



Tempus

**Analysis on the needs of West Balkan
universities for Bioengineering and Medical
Informatics degree programmes**

Executive Summary

BioEMIS is a European Commission Tempus project to develop new study programmes in Bioengineering and Medical Informatics at universities in the West Balkans. This report summarises the work undertaken in work package 1.4 to analyse the needs of West Balkan universities for Bioengineering and Medical Informatics degree programmes.

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1. Introduction

BioEMIS is a European Commission Tempus project to develop new study programmes in Bioengineering and Medical Informatics (BE&MI) at universities in the West Balkans (WB). This report summarises the work undertaken in work package 1.4 to analyse the needs of West Balkan universities for Bioengineering and Medical Informatics degree programmes.

2. Bosnia and Herzegovina

2.1 *Need for experts in biomedical engineering and medical informatics*

There is an increasing need for experts in BE&MI for medicine and the healthcare sector. In the world the occupation of biomedical engineers is expected to experience the highest relative growth in terms of new jobs available among all occupations until 2018. Furthermore, as many as eight out of the ten of the most wanted occupations in the world are connected to medicine and health care services.

2.2 *Need for education in biomedical engineering and medical informatics*

As result of the development in industry and the health care systems there is need for BE&MI education to:

- provide necessary human resources;
- make sure that quality of education and training satisfies needs of the employers;
- implying need for patient safety in health care services.

As important aspects of BE&MI study programs quality assurance need to be established:

- accreditation of BE&MI programs;
- certification of BE&MI (biomedical/clinical) engineers and professionals;
- continuing education (life-long learning).

European harmonization of higher education programs is an important political goal of the EU and desirable for all academic disciplines. For BE&MI disciplines that is expanding so fast it is important prerequisite for students to be able to select the BE&MI specialty of their choice, no matter where they come from. In contrast to the traditional academic disciplines where consensus about the necessary content of HE programs and the required qualifications of professionals could be established over many decades BE&MI as growing discipline did not yet have this opportunity. There are more universities, universities of applied science, polytechnic schools, academies and other institutions in Europe that offer educational programs in BE&MI at all academic levels, BSc, MSc as well as PhD levels. Europe promotes harmonization of BE&MI educational programs to:

- specify required minimum qualifications;
- establish criteria for an efficient quality control.

Europe is preparing creation of the European Higher Education Area in the field of BE&MI for the benefit of the universities, the students and the whole society. The aims are Europe wide:

- harmonization of high quality BE&MI programs;
- BE&MI programs accreditation;
- certification or registration and continuing education of professionals working in the health care systems.

It will:

- insure mobility in education and employment;
- improve competitiveness of the European biomedical industries;
- improve necessary safety for patients;
- contribute to the health and well-being of the European people.

National quality assessment and accreditation schemes have to be established and they have to be harmonized. They need to satisfy criteria which the European BE&MI community will establish on transnational basis and mutually agreed upon. There are many established academic programs within the classical engineering disciplines offering specialization in BE&MI up to different levels of qualification or competency.

2.3 Need knowledge, skills and competences in biomedical engineering and medical informatics

Every BE&MI engineer and expert must possess relatively broad knowledge of fundamental engineering and physical science principles. However, unlike other engineers and experts, she/he must be able to apply this knowledge to solve problems of biomedical origin, which requires the knowledge about the principles of living organisms.

BE&MI education should be based on commonly accepted, general guidelines for engineering programs and should add the necessary core competencies as well as specializations in BE&MI. It should provide:

- basic competencies in engineering, biology and medicine;
- general competencies (soft skills) which are felt to be necessary requirements for a BE&MI degree.

Two different basic types of BE&MI programs should be considered, defined and established:

- research oriented programs;
- professionally oriented programs.

