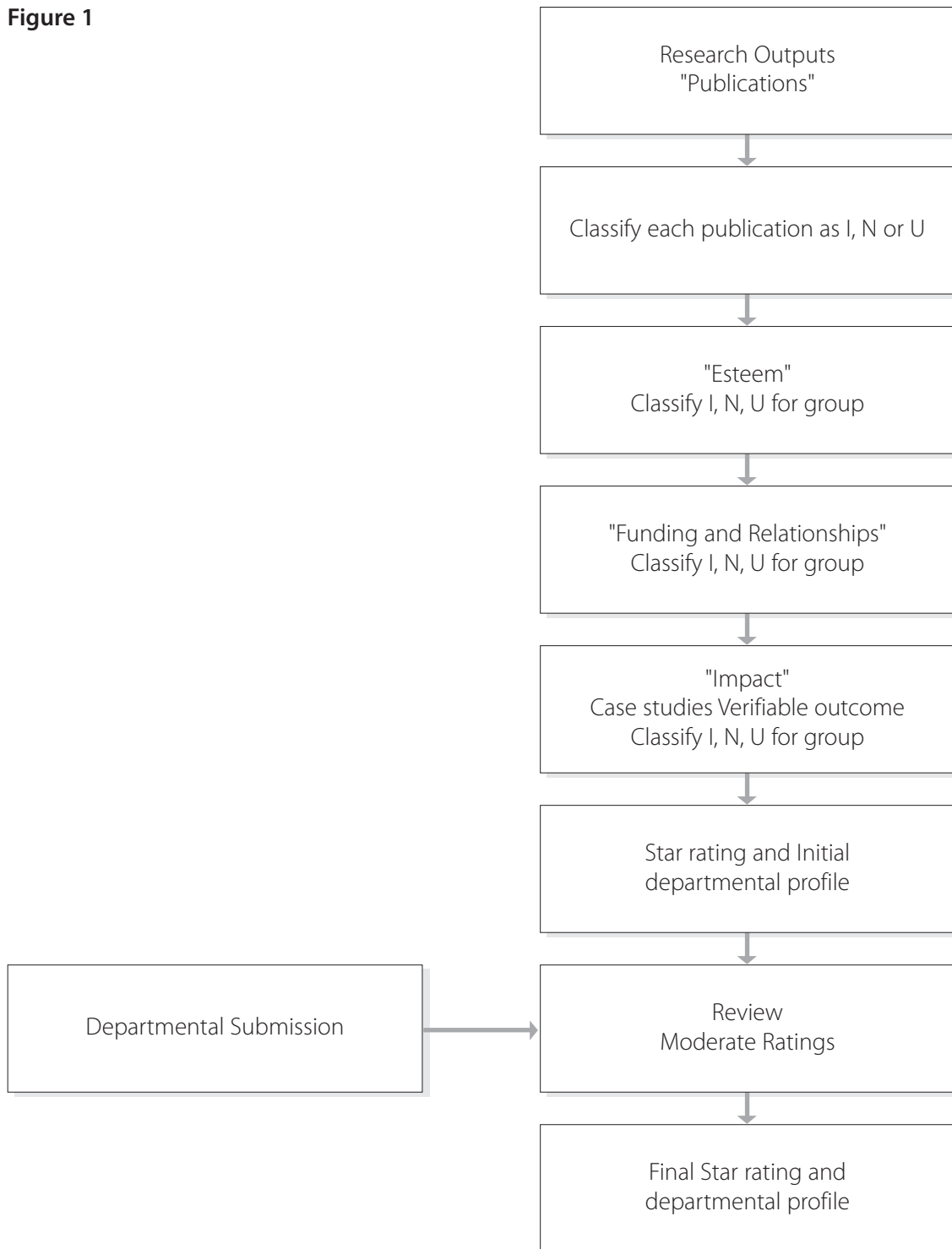
Suggested combinations to yield particular star ratings per publication

The resultant outcome is a distribution of "number of publications" vs star ratings for the research group concerned. The same process is followed for other groups in the department and the results added together to give a profile which can be expressed in percentage terms. This then results in the *Initial* departmental profile.

When considering how best to combine the four ratings, the Working Group rejected averaging, as it would tend to give greater weight to rewarding mediocrity than excellence. A premise of the chosen methodology is that not all categories need achieve the highest level of excellence (I) to secure a 4*. Also, discarding the lowest category for a group gives flexibility in the weighting given to Mode 1 and Mode 2 research. It is recognised that the criteria for a particular star rating will be defined by others but Table 1 is put forward as a starting point for discussion.

The resulting *Initial* departmental profile can then be moderated, as appropriate, according to the assessment of the overall departmental submission, leading ultimately to the *Final* profile for the department. Changes between the initial and final profiles will need to be justified by the Assessment Panel. This process is illustrated in the flowchart shown in Figure 1 (summarised in Annex 1)

Figure 1



3. Appropriate Evidence for Assessment

This section offers guidance to the Assessment Panels and gives examples of the type of material which might be required to provide evidence of research quality in an engineering department.

