Methodology of Modeling Hybrid Controller for University Management in Synergy with Industry

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Management of university is a very complex task in modern society. Universities are "producing" experts for different industrial sectors. New profiles of experts requiered from industry are rising almost every day. Accordingly, it is required from the university to change study programs and to introduce new disciplines of science in its curriculum. The paper presents the IDEF0 methodology for modeling hybrid controller for university management. The university, which has three groups of activities (teaching, research and management of overall business), falls into the category of complex systems, modeled by the methods and techniques from the theory of complex systems. For the hybrid controller with feedback (composed of the hybrid controller with lower levels of management), the object of management is university's integrated system in synergy with its own educational-business environment.

Keywords: *controller, university, synergy, modeling, IDEF.*

1. INTRODUCTION

The university is a dynamic system with many dynamic changes during the operation and function of time. Data and information are signals and functions of time. There is no consistent system of equations to describe the function of the university. There are primarily discrete data arising from the regular academic activities of universities. Basically, management system is an integrated system of digital university with the appropriate information and communication infrastructure. Such a system should have an integrated information resource with a single database/repository of knowledge and information. This is a special system that has a logical composition of related subsystems and modules, so that information combined with other components is to ensure continuous improvement of the quality of university activities. When designing a system for managing the university, it is necessary to define models and systems that will take into account all relevant elements important for the university. Modeling such systems requires the theoretical basis of several disciplines. This sets the requirement that the university is defined as a complex manageable system with defined characteristics (hierarchical system with centralized decision-making, whereby decision-making at lower levels of faculties and departments should keep certain principles of autonomy).

University and industry are very important business environments to each other, and together they form the world of education and business markets of products, technologies, knowledge and expert services. Facility management is a university with its educational and business environment as a complex system that can be organized and managed in different ways.

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2. FUNCTIONAL MODELING METHODOLOGY

Modeling is an engineering activity that contains elements of analysis and defining of the model, to design and implement modeled systems and processes. For the application of high information and communication technologies, a model of information integration is needed that includes functional and economic-financial integration [1]. The information integration framework model of integrated digital enterprise is a three-dimensional matrix model with basic activities, the third dimension referring to the levels of development and application [1,2], as shown in Fig. 1.

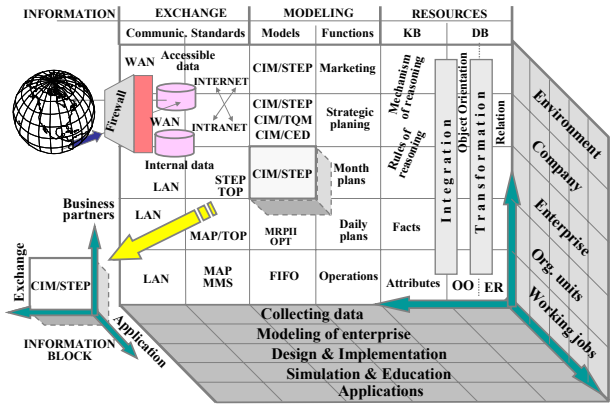

Figure 1. Information integration framework model of an integrated digital enterprise

There are many methods of analysis for information integration of product-business enterprise or integrated university that can be complementary, combined to ensure a consistent solution. These are computerized methods such as Design/IDEF, BPwin, Knowledge Ware, Jupiter and other [3-7]. These methods are suitable for solving system problems by using graphic symbols as a set of related activities, information, documentations and resources needed. Specifications

and a need for newly integrated quality system for digital university[1] are derived by the model shown in Fig. 2.

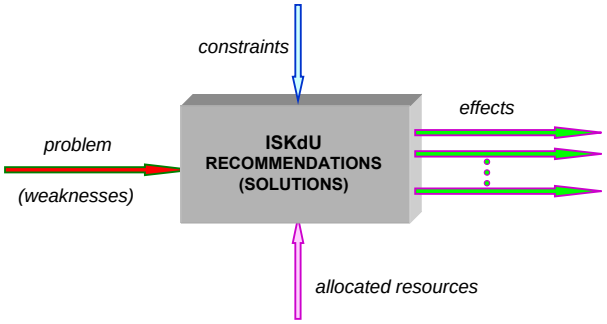

Figure 2. Model specification of requests for the new system

Inputs represent the problems (deficiencies or weaknesses) which should be eliminated in the projected solution. This is achieved by implementing the designer's recommendation of the system that provides concrete solutions. As a result, there are effects obtained in reference to a previous state in the functioning of the system. At the same time, one takes into account the constraints and perturbation factors that exist in the realization and implementation of project results and resources allocated to the system.