As in all engineering, first-year subjects in BE&MI studies are focused on mathematics, physics, chemistry, biology and statistics. From the second year the training is more specific and related to the professional areas such as medical imaging, biomechanics, biochemistry, nuclear medicine and medical informatics. Some of competences that are expected to get from BE&MI studies are:

General competences

- Capacity for analysis and synthesis.
- Ability to acquire, analyze, interpret and manage information.
- Ability to evaluate and compare decision-making criteria and exercise leadership.
- Ability to prepare reports and make judgments based on a critical analysis of reality.
- Ability to define, develop and elaborate regulatory own area.
- Ability to understand the social, technological and economic condition of the practice.
- Develop creativity and imagination.
- Ability to argue orally and in writing to both specialist and non-specialist.
- Ability to communicate in their own language and in English and to work in a multilingual environment.
- Ability to write and present technical reports and projects.
- Ability to communicate using graphic and symbolic languages.
- Capacity for teamwork in a multidisciplinary and multicultural environment.
- Ability to understand, anticipate and assume social responsibility, ethics and professional and socio-economic effects and environmental practice derived.
- Ability to organize, plan and manage the initiative, entrepreneurship and leadership.
- Motivation for quality and professionalism.
- Ability to learn new techniques and tools of analysis, modeling, design and optimization.
- Ability to adapt to new situations.

Specific competences

- Basic knowledge in health sciences and molecular cell biology, anatomy, physiology, biochemistry and human pathophysiology.
- Having knowledge of the underlying science and technology in which medical technology is based on different levels: macro, micro and nano level.
- Being able to understand the technical and functional characteristics of the systems, methods and procedures used in the prevention, diagnosis, therapy and rehabilitation.
- Being able to analyze and evaluate health technologies.

- Ability to develop, plan and apply mathematical methods in the analysis, modeling and simulation of the functioning of living organisms and the systems and processes used in biology and medicine.
- Ability to design, develop, deploy and manage experimental procedures, tools and systems to acquire, analyze and interpret data from living systems using engineering tools.
- Ability to plan, design, develop, install, operate and maintain procedures, devices, equipment and systems for the prevention, diagnosis, treatment and rehabilitation.
- Ability to model, interpret, select, perform and evaluate concepts and technological developments related to biomedical engineering and its application.
- Ability to efficiently use tools for analysis, design, calculation and testing in the development of biomedical products and services.
- Ability to plan, organize, direct and control systems and processes in the field of biomedical engineering.
- Basic knowledge of cardiovascular, neurological, metabolic, immunologic, infectious and assisted reproduction, as well as diseases and processes of locomotor apparatus.
- Capacity for organization and planning in the field of business, health centers and government agencies concerned with medical technology, based on principles and procedures of quality.
- Ability to interpret and apply the laws and regulations, both national and international, to own different application areas.
- Capacity to innovate in products and biomedical services.
- Entrepreneurial capacity in the biomedical sector.
- Ability to communicate with health professionals and understand their needs in relation to biomedical products and services.
- Ability to integrate into working with medical professionals to work in biology and experimentation and the development of new products and services in the field of biomedicine.
- Capacity for self-learning, consolidation and updating of new knowledge in the area of biomedical engineering, and to undertake further study with a high degree of autonomy.
- Ability to consolidate, expand and integrate knowledge of basic sciences (basic sciences and health sciences) in biomedical engineering.
- Ability to adapt to new knowledge about the functioning of living organisms and the evolution of medical technology.

- Have knowledge of systems and production and manufacturing processes in the field of medical technology.
- Have knowledge of the organization and management of health care systems, healthcare and technology industries and health services, as well as legislation, regulations and standards applicable in the field of biomedical engineering.
- Ability to integrate multidisciplinary knowledge related to engineering, biology and medicine.
- Ability to identify, formulate and solve problems at the interface between technology and health sciences, biology and medicine.

2.4 Needs for biomedical engineering and medical informatics studies in Bosnia and Herzegovina

Bosnia and Herzegovina is faced with problems related to transition to modern and democratic society and with the choice of steps towards integration into the family of European countries. Health care system is in an inadequate condition, not allowing, in some cases and in some regions, adequate health protection. Health care systems in Bosnia and Herzegovina are in reconstruction, development, improvement and modernization. Improvement of health care system can be obtained by systematic introduction of BE&MI systems and technologies and appropriate knowledge. Development in both areas of Biomedical Engineering and Medical Informatics, based on interdisciplinary approach, can provide in Bosnia and Herzegovina substantial advances and results in health care and protection fields.

The main need is to develop new curricula and to establish separated or common university studies in BE&MI interdisciplinary field for students of electrical engineering, mechanical engineering and medicine at Bosnia and Herzegovina universities. The need is to define regular and basic forms of the courses and make unification of the studies in the sense of encompassing students of electrical engineering, mechanical engineering and medicine. The European dimension and harmonization of the curriculum need to be maximized.

