HABILITATION THESIS

EXPLORING THE FIELDS OF QUALITY AND KNOWLEDGE MANAGEMENT: RESEARCH AND CONTRIBUTIONS

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A. ABSTRACT

Today, we are operating in a global knowledge economy, which is characterized by an increasing competition for survival, development and thriving. In this new environment, organizations have to maintain and enhance the factors that influence their competitiveness. Among the existing approaches, the quality and knowledge management methods, practices and tools are recognized to have a very important potential to improve the competitiveness of organizations.

Within this framework, the habilitation thesis presents the most important research and contributions of the author in the fields of quality and knowledge management after receiving his doctoral degree in 1998 and is organized in three main parts: Scientific, academic and professional achievements, Career development plan and References.

The first part of the habilitation thesis presents the most important scientific results as well as the main academic and professional achievements after obtaining the title of "doctor engineer". The section ***Scientific Achievements***, constitutes the core of the habilitation thesis. The scientific results presented in this section are mainly related to the research developed in different research grants. They are grouped in two main directions of the research activity: 1) Quality and reliability engineering, and 2) Knowledge management in higher education institutions. Each research field is shortly described next.

Quality and reliability engineering. The research activity in quality and reliability engineering has been oriented towards the following topics: (i) Monitoring the state of the technical systems, (ii) Reliability modeling and maintenance planning, and (iii) Quality and reliability improvement with the Taguchi approach of design of experiments.

The foundation of the quality and reliability analysis and modeling of the technical systems is represented by the establishment of the influence and causal determination of their failure processes. Since the failure detection methods have no universal application and accordingly with the process, equipment or technical system characteristics, specific methods must be used. Within this framework, the state of the technical systems was monitored with data acquisition systems as well as an infrared camera.

The effectiveness of the technical systems is based on their intrinsic reliability and on the characteristics of the maintenance interventions. Therefore, the reliability

modeling of technical systems was carried out first at the level of components based on the adoption of distribution law of the time-to-failure. The reliability modeling was also performed at the structural level. The preventive and predictive maintenance strategies were used to plan the maintenance actions to prevent failures, each having its advantages and challenges in industrial practice. The preventive maintenance was formulated based on the block replacement policy and the age replacement policy, respectively. Moreover, periodic inspections were also used to further improve the effectiveness of systems.

The recent advancement in the field of the data acquisition systems has accelerated the development of the condition-based maintenance. However, when different parameters such as vibrations and temperature are used to monitor the current state of a system and its components, different decision may be employed in carrying out the maintenance actions. Moreover, the estimation of the state of technical systems may be affected by some vagueness or uncertainty due to the limitation of the condition-based maintenance. In this direction, a fuzzy logic approach was used to plan the maintenance activities and the results show that fuzzy logic is a method which can be successfully employed for appropriate planning of maintenance activities.

In nowadays competitive business environment, the quality and reliability characteristics of products need to be improved at a minimal cost. While many potential factors may influence both the quality and reliability of products, some factors are more significant than others, so they are important to be established. The values of the relevant factors in improving the quality and reliability of products are also important to be identified. The Taguchi method of design of experiments was employed for this purpose and the results obtained by the author demonstrate the effectiveness of this approach in improving the quality and reliability of products.

Knowledge management in higher education institutions. Today higher education institutions operate within a global and dynamic world, where they have to face new roles and new challenges. In this new environment, the use of knowledge management in universities may be a promising solution for their success. However, the knowledge management in higher education institutions is an emerging field, where experiments are just at the beginning. Within this framework, the research interest in this field has been mainly directed towards the relationship between the knowledge management in universities and their nationwide environmental contexts. Moreover, the following topics have been addressed in the research activity: (i) Developing knowledge maps to describe a visual architecture of the investigated knowledge area; (ii) Identifying Knowledge Management Dimensions in Romanian higher education context, (iii) Knowledge management practices in Romanian higher education context.

Although knowledge management has lately attracted growing attention, very few studies have been carried out on how the Romanian national environmental realities affect the knowledge management activities in universities. Therefore, the knowledge management priorities, knowledge management tools and knowledge management practices were investigated in the Romanian higher education context. The results show the management of knowledge in universities as complex and multifaceted process sensitive to the nationwide context and realities.

The main professional and academic results are presented in the section ***Academic and professional achievements***. The didactic activity and the involvement in the implementation of several projects for the development of the students' competencies are described. The engagement in the academic management is presented. The main research projects and fellowships are also emphasized as well as the professional achievements: memberships in the editorial staff or scientific committees of journals or scientific manifestations; evaluator for different research projects; memberships in different professional associations and societies.

The Career development plan is illustrated **in the second part** of the habilitation thesis. Considering the results obtained until now, the author will continue with the advancement of his research that will complement the already existing research. New research topics are related to the collaboration between Industry-University in an Open Innovation context.

The publication of the future research results in mainstream journals indexed in international recognized databases (and especially in ISI journals with significant impact factor), will continue to be one of the main objectives to increase the international visibility of the research activity. Another important objective will be the publication of chapters of books or books in international recognized publishing houses. The development of new research projects at both national and international levels, especially within the frame of the Horizon 2020 program, will remain another main objective.

The dissemination of all research results will be accomplished together with the teams involved on each topic of interest. The aim of the author to contribute in the development of competitive young researchers will be achieved by including in these teams of an increase number of future doctoral students. Including the research results in the teaching programs, mainly for master and doctoral studies will also better link the research and didactic activities.

Knowledge management in higher education is a new area, where experiments are just beginning, so the implementation of a knowledge management environment in higher education institutions may be a challenging objective. Nevertheless, it will represent a major topic in the future work of the author, which can prove evidence that academics are able to manage their explicit and tacit knowledge, with considerable benefits in improving research competitiveness, enhancing teaching and learning or offering better opportunities for cooperation with industry.

The bibliographic references are included in **the last part** of the habilitation thesis.

REZUMAT

Organizațiile își desfășoară astăzi activitatea într-o economie globală bazată pe cunoaștere, caracterizată printr-o competiție tot mai crescută pentru supraviețuire, dezvoltare și prosperitate. În acest nou mediu, organizațiile trebuie să folosească abordări adecvate pentru a-și păstra și consolida acei factori care le influențează competitivitatea. Metodele, practicile și instrumentele calității și managementului cunoștințelor sunt recunoscute ca având un potențial foarte important pentru îmbunătățirea competitivității organizațiilor.

În acest context, teza de abilitare prezintă cele mai importante cercetări și contribuții ale autorului în domeniile calității și managementului cunoștințelor, după obținerea titlului de doctor în 1998 și este organizat în trei părți principale: Realizări științifice, academice și profesionale, Planul de dezvoltare a carierei și Bibliografie.

Prima parte a tezei de abilitare prezintă cele mai importante rezultate științifice, respectiv principalele realizări academice și profesionale obținute după acordarea titlului de "doctor inginer". ***Realizările științifice*** prezentate în această parte constituie nucleul tezei de abilitare și sunt, în principal, rezultatul activităților de cercetare desfășurate în diferite granturi de cercetare. Acestea realizări reflectă două domenii principale ale activității de cercetare: 1) Ingineria calității și fiabilității, și 2) Managementul cunoștințelor în instituțiile de învățământ superior. Fiecare domeniu de cercetare este descris pe scurt în continuare.

Ingineria calității și fiabilității. Activitatea de cercetare în domeniul ingineriei calității și fiabilității a fost orientată spre următoarele aspecte: (i) Monitorizarea stării sistemelor tehnice, (ii) Modelarea fiabilității și planificarea mentenanței, (iii) Îmbunătățirea calității și fiabilității prin intermediul metodei Taguchi de planificare a experimentelor.

Stabilirea influențelor și determinărilor cauzale ale proceselor de defectare constituie baza analizei și modelării calității și fiabilității sistemelor tehnice. Deoarece metodele de detectare a defectelor nu au o aplicabilitate generală, este necesară folosirea unor metode specifice, în funcție de caracteristicile proceselor, echipamentelor sau a sistemelor tehnice. În acest context, starea sistemelor tehnice a fost monitorizată prin intermediul unor sisteme de achiziție a datelor, respectiv prin intermediul unei camere termografice.

Eficacitatea sistemelor tehnice se bazează pe fiabilitatea lor intrinsecă, respectiv pe activităţile de mentenanţă. Modelarea fiabilității sistemelor tehnice a fost efectuată în primul rând la nivelul elementelor componente prin adoptarea legilor de

distribuție a timpului de funcţionare până la defectare a acestor elemente. De asemenea, modelarea fiabilității a fost realizată la nivel structural. Planificarea activităţilor de prevenire a defectelor s-a realizat prin intermediul strategiilor de mentenanţă preventivă și predictivă, fiecare strategie având propriile avantaje și provocări în practica industrială. Mentenanța preventivă a fost formulată pe baza strategiilor de reînnoire de tip block replacement policy, respectiv age replacement policy. Îmbunătățirea eficacității sistemelor a fost realizată și prin intermediul inspecțiile periodice.

Progresele rapide în domeniul sistemelor de achiziție de date au condus la dezvoltarea rapidă a mentenanței bazate pe urmărirea stării sistemului (condition-based maintenance). Utilizarea mai multor parametrii pentru monitorizarea stării curente a unui sistem și a componentelor sale, cum ar fi vibrațiile și temperatura, poate conduce la decizii diferite privind efectuarea activităţilor de mentenanţă. De asemenea, estimarea stării tehnice a sistemelor tehnice poate fi afectată de imprecizie sau incertitudine, ca urmare a limitărilor mentenanței bazate pe urmărirea stării sistemului. În acest context, planificarea activităţilor de mentenanţă s-a realizat printr-o abordare bazată pe logica fuzzy, iar rezultatele obţinute arată că o astfel de abordare poate fi folosită cu succes pentru planificarea adecvată a acestor activități.

Pentru a avea succes în mediul competitiv de afaceri din zilele noastre, calitatea și fiabilitatea produselor trebuie să fie îmbunătățite la un cost cât mai mic. Caracteristicile de calitate și fiabilitate ale produselor pot fi influențate de mai mulți factori, unii dintre acești factori având o importanță mai mare decât ceilalți. De asemenea, trebuie stabilite și nivelurile factorilor importanți. Pentru acest scop a fost folosită metoda Taguchi de planificare a experimentelor, iar rezultatele obținute de autor demonstrează eficacitatea acestei abordări în îmbunătățirea calității și fiabilității produselor.

Managementul cunoștințelor în instituțiile de învățământ superior. Astăzi, instituțiile de învățământ superior îşi desfăşoară activitatea într-o societate globală și dinamică, unde trebuie să facă față unor noi roluri și noi provocări. În acest nou mediu de lucru, utilizarea managementului cunoștințelor în universități poate fi o soluție promițătoare pentru succes. Însă, managementul cunoașterii în instituțiile de învățământ superior este un domeniu în curs de dezvoltare, în care cercetările sunt doar la început. Pornind de la aceste constatări, cercetările au fost orientate, în principal, către relația dintre managementul cunoștințelor în universitățile și contextul național în care acestea își desfășoară activitatea. În acest context, activitatea de cercetare a abordat următoarele subiecte: (i) Dezvoltarea hărților de cunoștințe pentru a descrie arhitectura zonei de cunoștințe investigate; (ii) Identificarea unor dimensiuni ale managementului cunoștințelor în cadrul învățământului superior românesc, (iii) Practici ale managementului cunoștințelor în contextul învățământul superior românesc.