2.1 System analysis using the methods of SADT® and DesignIDEF®

The methodology for the analysis such as SADT (SADT – Structured Analysis and Design Technique) involves both structural analysis and design techniques of complex modular systems that operate at several levels [8,9]. It is intended for engineers (modeling of design solutions), managers (coordination of complex projects and tasks), communication system engineers (communication networks design), information technology engineers (system design and specification of the program), technical staff (programming and documentation), researchers (theoretical-developmental approach) and other users who need to apply in their work simultaneously a number of mutually interactive elements. In the literature, this methodology is often referred to as IDEF0 methodology (IDEF0 – Integration Definition for Function Modeling). Modeling is performed from the general level of operations to specific business activities that are decomposed to the product specifications and to the more detailed business model. Modeling of product-business enterprise is possible by using its separated units, which could be combined into a single consistent model.

2.2 Modeling of the university activities

Modeling of digital university is realized by the Design/IDEF methodology based on an analysis of all activities of the university. Figure 3 shows the basic level of operations of an integrated university (level – A0). The main inputs are demands from stakeholders of education and research, demands for common educational and research area in Europe (EHEA + ERA – European Higher Educational Area + European Research Area) and requirements of the Bologna process that determine the Higher Educational reform.

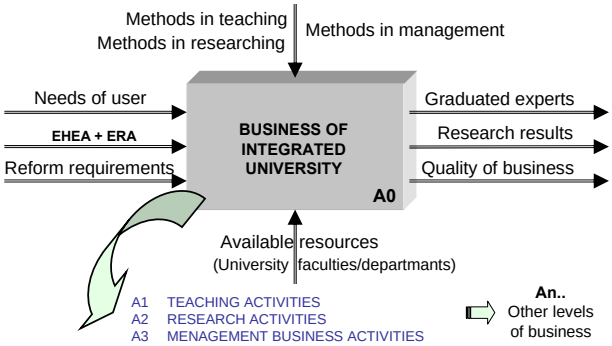

Figure 3. Business model of integrated university

The main outputs of the designed system are graduated experts of all profiles of expertise and all forms of university teaching. There follow the results of all types of research (basic, developmental, applied and innovative projects) as outputs of projects used to develop new products, technologies and methodologies.

The very process of modeling requires the knowledge of the digital university business faculties and institutes, as well as the rules of the methodology of modeling. Properly generated charts and reports in applied methodology confirm the consistency of functional and information model of an integrated university. Figure 4 displays the decomposition activity in three university-level operations, which define specific business tasks.

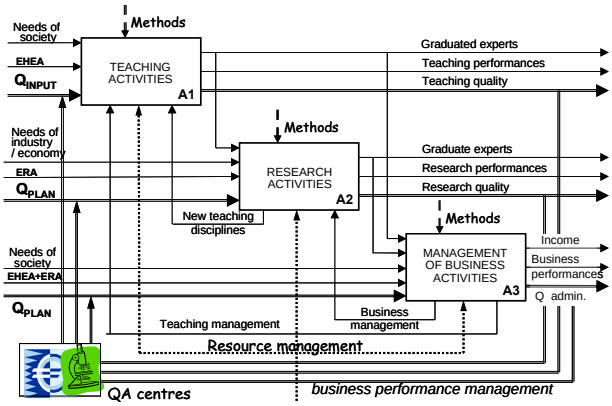

Figure 4. Diagram of integrated activities A1, A2 and A3 of digital university

Figure 4 shows the activity diagram of the next level of digital universities, which is further decomposed into project documentation [10] according to the levels defined in Table 1. In each of the main activities A1, A2 and A3 there are requirements of quality and results of relevant activities.

Continuous management of the quality of universities and faculties' operations could be achieved by measuring business and academic performance and the main indicators of performance may be compared with the planned values of strategic quality policy. Periodical or continuous evaluation is the task of Quality Assurance Centre at the faculty, Quality Assurance Centre of excellence at the university and national agencies/associations for the quality.

[1] Digital university – information integrated university where all activities are computerized, uses a database/knowledgebase and Internet to communicate with its customers and stakeholders

