“Lucian Blaga” University of Sibiu

Faculty of Engineering

Doctoral Dissertation

Research Schools for Increasing the Quality of Scientific Research in Engineering

Summary

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Key words: research assessment, ranking of universities, engineering, research school, benchmarking, multicriterial analysis, QFD

ABSTRACT

Evaluation of universities has become in the last decade a current practice in academia, with an important impact on internal organizational or financing decisions. Internal assessment is an essential component in the process of quality assurance and external evaluation and contributes to the recognition of the value of the university as a whole.

Indicators for academic research can be grouped in three groups, which quantify:

a) Productivity (*output*) measured in terms of quantity (e.g. number of scientific articles)

b) Performance (*outcome*), measured in terms of quality achievements (eg contributions to knowledge development, citations, awards, honors)

c) Impact (*impact*): effects on society, culture, environment, economy.

If productivity and performance benefit of a comprehensive set of indicators (starting with the bibliometric ones) the impact component is virtually absent. Unfortunately, the impact is the foundation of public perception, including of the policy makers, on the usefulness of the research.

The generic term "engineering research" requires consistent approaches in research, development and innovation, and it includes creative activities both in the theoretical and the practical area. Royal Academy of Engineering (RAE) in the UK aims to distill the opinions and solutions proposed by the experts from academia and industry in order to identify and quantify excellence in engineering research. Engineering research is perceived as critical from the perspective that it makes the necessary bridge between basic research in the traditional branches of science, and exploitation of the scientific discovery through technology, for creating wealth and enhance quality of life. Therefore, the qualitative and quantitative evaluation methodologies of the engineering research must take into account these particularities and encourage getting results with socio-economic impact.

The Aim of the Thesis

The topics addressed in this thesis is directly motivated by current trends at international and national level towards increasing competitiveness and enhancing the reputation of universities, given the increased competition, the decreased or limitation of (public) funding for research, respectively the growing difficulties in motivating and training human capital.

The aim of this thesis is to identify a model of self-organization of research teams for maximizing the performance by ensuring sustainability, relevance and impact of research approaches. The concept of "*research school*", approached in the thesis, combines naturally the scientific production and technological development component with the human resources development and training one. In particular, we aim to identify and analyze the main characteristics of research schools in engineering, in order to shape the evaluation methodologies to boost performance without diverting research efforts relevant for solving acute problems arising from the economic environment or the specific needs of the changing society.

Specific Objectives

The specific objectives of the thesis follow the necessary steps for developing the "research school" model proposed in the paper, namely:

- Critical analysis of national research systems, considered relevant in terms of performance, for highlighting the institutional organization for optimal resource management and scientific research, corelated with research policies specific for each country analyzed. In particular it is analised, the research, development and innovation system in Romania, with a focus on its dynamics in the past decade.
- Critical analysis of different types of assessment methodologies of scientific research in universities, used or under development at international level, with a focus on correlating the aim of evaluation and potential beneficiaries with the set of specific criteria and indicators.
- Identification of the specific features of engineering research in engineering sciences, in terms of correlating the objectives typical for engineering research approaches with criteria and indicators used for evaluating the results of these approaches. Opportunity analysis of using quasi-universal quantitative indicators, versus combinations of quantitative and qualitative indicators specific for the engineering sciences domains.
- Definition and defending a self-organization structure of research in universities, called "research school", which combines scientific research and technological development with training and development of human resources for research through doctoral programs.
- Development of a methodology for evaluating the activities and performances for research school, adapted to the specific research in engineering.

- Use of such an evaluation methodology for identifying the directions for improving the performance of the research schools, respectively for classification and ranking of such structures.

Research Methodology

Starting from the analysis of national research organization systems, respectively the analysis of methodologies for evaluating the research performance of different entities within these systems, a questionnaire has been developed for identifying the perception of the relevant academic community in the technical universities of Romania on the usefulness and relevance of different criteria and related indicators.

Using this questionnaire a social research is made on a representative sample of the academic community in Romanian technical universities, with relevant experience for management and evaluation of scientific research, respectively for the training of future researchers through doctoral and post-doctoral programs. Statistical processing of the social research results is made with the methodology implemented in SPSS16 program (Statistical Package for Social Sciences). Also, the multicriterial programming is applied as a methodological option for ranking the research schools. The methodology thus established is piloted within a case study for identifying the advantages and potential necessary corrections.

In the same time, it is applied the Quality Function Deployment (QFD) method for identifying the quality characteristics, on which the schools of engineering research should focus for improving their performance. In the associated case study are analyzed the performance of a research school by comparing it with two other direct competing research schools.

