Excellence, relevance and efficient application of research results at universities and institutes from the standpoint of economy developing

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Abstract. Product development is a creative task where is systematically created a new product, which makes possible to firms to offer attractive, innovative and market oriented products. In conditions of fierce competition and saturated markets, companies that do not innovate are stagnating and disappear from the market. Innovations are very important factor for surviving the company on the market because companies need to increase their competitive ability through development of new high quality products, introduction of new technologies in production, introduction of new organization in production, introduction of new information and communication techniques etc. Research, inventions and innovations are closely related to each other. The results of research projects can largely contribute to finding inventions and innovations and their application in creating new products and technologies. This is a very important resource that is insufficiently used in our country. The paper analyzes the role and importance of excellence and relevance of research at faculties and institutes from the aspect of their effective application in economic subjects.

1. Introduction

A company success in modern conditions is possible to achieve by introducing innovative products and product processes. Innovative products are characterized by strong logistic backup related to product exploitation maintenance and recycling.

Application of innovative products and product processes is very complex and demands new work approach, which is primarily related to resource optimization, precision defining of competence and cooperative work approach. In comparison to convectional primarily functional oriented approach, cooperative work process is based on interdisciplinary project teams, methodical work approach is connected to specific parallel process structure (simulate engineering) with use of modern information technologies. This approach has influence on shortening time period for creating and lunching new product (time to market), reduction of prices (design to cost) and to insure quality (best quality).

Cooperative processes foundation are methods and systems which in all phases transparently present complete product development process and manufacturing. Methodical approach implements application of different product development methods, methods for planning and process management, as well as project management and organization management. Systematic approach implements computer backup in all phases of the product development process and manufacturing.

Modern companies must have access to comprehensively educated engineers so that they can solve complex problems. This raises the need for universities to undertake a proper education reform, according to the demands of contemporary techniques and technology.

Product development is a creative task which implies a systematic creation of a new product. In the process of product development a significant role is played by innovations which enable one to create quality and commercially competitive products.

Innovations can emerge as a result of individual work, of the work carried out in a company, as well as a result of scientific research. Research is a principal component of the process of innovation and it represents a key element in the development of a new competitive advantage. The highest quality innovations arise as a result of the work of research organisations, at universities and institutes. In our circumstances this resource is not sufficiently used. The reasons are manifold and they require a thorough analysis. One of the main tasks in that respect is to establish a relevant interaction between the three key elements of the research triangle: knowledge creation (scientific research), knowledge dissemination (education) and knowledge application (innovations).

2. Situation at universities

2.1. Situation in the region

The word *university* is of Latin origin - *universitas magistrorum et scholarium,* which implies a community of teachers and scholars. Universities represent autonomous higher education institutions which award diplomas and degrees and comprise multifarious faculties.

Education plays a significant role in the development of economy and society. Such role of education was recognised in the Socialist Federal Republic of Yugoslavia in the last century. After 1960 a series of universities were founded throughout the country, so much so that over a comparably short time span, the number of highly educated people increased abruptly. However, the entire process developed under the close control of government institutions and relied upon the engagement of eminent and renowned professors of the existing public universities. On newly founded faculties, the aforementioned professors educated teaching and research staff, which resulted in a significant assistance and support for the development of economy and international co-operation.

After the disintegration of Yugoslavia, a process in education ensued bordering on chaos. It was followed by the opening of numerous public and especially private universities which have not reached an adequate educational or scientific level. It led to a precipitous decline in the quality of teaching staff in most of the newly opened educational institutions and, consequently, to a substantial decline of the quality of the people educated at them.

It should be noted that it is very difficult to ascertain the exact number of universities and similar educational institutions, both in Serbia and in the region. For instance, according to [1] the number of universities, autonomous faculties, higher vocational education institutions and similar educational institutions is as follows: Serbia 72, Croatia 50, Slovenia 35, Bosnia and Herzegovina 62, Macedonia 20, and Montenegro 3. On the basis of available data and by virtue of an appropriate selection, Figure 1 presents the number of universities and similar educational institutions in former Yugoslav republics.