Table 1. Hierarchy-modeled functional activities for university

A0 – Total business of integrated university			
A1 – Teaching activities			
	A11 – Development activities		
	A12 – Teaching activities		
		A121 – Methods and types of activities	
			A1211 – Undergraduate studies
			A1212 – Graduate studies
			A1213 – PhD studies
			A1214 – Specialist studies
			A1215 Professional studies
			A1216 – Distance education
			A1217 – Continual education
			A1218 – Additional worker education
			A1219 – Teaching in English
		A122 – Teaching and learning	
			A1221 – Characteristics of subject
			A1222 – Characteristics of teacher
			A1223 – Course material
		A123 – Assessment methods	
			A1231 – Preceding duties
			A1232 – Exams
	A13 – Performances of teacher and students		
		A131 – Academic performances of teacher	
		A132 – Academic performances of associate	
		A133 – Academic performances of student	
	A14 – Providing quality in teaching		
A2 – Research activities			
	A21 – Development of innovative activities		
	A22 – Project management		
		A221 – Project budget	
		A222 – Results of project	
		A223 – Application of results for user	
	A23 – Performance of teachers and associates		
		A231 – Performance of teacher in research	
			A2311 – Paper in indexed journal
			A2312 – Paper in international journal
			A2313 – Paper in national journal
			A2314 – Scientific-technical work
			A2315 – Management & project work
			A2316 – Monographs and books
			A2317 – Patents
		A232 – Performance of associates in research	
	A24 – Providing quality in research		
A3 – Management of business activities			
	A31 – Student activities and services		
		A311 – Admission of student at university	
		A312 – Tracking progress in study	
		A313 – Help students' employment	
		A314 – Students activities	
			A3141 – Student parliament
			A3142 – Student association
			A3143 – Sports activities & universiade
	A32 – Documentation for evaluation & accreditation		
	A33 – Economic-financial activities		
		A331 – Bookkeeping	
		A332 – Liquidation	
		A333 – Payroll	
		A334 – List of basic assets	
		A335 – Economic performance of university	
	A34 – Maintenance and security		
	A35 – Provide quality in management		

3. OBJECTIVES AND CONSTRAINTS OF THE UNIVERSITY AND INDUSTRY

University and industry have their own problems, but have some common problems in the areas of their activities [11-13]. The most prominent common problems that universities and industry are facing now at the time of their individual and joint development are lack of development strategy and lack of continuity of development policy.

The main consequences of the discontinuity in the business of university refer to the limited management of university, university formalized integrative functions, lack of integrated information system with integrated analysis of university operations, unclear criteria of the quality of study programs, as well as teaching and research results and activities, lack of accepted European and international academic standards, lack of accepted and adopted procedures of quality and incompleteness of the integrated system of quality assurance.

The main consequences of the discontinuity in the business of industry and economy are related to slow business transformation of large systems in small and medium enterprises, outdated product and information and communications equipment, restrictions of investing in new equipment, partial and incompatible information systems, costly and insufficient quality of final products, slow cycles of promoting new products to European and world markets, slow and often disputed ownership transformation, lack of cooperation with the university and unpreparedness of industry for the European integration processes.

The "University – Industry/Economy" relation [14] involves the establishment of business and information and communication connections of academic institutions (universities, institutes, university centres) and economic institutions (factories, companies, enterprises, offices, chambers and industry associations). The relations are one- or two-ways and refer to education, research, development, consulting services and definition of enrolment plans in communication with relevant government ministries and rectors of universities. For example, enrolment quotas for individual faculties should be determined by each university (individual faculty) and Government in the following way: faculties are to become aware of their capacity for quantitative and qualitative flow of students through labs and theatres, while relevant government ministry is responsible for understanding the real needs of economy. Actual enrolment quotas should determine exactly the tuition for each semester, specifying the cost for each faculty.

Integrated quality system includes information and communication links between universities and industry with regular activities of Alumni faculties' associations and universities. Interactive faculties' conferences, industry and economy, as well as feedback from graduates of experts improve the quality of education, study programs and results of research at the university.

4. ACTIVITY DIAGRAM FOR THE SYNERGY OF UNIVERSITY AND INDUSTRY

Figure 5 shows basic level of operation of an integrated university in synergetic cooperation with industry

(modeling level S-0). The basic inputs are requirements for entering the partnership of universities and industry, education, student practice and professional training in cooperation with industry and production, to all entering the partnership. The basic outputs are knowledge and expertise of students, new products and technologies, industry services and consulting of university.

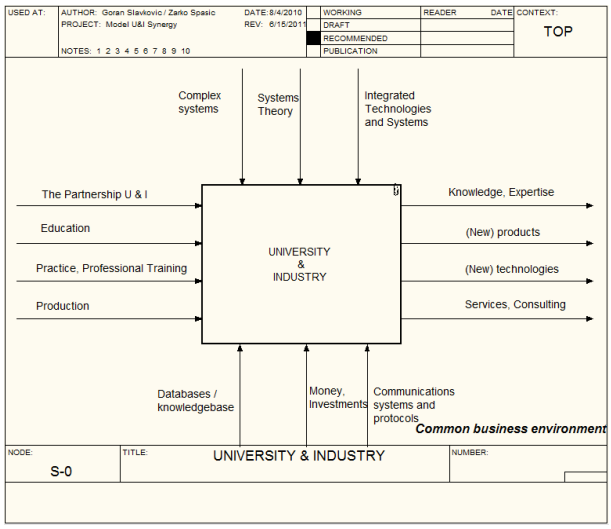

Figure 5. Synergistic business model of universities and industry

Figure 6 displays the decomposition of cooperation between universities and industry into three blocks at the next level of modeling. The main activities are related to the integrated university, industry and their synergetic partnership. Based on study programs accreditation, ISO/QA certification and models of cooperation define inputs and outputs for university and industry synergy.