3.1 Publications

It is proposed that four items per researcher are submitted as in the previous Research Assessment Exercise.

To assess the quality of academic or professional journal papers and conference contributions, it is recommended that the Assessment Panel judges the editorial and refereeing standard of the journal or conference in which the research is published. Generally those submitted items that are of international standing and have undergone a rigorous refereeing and editorial process should be regarded as being of high quality.

It is recommended that papers given at high-level international conferences can be given equal weight to comparable journal contributions, recognising that the style of publishing in different areas leads to different citation indices.

Evidence submitted can comprise any of the following:

- i. Refereed learned journal paper (including internet publications)
- ii. Refereed conference contribution
- iii. Authored/Edited/Chapter in book
- iv. Software
- v. Patent (as a publication)

3.2 Esteem

Attention should be drawn to instances of external recognition that indicate the standing of the group (but based on its individual members). Examples of such evidence are:

- i. Plenary addresses / keynote papers at major conferences, lecture tours, invited review papers
- ii. Prize-winning publications
- iii. Patents awarded (total number)
- iv. Honours and awards
- v. Editorships and participation in editorial boards or conference organisation
- vi. Participation in advisory, review, funding, standards or planning bodies
- vii. Prestigious Fellowships (e.g. Royal Society, Royal Academy of Engineering) or research fellowships
- viii. Learned Society involvement
- ix. Consultancies
- x. Leadership of consortia and management of large projects

3.3 Research Income and Relationships

The names and size of companies contributing a significant proportion of funding should be provided, together with evidence of the nature and timescale of the relationship (i.e. short term contract or long term partnership). Consideration will need to be given to the weighting and value of esteem placed on funding which comes from industrial sources and from Research Councils / other public streams, taking into account the nature of the research and the funding source.

External income acquired by each research group, together with the duration of the period of funding, should be used as an indicator of the standing of its research. Submitted information should categorise the

research income for each group according to the source:

- i Government funded, including Europe
- ii Charities (not for profit organisations)
- iii Industrial and other commercial income

3.4 Impact

The assessment of the impact of the research is an important addition to the assessment process.

This can be performed, for example, by identifying a selected sub-set of activities which have led to quantifiable impact described in the form of a "case study". These case studies would be allocated to groups, where appropriate, and would define the benefit in terms of its quantified impact. The case studies – which can include spin-off companies - should cover all types of practical output i.e. patents awarded, products, designs standards, design rules, technology or spin-offs.

For the first twenty "full time equivalent" (Category A) researchers, up to four examples should be presented and for a department with more than twenty such researchers, one additional report per ten further Category A researchers should be submitted. The use of a pro forma should be considered to ensure integrity in the material provided.

The case study should be endorsed by the Chief Executive of the participating organisation or, in larger companies, the Technical Director. The panels should reserve the right to make direct contact with this representative to validate the statements made.

For spin-off companies, a list should be provided of those companies that have either been launched or continued to develop during the period under review together with any impending ones. The size of the company, its growth rate and profitability may be presented as evidence. The submission should link this to the research contribution of the corresponding group. Similarly, the submission should detail any licence income, the nature of the licence and the impact that the product or process has had. In cases where this information no longer links to any proposed group, it may be submitted as part of the departmental assessment, but will be assessed in this part of the process. Supporting evidence should be submitted with detail of the delivered benefits of applied research or any other activities which have led to a measurable impact.

3.5 Department

The Head of Department should submit the standard data, the age profile of the researchers and a statement of the departmental strategy. The submission affords the Head of the Department the opportunity to state the strategy and to demonstrate the vitality and sustainability of the department. It also enables statements to be made on achievements not included in the individual or group submissions, but which exemplify collaboration across organisational boundaries and actions taken to sustain research excellence.

The submission could also review the department's encouragement of Scholarship. One aspect of scholarship in engineering is awareness of the "state-of-the-art" in applications, not simply confined to the specialisms of individual research groups, but more broadly in terms of all the engineering knowledge required to develop successful artefacts. A proxy for this could be a demonstration of lively interdisciplinary and inter-group activities.

The Assessment of Research Quality in Engineering Disciplines

The Assessment Panel should consider:

- i Strategic achievements by the department since the previous RAE
- ii The strategic vision of the department for Mode 1 and Mode 2 research
- iii How creativity is encouraged and maintained
- iv How funding is balanced between Modes 1 and 2 – justifying what is done and not simply quoting figures

The Head of Department should submit data on the number of trained researchers and PhD students, research staff with temporary and permanent positions, technical and administrative support staff. Total departmental income and expenditure should be shown including licence income and the research income presented under section 3.3.