During the more than one decade teaching and research staff of Bosnia and Herzegovina faculties of Mechanical Engineering and Electronic Engineering, together with Faculties of Medicine work to contribute solving complex multidisciplinary problems in BE&MI. Hospitals and clinical centers clearly expressed their needs in that course, and ministries of health, medical chambers, and private enterprises also support this initiative. Students of mechanical engineering, electronics and informational technology after graduation often look for the job in BE&MI area.

Analysis of all these facts, needs and requirements justifies beliefs that promotion and upgrading of study programs in BE&MI field is necessary and will improve the quality of clinical practice and health services in Bosnia and Herzegovina. BE&MI has tradition in Bosnia and Herzegovina. BE&MI industry was one of industries developing, manufacturing and marketing products over the world (for example company Medical Electronics in Banja Luka). The major actors in BE&MI field in Bosnia and Herzegovina are:

- industrial partners,
- public universities with Faculties of Electrical Engineering, Mechanical Engineering and Medicine,
- medical institutions.

There is significant interest and need for BE&MI education in Bosnia and Herzegovina. Every year there are more than thousand (approximately 2000 in last 5 years period) first year students in Bosnia and Herzegovina faculties of electrical engineering, mechanical engineering and medicine. It is estimated that many of them would want to study BE&MI. Every year there are few hundreds (approximately 800 in last 5 years period) of students graduated from the faculties of electrical engineering, mechanical engineering and medicine in Bosnia and Herzegovina. It is estimated that many of them would want to study BE&MI, and to continue with BE&MI studies at 2nd and 3rd study level. Many employed engineers and medical doctors would like to continue their education in BE&MI field at 2nd and 3rd study level.

In the last years we have been witnesses of decline in the number of students enrolled for the study of mechanical engineering and electrical engineering in Bosnia and Herzegovina what is trend shared with other engineering disciplines. Formation of new attractive and modern BE&MI programs of high quality and responsive to the urgent needs of the modern society may be the way to revoke the interest of students in engineering in general and to attract more students to the study of mechanical and electrical engineering.

Having in the mind capacities of Bosnia and Herzegovina universities and faculties of mechanical engineering, electrical engineering and medicine, and also relatively small number of potential students it is needed and recommended in Bosnia and Herzegovina BE&MI education to go in next directions:

- Modernize existing first cycle study programs at faculties of electrical engineering, mechanical engineering and medicine and introduce more study subjects from BE&MI, as mandatory or as optional ones,

- Reconsider and modernize existing second cycle study programs at faculties of electrical engineering, mechanical engineering and medicine or introduce new second cycle study programs or study directions from BE&MI field at the faculties.
- Reconsider possibility to develop and organize common second cycle study programs at university level for graduates from faculties of electrical engineering, mechanical engineering and medicine.
- Develop and organize common third cycle study programs at university level for candidates from mechanical engineering, electrical engineering and medicine.
- Develop and organize common interuniversity third cycle study programs for candidates from electrical engineering, mechanical engineering and medicine.

It is needed that the study programs should be created in a broad manner to enable candidates from all study fields (electrical engineering, mechanical engineering and all fields of medicine – general medicine, dentistry and pharmacy) to have access to the study programs. According to analysis of BE&MI study programs from EU universities, analysis of needs of Bosnia and Herzegovina society and analysis of capacities of Bosnia and Herzegovina universities it seems that next study subjects and courses need to be introduced and established in BE&MI study programs in Bosnia and Herzegovina.

For the first study cycle (bachelor) in BE:

- Medical Electronics;
- Basics of Anatomy and Physiology;
- Biochemistry;
- Medical Devices (and Sensors);
- Biomedical Instrumentation;
- Biomaterials;
- Introduction to Bioinformatics;
- Biomedical Statistics;
- Fundamentals of Biomedical Engineering;
- Biomedical Signal Processing.

For the first study cycle (bachelor) in MI:

- Health Services Management and Policy;
- Introduction to Bioinformatics;
- Health Information Systems;
- Medical Data Bases;
- Data Structures and Algorithms;

- Introduction to Biomedical Programming.

For the first study cycle (bachelor) of common BE&MI studies could be offered both above groups of courses.

