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THE POSSIBILITY OF USING MULTI-CRITERIA METHODS AS INNOVATIVE TOOLS FOR SUPPORTING POSTGRADUATE EDUCATION

MOŻLIWOŚCI ZASTOSOWANIA METOD WIELOKRYTERIALNYCH JAKO INNOWACYJNEGO NARZĘDZIA WSPARCIA W KSZTAŁCENIU NA STUDIACH PODYPLOMOWYCH

A b s t r a c t

The aim of the article is to analyse the possibility of using multi-criteria methods for support in planning the postgraduate program, their implementation and their evaluation. Multi-criteria methods, which are used to support the decision-making process, are a response to the complexity of contemporary problems, including uncertainty, incomplete data and changing environment. One of these issues is matching the postgraduate program to the current requirements of potential students. The research methods used in this article are a critical analysis of literary sources and a case study of the 'PIT Mobile postgraduate studies in collaboration with industry' project, financed by the European Social Fund.

Keywords: multi-criteria methods, analytical hierarchical process (AHP), postgraduate education

S t r e s z c z e n i e

Celem artykułu jest analiza możliwości wykorzystania metod wielokryterialnych jako narzędzia wsparcia w planowaniu programu studiów podyplomowych, ich realizacji oraz ewaluacji. Metody wielokryterialne, stosowane do wsparcia procesu decyzyjnego, są odpowiedzią na złożoność współczesnych problemów rozwiązywanych w warunkach niepewności, niepełnych danych oraz zmieniającego się otoczenia. Jednym z takich zagadnień jest właśnie dopasowanie programu studiów podyplomowych do aktualnych wymagań potencjalnych uczestników. Zastosowane metody badawcze to: analiza krytyczna źródeł literaturowych, *case study* na przykładzie projektu „PIT Mobilne studia podyplomowe we współpracy z przemysłem" finansowanego z Europejskiego Funduszu Społecznego.

Słowa kluczowe: metody wielokryterialne, analityczny proces hierarchiczny (AHP), kształcenie podyplomowe

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1. Introduction

The most important challenge for the educational system is to increase the productivity and efficiently the economy. Education, especially in the area of engineering, is crucial for the development and economic growth of each country. It is essential to develop a new, modern approach to supporting education, meeting the contemporary market requirements and predicting future trends. Despite the great importance of lifelong learning, relatively few people choose to undertake a programme of postgraduate study despite the potential future benefits [14, 22]. The data of the central statistical office of Poland [8–10] shows that there were approximately 163,628 postgraduate students in Poland during the 2013/2014 academic year – this is much lower than in 2009/10 when there were 194,212 students. Most people who undertake training at the postgraduate level are between 26 and 35 years old. Only 3% of Polish people have completed postgraduate studies.

There is a clear downward trend in postgraduate education, including studies in technical disciplines. Meeting the demand for highly skilled professionals and updating their skills in accordance with the changing ambient conditions can be problematic for the labour market. Despite the importance of postgraduate studies and the related personal benefits (statistically, higher remuneration), relatively few people choose this form of education. There are a variety of reasons for this [14, 22]:

- the programs of postgraduate studies were out-of-date;
- there is a lack of the implementation of modern tools in education, for example m-learning support;
- the lack of cooperation between science and business, and because of this, a lack of training programs tailored to the needs of the labour market;
- an overall decrease in the number of potential students due to a drop in the number of individuals fitting the typical demographic profile;
- relatively high unemployment among young people and low levels of income (graduates could not afford to fund attractive and expensive postgraduate courses).

The process of globalisation and the development of technology has caused the skills required in the professional arena to change. Nowadays, engineers should have not only technical knowledge, but also high levels of interpersonal competence, especially those related with communication (for example foreign languages), practical engineering, and business skills [21, 23]. Technical universities are facing an important challenge with regard to how to fulfil changeable requirements and predict future needs. Study programs that are suitable for meeting market needs are a crucial and urgent task for universities in order to improve their competitiveness; therefore, there is a necessity for all sector of higher education to develop new methods of academic support [14, 18].