Completing the steps above is, in our opinion, mandatory for the development of evaluation methodologies relevant for different segments of the academic community, on the one hand, and able to be understood and accepted by subjects undergoing evaluation process, on the other hand.

Structure of the Thesis

Chapter 1, for introducing and formulating the problem, includes an overview of the latest developments in universities evaluation methodologies, taking into consideration a wide range of existing approaches.

Chapter 2 presents in a consistent manner research systems in different countries (Germany, Poland, Finland, Japan), and is completed by analysing the strengths and weaknesses,

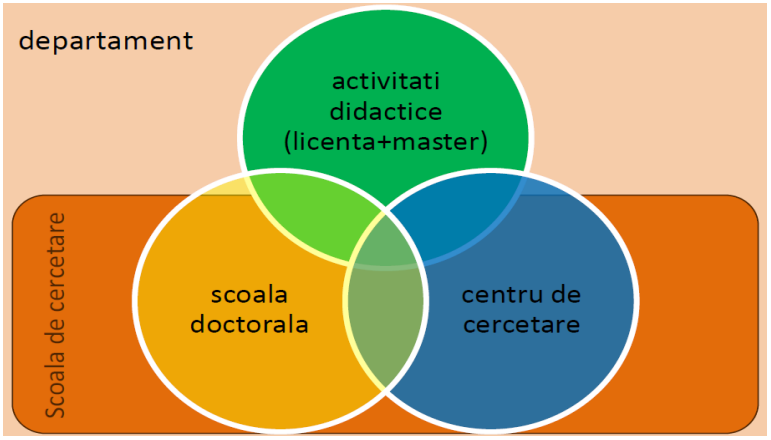
respectively the opportunities and threats (SWOT analysis). At the end of the chapter is presented the research system in Romania, and associated SWOT analysis.

In *Chapter 3* is addressed the issue of evaluating the quality of scientific research, with specific emphasis on academics. A special attention is given the correlation between the aim of evaluation and the set of criteria/indicators used. The main problem is that evaluation process tends to significantly disrupt activity of the evaluated subject, often distorting, with undesirable effects, the real and legitimate purpose of research approaches. These can become in extremis a collection of efforts directed towards the maximization of some indicators, if these indicators are purely quantitative, and restrict the direct access to resources, or the evolution in scientific and academic career. It is presented the evaluation methodology developed in Romania and used for correction of institutional funding for universities, respectively the methodology for certifying the RDI entities for access to public funds for research.

Chapter 4 customizes the general approaches of evaluating research to academic research in engineering sciences. Thus, it becomes clear that for research efforts intrinsically oriented towards practical applications, an essential component reffers to the selection of research topics and potential beneficiaries. To this qualitative component are added quantitative assessment elements, which serve to appraising performance made towards the goal achievement. Performance approached separately and strictly appreciated quantitatively, can be a convenient option in terms of strict application of a methodology, but can cause severe distortions by using the resources for maximizing the size of some indicators, with dilution or complete neglect of the real purpose of social, economic and life quality improvement impact.

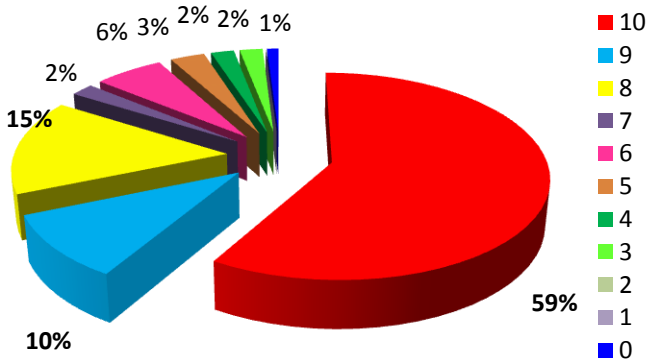
Also, there are presented the approaches of RAE (Royal Academy of Engineering, UK) and ENEC (National Research Evaluation Exercise, Romania) regarding the evaluation of research in engineering, and a comparative analysis of the two methodologies is provided.