It is possible to discern that in Croatia, Slovenia and even Serbia the ratio between the number of public and private universities is rather balanced, i.e. the process of emergence of educational institutions unfolded in a moderate manner, thus avoiding the chaotic trend. The worst situation occurred in Bosnia and Herzegovina and Macedonia where there has been an enormous increase in universities, i.e. educational institutions.

Should one observe the number of inhabitants per university (Figure 2) one can clearly perceive the demarcation. In Serbia, Croatia and Slovenia the number of inhabitants per university is approximately three times higher than in Bosnia and Herzegovina, Macedonia and Montenegro. This kind of scrutiny indubitably has its disadvantages since universities significantly differ in size and number.
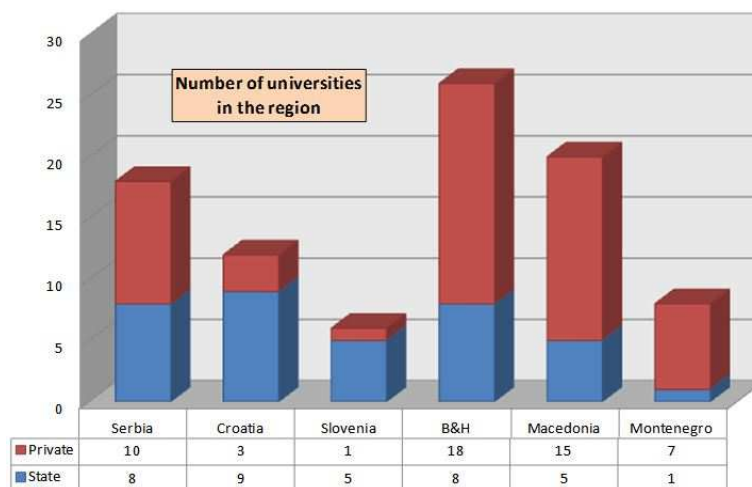
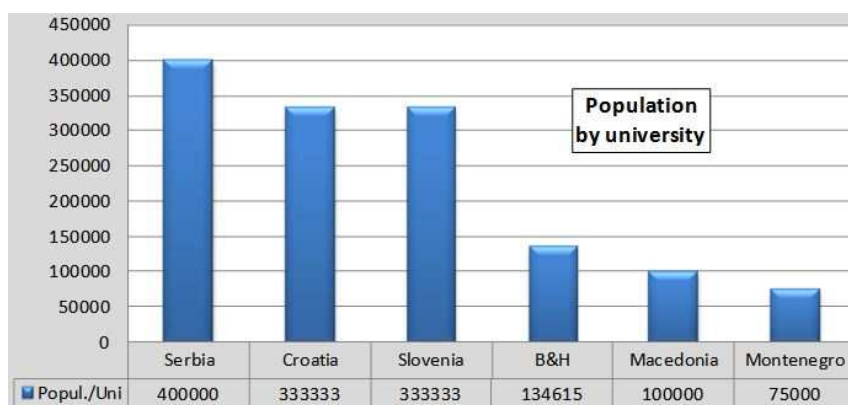**Figure 1.** Number of state and private universities in ex-YU states.

Figure 2. Population at the University of exYU countries.

However, aside from the number of educational institutions, the quality of these institutions bears equal importance. In that respect, it is convenient to resort to university ranking according to world standards. In this paper two ranking lists are considered: the Shanghai Ranking of World Universities [2] (world university ranking since 2003), and Webometrics Ranking of World Universities located in Spain [1].

The Shanghai Ranking of World Universities offers information only for the top 500 universities. Hitherto, only three universities from this region found their place on this list, and these are University of Ljubljana, University of Zagreb and University of Belgrade (Figure 3). The University of Ljubljana found its place on the list for the first time in 2003, only to be left out in the subsequent three years. From 2007 to 2017 it is steadily positioned between 400th and 500th place. The University of Zagreb was on the list between 2011 and 2013, positioned between 400th and 500th place, only to be left out for the subsequent two years. It was placed back on the list in 2016, to be left out again in 2017. The University of Belgrade has been included in the Shanghai Ranking of World Universities since 2012 (position 400-500) and it has advanced significantly ever since, so much so that in 2017 it was positioned between 200th and 300th place, which makes it the best positioned university in the region.