Deși managementul cunoștințelor a cunoscut un interes crescând în ultimul timp, au fost efectuate puține studii referitoare la modul în care contextul național românesc afectează activitățile de management al cunoștințelor în universități. Prin urmare au fost investigate priorități, instrumente și practici ale managementului cunoștințelor în contextul învățământului superior românesc. Rezultatele obţinute arată că managementul cunoașterii în universități este un proces complex şi multidimensional, sensibil la contextul şi realităţile naționale.

Principalele rezultatele profesionale și academice sunt descrise în secțiunea ***Realizări academice și profesionale***. Este prezentată activitatea didactică și implicarea în implementarea unor proiecte pentru dezvoltarea competențelor studenților, respectiv în managementul academic. De asemenea, este descrisă implicarea în principalele proiecte științifice și burse de cercetare, precum și principalele realizările profesionale: membru în comitetele editoriale sau științifice ale unor reviste sau manifestări științifice; evaluator pentru diferite proiecte de cercetare; membru în diferite asociații și societăți profesionale.

Planul de dezvoltare a carierei este ilustrat în **a doua parte** a tezei de abilitare. Având în vedere rezultatele obținute până în prezent, autorul își va continua cercetările în domeniile prezentate în cadrul tezei de abilitare, aceste cercetări urmând a completa realizările existente. Noi teme de cercetare sunt legate de colaborarea dintre industrie și Universități din contextul Inovării Deschise (Open Innovation).

Unul dintre principalele obiective de creștere a vizibilității internaționale a activității de cercetare va continua să fie publicarea rezultatelor viitoarelor cercetări în reviste indexate în baze de date internaționale recunoscute (și mai ales în reviste cotate ISI cu factor de impact semnificativ). Publicarea unor capitole sau cărți în edituri internaționale recunoscute va fi un alt obiectiv important. De asemenea, dezvoltarea de noi proiecte de cercetare la nivel național și internațional, în special în cadrul programului Horizon 2020, va reprezenta un alt obiectiv principal.

Diseminarea tuturor rezultatelor cercetărilor va fi realizată împreună cu echipele implicate în fiecare domeniu de interes. Formarea unor tineri cercetători competitivi va fi realizat prin includerea în cadrul acestor echipe a unui număr crescut de viitori doctoranzi. Includerea rezultatelor cercetărilor în programele de predare, în special pentru studiile de masterat și doctorat, va contribui la o mai bună conectare a activitățillor de cercetare cu cele didactice.

Managementul cunoștințelor în instituțiile de învățământ superior este un domeniu relativ nou, în care cercetările sunt la început. Prin urmare, implementarea unui mediu de lucru bazat pe managementul cunoștințelor poate fi un obiectiv provocator. Cu toate acestea, va reprezenta un domeniu important în viitoarele activități de cercetare ale autorului, pentru a dovedi că mediul academic este capabil să-și gestioneze cunoștințele explicite și implicite, cu beneficii considerabile în îmbunătățirea competitivității cercetării, predării și învățării, respectiv în oferirea unor mai bune oportunități de cooperare cu industria.

Referințele bibliografice sunt incluse în **ultima parte** a tezei de abilitare.

B. ACHIEVEMENTS AND CAREER DEVELOPMENT PLANS

PART I. SCIENTIFIC, ACADEMIC AND PROFESSIONAL ACHIEVEMENTS

I. THE ONGOING JOURNEY

The present habilitation thesis summarizes the author's activity carried out after defending his PhD thesis in July 1998, which was confirmed by the Ministry of National Education through the Order no. 5182/10.12.1998. The author received his PhD degree in Reliability from the University POLITEHNICA of Bucharest under the supervision of one of the founders of the Romanian university school in this field, the regretted professor Vasile M. Cătuneanu.

After obtaining his doctoral degree the author is expected to continue and advance with the accomplishment of the fundamental missions for which higher education institutions exist: teaching, research, and service to society. The author remains dedicated to the field of his doctoral thesis and continues to teach and conduct research in the quality and reliability engineering field. In the following years, the author has had the opportunity to apply at different competitions for projects and fellowship grants in this field. At the end, he was successful with the following projects:

1. Director, Grant ANSTI no. 6144/2000 ” Integrated mobile system for the diagnosis and reliability assurance of the equipments", financed by Romanian Ministry of Education and Research through the National Agency for Science, Technology and Innovation MEC-ANSTI, 2000-2001.
2. Research fellowship from the Romanian Ministry of Education and Research no. 3740/2002 ”Research concerning the development of a system based on knowledge for the diagnosis and prediction of the reliability of the technical systems”, University of Applied Science Furtwangen, Germany.
3. Director, Grant CNCSIS no. 253/2005 “Research based on diagnosis and prediction techniques for the reliability assurance of industrial robots”, financed by Romanian Ministry of Education and Research through the National Council for Scientific Research in Higher Education Institutions CNCSIS, 2005-2007.

New perspectives have been open after the author's fellowship in the field of knowledge-based systems at University of Applied Science Furtwangen. In his position, as professor and vice-dean of his faculty at that time, the author must deal with many of the knowledge management aspects in higher education. However, he has observed and asked why, the management of knowledge has been slowly embraced in higher education. A project of knowledge management in higher education was developed by the author, which was approved by the Romanian-USA Fulbright Commission. Then, the author was awarded with the Fulbright Research Grant no. 333/2005 "Building an Intelligent Organization: A Knowledge Management Approach in Higher Education", at The George Washington University, USA. In the Department of Engineering Management & Systems Engineering of the George Washington University, the author found a rich environment to create an academic foundation for advancing the knowledge management in higher education.

After the return at his home university, the author has continued his research in the field of knowledge management and in 2008 he received by competition as director, the grant 92074/2008 "Comparative Research Concerning Knowledge Management in Romanian Engineering Education". The grant was supported by Romanian Ministry of Education, Research and Innovation-National Authority for Scientific Research in the Partnership in Priority Domains Programme for the period 2008-2011. The author also has started to teach a new course in the field of knowledge management.

The author has also been involved in the third mission of higher education institutions, the knowledge transfer to the socio-economic environment. While these institutions have long served as a source of advances for the industry, the author has been aware that the new challenges of the global knowledge economy motivate both universities and industry to intensify their collaboration. The author recently received by competition as director, the grant 337/2014 "Knowledge Management-Based Research Concerning Industry-University Collaboration in an Open Innovation Context". This grant has been awarded by the Romanian Ministry of Education, through The Executive Agency for Higher Education Research Development and Innovation Funding (UEFISCDI) in the Priority Domains Programme for the period 2014-2016.

Within this framework, the main scientific contributions of the author in the field of quality and reliability engineering, and knowledge management in higher education institutions after obtaining the title of "doctor engineer" are presented. They are mainly related to the research developed in the above mentioned scientific grants, and are summarized in the next chapters. The author's professional and academic achievements are also briefly presented.

II. SCIENTIFIC ACHIEVEMENTS

II.1. INTRODUCTION

Today, networks have expanded and interdependencies grown [36]: we are operating in a global knowledge economy, which is characterized by an increasing competition for survival, development and thriving. In this new environment, the competitiveness of organizations depends on their capabilities to develop and deliver products and services that highly fulfill the demands and expectations of customers [133]. In order to compete and thrive, it is important for organizations to focus on those factors that can improve their competitiveness. Defined as ”the variables in which the organization needs to perform well to survive and stand out in the market” [122, p. 26], the competitiveness factors are essential for organizations to achieve their mission, vision and goals.

According to the existing literature, the factors that influence organizational competitiveness have a multi-dimensional structure [94, 122, 133]. To be successful, organizations have to demonstrate the ability to better perform than their competitors on one or more factors from different fundamental dimensions [16, 17, 39, 51, 146, 158]. Nevertheless, there is a consensus that an organization’s competitiveness depends on its capability to deliver high quality and reliable products and services, which have been emphasized in numerous studies among the most important factors that influence the competitiveness [47, 88, 136]. On the other hand, the knowledge assets have increasingly become strategic resources for success [2, 159, 163], while knowledge management has been reported as an essential factor for competitiveness in the global knowledge economy [8, 106, 147, 153].

To remain competitive and successful, organizations have to maintain and enhance the factors that influence competitiveness through appropriate approaches. Therefore, using quality, reliability and knowledge management methods, practices and tools has a very important potential to improve the competitiveness of organizations. Within this framework, the scientific achievements described in the habilitation thesis are grouped within two main thematic directions: 1) Quality and reliability engineering and 2) Knowledge management in higher education institutions.

II.2. QUALITY AND RELIABILITY ENGINEERING

II.2.1. Quality and its main dimensions

Quality has become today one of the most important factors supporting and enhancing organizational competitiveness. To be successful, organizations must demonstrate the ability to deliver products and services of a greater quality than their competitors.

Since the influential work of Garvin [66], the conformance to specifications, reliability and maintainability have been pointed among the main dimensions of the quality [44, 50, 116]. The customers need or expect that the product's characteristics fit within their prescribed specifications at a moment of time. This capacity, usually at the initial moment of the product's operation, is called conformance quality [78]. However, the conformance level is valid only at the specific moment when the characteristics of the product were measured. Products must meet customers' specifications both when they are initially put into operation and for their expected life. Since the characteristics of a product generally change during its function, the aspects regarding the modification in time of the characteristics should also be considered. The general property of a product to preserve its characteristics in time has become reliability [43]. The quality of a product also depends on how the product can be maintained in service. The capability to restore the performances of products within their prescribed limits through inspection and repair operations is called maintainability [43].

II.2.2. Monitoring the state of the technical systems

The foundation of quality and reliability analysis and modeling is represented by the determination of the influence and causal determination of the failure processes. In these conditions, the investigation of the behavior and the failure monitoring must be used to establish the failure of any technical system. In the reliability field, the notion of failure is understood as the transgression by one of the system's characteristics of its prescribed limits [43].

The failure monitoring has known an important development in the recent time and is being sustained by a considerable theoretic and practical support [52, 125, 129]. However, the failure detection methods have no universal application and accordingly with the characteristics of process, equipment or technical system, a specific method must be used.

One of the most used ways in industrial monitoring is the employment of a data acquisition system. Generally, such system is composed of:

Transducers ⇒ Data acquisition hardware ⇒ Personal computer and specialized software

A the first data acquisition systems was developed based on resistive strain gauges and was consisted of ”resistive strain gages-strain indicator-connector block-board acquisition-personal computer” [34, p. 213]. The data acquisition system was employed in the monitoring of the deformation of the electrode of a welding by pressure equipment [28]. The failure was identified by comparing the deformation value of the electrode with the deformation value when the electrode was new and when it failed. In [34], the data acquisition system based on resistive strain gauges was also employed in monitoring the force of a cold plastic deformation tool used in the car industry (a combine stamping die). In this case, the force was used to detect the failure by comparing its value at one moment with the force value when the tool was new and when it failed.