For the second study cycle (master) in BE:

- Biomechanics;
- Physics (optics, nuclear, biophysics...);
- Bioinformatics;
- Biochemistry;
- Biomedical Instrumentation;
- Clinical and Biochemistry;
- Geometrical Modeling in Medicine;
- Navigation and Robotic Systems in Medicine;
- Computer Aided Medical Procedures;
- Computer Assisted Surgery;
- Biomedical Image Processing;
- Management in Health Care.

For the second study cycle (master) in MI:

- Bioinformatics;
- Geometrical Modeling in Medicine;
- Navigation and Robotic Systems in Medicine;
- Computer Aided Medical Procedures;
- Computer Assisted Surgery;
- Biomedical Statistics;
- Biomedical Data Analysis and Processing;
- Medical Information Systems;
- Computer Graphics in Medicine;
- Artificial Intelligence in Medicine;
- Computer Aided Diagnosis;
- E-learning in Medicine.

For the second study cycle (master) of common BE&MI studies could be offered both above groups of courses.

For the third study cycle (Ph.D.) in BE:

- Biomaterials;
- Biomedical Statistics;
- Biomedical Signal Processing;
- Methods for Biomedical Research;
- Biomechanics of Musculoskeletal System;
- Genomics and Proteomics;
- Genetic Engineering;
- Healthcare Economy;
- Biomechanics of Cardiovascular System;
- Computer Graphics in Medicine;
- Tissue Engineering;
- Medical Electronics and Measurement;
- Rehabilitation Engineering;
- Artificial Intelligence in Medicine.

For the third study cycle (Ph.D.) in MI:

- Biomedical Data Analysis and Processing;
- Medical Information Systems;
- Computer Graphics in Medicine;
- Artificial Intelligence in Medicine;
- Computer Aided Diagnosis;
- E-learning in Medicine;
- Programming in Biomedical Engineering;
- Augmented Reality in Medicine;
- Telemedicine;
- E-health.

For the third study cycle (Ph.D.) of common BE&MI studies could be offered both above groups of courses.

It is needed to have licensing and accreditation of BE&MI study programs in Bosnia and Herzegovina. Licensing of study programs in Bosnia and Herzegovina:

- Entity level in Republic of Srpska – Ministry of education and culture;
- Cantonal level in Federation of Bosnia and Herzegovina – cantonal ministries;
- District level in Brcko district – district education authorities.

Accreditation of study programs in Bosnia and Herzegovina:

- Agency at Bosnia and Herzegovina level – coordination of accreditation processes;
- Agency for HE institutions accreditation in Republic of Srpska;
- No agencies or bodies for accreditation in Federation of Bosnia and Herzegovina, cantons and Brcko district.

Financing of study programs in Bosnia and Herzegovina:

- Trying to be self sustainable;
- Problems – relatively small number of candidates at all study levels.

Ways of financing:

- Public financing – from public institutions budget;
- Private financing – from candidates completely or partially;
- Companies financing – from interested companies.

2.5 SWAT analysis

A SWAT analysis of needs to establish and develop BE&MI studies in Bosnia and Herzegovina is shown below.

Strengths

- Good established HE system and HE institutions;
- Support from HE institutions, Ministries of Health, Medical Chambers, BE&MI enterprises and industry;
- Good faculties of electrical engineering, mechanical engineering and medicine;
- Existing of cooperation of medical institutions, Ministries of Health, Faculties of Medicine and Universities.

Weaknesses

- Relatively small number of potential students;
- Relatively small number of BE&MI experienced professors;
- Lack of modern BE&MI equipment at faculties and medical institutions;
- No qualification framework in BE&MI areas – engineering or medicine professions;
- No degrees in BE&MI – engineering or medical degrees.

Opportunities

- Development and increase of growth of BE&MI sector in the world and Bosnia and Herzegovina;
- Increasing of working places and jobs in BE&MI sector;

- Increase of interest for BE&MI education in the world and in Bosnia and Herzegovina;
- More interest and investments in health care and protection systems in Bosnia and Herzegovina;
- Support from EU institutions and funds;
- Development and establishing of good BE&MI study programs.

Threats

- No completely established system for licensing and accreditation of HE institutions;
- Problems with financing of study;
- No enough working places and jobs.