2. The use of the multi-criteria methods in higher education sector

Nowadays, decision makers often face complicated dilemmas with tangible, intangible and sometimes conflicting criteria [20] – this certainly applies in the higher education sector. Numerous multi-criteria, decision-making methods are applied to various problems in universities such as resource allocation, performance measurement, budgeting and scheduling

[12]. These methods are used for solving general as well as specific problems. For example, this methods will have been successfully used for the assessment of the quality of higher education in different countries [1, 2, 24, 17]. The multi-criteria methods allow not only factors influenced the quality aspects for all education related services to be determined, but also optimise university (or faculty) performance evaluation in terms of research, teaching, university and community service [2], but also help manage effectively for example define strategies for the universities and to reach their pre-defined standards and goals [1]. It is possible to use the multi-criteria methods for restructuring and reforming higher education [1, 4]. The models, designed with using a multi-criteria methods such as Analytic Hierarchy Process (AHP), were analysed for different challenges in higher education, in several countries, for example, at the United Arab Emirates University [2], in Greece [24] and Italy [17]. Thanks to multi-criteria models, it is possible to compare different points of view.

Multi-criteria methods can be also used for some divisions of higher education exemplary to evaluate faculty performance in engineering education [1, 8] or in the specific area of higher education. Exemplary, AHP/DEA method was used for measurement of the efficiency of R&D management activities in universities [7] or identifying and ranking academic entrepreneurship [19]. Multi-criteria methods can be effective tools for the assessment of the management performance of research and development (R&D) activities in research-oriented universities – this application was investigated in twenty-nine universities in China where thanks to this method, the universities improved their management work which achieved a high level of efficiency. The method was also helpful in motivating the universities to keep on improving their R&D management [7]. Other examples include the use of AHP for identifying and ranking academic entrepreneurships in Iran. The methods help to determinate a clue factors of development the academic entrepreneurship and made easier decision in this area [19].

Multi-criteria methods can also be used in particular problems in higher education such as human resource management exemplary to rank faculty members within each discipline or major [2] or to make judgment on the qualification of candidates for such systems [2]. It is also possible to evaluate the criteria for human resources for science and technology as a whole [3] as well as for the department college or university level.

Another particular problem that can be solved by using multi-criteria methods is managing an intellectual capital. Multi-criteria methods have been successfully applied at universities in Taiwan for this purpose [16] – an evaluation model was created to facilitate the understanding of an intellectual capital contribution to the performance of the university. The AHP method was applied to formulate and prioritise the intellectual capital measurement indicators for constructing model. The model was used to evaluation as decision guidelines. Thanks to it was possible to develop and increase the productivity of investments in intangible assets [16].

Multi-criteria methods can be used during classes in higher education as a tool for solving real problems, for example, as a tool for simulations that can help students deal with complex real problems in the field of thermal engineering [5]. Exemplary this methods can be used as tools for education for undergraduate and postgraduate student projects to formalise the process of selection of `hard’ and `soft’ system components [6].

Multi-criteria methods can be applied to a wide range of important academic problems. These kinds of methods are especially valuable because:

– an application across the spectrum of decision-making activities, include evaluation, scheduling, budgeting;

– and possibilities decision-making problems in academia by committees or groups where a consensus must be reached.

Despite widespread use of this approach in other areas, there is a lack of use of this kind of method with the field of postgraduate education.

3. Case study of the 'PIT Mobile postgraduate studies in collaboration with industry' project

The 'PIT Mobile Postgraduate Studies in Collaboration with Industry' project ('PIT Mobilne studia podyplomowe we współpracy z przemysłem') is financed by the European Social Fund as part of the Human Capital Operational Program. The project is funded through a special programme for innovative ideas and based on research conducted on three groups made up of academic staff, future students and industry representatives. The project covers two technical postgraduate programmes realised in the form of blended learning at Cracow University of Technology Faculty of Mechanical Engineering over the years 2013 to 2015, these are:

– the International Welding Engineer programme (IWE),
– the Fluid Power Studies (hydraulic and pneumatic) programme (compliant with CETOP requirements).

The basic strategy was to identify the needs of both of these groups and combine them in one coherent program of postgraduate education. The main aim of the project is the design and implementation of various forms of learning support such as remote access tools for postgraduate studies which allow creating modern postgraduate studies tailored to the needs of students and the contemporary labour market [15]. For this purpose, an analytic hierarchy process (AHP) was applied in the project.

AHP is a multi-criteria method that was created and developed by Thomas L. Saaty in the nineteen-seventies. AHP was designed to incorporate both subjective and objective evaluation measures, providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team, thus reducing bias in decision making [17]. This method is particularly useful in cases where there are the subjective judgments of different individuals that constitute an important part of the decision-making process [10].