Vibration monitoring is among the most employed approaches for the failure detection, especially for the components in rotational motion [104, 117]. Each technical system generates a particular vibration signal and any change in vibration spectrum can be measured and analyzed for failure identification. By comparing the vibration amplitude value at one moment with its reference value (good and failure state), the failure of the element can be identified. Within this context, a more recent data acquisition system was developed based on accelerometer sensors for vibration monitoring, and is presented in figure 1.

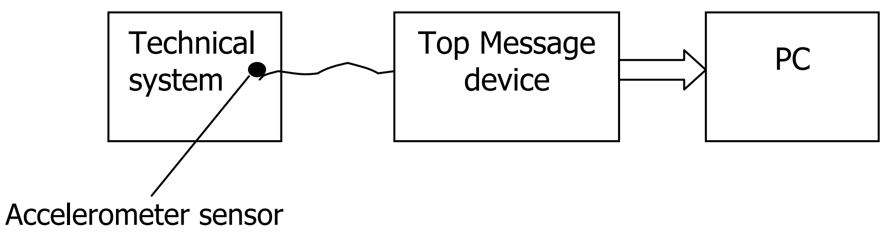


Figure 1. The data acquisition system based on accelerometer sensor

The signal from accelerometer sensor is transferred to the TopMessage device (from Delphin Technology AG, Germany), which is based on the AMDT/V module for vibration monitoring. The Vibrolab software developed by Delphin Technology AG was used for vibration analysis. This data acquisition system was employed in two studies [19, 23].

In [23], the data acquisition system was used to achieve the times-to-failure of the active elements of the complex tools used in the cold plastic deformation process. The failure of the active elements of such tools, which move relative to each other, is mainly due to the wear and vibration analysis was employed to identify their failure. The data acquisition system based on accelerometer sensor was used to monitor the vibration amplitude of the active elements, which was expressed in velocity units [mm/sec]. The vibration amplitude of the active elements was measured in the case of their good state and failure state, respectively. The failure of the active elements was detected by comparing the vibration amplitude with the reference values of the good state and the failure state.

The estimation of the technical condition of disc brakes of the automotive is presented in [19]. For this purpose an experimental stand based on a powertrain was developed, which is depicted in figure 2 [19, p. 533].

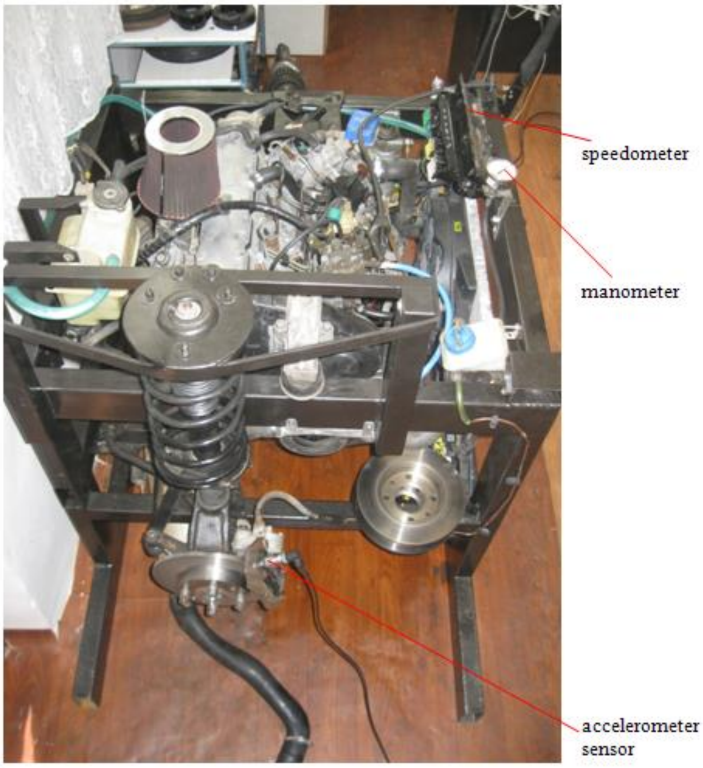


Figure 2. The stand for the estimation of the technical condition
of the disc brakes of the automotive [19, p. 533]

In order to estimate the technical condition of the disc brakes, both the vibrations and temperature of a new disc and of a disc with the thickness at the lower limit prescribed by the manufacturer were monitored on the stand depicted in figure 2. The vibration monitoring of the automotive disk brakes was performed using the same data acquisition system based on accelerometer sensor (figure 1). Investigation on the temperature of automotive disk brakes was accomplished with a FLIR SC 640 infrared camera.

II.2.3. The effectiveness of technical systems: reliability modeling and maintenance planning

The overall capacity of a technical system to fulfil its specified function, that is system effectiveness or the reliability in the broad sense, depends on both their intrinsic reliability and the characteristics of maintenance interventions [43, p. 119].

Moreover, the same mathematical approach is used for reliability and maintainability modeling, while the data obtained in the reliability studies are used as input data in the maintainability analysis. With an adequate consideration of reliability and maintainability, the number of failures and their effect could be diminished [126], so the effectiveness of the system will be improved. To sum up, the system effectiveness is significantly influenced by the structural design of the system, the intrinsic reliability of its components, as well as the characteristics of the maintenance program and procedures [63].

II.2.3.1. Reliability modeling of the technical systems

In the intense competition of the global knowledge economy, reliability is one of the most desired features of the technical systems. The performances of a system have to meet the expectations of the customers when the system is placed in function as well as for its expected life. Reliability, which represents the general property of a technical system to preserve its properties in time [43], is an important factor that influence the competitiveness of a product since the period of warranty may be extended for reliable products. On the other hand, to be able to adapt at the complex and variable environment conditions where they are working, the structure of the actual technical systems is based on non-homogenous components with both an increasing complexity and a higher degree of intelligence [57]. The increasing structural complexity of the actual technical systems and the integration of their non-homogenous components and subsystems that can fail relatively frequently have influence upon the temporal dimension of quality, which is reliability. Therefore, appropriate approaches to ensure a proper function of the system within specified periods of time have to be put in place.

In the reliability theory, the mathematical modeling of the systems' reliability may be achieved at the global level as well as at the structural level [43]. In the first case, the analysis of reliability is performed without considering the structure of systems, while in the second case is based on the reliability of the elements of the systems and their relationships. In both situations, the mathematical modeling is accomplished based on the time interval passed from the initial moment when the system is placed in service up to the moment of its failure, when at least one of the system characteristics exceeds its specified tolerances.

Within this framework, the reliability modeling of technical systems was performed in the author's approach first at the level of components, then at the subsystems and structural level. The reliability modeling of elements requires the adoption of distribution law of the time-to-failure. For the structural reliability modeling, a complex system can be considered a reunion of components and subsystems, each having its specific and known reliability measures, and it can be analyzed based upon logical models [43].

II.2.3.1.1. The reliability modeling of the components of the technical systems

The failure mechanisms of the components of the technical systems are based on physical and chemical degradation phenomena that are not under the government of deterministic laws so that the prediction of failure occurrence is affected by uncertainty. Therefore, the theory of probability and mathematical statistics have been used by the author to model the reliability of the technical systems. The statistical model of the times-to-failure has been represented by the cumulative distribution function F(t) and has been employed for the reliability modeling of the components. The most important step in the reliability analysis of the components of the technical systems is represented by the adoption of the distribution laws to model their reliability.

The research in the field of reliability has been initially developed for the components and systems in the aeronautics and military industry because of the cost and their importance. However, the theory and practice of reliability can be applied to any component and system, and have been extensively developed for electronic components and systems. Such systems are often composed of standardized elements, which are typically characterized by a constant failure rate. On the other hand, the mechanical systems included components with different failure modes and different distribution laws. Therefore, using reliability models of the electronic systems for predicting the reliability of mechanical ones limits the accuracy and usefulness of quantitative results. In addition, the lack of experimental data on the failure of different mechanical components makes more difficult the development of procedures for predicting their reliability.

Within this framework, the author focused on the reliability analysis of mechanical components of the technical system and three distribution laws were used extensively in his research for the reliability modeling of such elements: alpha, power and/or Weibull [26, 28, 29, 33, 34, 35]. The mathematical expression of the cumulative distribution function F(t) of each of the three distribution laws is [58, 156]:

- alpha law (approximate form):

$$F(t) = 1 - \phi(\frac{\beta}{t} - \alpha) \tag{1}$$

where $\phi(u) = \frac{1}{\sqrt{2\tau}} \int_{-\infty}^{u} e^{-\frac{x^2}{2}} dx$, while α and β are the parameters of the distribution;

-power law:

$$F(t) = \begin{cases} (\frac{t}{b})^{\delta}, 0 \le t < b \\ 1, t \ge b \end{cases} \tag{2}$$

where b and δ are the parameters of the distribution;

- Weibull law:

$$F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}} \tag{3}$$

where η and β are the parameters of the distribution.

The Weibull distribution is among the most employed distributions in reliability prediction of technical systems, having the ability to model all the three stages of a system aging process through the parameter β in the relation (3): β<1 can be used for a decreasing failure rate system, β=1 can be used when the failure rate of a system is constant, while β>1 can be used for an increasing failure rate system [1]. However, there are many situations when the reliability modeling can not be performed with the Weibull distribution [156]. The alpha and power distributions, which are among the most recently adopted distributions in the reliability field [58, 156] are recommended to be considered in such cases [156].

The approach of the author to associate one of these laws with the failure mechanisms of the analyzed mechanical components was based on a combination of physical interpretation and the confrontation with the experimental data through a goodness-of-fit test. Founded on the theory of hypothesis testing, a goodness-of-fit test [43] was used to decide between the null hypothesis H_0 and the alternative hypothesis H_1. The H_0 hypothesis was stated by selecting one of the three distribution laws to be associated with the failure mechanisms. The alternative hypothesis H_1 included other distribution laws, but not the one selected by the H_0 hypothesis. The Kolmogorov-Smirnov goodness-of-fit test is one of the most employed in the reliability studies and was applied by the author. For this test, the H_0 hypothesis is accepted if and only if [43, p. 34]:

$$\sup_{1 \le i \le n} \left| F(t_i) - \hat{F}(t_i) \right| < D_{1-\alpha}(n) \tag{4}$$

where $F(t_i)$ and $\hat{F}(t_i)$ are the true and estimated value of the cumulative distribution function of the time-to-failure t_i ($i = \overline{1..n}$), while $D_{1-\alpha}(n)$ is the 1-α percentile of the Kolmogorov-Smirnov distribution and α is the risk of the first order.

For the employment of the Kolmogorov-Smirnov goodness-of-fit test, the ordered times-to-failure t_i ($i = \overline{1..n}$) of all elements of a sample must be known. The times-to-failure t_i can be obtained from life tests data or from historical data during the exploitation of the units under consideration. In both cases, a representative sample is followed for a specific period under normal operating conditions, the times of failure are recorded and they are used as experimental data in the Kolmogorov-Smirnov goodness-of-fit test. The parameters of the three distribution laws in relations (1), (2) and (3) are unknown and they need to be estimated from the experimental data. There are several methods for this purpose and one of the most used is the least squares estimation method, which was generally employed by the author. After the adoption of the distribution law, all reliability measures can be predicted.