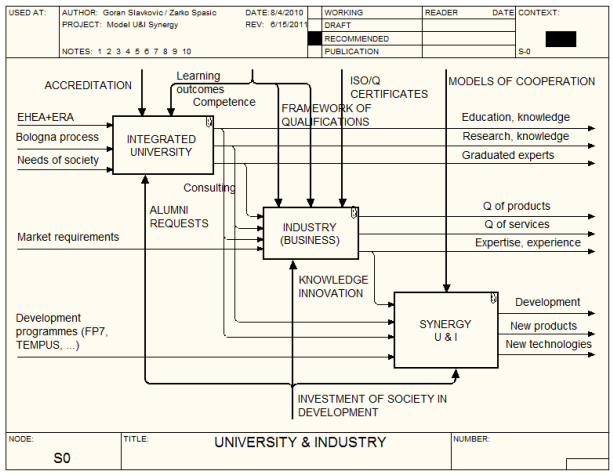

Figure 6. Decomposition of cooperation between university and industry

Further decomposition of the activity S3 (shown in Fig. 7) defines blocks development of teaching and research at university, products development in industry and development of integrated technologies at the university and in industry. In these activities, the development of quality procedures within specific quality assurance system is an essential condition for business success.

Figure 8 shows further decomposition of the level S3 and defines blocks such as: teaching, research and management at the university. Teaching is conducted in compliance with accredited degree programs which also include accredited courses and modules with defined learning outcomes.

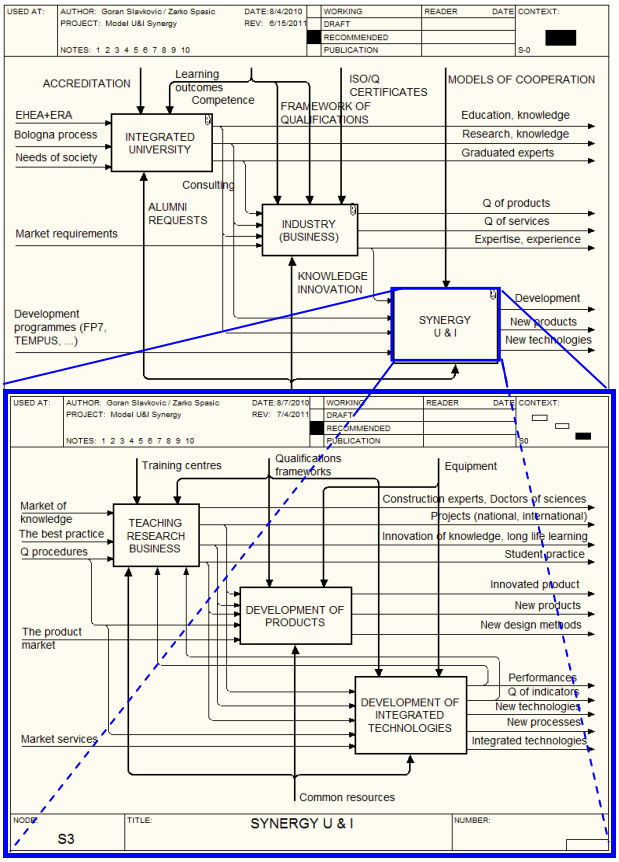

Figure 7. Synergy of cooperation between university and industry

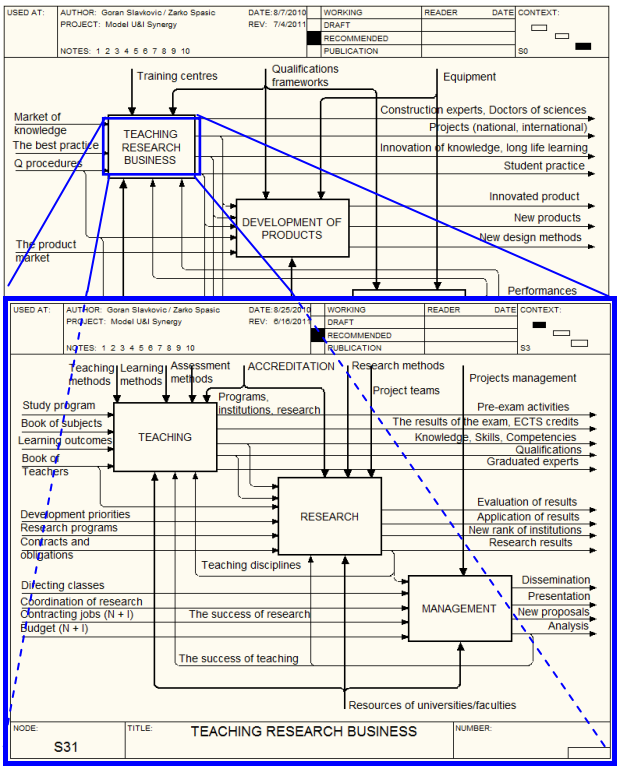

Figure 8. Integrated activities of teaching, research and management in synergy of university and industry