The Webometrics university ranking methodology [1] relies exclusively on Internet contents. University lists ranked according to the Webometrics methodology are published twice a year on the following web page: www.webometrics.info. University ranking according to the Webometrics methodology is determined on the basis of four indicators classified into two groups: 1. **Visibility**, and 2. **Activity**. The impact of each group is 50%.

Figure 3. The ranking list of the universities in exYU state according to the Shanghai list.

1. **Visibility** (V) is measured according to the number of obtained unique external links to a university website and it is presented via Impact parameter. External links take into consideration the institutional prestige, academic performance, information value and usefulness of the service.

2. **Activity** (S) comprises three parameters: presence (impact 10%), openness (10%) and excellence (30%). **Presence** is measured by the total number of university web pages from where the data are downloaded via Google. **Openness** is measured by the number of rich files, whereby the following formats are taken into consideration: Adobe Acrobat (.pdf), Adobe PostScript (.ps), Microsoft Word (.doc) and Microsoft PowerPoint (.ppt). **Excellence** takes into consideration the quality of scientific papers published by a university, the most significant quality indicator being the number of citations of scientific papers. This is the manner in which a university excellence is measured, whereby the Scimago database is used as a source.

Table 1. Webometrics ranking list for universities in ex-YU countries.

Ranking	World Rank	University	Presence Rank*	Impact Rank*	Openness Rank*	Excellence Rank*
1	325	University of Ljubljana	76	350	763	354
2	512	University of Belgrade	103	1049	991	356
3	692	University of Zagreb	292	754	3878	550
4	1015	University of Split	929	2304	771	847
5	1108	University of Novi Sad	247	1900	1564	1061
6	1244	University of Maribor	342	3489	1485	868
7	1498	University of Niš	820	3292	1908	1298
8	1534	University of Rijeka	1061	2953	1004	1607
9	1612	Ss Cyril and Methodius University Skopje	678	2342	2411	1721
10	1840	University of Kragujevac	467	4477	1992	1613

The Webometrics currently encompasses the ranking of approximately 25 000 universities worldwide, whereas the ranking list comprises the first 12 000 universities. On the basis of the Webometrics ranking list (since January 2018) of the first 2000 universities, Table 1 presents the data for all universities of the former Yugoslavia. The list comprises 10 such universities in total: 4 from Serbia, 3 from Croatia, 2 from Slovenia and 1 from Macedonia. The best ranked university from Bosnia and Herzegovina is the public University of Sarajevo, which takes the 2019th place, while the University of Podgorica takes the 3380th place. The Universities of Ljubljana, Zagreb and Belgrade significantly differ from other regional universities, both regarding the complete ranking list and the list of excellence.

2.2. Situation in Serbia
Nowadays, there are 8 public and 10 private universities in Serbia (Table 2). Among the aforementioned universities only the University of Belgrade is ranked according to the Shanghai Ranking of World Universities. It was positioned on this list for the first time in 2012 between the 400th and 500th place, and it is currently ranked between the 200th and 300th place.

Table 2. State and private university in Serbia.

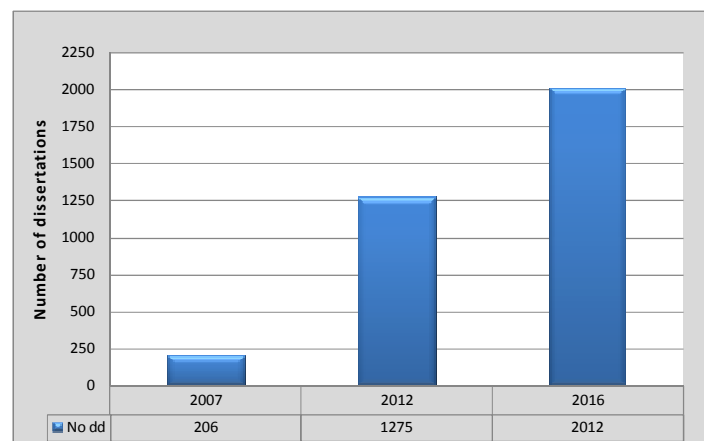| No	State university	Private university
1	University of Belgrade	Singidunum University
2	University of Arts in Belgrade	Megatrend University
3	University of Defence in Belgrade	University of Business Akademy
4	University of Novi Sad	Educons University
5	University of Niš	Metropolitan University
6	University of Kragujevac	Union University
7	University of Pristina (Kos. Mitrovica)	Union University – Nikola Tesla
8	State University of Novi Pazar	Alfa university
9		European University
10		University of Novi Pazar