In the author's research, the times-to-failure t_i ($i = \overline{1..n}$) were acquired with the different data acquisition systems presented in the section II.2.2 or from the historical data during the exploitation of the analyzed technical systems. The Kolmogorov-Smirnov goodness-of-fit test was employed for the adoption of the distribution laws of several cold plastic deformation tools and equipments [26, 29, 34], welding by pressure equipments [28], industrial robots [30], automotive crankshafts [33] or planar manipulators [35]. In most of the studies, the power law was adopted and in each case the parameters of the distribution law were also computed.

II.2.3.1.2. The structural reliability modeling

The aim of the structural reliability of a technical system based on the logical model is to estimate the reliability function of the system R_{sistem} taking into account its structure function $S=\varphi(x_1, x_2,..., x_n)$ and the reliability functions of its components $R_i\,(i=\overline{1..n})$:

$$R_{sistem}=f(R_1, R_2,..., R_n) \quad (5)$$

It should be noted that the structure function S indicates the logical combinations of component states that involve the proper functioning of the system. The series and the parallel system are the basic structures used in the logical model. On the other hand, complex systems can include structure types different from that of the series and parallel (or their combinations). The total probability formula can be used in such cases, to simplify the structure of the system to combinations of series-parallel type, which can be then used to compute the reliability function of the system [43]. However, as the system structure becomes more complex the total probability formula, which is well suited for manual computations, is more difficult to be employed.

In such cases, a numerical estimation of the reliability of the system may be made by a Monte-Carlo simulation and was used by the author in structural reliability modeling. Considering as known the reliability functions of the components x_i $(i=\overline{1..n})$, the method is based on generating possible states of the components considering their reliability functions $R_i\,(i=\overline{1..n})$ and evaluating the system structure function $S_j=\varphi((x_1)_j,(x_2)_j,...,(x_n)_j)$ for each combination of individual states [43]. A point estimation of the reliability function of the system can be obtained as [43, p. 198]:

$$\hat{R}_{sistem}=\frac{\sum_{j=1}^{k} S_j}{k} \quad (6)$$

where S_j is the value of the structure function for simulation j and k is the number of simulations. The Monte-Carlo simulation was employed by the author to predict the structural reliability of different systems, such as industrial robots ($\hat{R}_{industrial\_robot}$=0.79) [30] or car braking systems ($\hat{R}_{car\_braking\_system}$=0.9002) [32].

II.2.3.2. Maintenance planning

As the complexity of the technical systems is increasing, they should also function after the first failure occurs. In addition, specific restrictions on size, weight or cost may prevent the achievement of a high reliability. For such systems, beside their intrinsic reliability, the maintainability should be considered to characterize their effectiveness and recondition possibilities must be provided. Maintainability, which is defined as the property of a technical system to restore its performance, depends on how a system structure was designed so the failure can be easily detected and maintenance activities can be carried out to inhibit or eliminate the wear of the system [43]. For this purpose, inspections and maintenance interventions should be planned and performed to control the advance of the deterioration processes [165].

Reactive maintenance and proactive maintenance are the two broad types of maintenance strategies [92]. The reactive maintenance, which included corrective and emergency maintenance [92], is an unplanned strategy. The emergency maintenance is based on the actions that must be immediately taken to avoid critical situations. In the corrective maintenance, maintenance actions are performed only when the system fails. In such case, the system is restored to its initial condition after the failure through repair or replacement, within an average period equal with the mean time-to-failure. This situation can be described as a failure replacement policy (FRP). If c_f is the cost of a corrective replacement upon failure, the average cost rate of the failure replacement policy is [43]:

$$C_{FRP} = \frac{c_f}{m} \tag{7}$$

where m is the mean time-to-failure. However, such strategy is usually associated with higher maintenance costs [148].

Therefore, the proactive maintenance strategies, which are based on planned maintenance actions to prevent failure have been developed to reduce maintenance costs and production loss. They can be divided into preventive and predictive maintenance [92, 137]. The preventive maintenance actions are effective for systems with an increasing failure rate [62], which is a usual situation in the manufacturing industry and they are scheduled on the basis of statistical analysis of system failure [43, 101]. The predictive maintenance is usually based on different monitoring techniques, which are used to observe the degradation of the system so the maintenance activities are carried out only on a when-needed basis [101, 104]. Each proactive maintenance strategy has its advantages and challenges in industrial practice [7, 101] and both preventive and predictive maintenance techniques have been used in the author's research.

II.2.3.2.1. The preventive maintenance and inspection planning

The preventive maintenance can be formulated as renewal policy, which consists of maintenance actions performed after a scheduled time to eliminate the cumulated wear of the system. After a renewal policy the system is considered "good as new" and its time-to-failure is, therefore, extended. According to the nature of renewal policy, a preventive renewal may be a deterministic or a random event. The periodic and non-periodic renewal policies are the two main categories of preventive renewal and they are placed over the corrective actions generated by the failures of the system.

The periodic renewal policies are performed at an equally spaced time interval between any two successive preventive renewals. On the other hand, the non-periodic renewal policies are undertaken based on wear or age of the system. Several criteria may be used in designing a replacement policy [64, 157] and two of them have been used in the author's research. The first criterion is that the renewal policy should minimize the average maintenance cost rate, which has traditionally been the most employed criterion [157]. The second criterion is represented by the minimum value that can be reached by the operational reliability.

Among the periodic renewal policies, the block replacement policy was employed in the author's research [29, 34]. According to the block replacement policy, the preventive renewals are carried out at constant time instants kT (k=1, 2,…) and the system is also restored to its required state when a failure occurs [43]. One of the main disadvantages of the block replacement policy occurs from the situation when a preventive renewal is carried out immediately after a renewal due to the system failure. Therefore, this may increase the cost of the block replacement policy.

The maintenance cost rate of the block replacement policy in the [(k-1)T, kT] interval can be calculated as a sum of the cost of a preventive renewal and the cost of the corrective replacement upon failure c_f that occur in the time interval. Considering the cost of a preventive renewal of the block replacement policy during the [(k-1)T,kT] interval as $(c_p)_{BRP}$ and the mean number of failures in the same interval H(T), the average maintenance cost rate can be written as [43]:

$$C_{BRP}(T) = \frac{(c_p)_{BRP} + c_f \cdot H(T)}{T} = \frac{a + H(T)}{T} c_f \tag{8}$$

where $a = \frac{(c_p)_{BRP}}{c_f}$. The main difficulty in calculating the C_{BRP} cost in relation (8) is related to the impossibility of computing the renewal function H(T) for most distribution laws employed by the author in reliability studies. Since the computation of an analytical expression of the H(T) for the three distribution laws described by relations (1), (2) and (3) is very difficult or impossible, the criterion of the minimization of the average maintenance cost rate was not used for this type of renewal policy.

Therefore, in the author's work the minimum level of operational reliability was employed for the block replacement policy. Considering this criterion, the equally spaced time interval T between any two successive preventive renewals of the block replacement policy was established from the relation:

$$R(T) \geq R_0 \tag{9}$$

where R_0 is the specific lower value of reliability function. For example, this criterion was employed in [29] considering a minimal reliability value of 0.80 and the time interval for performing the preventive renewal of the analyzed equipment resulted equal to 9496 cycles of function. In [34], a minimum level of reliability of 0.80 was also considered and the time of preventive renewals based on the criterion of minimum reliability level was determined as 14697 cycles.

Another replacement policy that was used in the author's research is the age replacement policy [28, 29], which is a non-periodic renewal policy. In this policy, the system is renewed if and only if has attained a specific age T [43]. In addition, the system is restored to its required state when it has failed. If $(c_p)_{ARP}$ is the cost of a preventive renewal of the age replacement policy, the maintenance cost rate of such policy is equal to [43]: a) $(c_p)_{ARP}$ if the system doesn't fail before the specific age T, which is an event with the probability of R(t) and b) c_f if the system fails before has reached the specific age T that is an event with the probability of F(t). Therefore, the average maintenance cost rate is [43]:

$$C_{ARP} = \frac{(c_p)_{ARP} \cdot R(T) + c_f \cdot F(T)}{\int_0^T R(t)dt} = \frac{b \cdot R(T) + F(T)}{\int_0^T R(t)dt} \cdot c_f \tag{10}$$

where $b = \frac{(c_p)_{ARP}}{c_f}$. The optimal age T^* when preventive renewal should be made is obtained through the minimization of expression (10) and can be computed from the equation [43]:

$$z(T^*)\int_o^{T^*} R(t)dt + R(T^*) = \frac{1}{1-b} \tag{11}$$

where z(t) is the failure rate. If the equation (11) has a solution, the minimum value of the average cost rate can be obtained from [43]:

$$C^*_{ARP} = c_f \cdot (1-b) \cdot z(T^*) \tag{12}$$

Equation (11) is difficult to be solved for the Weibull and alpha distribution laws, so the criterion of minimization of the average maintenance cost rate is adequate only for the power distribution law. On the other hand, the criterion of the minimum value of the operational reliability may also be used to design an age replacement policy, when the replacement age T is computed using the same relation (9) for the block replacement policy.

For the age replacement policy, an example of the employment of criterion of the minimization of the average maintenance cost is presented in [28]. The age after which a welding by pressure equipment should be restored through a preventive renewal was 1624 cycles, for which reliability function resulted equal 0.87. Considering the cost of a renewal caused by a failure as the unity and the cost of preventive renewal as 35% of the cost when no preventive renewals are made, the average maintenance cost rate was also computed as $3.9553 \cdot 10^{-4}$ cycles^{-1}. In the case of a cold plastic die [29], the time interval between two successive preventive renewals was established as 17573 cycles. However, the reliability function became 0.51, while the average maintenance cost rate was computed as $3.48589 \cdot 10^{-5}$ cycles^{-1} (the cost of a renewal caused by a failure was considered as the unity and the cost of preventive renewal as 40% of the cost when no preventive renewals are made).

To sum up, carrying out preventive renewal will extend the time-to-failure of a system and its effectiveness will be improved. In addition, a periodic inspection can be used to further improve the effectiveness of systems. The state of the system can be determined through inspection and if a failure is detected, the wear is eliminated and the system is restored to its required state. The predictive measures of reliability may be used for planning the inspections so the wear can be eliminated before the system is inoperable. Among such predictive measures, the percentile of the time-to-failure $X_{R_0,t}$ was employed by the author [29, 34]. This percentile is obtained from the equation:

$$\frac{R(t+x)}{R(t)} = R_0 \tag{13}$$

Considering t=0, the moment of first inspection is equal to the scheduled time of preventive renewal from the relation (9). This equality is natural since a common criterion was used in both relations (9) and (13): the minimum value of reliability function. The difference occurs in the calculation of the next inspection moment and scheduled time of preventive renewal. After each inspection, the moment of the next inspection must be computed again according to the relation (13), while the time interval between two successive renewals is the same, see the relation (9).

For example, in [29], a minimum level of reliability of 0.80 was considered and the first inspection must be done after 9496 cycles. The time for next verification can be computed as 5548 cycles and so on. On the other hand, the scheduled time of preventive renewals considering the criterion of minimum reliability level was determined as the constant value of 9496 cycles. In [34] the same minimum reliability level of 0.80 was also considered and the first inspection of a combined stamping die used in the car industry must be performed after 14697 cycles. The time for next verification was computed as 3015 cycles, and so on, while the preventive renewals based on the minimum reliability level of 0.80 should be performed at the equally spaced interval of 14697 cycles.