The first step of AHP is to create a decision hierarchy by breaking down the problem into a hierarchy of decision elements. In the project the decision elements was chosen on the base of questionnaire made in expert group. A hierarchical tree was created with the following main criteria and sub-criteria:

– knowledge (sub-criteria: presentation of basic knowledge useful for performing basic tasks; a wide range of issues discussed in the field of study; knowledge showing different points of view for particular issues; linking theoretical knowledge with practical experience; teaching materials for students that aid the revision of knowledge; e-learning support; the presentation of the latest scientific knowledge);
– practice (sub-criteria: many practical classes; solving problems using software for simulation; industrial training; industrial internship – minimum of 3 months; internship opportunities in foreign organisations; organisation of study visits in companies; implementation of projects in cooperation with selected enterprise);

- the quality of the training staff (sub-criteria: teaching by people with experience in industrial companies; knowledge presented in available way for students; the high professionalism of the courses; constant development of professional staff; lectures by international authorities in the particular field od study; interpersonal features of the lecturers; assisting qualified technical personnel during laboratory classes);
- organisation of studies (sub-criteria: duration of study tailored to the needs of students; individual approach to the participant; small groups; reliability of the supply of information; good administrative services; possibility of remote administrative services; cooperation with other institutions (domestic and foreign) in the framework of study; organisation of postgraduate studies by the high prestige universities; providing opportunities for people with disabilities to participate in postgraduate courses);
- the level of knowledge of candidates (sub-criteria: entrance exams; the field of the previous study coherent with the profile of postgraduate studies; professional experience of the students; the motivation of candidates undertaking postgraduate studies; individual approach to student for example the division into groups by level);
- skills development (sub-criteria: obtaining a special license/certificate of competence; emphasis on mastering practical skills; development of professional qualifications; obtaining new professional skills (in a new field); develop the ability to act independently and solve problems; the development of social skills; the development of managerial skills);
- teaching facilities (sub-criteria: high quality reliable facilities; the use of information technology for support of the educational process; modern multimedia facilities; modern laboratory equipment; diversification of laboratory facilities – the opportunity to work on various types of equipment; the possibility of mobile/remote classes; access to the latest scientific literature/standards/databases; access to the latest software; proper teaching aids).

The second step is to collect input. It is made by a pair wise comparison of decision elements. The next step is to determine whether the input data satisfies a consistency test. The research involved twenty-three experts in the projects – most of them represented universities or research institutions (17) and business (6). The next step is to calculate the relative weights of the decision elements (cost and benefits). There were calculated so called global and local priorities. The local priorities are formulate for each group at each level (for sub-criteria with respect to main criterion). The global priorities are formulate for whole decision hierarchy (for sub-criteria with respect to general problem). Eventually, the researcher must aggregate the relative weights to obtain scores and therefore rankings for the decision alternatives (or elements).

For each sub-criteria, proper values for cost and benefits were calculated and these values were compared. The results of the comparison are presented in Table 1 [22].

The pairwise comparison were made for costs and benefits separately as well as taking into account both of them. As a results the most important criteria and sub-criteria was chosen. The most important criterion is knowledge, mainly because high benefits and low costs. Other important criteria are practice and skills development, because a similar levels (ranking points) of benefits and costs. According to benefits the highest notes has criterion the quality of the training staff, but it has also high level of cost and because of that it has not so high position in general rank. The same situation was for criterion the teaching facilities. The high costs (ranking points for this category) decided about low position this criterion in general rank. The criteria organization of studies and the level of knowledge of candidates are not so important according to the experts evaluation.

Table 1

The calculation of global priorities according to AHP [22]