3. Montenegro

3.1 Primary health care level in Montenegro

Montenegro has a population of 621,081 and is divided in 22 municipalities without official districts, regions or provinces. Primary health in Montenegro is basically provided on the municipality level by 18 medical centers (known as “Domovi Zdravlja”). In 4 municipalities there are health stations (ambulances). Health stations in Plužine and Šavnik municipalities belong to Health center Nikšić, health station in Žabljak to Health center Pljevlja and health station Petnjica to Health Centre Berane

Two public-health institutions Institute for Public Health and State Pharmacy Institution „Montefarm” are of importance for overall health system. “Montefarm” has 41 public pharmacies (Podgorica 10, Plav 3, Bar, Berane, Budva, Danilovgrad, Kolašin, Kotor, Nikšić, Ulcinj i H. Novi 2, and 1 per the remaining 10 municipalities). Of course, there are numerous private pharmacies in all cities, even in middle size places.

A special role in the primary health care of Montenegro has 182 private health institutions-ambulances. They are located in all municipalities and provide services from 38 medical fields. The majority is located in Podgorica (41,5%), Budva (12,6%), Bar (12,0%), Herceg Novi (9,8%),etc. Dental institutions are 88 (48,08%), gynaecology domain 18 (9,8%), internal medicine 17 (9,28%), eye disease 9 (4,91%), paediatrics 10 (5,78%) etc.

3.2 Secondary and tertiary health care in Montenegro

This level of health care is provided by

- Seven general hospitals: Bar (for municipalities Bar and Ulcinj); Bijelo Polje (for municipalities Bijelo Polje and Mojkovac); Berane (for municipalities Berane, Andrijević, Plav and Rožaje); Kotor (for municipalities Kotor, Tivat and Herceg Novi);

Nikšić (for municipalities Nikšić, Plužine and Šavnik); Pljevlja (for municipalities Pljevlja and Žabljak); Cetinje (for municipalities Cetinje and Budva).

- Five health stations (ambulances) located in municipalities: Mojkovac, Plav, Plužine, Rožaje i Šavnik.
- One Clinical Centre of Montenegro in Podgorica, the most important health institution in country, that besides primary and secondary health care level for municipalities Podgorica, Danilovgrad and Kolašin provides tertiary health care for overall Montenegro.
- Three Specialized hospitals: Mental hospital Dobrota, Kotor; Specialized hospital for orthopedic traumatology, neurology and neurosurgery „Vaso Cukovic” Risan; Special hospital for pulmonary diseases „Dr Jovan Bulajic” Brezovik in Nikšić;
- One institute for physical medicine, rehabilitation and rheumatology „Dr Simo Milošević” AD Igalo in Herceg Novi municipality.
- Several modern private hospitals like Codra in Podgorica, Meljine in Herceg Novi etc.

3.3 Companies in medical, pharmaceutical and ICT sector

In fact, this sector is not developed on the level of production. However, there are numerous public and private companies working in medical and pharmaceutical sector in Montenegro, providing supplying or services. Some of them are: Baypharm, Hemofarm, Farmegra, Montefarm, Hemomont, Glosarij, Farmont, Novifarm, ICN Galenika, Siemens Podgorica, Rudo-Montenegro, Urion Medical Equipment, ALPHA IMAGING MNE, MG-Soft, Cikom, Digit Montenegro etc.

3.4 Management and Financing of health care system in Montenegro

Management and control of Health care system in Montenegro has been performed by Ministry of Health, while Republic Fund for Health (www.fzocg.me) is responsible for its financing. For individuals that have no health insurance, the financial means are provided from the state budget of the Republic of Montenegro.

3.5 Summary on the needs

Table 3.1 gives a projection on 10 years needs for BE and MI profiles in Montenegro resulted by internal analyze performed by Montenegrin BioEMIS team. As seen, 192, near 200 qualified persons on Spec or MSc level are required in Montenegro in period of further 10 years. Since the programmes planned by BioEMIS intend to provide 10-15 graduates yearly, it means that BioEMIS will be justified in Montenegro for following 10-15 years. On the other side, it is expected that 5-10 persons will disperse from a sector each year that indicating a continued need for BioEMIS profile during long period.

Table 3.1. Overview of needs for BE and MI profiles in Montenegro on Spec and MSc level.