According to the Webometrics Ranking of World Universities encompassing the first 5000 universities, 8 universities from Serbia found their place on this list (Table 3). The public universities of Belgrade, Novi Sad, Niš and Kragujevac are significantly more prominent in comparison to other Serbian universities according to all criteria, especially with respect to excellence.

Table 3. Webometrics rank list for universities in Serbia.

Ranking	World Rank	Ranking	World Rank	Ranking	World Rank	Ranking
1	512	University of Belgrade	103	1049	991	356
2	1108	University of Novi Sad	247	1900	1564	1061
3	1498	University of Niš	820	3292	1908	1298
4	1840	University of Kragujevac	467	4477	1992	1613
5	3294	Singidunum University	1697	7136	3429	3383
6	4477	Megatrend University	9425	12520	7462	3066
7	4639	University of Pristina - Kosovska Mitrovica	4908	12422	4108	3839
8	4658	State University of Novi Pazar	7862	13748	6128	3265

One of the more serious issues in the Serbian higher education is a significant increase in the number of PhD titles. According to the statistics, the number of PhD titles in Serbia is dramatically increasing. Since the founding of the first university in Serbia in 1905 until 2005 some 400 to 500 scientists per year obtained their doctoral titles. In one hundred years the total of 16860 PhDs have been promoted. In the period between 2007 and 2016 a PhD title was obtained by almost 9000 scientists, whereby in 2007 there were 206 dissertations, while in 2013 this number rose to 2012 (Figure 4).

Such abrupt increase in the number of defended doctoral theses implies that new knowledge was created the application of which would result in an increase of economic competitiveness. Since the latter never occurred, one needs to pose the question of the quality of defended theses, primarily of the matter of their excellence and relevance.

Figure 4. Doctoral Thesis in Serbia.

3. Knowledge as a dominant resource in the development of the economy
The main missions of any university are as follows: scientific research (knowledge creation), education (knowledge dissemination) and transfer of technology and innovations (knowledge application).

3.1 Significance of scientific research (knowledge creation)
Scientific research represents the set of deliberate, systematic and methodologically organised activities (disciplinary/interdisciplinary) which enable one to discover and attest scientific truths regarding objects and phenomena in nature and society by means of scientific methods.

Science is, therefore, organised, systematised and certified knowledge of a certain matter, achieved by means of a methodical, careful and conscientious research and contemplation. Knowledge can be defined as an accumulation of objective information related to human beings and their needs. One

should make a difference between the amount of knowledge (**quantity**) and its significance (**quality**). Excellence and relevance are most frequently used as a measure of the quality of a scientific research.

Excellence in science is observed as a measure of the quality of the scientific work, primarily from the standpoint of international visibility. Important parameters for evaluating excellence are the number of papers per year in the WoS network, the number of monographs published by prominent international publishers, citation index, etc.

Relevance is also a measure of the quality of the scientific work, but from the standpoint of its impact on social and economic growth. The relevance of scientific research comprises primarily the number of patent applications or patents, inventions which can be applied, the work on projects in which research results are applied, as well as the income obtained in that manner.

Knowledge is a key resource and the only resource which increases when shared. In modern circumstances, the development of science and technology is increasingly rapid and dynamic, which results in an enormously rapid increase in knowledge in various fields of technology. Knowledge is difficult to shield and protect, it quickly loses its market value and it is not subject to known management procedures and methods. Every seven to ten years, the quantity of knowledge is doubled. Modern communication and information technologies contribute to a rapid dissemination of knowledge. However, knowledge quickly becomes obsolete. In current conditions, after three to four years the level of actual knowledge of development engineers decreases by 50%.