In Chapter 5 is introduced and argumented the concept of "research school" as a model of self-organization of human resources and research infrastructure in universities, as follows:

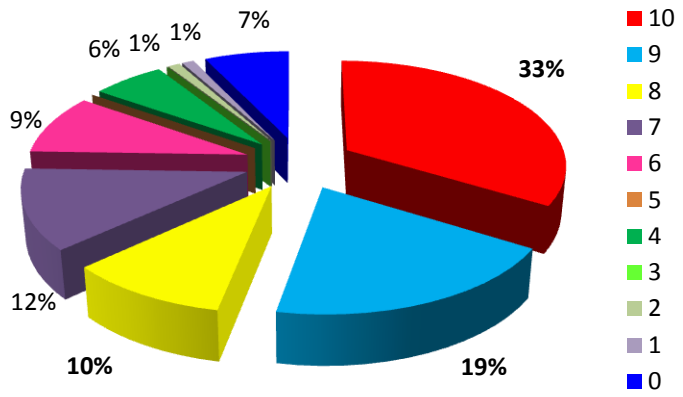


Thus, there are analysed the advantages of immersing PhD students in the research environment offered by research groups having a well-defined identity regarding the portfolio of addressed issues and expertise, both from the point of view of maximizing the performance in PhD learning, and from the point of view of the research group sustainability. Allocation and/or raising necessary resources to carry out research approaches in such research schools are critical issues, also addressed in this chapter.

In *Chapter 6* is proposed an evaluation methodology for the performance of research schools in engineering sciences, using a sociological research to establish the set of criteria and indicators. The results were processed with SPSS 16 and the representations were made in a pie-type histogram. Foe exemple: the respondes appreciation of the importance of criteria ISI Articles and patents are presented in the following charts:



Articles in Web of Knowledge



Patents

We consider as being crucial that potential subjects of research evaluation to be involved in the development of evaluation methodologies, for providing a-priori a higher degree of acceptability, and hence relevance, for the results of assessment approaches.

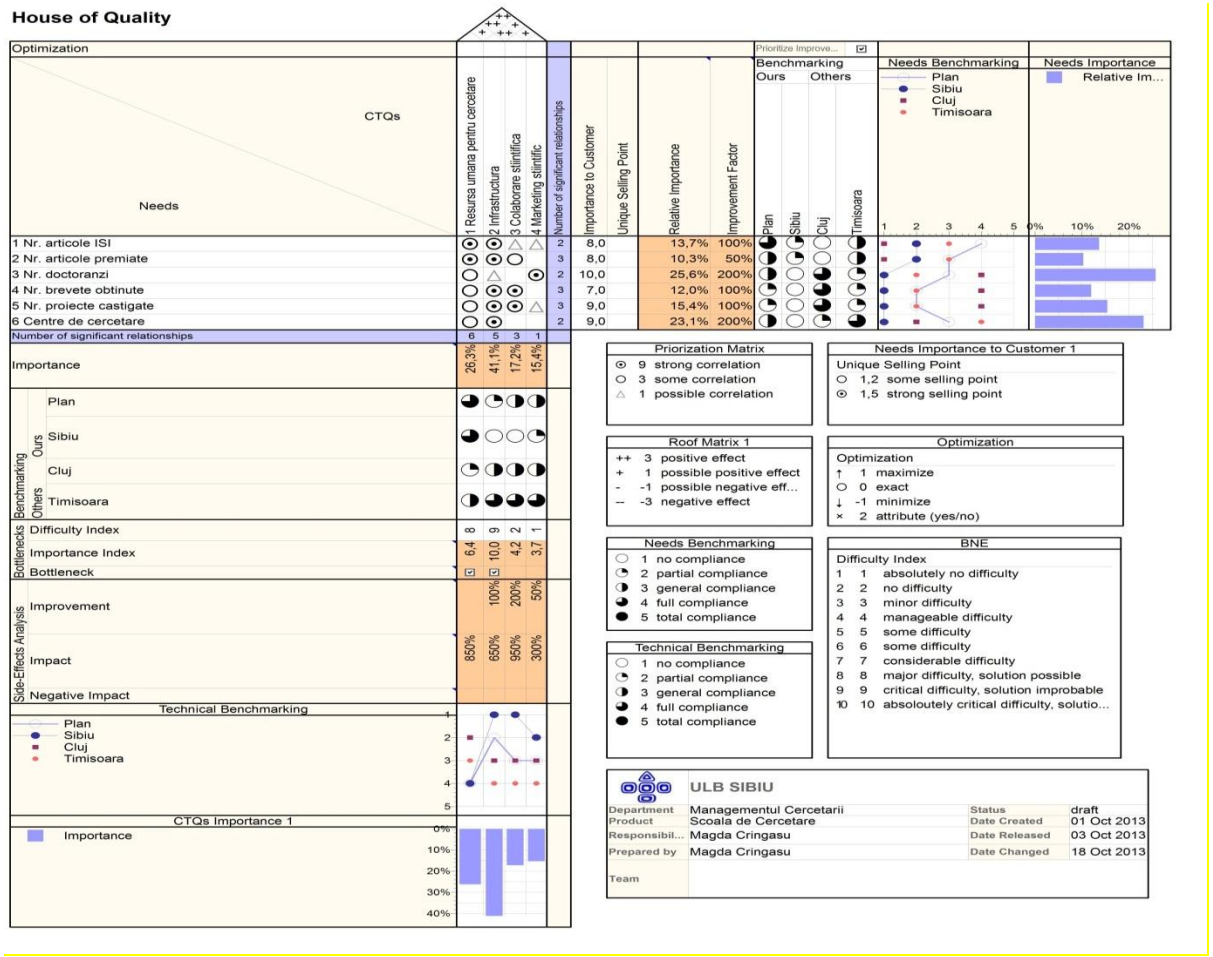
Chapter 7 uses specific techniques and methods of quality management for conducting a comparative evaluation of the research schools and improving their performance, using constitutive elements of the evaluation methodology proposed in Chapter 6.