Students perform pre-exam activities and obtain the final exam scores, as well as knowledge, skills and

competencies for specific qualifications. Research activities are conducted on the basis of agreed projects within research programs that are defined by research priorities. Feedback results of the survey are embedded in the current teaching discipline.

The block, together with management activities, disseminates research results to users of research and contracts new jobs in collaboration with industry. The block S31 is further decomposed into the activities of preparation, execution and evaluation of teaching, as shown in Fig. 9.

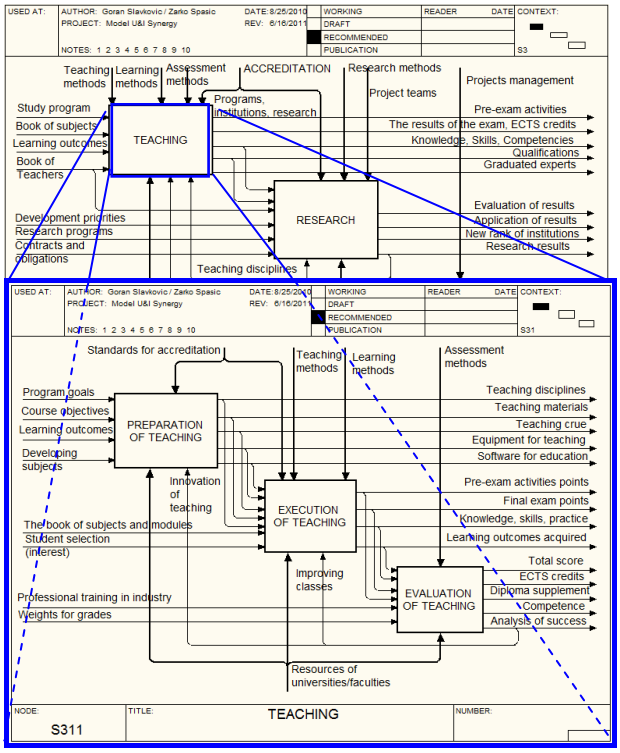

Figure 9. Diagram of integrated activities of preparation, execution and evaluation of teaching

Preparation of teaching involves constant innovation of teaching disciplines, preparation of teaching materials, and provision of laboratory equipment and teaching or commercial software. Along with the activities involving block-execution of teaching, it is necessary to establish a method of monitoring student progress trough courses during the semester. The analysis of achievement in the final part of the examination and an assessment of teaching are the initial criteria for further improvement and innovation of teaching.

The execution of teaching as a block S3112 from the previous level, as shown in Fig. 10, is decomposed into individual blocks for pre-exam activities, final examination and reporting on progress of students and subjects. The last block requires a well-organized work of faculty's student service with its integrated information system, as a part of the university's integrated information and communication system of university. Monitoring the performance statistics of each course and module is a special procedure of quality that belongs to the integrated system of quality assurance.

Preparation and contracting of research (shown in Fig. 11) is defined on the basis of development strategies and current trends in society. All defined terms and duties, as well as using the budget allocated for projects, must be respected during the implementation of research goals to achieve the possible level of the projects. Based on the criteria of research evaluation, research results are disseminated to contracted and new users of project results.