One should bear in mind that there are no boundaries to the growth of knowledge, i.e. the research front is constantly expanding while the realm of the unknown constantly increases. This requires the engagement of a larger number of people in the field of research and knowledge transfer, as well as in modern conditions specialisation in particular fields.

In modern conditions, knowledge as a result of research in science and technology becomes a dominant resource in the field of development of a country, with ever growing potentials with respect to natural resources, bearing in mind that it is the precondition of the development of new high quality products and high productivity and efficiency.

For the purposes of a more efficient use of available resources for scientific research in our conditions, two problems require immediate solutions. The first one is related to the quality of knowledge from the standpoint of its application in the economy. In the Strategy of Scientific and Technological Development in the Republic of Serbia for the period between 2016 and 2020 [3] a piece of information was presented stating that out of the total number of scientific papers 40% are those published in WoS journals, while 60% are the papers published in national journals. The number of internationally visible results increases in recent years, which can be seen from the ranking results (Figure 3 and Table 2). Therefore, some visible results regarding excellence have been achieved. However, it has been asserted that the number of results which can be significant to the economy is rather low, since patents and technical solutions comprise 3,3% of all achieved results.

According to the diagram presented in Figure 5 the number of defended PhD theses rapidly increases, but the effect of applying the research results in the economy is lacking. One can assert that in current conditions the number of scientific research results from the standpoint of application in industry is quite low, i.e. the quality of scientific work regarding relevance has not been accomplished. It is quite evident that the elements of research orientation are not sufficiently represented.

The second issue is related to a quick and efficient application of the results of the scientific work. Bearing in mind the enormously rapid development of science and technology, as well as the speed of knowledge obsolescence, the main problem which requires solution is how to translate the results of scientific work in a rapid and effective manner into the development of new products and technologies.

In that respect a Strategy of Scientific and Technological Development of the Republic of Serbia for the period between 2016 and 2020 has already been presented. The proposal [3] is generally satisfying, but its implementation is rather slow and it is likely that the envisaged effects of the application of this strategy will not be met.

3.2. The role of education (knowledge dissemination)

The task of education is to acquire scientific knowledge in the function of development of work skills and abilities. If one is to observe scientific research as a process of knowledge creation, then the function of education is knowledge dissemination. An innovative approach in product development is mostly based on the application of the results of scientific work for the purpose of solving numerous tasks and issues. Considering the scope of knowledge and information necessary in such circumstances, team work may be considered purposeful. However, when one co-operates in interdisciplinary project teams, team work can be rather complex and it requires a new approach to work, as well as engineers who have acquired suitable competences in the course of their education.

Task of teams in Product Development is to achieve multiple compliance, exchange of information, to debate, dispute resolution and formal policies. It is important to establish the personal competencies, which are very important for the successful operation of the team. It is also important real competence, which team members have in relation to the upcoming task, only to be successfully solved. After extensive research in this direction, clearly defined following relevant competencies: professional competence, methodological competence, social competence, creative potential and ability elaboration. Furthermore will be defined the above mentioned competences. Figures 5 and 6 shows the field and the areas of education development engineers, whose acquisition can be achieved specified competences.