II.2.3.2.2. The predictive maintenance

An alternative to preventive renewal and periodic inspection may be represented by a predictive maintenance approach, that is the condition-based maintenance. The rapid growth of computer performances, the spread of information technology and the recent advancement of the components of data acquisition systems (sensors, acquisition hardware and software for data analysis and processing) have accelerated the development of the condition-based maintenance [45].

Therefore, condition-based maintenance becomes today one of the most modern maintenance techniques, which has been applied in different industries, including the manufacturing, automotive, aerospace and military industries [115]. Several extensive overviews of the application of the condition-based maintenance in the case of mechanical systems or industrial application are provided in the literature

[7, 82]. Different types of industrial equipments and the parameters of each equipment that may be monitored through condition-based maintenance are shown in [73]. The study [73] also depicts examples of using the condition-based maintenance for industrial equipments and processes.

In this maintenance technique, the state of a system and its components is intermittently or continuously monitored and maintenance actions are based on their conditions [101, 104]. For this purpose, different parameters, such as vibration, temperature, sound or oil are monitored and compared with their expected values so the maintenance activities are performed only when they are necessary. Among the existing nondestructive techniques, the vibration monitoring and thermography have been used by the author. In [19], both the vibrations and temperature were monitored on the stand shown in figure 2 and they were employed to estimate the technical state of the disc brakes of automotive.

II.2.3.2.3. Planning the maintenance activities: a fuzzy logic approach

There are situations when the distribution law, which is needed in the preventive maintenance can not be adopted through a goodness-of-fit test. Considering the transition between good function and failure of a system is achieved by several intermediate stages characterized by specific levels of performance, the fuzzy logic can be used in such cases. In this direction, the maintenance activities of a combined shearing tool were performed based on a fuzzy logic approach [23]. The fuzzy logic decision process in planning the maintenance activities of such tool was presented in [23, p. 22-23] and is described next.

Two inputs were set up in the fuzzy decision system: the amplitude of vibration of the active elements C_1 [mm/s] and the break clearance (distance) between the active elements of the plastic deformation tool C_2 [mm]. The tolerance intervals for the two inputs were established as [16.75;20.45] and [1.40;1.65], respectively. The output was set up as the number of cycles to the next preventive renewal O_1 [cycles] of the combined shearing tool. The tolerance interval for the output was established as [0;22500].

The Fuzzy Logic Toolbox™ of the Matlab® software was used to develop the fuzzy decision system, which is depicted in figure 3 [23, p. 24]. The inference rules of the fuzzy decision system are depicted in figure 4 [23, p. 24]. The dependence between the output and inputs in the fuzzy decision system is graphically shown in figure 5 [23, p. 25].

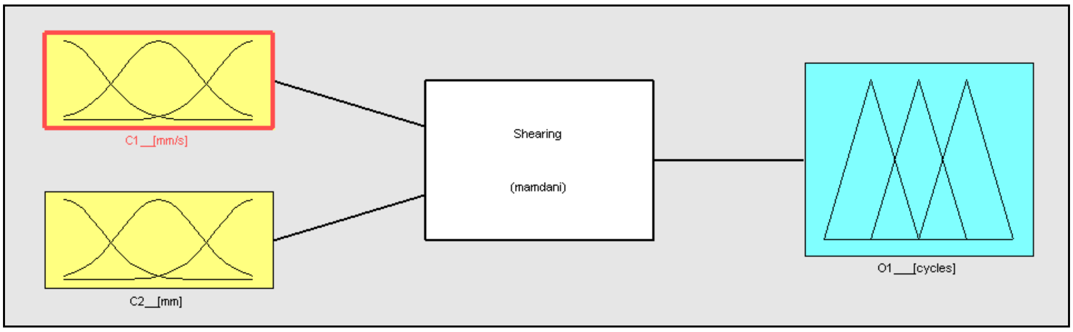


Figure 3. The fuzzy decision system for the combined shearing tool [23, p. 24]

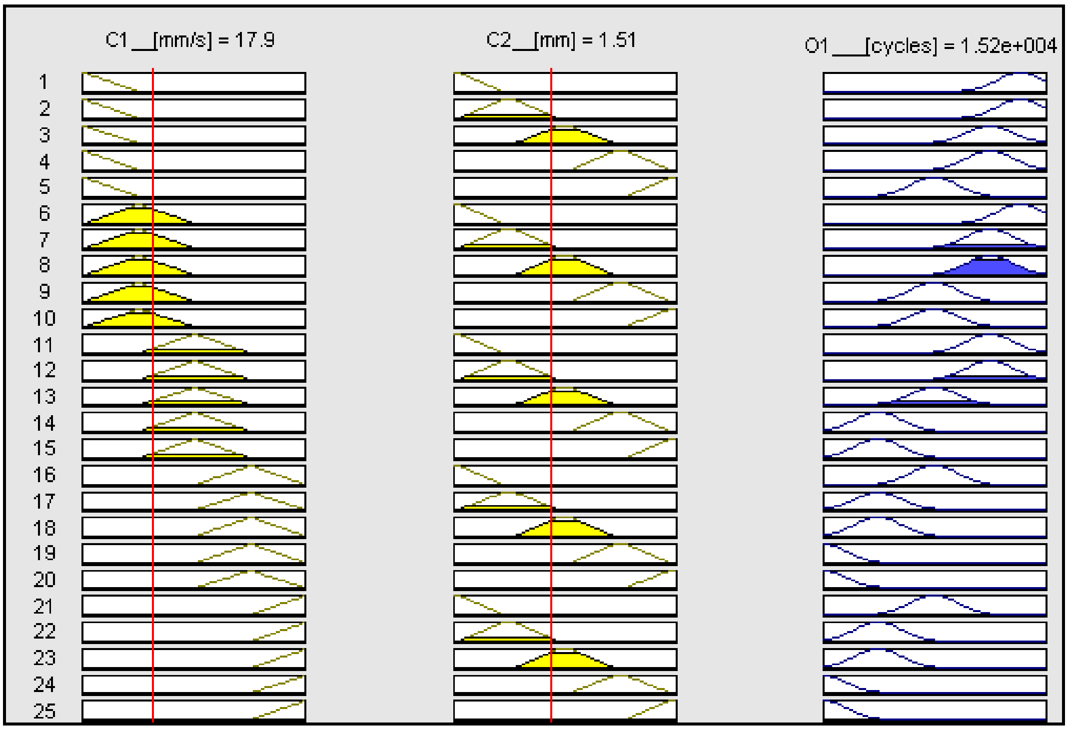


Fig. 4. The inference rules of the fuzzy decision system [23, p. 24]

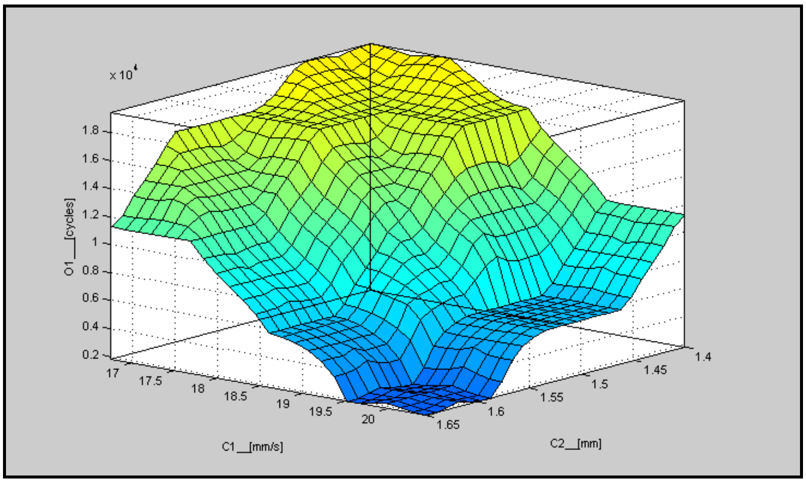


Figure 5. The graphical dependence $O_1=f(D_1, D_2)$ [23, p. 25]

Considering any two values of the inputs within their tolerance intervals, the scheduled moment (expressed in cycles) for the next renewal of the combined shearing tool can be obtained. An example was presented in [23]: if the amplitude of vibration is equal to 17.9 mm/s and the break clearance is 1.51 mm, then the next renewal should be carried out after 15200 cycles.

On the other hand, when different parameters such as vibrations and temperature are monitored, different decision may be employed in carrying out the maintenance actions. Moreover, the estimation of the state of machines may be affected by some vagueness or uncertainty due to the limitation of the condition-based maintenance [108, 155]. In such cases, a fuzzy logic approach can be used for planning the maintenance activities. A such approach was used in [19] to estimate the technical state of the disc brakes and was done as follows. In the case of a new disc brake (10 mm), a lowest value of the vibration amplitude of 1.46 mm/s rms was measured on the stand depicted in figure 2 at 50.9 ^{0}C. For a disc brake with the thickness at the lower limit prescribed by the manufacturer (8.5 mm), a highest value of the vibration amplitude of 2.4 mm/s rms was measured on the stand at 154.2 ^{0}C. The input linguistic variables in the fuzzy system were established as the temperature T [^{0}C] and amplitude of vibration Avib [mm/s] rms. The domain values of the T and Avib variables were defined as [50.9; 154.2] and [1.46; 2.4], respectively. The output linguistic variable in the fuzzy system was established as the thickness of the brake disc, TBD [mm]. The domain values of the TBD variable was defined as [8.5; 10]. The Fuzzy Logic Toolbox™ of the Matlab® software was employed to implement the fuzzy logic decision approach (figure 6 [19, p. 536]).

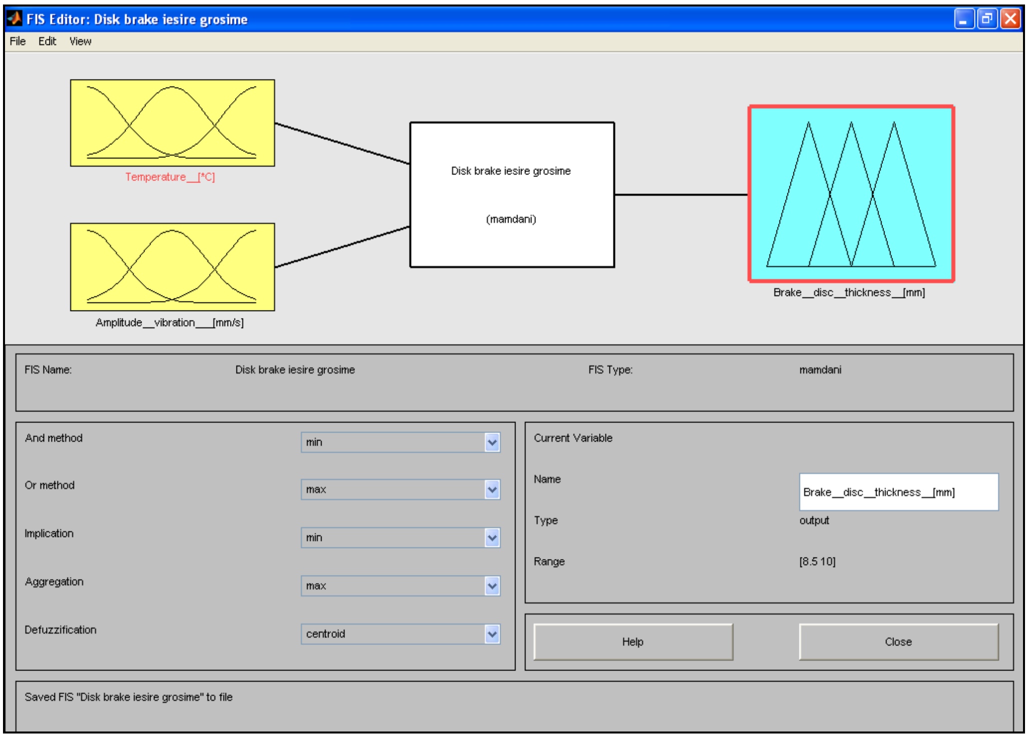


Figure 6. The fuzzy logic decision system Technical_state_automotive_disc_brakes.fis [19, p. 536]

For any two values of the temperature and amplitude of vibration within their domain values, the technical state of a disc brake (represented by its thickness variation) can be established. For example [19], if T is 116 ^{0}C and Avib is 2.16 mm/s, the TBD results equal to 8.9 mm. According to the domain value of the TBD variable, the thickness of the brake disc is within its prescribed limits.