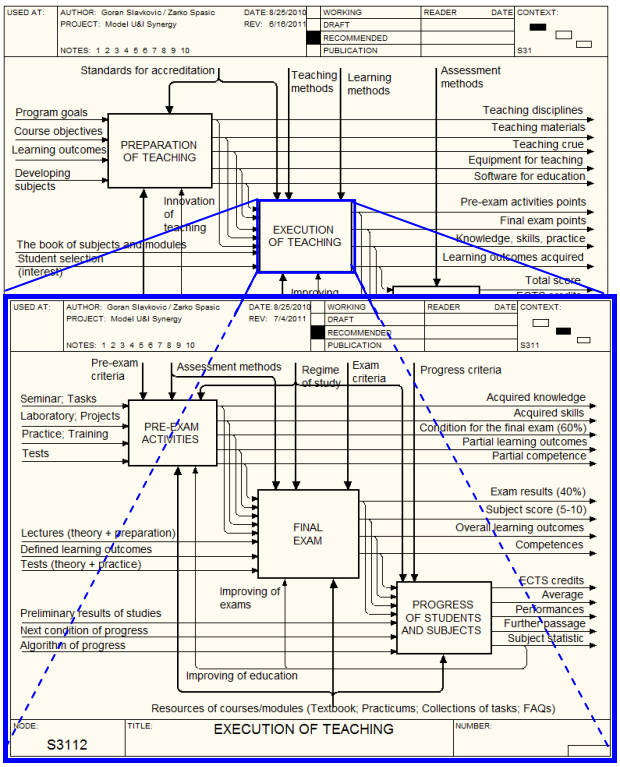

Figure 10. Diagram of the integrated activities in execution of teaching

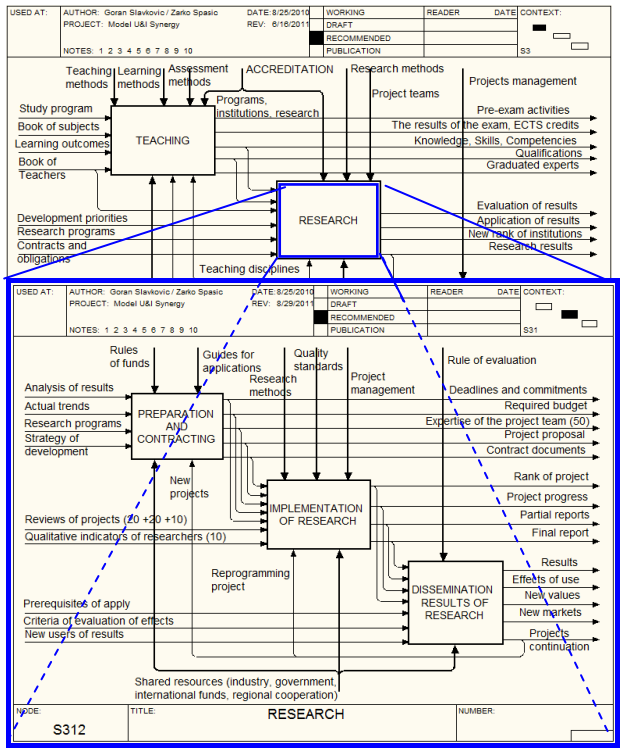

Figure 11. Diagram of integrated research activities in synergy of university and industry

Figure 12 shows the blocks of activities related to internal, external and international quality procedures. Internal quality procedures are those performed at the university and within its organizational units.

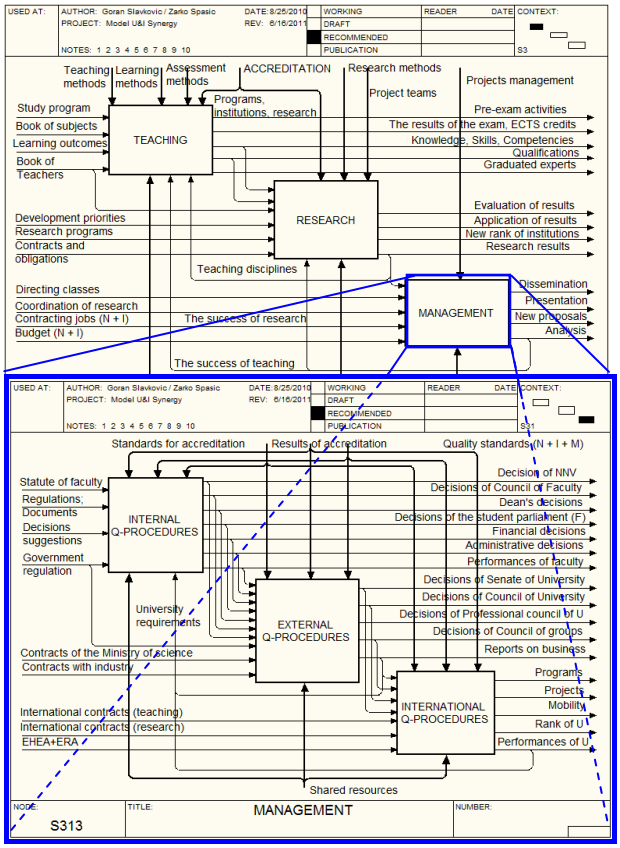

Figure 12. Diagram of quality procedures management at university

External quality procedures are relating to the communication universities and faculties with education, research and business environment. International quality procedures are implemented by the university under the rules of common EHEA, the common ERA, and according to cooperation with other universities of the world.