The multicriterial analysis is performed on the research schools, allowing a unified vision of the research schools in engineering sciences from Romania and not a separate analysis, distinct for each one. There were identified two general objectives that can be set by research schools strategies: S1 - prestige of the academic research; Research school approaches are focused on the creation of scientific knowledge, on problems defined and solved by the academic community, and disseminated through publications, S2 - research with impact in society; Research school approaches are focused on solving problems identified by the general society, on the production of knowledge in the context of development of products, systems and services. The dissemination of research results occurs as they are generated.

Also, in this chapter it is performed a benchmarking analysis of the research schools by using the method QFD (Quality Function Deployment). There have been identified the quality characteristics that research schools in engineering sciences should focus in order to boost their performance in relation to the quality requirements and their importance from the perspective of customers.

Technical or quality characteristics, considered to be representative to research activity within a research school type structure are human resources for research and research infrastructure (inputs for the research activity), scientific collaboration and scientific marketing.

After calculations, performed with the software QUAL QFD the feature "Infrastructure" has resulted as the most important characteristic that must be paid attention in order to improve results in scientific research. The next feature as importance is "Human Resources."



House of Quality (QUAL) for benchmarking analysis on the research schools

Applying the QFD method on the research school model proposed and analyzed in this thesis reveals useful information for the efficiently and effectively focus of the efforts made to boost the performance of the research activity.

Thus, we consider that these approach provides a robust and general framework for designing evaluation and ranking methodologies in connection with the objectives of the evaluation process.

The conclusions are summarized in *Chapter 8*, along with personal contributions included in the thesis, respectively the prospects for development and use of the results.

Conclusions

Customizing evaluation methodologies of research and development in engineering sciences emphasises clearly that engineering research produces results that should not to be separated from the context of their application in industry or in any other segment of society. One of weaknesses of the methodologies analyzed in the context of engineering research, and not only, is the absence of explicit evaluation of formative component, by not taking into account the doctoral and post-doctoral programs, essential elements in developing a body of researchers, and consequently securing the sustainability of the entity. Such a choice has the advantage that it can be applied simultaneously to universities and research institutes, as the latter ones do not have the mission to develop human resources. But if we aim to develop a methodology customised for research entities within universities it is necessary to consider the training component (PhD students and postdocs) which is reflected in the mission of the research universities. This approach underlies the concept of "research school" that combines human resources and research infrastructure specific for a research group (team, center, laboratory, etc.) with the formative component for research (doctoral school type structure associated with a domain or a portfolio of issues specific for the research group).

Among the advantages of the “research school”-type structures, we identified: i) the access of the PhD students to infrastructure of the research center and to the expertise for using the infrastructure ii) the immersion of the PhD students in a research team where they can learn quickly essential knowledge to address successfully the topic of the thesis iii) the connection of the topics for doctoral research projects with projects implemented by the research group iv) providing to research center with human resources - PhD students and postdocs - with the distinct financing on a determined period.

The design of a methodology for the evaluation of the research schools in engineering sciences took into account the specific features mentioned above.

Moreover, for achieving a robust methodology with high degree of acceptance in the academic community, we developed a specific questionnaire, and applied it in a sociological study with a representative sample of academics and researchers from universities with predominantly technical profile in Romania.

The questionnaire included a comprehensive set of criteria and indicators meant to cover the entire spectrum of scientific production and all categories of research and formative activities. The results of the questionnaires were processed using the *Statistical Package for Social Sciences* SPSS16, for the six categories of information relevant to research school: i) publications, ii) prestige iii) income from research activities, iv) impact v) research environment, vi) strategy for research and training/retraining for researchers.