The main part of the education of product development engineers and acquiring of the necessary competencies are achieved during the master studies. Professional competence leaning on the knowledge acquired at the bachelor level are primarily oriented to obtain knowledge and skills in the areas of product development and the processes which are carried out at the same time. To acquire methodological competencies presented is the practical application of a number of methods to solve problems in Product Development, the ability to synthesize technical solutions, as well as the successful implementation of innovations. Social competences are focused on communication and articulation skills, teamwork and leadership as well as the ability to solve problems through their own initiatives. Very important are the competences related to the ability of elaboration. These competencies are expressed through the skills of systematic work style, integration of technical and
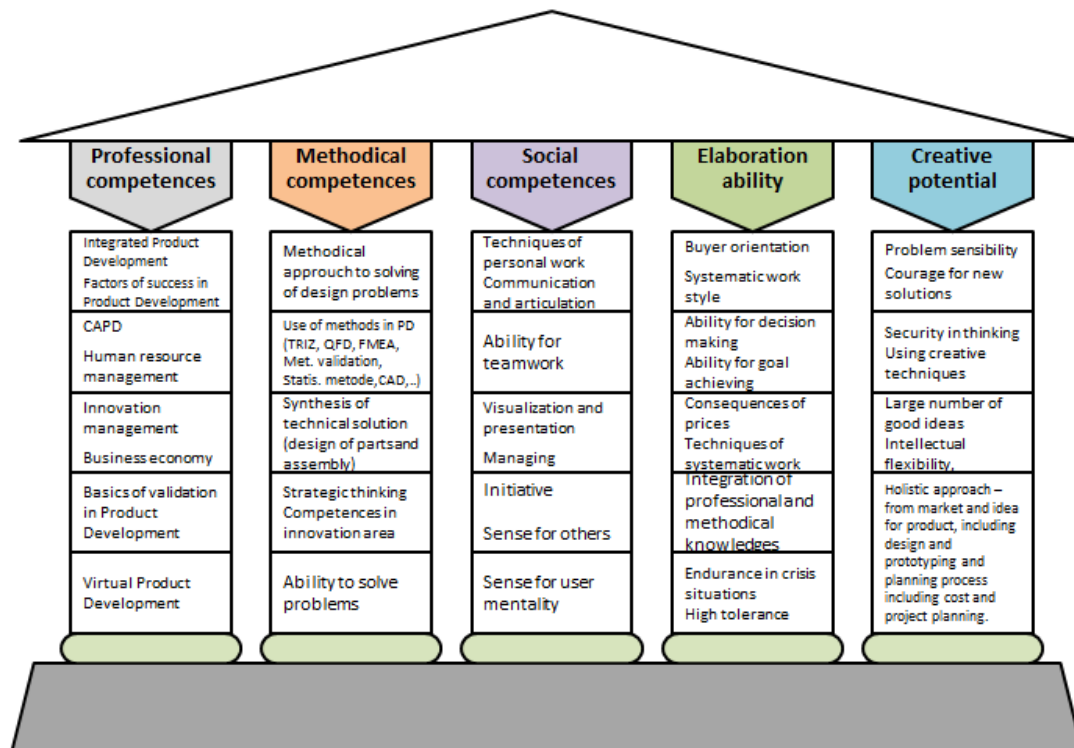

Figure 5. Authoritative competences in field Product Development on master studies.

methodological knowledge and managing in crisis situations. Competencies related to the creative potential include acquiring skills for applying creative techniques, safety at work and the implementation of new solutions as well as a holistic approach to product development.

In education of product developers engineers in doctoral studies (Figure 6) is planned acquisition of expert scientific competencies related to the methods of scientific research, but primarily for application and development research that can be successfully applied in the development of new, sophisticated and commercially successful products. Methodical competences primarily are aimed at developing methods and procedures for the rapid implementation of the results of basic and applied research in the development of new products. Social competences are aimed at acquiring the ability to create and manage multi-disciplinary project teams, skills for conflict resolution and stability in critical situations. Competencies related to the ability of elaborating are referring to the successfully hypothesis, identification of scientific research of interest to engineering practice and formulation of research results in writing form. Creative potential involves acquiring the ability to create models for testing, prototyping and pilot plant, creating innovations and new technical solutions.
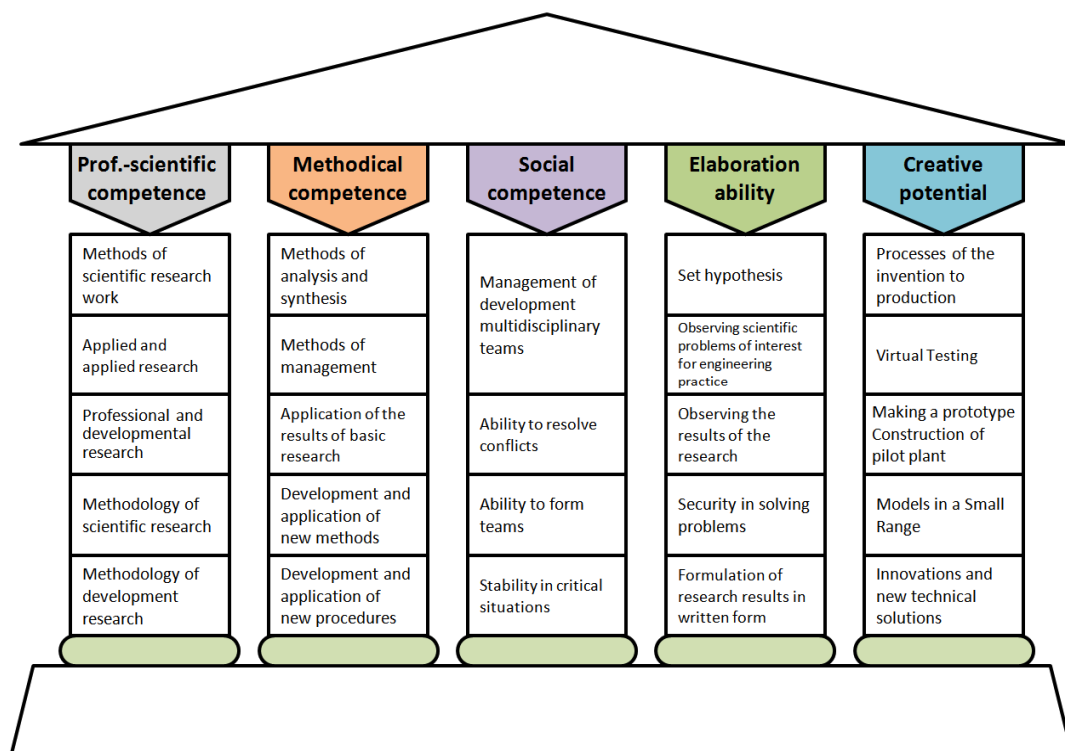