5. CONTROLLER FOR THE SYSTEM OF INTEGRATED MANAGEMENT OF UNIVERSITY

Controller is a key element in the projected system of integrated management of university, which is viewed as a complex system of many components and with synergy of partnership in educational, research and business environment. The hybrid controller processes and the information of different types by built-in algorithms generate output values for other system components. Using the input requirements of the EHEA, ERA and feedback information, the hybrid controller should provide a computerized decision-making at all levels, with a certain autonomy of departments, faculties and universities to intervene as the parent component of management (Fig. 13). This is also a requirement for the design of an integrated quality assurance system of digital university, whose principles are also incorporated into the algorithms of decision-making and management mechanism of the hybrid controller [6, 15-17].

A block diagram of the hybrid controller shown in Fig. 13 is given in more detail in Fig. 14 [18]. The input block in the hybrid controller is a block for analyzing the input signals and information. The mechanism of decision-making in the next block processes the input signals and information using an appropriate algorithm for a given class of problems it was designed for. At the same time, a database/knowledgebase is used and programs upon which it is possible to generate reports for decision-making.

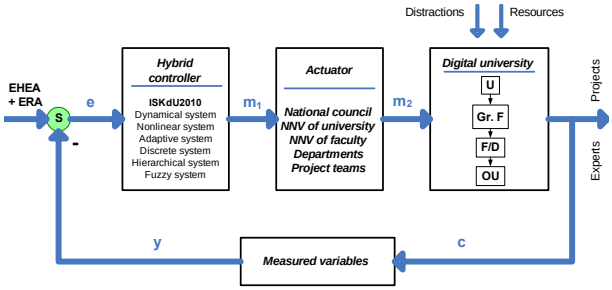

Figure 13. Hybrid controller and integrated university management

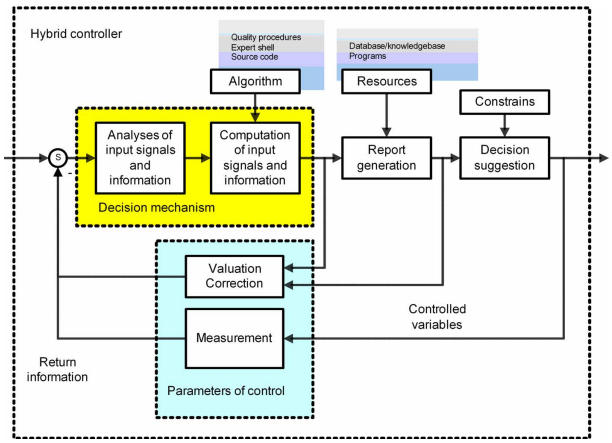

Figure 14. Block diagram of hybrid controller

If a collision occurs when processing data, feedback is used for corrections. At the exit of the hybrid controller, proposals are formulated taking into account the limitations of the system. The particular feedback line performs the measurement and evaluation of relevant parameters and control variables, based on which an appropriate action is taken.

Generally, the hybrid controller is a compound of a many hybrid controllers at lower levels of management at the university. Each of these hybrid controllers at lower level of management is modeled by appropriate function in the field of complex systems, depending on the type of processes involved. Controllers of lower-level management are developed according to the business functions of the analyzed system.

A particular example of a hybrid controller composed of two hybrid controllers at lower level of management is shown in Fig. 15 [17]. The first controller for lower-level management for integrated university system maps the business function "innovation of curricula content in terms of the needs of universities and business environment".

The controller contains a section that collects requests from university and industry on the contents of expert's knowledge after graduation for an adequate job position. The university is required to assess the relevance of the innovation of some curricula, and on the basis of that assessment changes would be accepted or rejected. The accepted changes are implemented in appropriate educational programs. Such lower-level management controller is implemented using the CA

(Cellular Automata) and AHP (Analytical Hierarchy Process) [17,18].

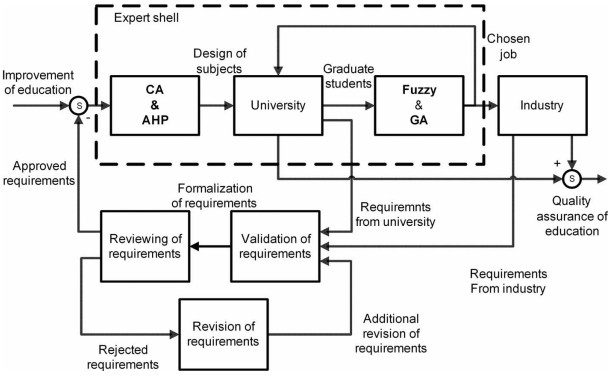

Figure 15. Block of hybrid controller for improvement of education

One of the main problems was an evident disagreement profile of educated experts with market demand. The system of quality assurance (trough feedback from employers about their expert profile needs) is giving students the opportunity to select individual programs in education, knowing in advance where they will use such programs after graduation. In this way, it is possible for an employer to hire experts with adequate knowledge for a given job. The Agency for Quality Assurance should be tasked to continuously collect feedback from graduates, employees, employers, labor representatives and other relevant organizations (stakeholders) to further innovate the curriculum.