Institutions	BE	MI
18 Health Centers	18	18
7 General Hospitals	14	7
1 Clinical Centre	10	10
3 Specialized Hospitals	4	4
Private Hospitals	5	5
Other private health institutions	5	5
Medical and Pharmaceutical Industry and Suppliers	20	30
Ministry of health	2	2
Health insurance fund	2	10
Education institutions, universities and colleges	3	5
NGOs	1	5
Others	2	5
SUM	86	106

4. Serbia

4.1 *Current problems in the field addressed by the project*

The medical technologies are among the most expensive chapters in the national budget. Medical devices represent potential risks if they are not set-up, checked, used, cleaned, calibrated or serviced properly. Operator errors and misuses are more prevalent and serious problem than defective equipment, so health care system needs well educated but also well trained staff. It is strongly recommended to enterprises to turn their employment politics towards young people which are usually well educated but without any experience with expensive equipment. Thus, it has been proved that the training/retraining of the users and technical personnel can minimise operator errors and by implication to decrease the failure rate, equipment downtime and consequently the expenses due to corrective maintenance. The biomedical engineers are those aimed to fill the gap and to provide the dialogue between the two worlds: medical and technical. The technical assistance to the health care service is active in partner countries but on a background level, as the equipment is old in a great extent and the technical people involved in the area do not have the proper education, being mainly physicists, electrical or mechanical engineers who just managed to get a job within the area. They are specialised in the specific instrumentation on the field, this highly depending on their personal skills and dedication.

In general, it can be stated that the main weaknesses reflected in the health care system, in the last years, are the following:

- insufficiency of the national budget allocated to the education and to the training/retraining programmes;
- serious need in hospitals and medical equipment manufactures for well-prepared (bio)medical technician engineers who understand the complex medical equipment;
- a strong inertia within the managerial structures;
- the lack of information and direct contacts with European peer-institutions (universities, research centres, institutes, etc.) active in the field of medical engineering and medical physics;
- the need for facing the new situation raised by the adoption of the Medical Device Directives by the EU.

In order to response to the more urgent regional needs in the field of health care the partner universities, have identified the following common training needs in the development plan of their own universities:

- the restructuring of the syllabuses and make them flexibly through the introduction and development of multidisciplinary practically oriented studies in Bio-Medical Engineering (BME) domains, in accordance with the EU educational practice;
- the development of a continuing education system for either the graduates in BME or other categories of personnel active in the field of health care;
- the improvement of the links between universities, hospitals, manufactures and other professionals engaged in the health care sector in order to support the acquisition of practical experience by the students, and their placement after.

4.2 Current needs for educational system

The current needs in the partnership of health care system and educational system can be summarised as following:

- the education of the students in the safe and efficient use of medical equipment and the quality assurance services offered by the clinical engineering department, according to the internationally recognised quality standards;
- to provide quality programs of education, research and service in the area of medical engineering and medical physics; this can be achieved by giving a multidisciplinary character to the curricula;
- to provide a well-prepared category of medical technicians serious need in hospitals and medical industry;
- concerning the continuing professional development (CPD) it is an University role to change degree-oriented education to lifelong learning using the technological tools

offered by the information society, i.e. telematics and multimedia, allow universities to assume the challenge they are faced with by the knowledge society;

- to include medical institutions, industry and enterprises in education and training process considering them as more than transfer of knowledge.

From the standpoint of society the future programme will:

- harmonize of the medical engineer concept in front of local and national authorities, by establishing a true dialog between teachers, specialists and students in this field;
- facilitate the improvement of the links between universities and manufactures and other professionals active in the health care sector in order to support: the acquisition of practical experience by the students and their placement after graduation;
- enable restructuring the Medical Engineering education for the enhancement of the instruction system flexibility in accordance with the EU norms;
- provide the improvement of the teaching materials for the faculties;
- allow the development of new well equipped laboratories;
- update the knowledge of the teachers according to the new technology, etc.

4.3 Expected program objectives according to current needs

The objective of our program development was to propose an updated specialization study curriculum in the field of biomedical engineering, in order to meet recent and future developments in the area and address new and emerging interdisciplinary domains that appear as a result of the R&D progress and respond to the demands of the BME job market. Adoption of the core program structure will facilitate harmonization of studies as well as student and staff exchange in Europe.