The correlations analysis between various pairs of indicators, considered in this study, reveals that analyzed indicators are quasi-independent and with a low-intensity correlation between them. Consequently, the axes of multi-dimensional evaluation system are quasi-orthogonal, which suggests the avoidance of redundancy (assessing the same issues with different indicators).

Although not all indicators proposed for each of the 6 criteria mentioned above were found to be relevant, the multicriterial analysis of the set of questionnaires revealed a useful and clear conclusion: in average, the weight of each criterion is practically the same, in terms of importance, which demonstrates the balanced formulation of criteria.

Main Personal Contributions

The main contributions of the author of this thesis are summarized below:

1) The critical analysis and the synthesis in SWOT format (strengths, weaknesses, opportunities and threats) of the national systems for the organization and conduct of research activities in Germany, Finland, Poland and Japan.
2) The presentation of evolution and the critical analysis of the RDI system in Romania summarized in SWOT format.
3) The analysis of the defining characteristics of the methodologies for evaluating the quality of research, and the correlation between the sets of criteria and indicators with the aim of the evaluation and the preliminary users of evaluation results.
4) The synthetic presentation of the first evaluation processes in RDI entities from Romania, focusing on the evaluation of the research in universities, and highlighting the main features

in conjunction with evaluation purpose (bonus in core funding, certification and accreditation for access to public funds for research).

5) Highlighting the specific features of the research in engineering sciences and their correlation with specific evaluation methodologies. It is clearly demonstrated that the use of "universal methodologies" leads to results with low relevance and to conclusions at least irrelevant from the perspective of identifying lines of action for improving the RDI activities and results.
6) The unitary analysis of the criteria used for assessing the research in engineering sciences within the methodologies proposed by the Royal Academy of Engineering (UK) and the Research Evaluation Exercise in Universities - ENEC (Romania).
7) The introduction, argumentation and analysis of the concept of "research school" as efficient and effective form of self-organization of entities implementing research projects and providing training/improvement of human resources for research through doctoral/postdoctoral programs, within the universities. Such a research school has a clear identity in terms of the domain/subdomain of science in which the research and the training efforts are falling.
8) The determination of one set of criteria and specific indicators for the evaluation of the research schools in engineering sciences. This set of criteria is investigated through a social survey based on a questionnaire developed by the PhD student, applied to a representative sample of academics from technical universities in Romania.
9) The application of multicriterial programming for processing the results of the social survey and for developing an objective ranking method for the research schools in engineering sciences.
10) The presentation of a case study by using the methodology developed in the thesis for 5 universities in Romania, and the determination of their footprint in the research activities in relation with the two general objectives (S1 - prestige of the academic research and S2 - research with impact in society) established in the multicriterial analysis.
11) Application of QFD method to identify quality characteristics on which the schools of engineering research should focus for improving their performance.
12) The presentation of a case study associated with the QFD method for 3 universities from Romania and development of rigorous argumentation for priority directions for action for improving the performance of research activity.

Potential Research Directions in the Future

It is obvious that this thesis is a work limited in extension in the portfolio of issues and also of the effective period of development of the doctoral research program. Therefore, it was selected a relatively narrow set of objectives and activities undertaken for achieving them. Further research should include, in our opinion, the following directions:

1) The extension of the sociological research on the concept of "research school" introduced in this thesis, respectively on the methodology for assessing these entities. For this purpose, the representative sample should include mainly managers of research centers and doctoral schools, vice-rectors with relevant competence, in order to achieve a higher degree of acceptance and/or ownership of the academic community.
2) Piloting evaluation methodology on a representative set of research schools. In this process, it is essential to minimize the effort of assessed entities by using available and verified/validated information. The process of collection and selection of the quantitative data will be the preliminary stage for the qualitative peer-review. The conclusions of the evaluation exercise should be analysed in partnership with research schools coordinators in order to devise a classification/ranking accepted by the community, on one hand, and for ensuring the correlation with development strategies assumed by the research schools, on the other hand.
3) During the doctoral program and the PhD thesis development 2008-2013, I published a number of 5 scientific papers in journals indexed BDI, respectively indexed specialty volumes, and presented at national and international conferences (3 papers as first author and 2 as co-author). Also, I participated in the implementation of a number of 7 research projects in the specific field of the thesis, including 3 with national financing (1 as project manager) and 4 with international finance (Framework Programmes 6 and 7 of the European Commission) as deputy project manager (1) and as coordinating partner from Romania (2).