II.2.4. Quality and reliability improvement: a Taguchi design of experiments approach

II.2.4.1. Taguchi design of experiments: an overview

Manufacturing companies are operating nowadays in a dynamic global market, where the continuing satisfaction of more and more demanding customers may be achieved through the quality and price of their products. Therefore, they need to improve the quality and reliability of their products at a minimal cost to have success in such competitive business environment.

Although many potential factors may influence both the quality and reliability of products and processes, some factors are more significant than others so they are important to be determined. The values of the important factors in improving the quality and reliability are also important to be identified. For many manufacturing companies, the trial and error approach is still used for these purposes [68]. However, design of experiments is recognized among the most powerful tools for improving the quality and reliability of products and processes [11, 54] and has been more and more employed by industry in the last time [139, 140].

The classical design of experiments and Taguchi method of design of experiments are the main approaches to identify the significant factors that affect the quality and reliability [11, 142]. The mathematical and statistical base of classical design of experiments is known as more rigorous than the Taguchi approach [142]. On the other hand, the classical design of experiments may be more complex and more difficult to carry out [107]. Therefore, the classical design of experiments has been mainly used in applications related to the space field, medical trials or fundamental research and development projects [142]. The Taguchi methods are more suitable where the results are required quickly and the experiment can be repeated several times [142]. Since the Taguchi methods employ a statistical approach from an engineer’s perspective, they are extensively employed in industrial applications because of their practicality [81, 142] and have been used in the author’s research.

The quality of a product begins with its design, is developed by experimental test, is achieved through manufacturing and is validated in exploitation. On the other hand, there is a recognition the quality and reliability characteristics are mostly established in the early design phases of the new product generation cycle [114, 165]. The on-line and off-line quality engineering methods have been distinguished by Taguchi in the quality engineering system [Taguchi as cited in 12, p. 18]. The on-line quality system refers to the activities that are required to be implemented during the manufacturing stage. The off-line quality system is related to all activities that are carried out in the stages before the production begins such as design and development. Since Taguchi has considered the quality of the process or product design as having an impact greater than inspection, the off-line quality activities are focused to minimize the variability of the products or processes through three steps: system design, parameter design and tolerance design [138, p. 314]. Among the three steps, the parameter design is seen as one of the most efficient ways to reduce the lack of robustness of a new product or process [138].

In Taguchi's viewpoint, the controllable and noise (uncontrollable) factors are the two categories of factors that affect the function of a product or process [121]. The controllable factors are those factors that may be easily manipulated or adjusted by the manufacturer, which remain unchanged after selection of their levels. The noise factors are expensive, difficult or impossible to be controlled and represent the main source of variability since they may change and cause the deviation of a characteristic from its target. The noise factors can be classified into external, unit-to-unit noise and deterioration noise factors [65, 69, 138].

Since the uncertainty and variability are caused by the noise factors, the aim of parameter design is to identify the values of the controllable factors that make the product or process more robust to the variation generated by the noise factors [121]. Therefore, the Taguchi’s approach has also been called robust parameter design or robust design [105, 121].

Although the objective of Taguchi’s approach of robust design is to reduce the variability of products or processes characteristics around their nominal or target values, any deviation from the target values result in financial losses to companies [131, 138]. Taguchi introduced the loss function as a measure of cost associated with the deviation of the quality or reliability characteristic of products from their target value. The loss function estimates the loss to society during entire lifetime of the product and may include the warranty and service costs, or other cost that cannot be measured quantitatively, such as customer dissatisfaction and loss of market share [138]. Instead of measuring the conformity to specifications, the aim of Taguchi approach is to minimize the financial loss of society, which is related to the quality or reliability characteristics through a quadratic relationship. The expression of loss function may be expressed as [138, p. 173]:

$$L(y) = k(y - y_T)^2 \tag{14}$$

where L(y) is the loss function, y is the quality or reliability characteristic of a product or process, y_T is the target value of the y and k is the quality loss coefficient that must be estimated based on economic arguments. If the tolerance interval is (y_T-Δ, y_T+Δ) and A is the cost of the countermeasure when the characteristic y transgresses the prescribed tolerance interval, then $k=A/\Delta^2$ [138, p. 174].

Taguchi supports the achievement of product or process that is robust to the noise factors and develops the signal-to-noise ratio to measure of how sensitive a product or process is to the variability produced by such factors [138]. As a product or process will have a higher signal-to-noise ratio, it will be less sensitive to noise factors [12, 107, 138]. Therefore, this ratio is used to design products or processes that are insensitive enough to work properly in the presence of noise factors and its expression is related to the criterion for the quality or reliability characteristic to be improved.

Although different signal-to-noise ratios have been developed [65], three of them are usually employed [65, 107, 138]: a) the specific value (nominal-the-best quality or reliability characteristic); b) the lowest value (smaller-the-better quality or reliability characteristic) and c) the highest value (larger-the-better quality or reliability characteristic). The signal-to-noise ratio takes into consideration both the mean and variability of the characteristic and their expressions for the three criteria are presented in the literature [65]. The expressions of loss function (14), in the terms of mean and variance of a quality or reliability characteristic, are also available in the literature [65].

The Taguchi's approach of robust design is based on experimental methods in which orthogonal arrays are used in conducting the experiments. Two orthogonal arrays are employed to design the experiments: one orthogonal array- the inner array is selected for the controllable factors, while the other- the outer array, is chosen for the noise factors [161]. Different levels are assigned to both controllable and noise factors in the inner and the outer array. The product of the two arrays is called cross array or inner-outer array [161] and specifies the combinations of controllable and noise factors at which a quality or reliability characteristic is observed.

A two-step procedure is typically used in the Taguchi method of robust design. In the first step the signal-to-noise ratio is maximized while in the next step the mean value of the response is fine set to the target value of the quality or reliability characteristic [37, 138]. However, a compromise between reduction of variability and adjustment of mean to the target value might be required when the levels of controllable factors are determined. At the end, the results of the method should be verified through a confirmation run and should be monitored in practice.

The loss function at the optimum condition L_{optim} should also be compared with the loss function at initial condition $L_{existing}$ to establish how successful the approach has been:

$$\Psi = L_{existing} - L_{optim} \tag{15}$$

II.2.4.2. Using Taguchi design of experiments for quality and reliability improvement

The Taguchi design of experiments approach was employed in the author's work for both quality and reliability improvement. In [27], the quality of the mould injection equipment used in the manufacturing of a disk by injection was improved with Taguchi method. For this product, the surface roughness of the disk was selected as the quality characteristic and its target value was established as y_T=0.4 μm, which corresponds to the nominal-the-best criterion. A number of seven controllable factors were selected among the factors of the mould injection equipment that can be manipulated, while two levels were chosen for each controllable factor [27, p. 85]. Figure 7 depicts these controllable factors as well as their level values. Three noise factors were selected and for each noise factor two levels were chosen to be used in the experiment [27, p. 85].

Since each of the seven controllable factors had two levels, the $L_8(2\text{^}7)$ orthogonal array was selected as the inner array. In the case of the three noise factors that had two levels each, the $L_4(2\text{^}3)$ orthogonal array was selected as the outer array. The two arrays are combined, so that a number of 32 experiments resulted in the inner-outer array [27, p. 86].

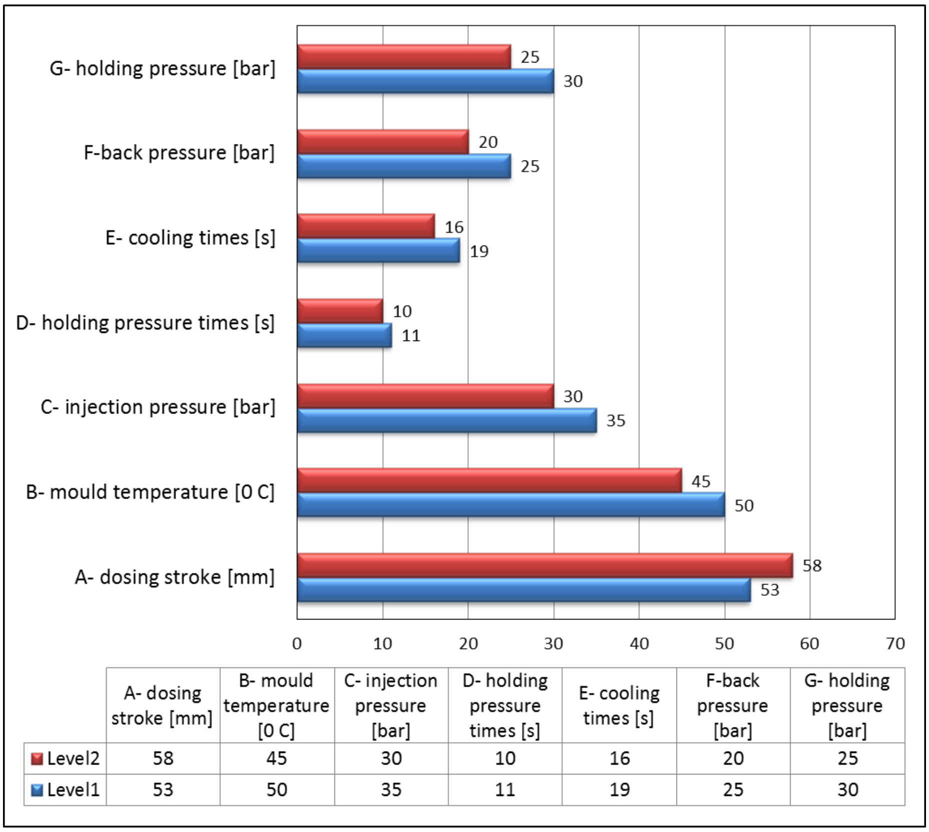


Figure 7. The controllable factors of the mould injection equipment and their level values [27, p. 85]

The experimental results were analyzed to establish the levels of controllable factors. First, the signal-to-noise ratio analysis was carried out based on the nominal-the-best criterion. The signal-to-noise ratio was computed for each line of the inner-outer array. For each controllable factor, the average value of the signal-to-noise ratios at the same level was computed. The results are shown in figure 8.