Main criteria priorities P_{Si}	Local priorities of sub-criteria P_{Lij}	Global priorities of sub-criteria $P_{Gij} = P_{Si} \times P_{Lij}$
Knowledge P_{Lij}	Presentation of basic knowledge useful for performing basic tasks $P_{L11} = 0.19220$	$P_{G11} = 0.06847$
	A wide range of issues discussed in the field of study $P_{L12} = 0.13575$	$P_{G12} = 0.04836$
	Knowledge showing different points of view for particular issues $P_{L13} = 0.13575$	$P_{G13} = 0.04836$
	Linking the theoretical knowledge with experience $P_{L14} = 0.24713$	$P_{G14} = 0.08803$
	Teaching materials for students that aid the revision of knowledge $P_{L15} = 0.07788$	$P_{G15} = 0.02774$
	E-learning support $P_{L16} = 0.07949$	$P_{G16} = 0.02832$
	The presentation of the latest scientific knowledge $P_{L17} = 0.13181$	$P_{G17} = 0.04695$
Practice $P_{S2} = 0.15177$	Many practical classes $P_{L21} = 0.15126$	$P_{G21} = 0.02296$
	Solving problems using software for simulation $P_{L22} = 0.12851$	$P_{G22} = 0.01950$
	Industrial training $P_{L23} = 0.10090$	$P_{G23} = 0.01531$
	Industrial internship – minimum of 3 months $P_{L24} = 0.09087$	$P_{G24} = 0.01379$
	Internship opportunities in foreign organizations $P_{L25} = 0.08159$	$P_{G25} = 0.01238$
	Organisation of study visits in companies $P_{L26} = 0.16452$	$P_{G26} = 0.02497$
	Implementation of projects in cooperation with selected enterprise $P_{L27} = 0.28237$	$P_{G27} = 0.04285$

The quality of the training staff $P_{S3} = 0.13978$	Teaching from people with experience in industrial companies $P_{L31} = 0.10596$	$P_{G31} = 0.01481$
	Knowledge presented in available way for students $P_{L32} = 0.27246$	$P_{G32} = 0.03808$
	The high professionalism of the courses $P_{L33} = 0.18500$	$P_{G33} = 0.02586$
	Constant development of professional staff $P_{L34} = 0.09555$	$P_{G34} = 0.01336$
	Lectures by international authorities in the particular field of study $P_{L35} = 0.04591$	$P_{G35} = 0.00642$
	Interpersonal features of the lecturers $P_{L36} = 0.19418$	$P_{G36} = 0.02714$
	Assisting qualified technical personnel during laboratory classes $P_{L37} = 0.10094$	$P_{G37} = 0.01411$
Organization of studies $P_{S4} = 0.04628$	Duration of study tailored to the needs of students $P_{L41} =0.09327$	$P_{G41} = 0.00432$
	Individual approach to the participant $P_{L42} = 0.15209$	$P_{G42} = 0.00704$
	Small groups $P_{L43} = 0.13692$	$P_{G43} = 0.00634$
	Reliability of the supply of information $P_{L44} = 0.14447$	$P_{G44} = 0.00669$
	Good administrative services $P_{L45} = 0.16441$	$P_{G45} = 0.00761$
	Possibility of remote administrative services $P_{L46} = 0.14259$	$P_{G46} = 0.00660$
	Cooperation with other institutions (domestic and foreign) in the framework of the study $P_{L47} = 0.06288$	$P_{G47} = 0.00291$
	Organisation of postgraduate studies by the high prestige universities $P_{L48} = 0.05600$	$P_{G48} = 0.00259$
	Providing people with disabilities opportunities to participate in postgraduate courses $P_{L49} = 0.04736$	$P_{G49} = 0.00219$

Continue Table 1

Main criteria priorities P_{Si}	Local priorities of sub-criteria P_{Lij}	Global priorities of sub-criteria $P_{Gij} = P_{Si} \times P_{Lij}$
The level of knowledge of candidates $P_{S5} = 0.11081$	Entrance exams $P_{L51} = 0.18310$	$P_{G51} = 0.02029$
	The field of the previous study coherent with the profile of postgraduate studies $P_{L52} = 0.25206$	$P_{G52} = 0.02793$
	Professional experience of the students $P_{L53} = 0.25563$	$P_{G53} = 0.02833$
	The motivation of candidates undertaking postgraduate studies $P_{L54} = 0.19464$	$P_{G54} = 0.02157$
	Individual approach to student for example the division into groups by level $P_{L55} = 0.11456$	$P_{G55} = 0.01269$
Skills development $P_{S6} = 0.14972$	Obtaining a special license/certificate of competences $P_{L61} = 0.07994$	$P_{G61} = 0.00886$
	Emphasis on mastering practical skills $P_{L62} = 0.22970$	$P_{G62} = 0.02545$
	Development of professional qualifications $P_{L63} = 0.10121$	$P_{G63} = 0.01122$
	Obtaining new professional skills (in a new field) $P_{L64} = 0.11464$	$P_{G64} = 0.01270$
	Develop the ability to act independently and solve problems $P_{L65} = 0.26530$	$P_{G65} = 0.02940$
	The development of social skills $P_{L66} = 0.13997$	$P_{G66} = 0.01551$
	The development of managerial skills $P_{L67} = 0.06924$	$P_{G67} = 0.00767$
Teaching facilities $P_{S7} = 0.04542$	High quality reliable facilities $P_{L71} = 0.09246$	$P_{G71} = 0.00420$
	The use of information technology for the support of the educational process $P_{L72} = 0.13370$	$P_{G72} = 0.00607$
	Modern multimedia facilities $P_{L73} = 0.08321$	$P_{G73} = 0.00378$