The specialization programs in biomedical engineering prepare students to apply the principles of engineering and applied science to problems in biology and medicine, to understand the dynamics of living systems, and to develop biomedical systems and devices. Modern engineering encompasses sophisticated approaches to measurement, acquisition, storage and analysis of data, model simulations, and materials and systems identification. These techniques are used in the study of individual cells, tissues, organs, and entire organisms. The increasing value of mathematical models in the analysis of living systems is an important sign of the success of contemporary biomedical engineering activity. Expected program objectives:

- the education of the students in the safe and efficient use of medical equipment and the quality assurance services offered by the clinical engineering department;
- providing quality programs of education, research and service in the area of medical engineering by giving a multidisciplinary character to the curricula;

- providing a well-prepared category of medical technicians serious need in hospitals and medical industry;
- establishing the joint programmes for continuing professional development (CPD) for employers in health care system;
- inclusion of medical institutions, industry and enterprises in education and training process;
- improvement of the links between universities and manufactures and other professionals active in the health care sector in order to support: the acquisition of practical experience by the students, their placement after graduation and the correlation between instruction and the domain of Biomedical Engineering;
- improvement of the teaching materials for the faculties through the partnership with health care enterprises;
- development of new well equipped laboratories compatible with partner universities;
- updating the knowledge of the teachers and hospital management and staff according to the new technology etc.;
- harmonization of the (bio)medical engineer concept in front of local and national authorities, by establishing a true dialog between teachers, specialists and students in this field.

4.4. Example of Labor Market needs: The estimated number of biomedical engineers required at Military Medical Academy

Modern Health Care Services are provided with ever-increasing demands for competence, specialization and cost effectiveness. Biomedical engineers are the vital part of Health Care Profession whose training and function are specifically directed towards Health Care.

EEC Directive 97/43/Euratom (Official Journal of the European Communities No L180, 9.7.1997) recognized special groups of technical professionals whose training and competence enable the development and use of complex techniques and equipment, optimization, quality assurance, including quality control, and other matters relating to diagnostic and therapy techniques including ionizing and non-ionizing radiation protection of patients, staff and general public.

Biomedical engineering Departments generally serve a variety of medical specialities. as are radiological field (radiotherapy, nuclear medicine, X-ray diagnostics and radiation protection), magnetic resonance and ultrasound imaging, physiological measurements, clinical applications of non-ionising radiations (lasers, ultraviolet light and microwaves), bioengineering, electronics, information technology, general data processing and computer technology. The role of biomedical engineers in these areas is expected to increase in the future.

Generally the total number of staff required in hospital depends upon:

- the range of applications of technical service to medicine;
- the scale of organisational and management responsibilities (number of clinics, population served);
- the amount and complexity of equipment and procedures used in related clinical specialities;
- the number of patients examined and treated in the relevant modalities and the complexities of these examinations or treatments;
- the load for formal teaching and training;
- the level of participation in maintenance, development, research and clinical trials.

Minimum staffing levels should be calculated from factors depending both on equipment load, number of patients treated and sophistication of treatments. General guidelines are based upon WTE (whole time equivalent) for assessment of minimum staffing levels for routine clinical work in various medical disciplines. The basic document used for calculation is EFOM Policy document *Criteria for the staffing levels in Medical Physics Department* and related documents.

Table 4.1. The estimated number of biomedical engineers required at MMA

Subject	Total staff	Minimum number of qualified biomedical engineers
Nuclear medicine including PET	12	6
Radiotherapy (External beam therapy only)	7	3
Diagnostic radiology	18	8
Ionizing radiation protection (based upon 100 person to supervise)	5	2
Non-ionizing radiation protection	4	2
Magnetic Resonance Imaging, Ultrasound, Laser and thermo-vision diagnostic and therapy procedures	27	12

Other	5	2
Software	5	2
Maintenance	12	7
Total	95	44

4.5 Conclusion

After achieving the learning outcomes the students should use the acquired knowledge in further education including lifelong learning. Students should be able to communicate effectively in both oral and written form, to participate in social debates pertaining to technology, to carry out independent and multidisciplinary team work, to perform project management duties, and to understand the societal impact of engineering solutions. Students will be able to identify and formulate challenges in the biomedical and health science domains which belong to the biomedical engineers. Students should learn to work as members of multidisciplinary teams and to apply advanced methodologies at the interface between engineering and medical sciences.