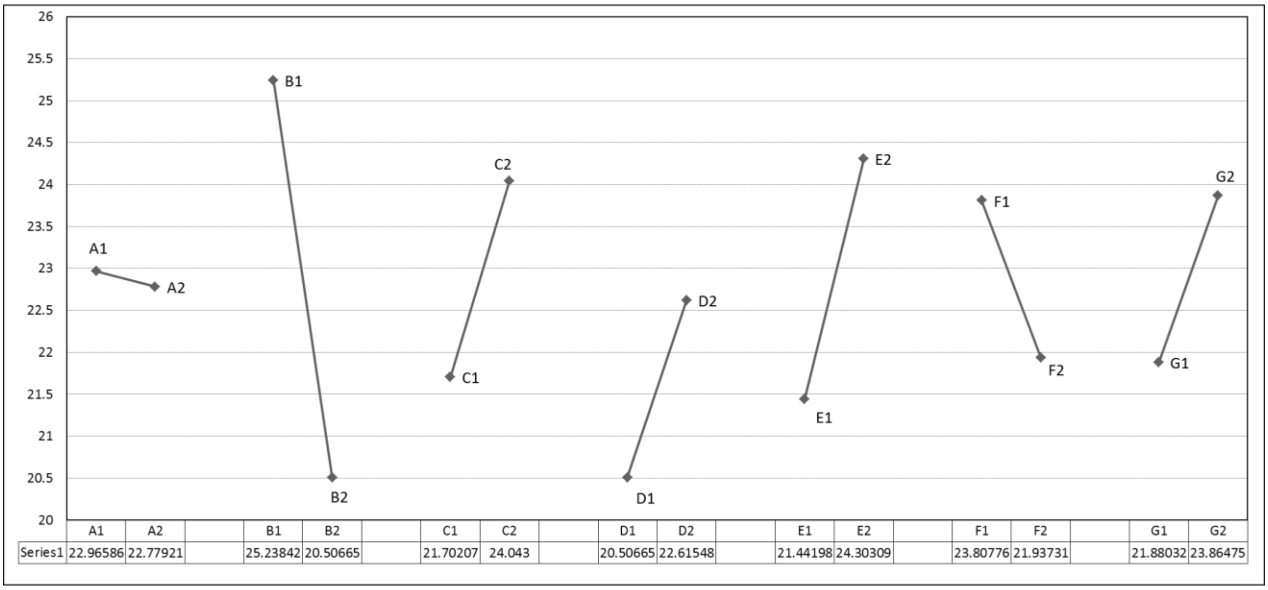


Figure 8. The averages of signal-to-noise ratios at the same level of each controllable factor of the mould injection equipment

A similar approach was used for the mean analysis: the mean was computed for each line of the cross array, then the average value of the means at the same level was computed for each controllable factor. Figure 9 depicts the results of the mean analysis.

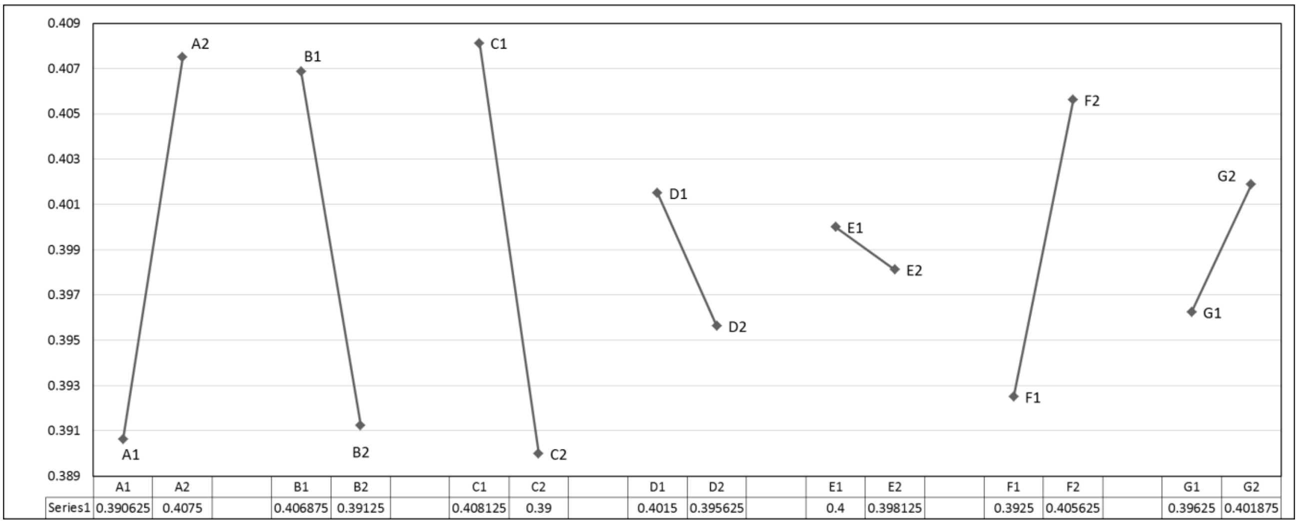


Figure 9. The averages of means at the same level of each controllable factor of the mould injection equipment

The selection of the optimum values of controllable factors of the mould injection equipment was based on the two-step procedure, so that the optimum level of each controllable factor was obtained [27, p. 87].

A confirmation of the experiment was performed to verify the optimal values of the controllable factors. Since the nominal-the-best criterion was used for the surface roughness of y_T=0.4 μm and considering the expressions of loss function for this criterion [65], the relation (15) became:

$$\Psi = L_{existing} - L_{optim} = k\left[s_y{}^2 + \left(\bar{y} - y_T\right)^2\right]_{existing} - k\left[s_y{}^2 + \left(\bar{y} - y_T\right)^2\right]_{optim} \qquad (16)$$

In relationship (16) $\bar{y}$ is the mean, s_y^2 is the variance of the observed results and y_T is the target value for y. In order to compute L_{optim}, the surface roughness was measured for 50 disks that were manufactured at the optimal condition. The initial conditions were included in one of the lines of the controllable factor array [27, p. 86]. The comparison of the value of the loss function at initial condition $L_{existing}$ with the value of the loss function at the optimum condition L_{optim} conducted to a reduction by 22.71% of the loss comparing with the initial conditions.

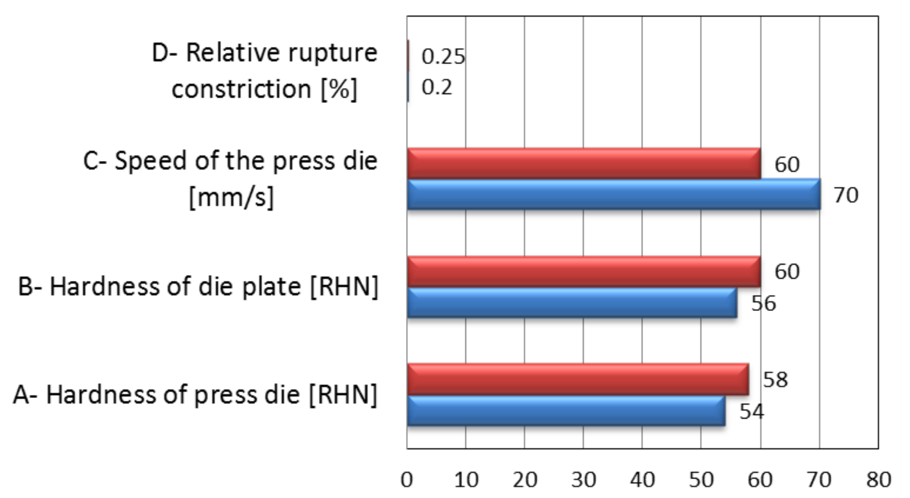
Although the Taguchi method of design of experiments has been extensively used to improve different quality characteristics [81, 121], it has been less employed in the improvement of reliability characteristics. However, several publications are available in the literature on applying the Taguchi method to improve reliability.

Examples of the use of the Taguchi's approach of robust design to reduce the effect of noise factors on reliability of products are shown in [46, 93, 161, 162]. These studies have shown evidence the Taguchi method is a suitable approach for an efficient reliability enhancement. Nonetheless, since a longer period of the good function of products is expected, it may be challenging to obtain the times-to-failure even if accelerated tests are used [161]. Thus, the experimental data in reliability improvement using Taguchi method are more difficult to be gathered than for the improvement of quality characteristics [87, 161].

On the other hand, as was shown in section II.2.3.2, the proactive maintenance strategies which consist of planned maintenance actions prior to failure of products, are usually employed to eliminate the wear and to extend the lifetime of the products. Therefore, the time interval between two successive proactive maintenance actions may be used to gather the data for the design of experiments. Such approach was presented in the [26], where renewal policies were used to collect the data and the Taguchi method was employed in the reliability improvement of deformation tools used in the automotive industry. The Taguchi's robust design approach to improve the reliability of such tools is described next.

It is known that after a renewal policy the cumulative wear of deformation tools is eliminated and they are considered "good as new". Thus, the moments when preventive renewals are carried out were proposed in gathering the data of experiments design and Taguchi method was applied to enhance the reliability of the active elements of the deformation tools. These tools were used to manufacture pieces with a target value of the dimension y_T=80 mm. For this purpose, the times-to-failure were identified with a data acquisition system based on resistive strain gauges. The Kolmogorov-Smirnov goodness-of-fit test was employed to perform the reliability modeling of the active elements of deformation tools. The power distribution law was adopted and its parameters were also estimated from the experimental data, so that the reliability model R(t) was completely specified. Because for this reliability function was not possible to compute the Laplace transformations, only the age replacement policy was employed as renewal policy. The criterion of the minimization of the average maintenance cost rate described by the relation (11) was used to establish the optimal age when preventive renewal should be carried out. The age T^* at which preventive renewal should be done was computed (T^*=14946 cycles) as well as the reliability function for this age of preventive renewal.

Five controllable factors that influence the reliability of the deformation tool were identified and two levels were considered for each factor. Four controllable factors had numerical values [26, p. 223] and they are shown in figure 10. The lubricant was used as the fifth factor (E), with two levels: emulsion as the level 1 and mixture of emulsion with oil as the level 2 [26, p. 223].



	A- Hardness of press die [RHN]	B- Hardness of die plate [RHN]	C- Speed of the press die [mm/s]	D- Relative rupture constriction [%]
Level 2	58	60	60	0.25
Level 1	54	56	70	0.2

Figure 10. The controllable factors and of the active elements of the plastic deformation tool and their level values [26, p. 223]

Since there were five two-level factors, the L8 (2^7) orthogonal array was employed in the experiment to study these controllable factors. For the L8 (2^7) orthogonal array, eight pairs of active elements were used in each line of the experiment layout. The dimensions of the manufactured pieces at each $k \cdot T^{*}$cycles ($k = \overline{1,4}$) were measured and used as data in the experiment.