Figure 6. Authoritative competences in field Product Development on doctoral studies.

3.3. The transfer of technology, innovations and product development (knowledge application)
If activities relating to one´s scientific work have been successfully performed from the standpoint of excellence and relevance and if the acquired knowledge has been transferred to development engineers in a quality manner through the system of education, then one reaches the phase of knowledge application. It is primarily reflected in the process of technology transfer, product development and adequate application of innovations.

In the narrow sense, technology transfer can be observed as a process of the flow of knowledge from its source (scientific research) to its user (business entity).

Product development implies an interdisciplinary process in the company. This process is based on product planning, begins by defining the product profile, within this process continuously running further development, and ends with the product that is feasible for production and it can properly

work. In new, as well as in improved products the level of product innovation is the factor which mostly contributes to its competitive advantage.

Innovation literally signifies "a change" or "renovation". The word derives from a Latin word *innovare* which means *to renovate*. Innovation does not necessarily imply invention. However, an invention can be considered innovation. In everyday use this word is used to denote the application of new ideas and inventions and, consequently, the achieved commercial effects. In the narrow sense, **innovation** is an application of ideas which bring new benefits and qualities in the application of new products, services and processes. In a broad sense, innovations bring improvements in the field of product design (technological innovations), processes, work organisation or management, marketing, service innovation, etc.

According to the degree of innovation, one can distinguish between **radical innovations** (significant, clearly perceptible degree of innovation) and **incremental innovations** (less conspicuous degree of innovation). Innovations can increase competitive advantage of business enterprises by means of developing new high quality products, introduction of new technologies in the process of production, introduction of new models of organisation into the process of production, conquering new markets, establishing new market relations, etc.

Knowledge as a result of work of research organisations is a basic precondition for obtaining quality innovation with a high level of authenticity and a potential for creating commercially competitive products.

One should bear in mind that the path leading from invention to innovation is a long and time-consuming one, bearing the risk of being unsuccessful. Every successful innovation requires a lot of time, discipline and analysis. In addition to creativity, preconditions for innovation are practical experience, focus on the essence and attention to details. Innovations and product development are tightly connected. The beginning of innovation is in fact the beginning of a product development. In that respect, the phrase "innovative product development" has been introduced. With respect to innovative product development it would be purposeful to obtain answers to the following questions:

- How to generate and evaluate creative and efficient innovative ideas?
- How to turn an idea into innovation which will be applied to a new product development?
- How to systematically manage the innovative process of generating ideas, assess their applicability and their transformation into a commercially competitive product?
- How to master creativity techniques (Brainstorming, Mind Mapping, TRIZ...)?
- How to promote radical innovation and how to apply profitable services from incremental (gradual) innovation?