Teaching facilities P_{S7} = 0.04542	Modern laboratory equipment P_{L74} = 0.06932	P_{G74} = 0.00315
	Diversification of laboratory facilities – the opportunity to work on various types of equipment P_{L75} = 0.07790	P_{G75} = 0.00354
	The possibility of mobile/remote classes P_{L76} = 0.17663	P_{G76} = 0.00802
	Access to the latest scientific literature/standards/ databases P_{L77} = 0.14759	P_{G77} = 0.00670
	Access to the latest software P_{L78} = 0.11534	P_{G78} = 0.00524
	Proper teaching aids P_{L79} = 0.10385	P_{G79} = 0.00472

The comparison of the sub-criteria according to local priorities allow the determination of their position in every category and next determine a value of global priorities. Thanks to the global priorities, it is possible to compare sub-criteria between categories. The determination of global priorities give a possibility of choice the factors that are the most important for the model of postgraduate studies. In the model, the following sub-criteria were included [22]:

– interpersonal features of the lecturers;
– professional experience of the students;
– many practical classes;
– entrance exams;
– e-learning support;
– the field of the previous study coherent with the profile of postgraduate studies;
– the motivation of candidates undertaking postgraduate studies;
– internship opportunities in foreign organizations;
– emphasis on mastering practical skills;
– industrial training;
– industrial internship – minimum of 3 months;
– organization of study visits in companies;
– linking the theoretical knowledge with experience;
– presentation of basic knowledge useful for performing basic tasks;
– knowledge presented in available way for students;
– implementation of projects in cooperation with selected enterprise;
– develop the ability to act independently and solve problems;
– teaching materials for students that aid the revision of knowledge;
– a wide range of issues discussed in the field of study;
– the presentation of the latest scientific knowledge;
– knowledge showing different points of view for particular issues;
– the high professionalism of the courses.

The sub-criteria were taken into account during the development of programs of study and the selection of tools that support the learning process. It has not been possible to include all elements in the scope of the model, but the most important elements were included in curricula and lecture notes for two postgraduate curses (international welding engineer and fluid power studies). The sub-criteria were also taken into consideration during the design of tools for postgraduate studies. New tools for teaching such as a mobile platform, the remote control laboratories and mobile software were designed and implemented [13, 17]. The solutions proposed in the project were mainly based on mobile technologies, because of the growing prevalence of m-technologies (access to the Internet is more often provided by equipment other than a computer, e.g. smartphones, tablets). M-technology is also convenient for students, because they carry mobile devices rather than computers with them at all times – this provides easy access to the accumulated knowledge, this also applies in the workplace [13, 14].

4. Conclusions

Multi-criteria methods were successfully applied in different fields of higher education, but there is a lack of use of this method in postgraduate education. The case study of the 'PIT Mobile Postgraduate Studies in Collaboration with Industry' project shows that it may be a valuable tool for supporting postgraduate study especially during the design of programmes that require the consideration of a lot of elements. These kinds of methods are especially valuable for complex decision-making activities and decisions made by academic groups.

The model described above is general and can be used in different fields of engineering. Thanks to support from external funds, the model as well as each of the designed components is widely available to other organisations interested in its use. Developed elements can be used by all the institutions (mainly universities) that offer postgraduate education in the field of technical sciences. The model can also be used in education at the second stage of technical studies, due to the similarity of expectations and previous experience of undergraduate students which should guarantee an adequate level of knowledge. The postgraduate students as well as MSc candidates should have a similar knowledge, because they have ended BSc course. In addition, the particular tools based on the model can be used for: courses in the field of welding; hydraulics and pneumatics; BSc degree courses in engineering; MSc degree courses, especially in the field of technical education; PhD studies in engineering sciences; education provided in the workplace.

The project provided an opportunity to create a new conception of innovative studies and gives valuable tools for futures teaching – it also made for a stronger collaboration between companies and the university.

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