The second controller at a lower level of management is related to the business function of "job seekers". After graduation, every graduate expert tends to get a job as close as possible to achieved education. The controller should allow the optimal determination of graduate expert for the best job, according to the pre-defined requirements by university and business environment for every particular job position. If the university accepted and implemented in the curriculum some of the previously business environment requirements, then the students, according to those requirements, choose the courses they will attend, wishing the kind of education for that particular job position. In this way, there should be optimal distribution of graduates to the workplace adequately for their education. Such controller of lower-level management is implemented using the FL (Fuzzy Logic) and GA (Genetic Algorithms).

Combining only those two controllers at a lower level of management in hybrid controller makes the controller on high-level management extremely non-linear. For example, if studies last dramatically longer than the time range prescribed by the Statute of faculty, it may happen that after graduation there is no longer need for that particular profile of professionals in the market. During the extended period of study, requirements for that particular profile of expertise change due to the dynamic development of the business environment.

6. CONCLUSION

All universities are facing economic problems, reduced social values and norms, as well as the level and way of funds distribution. Universities do not have the necessary internal financial structures and competencies to function as modern European universities. Universities lack effective systems for managing information. Strategic planning and management is impossible as well as performance monitoring for comparison with other institutions. The university must have a way to fulfill its mission as a provider of higher education services, organized to meet the needs of the state and citizens. The main task of higher education is to promote graduation of experts of all profiles to meet the needs of all users of education (stakeholders), according to the priorities of Europe and the development of integrated national priorities. For technical universities and faculties, the main beneficiaries of the research are industry or economy, students – partners in the reform, as well as society as a whole. The integrated system of quality assurance with defined appropriate quality procedures is the basic dimension of European integration in the reforms that apply to the university and faculty.

University and industry are very important business environments to each other, and together they form a global educational market of research and business products, technologies, knowledge and expert services. Trends in European integrations indicate the necessity of cooperation between universities and industry to create new values in Europe as society, where the quality of life is based on knowledge. This is especially true for industries and businesses that do not have their own research units. Without continuous education that provides innovation of employees' knowledge for industry, it is difficult to achieve competitiveness and technological progress. This means that the university should establish partnerships with educational research and business environment that is mainly using educational and research activities of universities. The most obvious common problems of university and industry, of their separate and common development at the same time are the lack of strategy development and lack of continuity in development policy. The major consequences of the discontinuity in the university business relating to the limited maneuverability of university are the lack of integrated information systems, lack of set and approved quality procedures, and the incompleteness of an integrated quality assurance system. The main consequences of the discontinuity in the business industry and economy are related to the slow business transformation of large systems in small and medium enterprises, outdated production and information-communication equipment, restrictions of investment in new equipment, partial and incompatible information systems, slow cycles to promote new products to the European and world markets, slow and often disputed ownership transformation, lack of cooperation with the university, and the industry is not prepared for European integration processes. The central place in the management of the university belongs to the digital integrated quality assurance system as a part of an integrated information and communication system also integrated with the university information resources.

This paper presented a model of hybrid controller as a result of applying the IDEF0 methodology. The hybrid

controller features programmed algorithms of the quality procedures, which ensure continuous monitoring and improvement of the quality of academic activities in teaching and research management. Quality procedures are the basis for the implementation of an integrated system of quality in institutions of higher education. Procedures in a standardized manner, consistent with the specifications of ISO 9000, describe the activities of education, research and management of universities, faculties or institutes. The application of IDEF0 methodology proved to be very successful in describing the business function and activities during modeling the hybrid controller for management of a complex system such as university in synergy with industry.

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МЕТОДОЛОГИЈА ЗА МОДЕЛИРАЊЕ ХИБРИДНОГ КОНТРОЛЕРА ЗА УПРАВЉАЊЕ УНИВЕРЗИТЕТОМ У СИНЕРГИЈИ СА ИНДУСТРИЈОМ

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Управљање универзитетом је веома сложен задатак у савременом друштву. Универзитети „производе" стручњаке за различите врсте индустрија. Захтеви за новим профилима стручњака у индустрији јављају се готово сваки дан. Адекватно томе, универзитети теже ка промени програма студија и покушавају да уведу нове научне дисциплине у своје програме образовања. У раду је приказана *IDEF0* методологија за моделирање хибридног контролера за управљање универзитетом. Универзитет, који има три групе активности (настава, истраживање и управљање укупним пословањем), спада у категорију комплексних система и управљање се моделира коришћењем метода и техника из теорије комплексних система. За хибридни контролер са повратном спрегом (који се састоји од хибридних контролера на нижим нивоима управљања), као објекат управљања посматра се интегрисани систем универзитета у синергији са сопственим образовно-пословним окружењем.