4. Conclusions

1. The methodology derived by the group of Fellows drawn from industry and academia is recommended to HEFCE for use in the 2008 Research Assessment Exercise as the foundation for measuring research quality in engineering disciplines. The recommended methodology whilst directed at engineering disciplines is believed to be equally relevant to any applied research as it recognises both knowledge acquisition and its application.
2. The existing methodology, as applied in previous Research Assessment Exercises, is effective at recognising excellence in Mode 1 research. However, it was felt that there was a need for a sharper focus on Mode 2 research together with recognition of sustained performance, sustainability and vitality of the research group. The proposed methodology affords the opportunity to recognise and reward excellence in both Mode 1 and Mode 2 research without giving undue importance to either element or introducing additional impediments for those engaged in applied research.
3. The recommended methodology is based on the assessment of: Publications; and two out of the three categories of Esteem; Research Income and Relationships; and Impact. The advantage of such a process is that whilst Mode 1 (represented by Publications) accounts for one third of the assessment, Mode 2 must also constitute at least one third. An individual active in applied research cannot secure the highest rating without achieving excellence in those areas particular to Mode 2 research.
4. An especially important consideration is the demonstrable and quantifiable impact of the research output. This may be presented as a case study covering all types of practical output and include a statement on the impact the product or process has had.
5. An important element of the methodology, which features in moderating the initial outlet profile to yield the final departmental profile, is the statement provided by the Head of Department. This affords an opportunity for the strategy and vitality and sustainability of the department to be highlighted. Also, it permits statements to be made on achievements and collaborations not included elsewhere but which may form an important part of the department's research activity.

Annex 1

Summary of the Assessment process

Step 1: Research output "Publications"

Four research "Publications" should be submitted from each researcher declared for assessment. Each of these will be assessed as either "International", "National" or "Unrated" (I, N or U).

Step 2: Esteem

Determination of "Esteem", (I, N or U), of identified groups of researchers and allocation of the rating to each publication associated with the group.

Step 3: Research Income and Relationships

Determination of "Research Income and Relationships", (I, N or U), of identified groups of researchers and allocation of the rating to each publication associated with the group.

Step 4: Impact

Determination of "Impact", (I, N or U), of identified groups of researchers and allocation of rating to each publication associated with the group, considering also the verifiable impact.

Step 5: Allocation of Star rating

Combine the ratings (I, N, U) for publications and the best two of the three group assessment categories using Table 1 to yield a star rating.

Step 6: *Initial* departmental profile

Combine all group ratings to yield an *initial* departmental profile based on the number of "Publications" with each rating, rounding to the nearest 5%.

Step 7: Departmental assessment

The statement provided by the Head of Department, together with data on the numbers of researchers, their age profile, evidence of strategy, vitality and sustainability to be assessed.

Step 8: Determination of *Final* departmental profile

The evaluation of the statement by the Head of Department to be compared with the *Initial* profile and anomalies inspected and revisions made to the profile, with any changes justified, to yield the *Final* departmental profile.

Annex 2

Working Group Members

Chairman: Mr Philip Ruffles CBE RDI FREng FRS

Members: Dr Stephen Bold FREng
Professor David Clarke FREng FRS
Dr Richard Dolby OBE FREng
Professor Rodney Eatock Taylor FREng
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Mr Peter Saraga OBE FREng

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Mrs Julia Christie, Assistant Manager, Engineering Policy

The Royal Academy of Engineering

The Royal Academy of Engineering - Britain's national academy for engineering - brings together the country's most eminent engineers from all disciplines to promote excellence in the science, art and practice of engineering. Our strategic priorities are to enhance the UK's engineering capabilities; to celebrate excellence and inspire the next generation; and to lead debate by guiding informed thinking and influencing public policy.

Strategic Priorities

The Academy's work programmes are driven by three strategic priorities, each of which provides a key contribution to a strong and vibrant engineering sector and to the health and wealth of society.

Enhancing national capabilities

As a priority, we encourage, support and facilitate links between academia and industry. Through targeted national and international programmes, we enhance – and reflect abroad – the UK's performance in the application of science, technology transfer, and the promotion and exploitation of innovation. We support high quality engineering research, encourage an interdisciplinary ethos, facilitate international exchange and provide a means of determining and disseminating best practice. In particular, our activities focus on complex and multidisciplinary areas of rapid development.

Recognising excellence and inspiring the next generation

Excellence breeds excellence. We celebrate engineering excellence and use it to inspire, support and challenge tomorrow's engineering leaders. We focus our initiatives to develop excellence and, through creative and collaborative activity, we demonstrate to the young, and those who influence them, the relevance of engineering to society.

Leading debate

Using the leadership and expertise of our Fellowship, we guide informed thinking; influence public policy making; provide a forum for the mutual exchange of ideas; and pursue effective engagement with society on matters within our competence. The Academy advocates progressive, forward-looking solutions based on impartial advice and quality foundations, and works to enhance appreciation of the positive role of engineering and its contribution to the economic strength of the nation.