For the purpose of systematic innovation planning one can use the W-model. This model comprises seven phases (Figure 7), by means of which one can define the process of creating a road map of
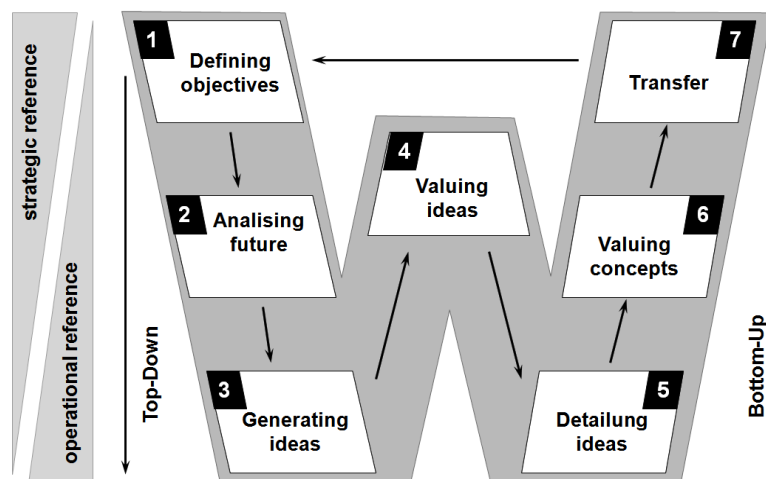

Figure 7. Innovation RoadMap – W-modell [6, 7].

innovation [6, 7]. This approach offers the possibility of using the total corporate goals achieved through product innovation to define new products which are then translated into product concept and its further implementation. Ideas defined at the beginning are successively evaluated and concretised and they are constantly reduced.

Bearing in mind the dynamics of market, technology and business development, the main activities within phases 1, 2 and 7 within the W-model are constantly iterated. Although the W-model has a universal character one needs to adjust to the business model and environment characteristic of the enterprise. The development of innovation map plans can be accelerated by means of parallel and networked execution of individual phases.

An important condition for the success of innovation is creating a suitable climate in the society related primarily to the dissemination of scientific, technological and innovation culture.

4. Conclusion

In modern conditions, knowledge as a result of research in science and technology becomes a dominant resource in the development of a country, bearing greater potential and possibilities than natural resources, since it is the precondition of the development of high quality products and production, as well as of high productivity and efficiency. In order for this resource to be adequately used it is necessary to establish a relevant interaction between three key elements of the research triangle: knowledge creation (scientific research), knowledge dissemination (education) and knowledge application (transfer of technology and innovation).

The presented analysis of the situation at the universities in this region indicated that, in spite of numerous challenges in the past period, most of these countries preserved the critical mass for scientific research and that certain universities became stronger and presented significant results in science, research and education quality. According to global ranking lists one can distinguish universities of Belgrade, Ljubljana and Zagreb. According to all ranking criteria, public universities exhibit high superiority in relation to private universities. Chaotic development of education in certain countries has significantly decreased the quality of education.

The three basic missions of universities are scientific research, education and transfer of technology and innovation. The mission of Serbian universities related to scientific research from the standpoint of excellence has been significantly achieved in recent years, which is confirmed by the number of internationally visible results, i.e. by their position on global university ranking lists. However, the number of results of the scientific work which found its application in business enterprises is very low, i.e. the quality of scientific work from the standpoint of relevance has not been achieved. One can conclude that it is high time that measures were taken for the purpose of fulfilling the third university mission – transfer of technology and innovation.

Innovations are a basic precondition for the development of quality products and achievement of competitive advantage, both regarding business enterprises and country as a whole. In order for a company to survive and develop in a modern and turbulent environment, it is necessary to do everything in its power to introduce an innovative approach and creativity. The key role is to be played by human resources who are at companies´ disposal. In that respect, an important task of universities, according to the requirements of modern technique and technology, is to educate development engineers with relevant competences for the successful solution of work tasks within interdisciplinary project teams.

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