As in the case of the quality of the mould injection equipment, the same two steps approach was used to determine the levels of controllable factors. Both the signal-to-noise ratio and mean analysis were carried out for the nominal-the-best criterion. Figure 11 depicts the averages of signal-to-noise ratios at the same level of each controllable factor while figure 12 shows the averages of means at the same level of each controllable factor.

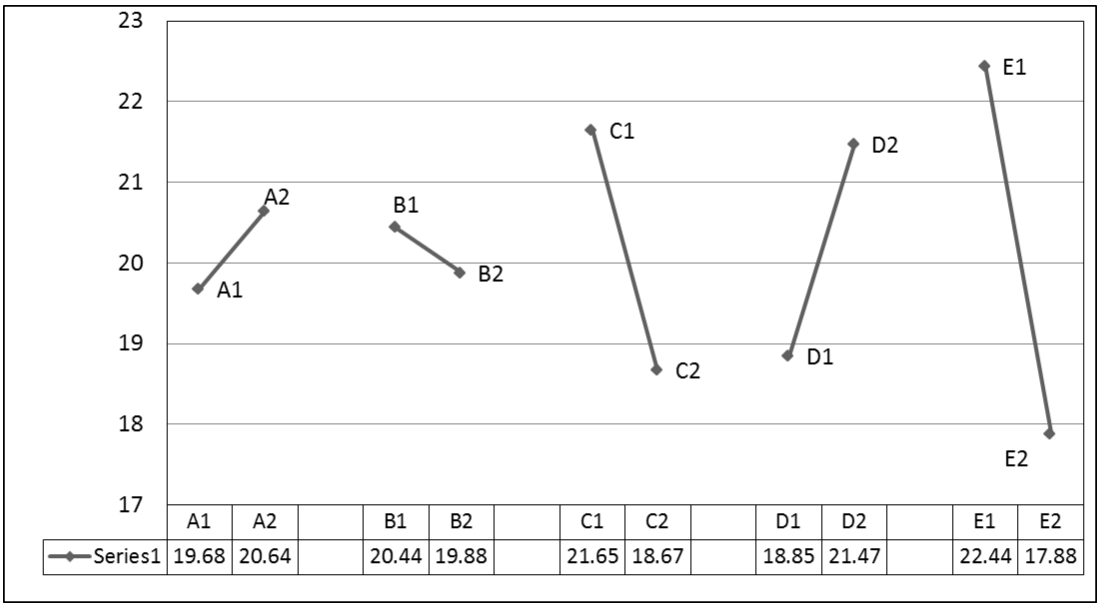


Figure 11. The averages of signal-to-noise ratios at the same level of each controllable factor of the active elements

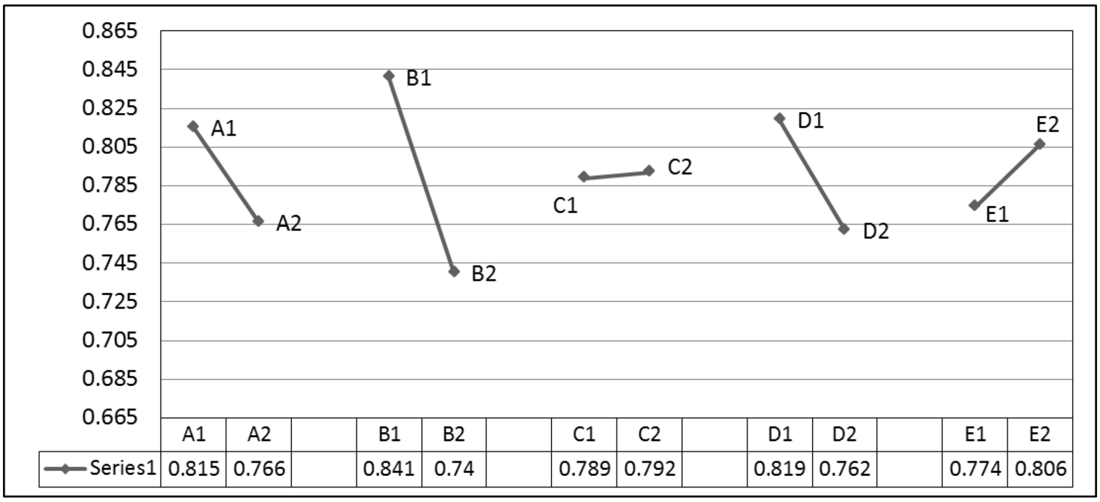


Figure 12. The averages of means at the same level of each controllable factor of the active elements

On the base of the two-step procedure, the optimum levels of controllable factors of the active elements was established [26, p. 224]. Taking into account the optimum values of the controllable factors, a new reliability model was developed for the active elements. For the new model, the reliability function R_{new} at the age T^* when the active elements should be restored through a preventive renewal was computed. The results shown the reliability of the active elements was enhanced by 25.52%. A new optimal replacement age was also established, T_{new}^*=16909 cycles. Comparing the average maintenance cost rate $C_{ARP}\big|_{T*}$ at the T^* age with the average maintenance cost rate $C_{ARP}\big|_{Tnew*}$ at the T_{new}^* age, this cost was diminished by 25.13%.

II.2.5. Concluding remarks

The foundation of quality and reliability analysis and modeling of any technical system is represented by the investigation of its behavior and the failure monitoring of its components, subsystems as well as the whole system. Since the failure detection methods have no universal application, a specific method must be used for each technical system accordingly with its characteristics. The continuous advancement in the fields of signal monitoring, processing and analysis is accelerating the development of the monitoring techniques that can be used to identify the failure of systems, which is the basis of their reliability modeling. Therefore, the failure detection was based on the use of a data acquisition system, which employed different transducers. The thermography was also used for the failure detection.

As we have already seen, the reliability modeling can be performed if the distribution laws are known. One fundamental problem that can occur in reliability modeling and thus in preventive renewal or inspection planning is related to the adoption of the distribution law. A considerable effort should be made to associate a distribution law to specific failure mechanisms of each system. A large number of observations should be conducted to record the times-to-failure that are required in reliability modeling. That implies a rigorous system of recording and tracking the failures of each type of system [55] by a trained staff on the use of the investigation methods. Other disadvantages in the adoption of the distribution laws associated with failure mechanisms are related to the poor discrimination of the goodness-of-fit tests or to the validity of the adopted distribution law outside the time interval in which the goodness-of-fit test has been carried out [43].

A general drawback appears when the available distribution laws in reliability theory are rejected by the goodness-of-fit test. Such case is presented in [23], where the proposed distribution laws for reliability modeling of a cold plastic deformation tool were rejected by the Kolmogorov-Smirnov goodness-of-fit test. Therefore, the reliability measures cannot be computed and the renewal policies and inspection plans cannot be designed. In [43] it is shown that different combinations of exponential laws may approximate a reliability model at any level of accuracy. Nevertheless, is almost impossible to formulate the renewal policies and inspection plans based on such distribution law of the time-to-failure.

Despite its disadvantages, the preventive maintenance has been employed in many different industries, due to its large applicability for both simple (single) and complex (multi-component) systems, as well as for both non-repairable and repairable components [7]. An appropriate preventive maintenance policy not only prolongs the time-to-failure of a system, but also may reduce the maintenance costs associated with the repair in the case of a failure. The results presented in [28, 29] support this assumption and they are in concordance with the point of view of current literature [113]. It also may assure a specific lower bound of reliability [29, 34], if the requirements are to guarantee a predetermined reliability level.

The condition-based maintenance may be considered better than the preventive maintenance in terms of the maintenance planning since is based on observing different parameters that reflect the current condition of the analyzed system [84, 108]. In addition, only those elements of the system for which their characteristics exceed the prescribed limits are considered for maintenance actions. The elements in good states are kept as they are, which lead to cost savings and shorter downtime [63]. Nevertheless, condition-based maintenance is facing some challenges [15, 108]. The monitoring instrumentation used in this approach can be costly sometimes [108] while trained and knowledgeable staff is required to operate such instrumentation tools [104]. The complexity and the noise factors of the working environment, the knowledge of the structure of systems to identify the critical components that must be monitored and other variables may affect the accuracy of continuous based monitoring [108].

Considering the transition between good function and failure of a system is achieved by several intermediate stages characterized by specific levels of performance, a fuzzy logic decision process was proposed in [23] as a solution to plan the maintenance actions when the distribution law is not adopted by the goodness-of-fit test. The results from the research [19] also show that fuzzy logic is a method which can be successfully employed for appropriate planning of maintenance activities. Beside fuzzy logic, other techniques of soft computing, such as neural networks and evolutionary algorithms represent useful approaches [63, 82, 165] and their combination could represent an important step forward in the planning of the maintenance activities.

On the other hand, the quality and reliability of products and processes are influenced by many factors. The Taguchi method of design of experiments is recognized among the most powerful method to identify the significant factors that affect the quality and reliability as well as of the values of such factors. The aim of

Taguchi method is to reduce the variability of a quality or reliability characteristic from its target by making the product or process insensitive to the causes of variability, which are the noise factors. The Taguchi's design of experiments method has conducted to an important change in the view of quality, which can no be longer considered conformity with the specifications. Although the Taguchi's approach of robust design has been extensively employed in different fields, it has been subjected to several critics over time [141, 142, 149]. Most of them are related to the mathematical and statistical analysis of the data and its experimental designs [14, 142]. However, there is no dispute on using the robust design to improve quality and reliability characteristics and the existing results, including those of the author [26, 27], clearly show evidence of the effectiveness of the Taguchi's design of experiments method in improving both the quality and reliability of products and processes.

II.3. KNOWLEDGE MANAGEMENT IN HIGHER EDUCATION INSTITUTIONS

II.3.1. Representing knowledge: a knowledge map approach

Knowledge mapping is seen as an important approach to capture and integrate knowledge [160] while knowledge maps are representations of the captured knowledge and relationships [154]. Having the ability to depict knowledge on diverse levels of abstraction [79], knowledge maps have been described as a visual architecture of a knowledge area [74]. Therefore, knowledge maps can be used to visualize [71] and capitalize both explicit and tacit knowledge [164], and have been seen as an important technique in implementing knowledge management [91, 154]. Specific knowledge maps were presented in two studies of the author [21, 59].

The Partnership in Priority Domains Programme project no. 337/2014 ”Knowledge Management-Based Research Concerning Industry-University Collaboration in an Open Innovation Context”, gets together in a consortium researchers from University of Oradea, Politechnical University Timişoara, Technical University of Cluj-Napoca and S.C. Emsiltech Trans SRL, for the development of an environment that promote Industry-University collaboration in Open Innovation through research activities based on knowledge management and carried out in collaboration by the consortium partners.

In the development of the research consortium of this project, the acknowledgment and acceptance of an ontology must be used for building a collaborative environment. The main dimensions of the Industry-University collaboration in an Open Innovation context are among the concepts of the first level of such ontology. Based on the literature review, the following items were established as the main dimensions of the Industry-University collaboration in an Open Innovation context [59]: 1) motivation factors; 2) barriers; 3) channels of the knowledge transfer; 4) benefits and 5) disadvantages. The ontology of the main dimensions of the Industry-University collaboration in an Open Innovation context has been developed and its representation was presented in [59].

The knowledge map of each of the five dimensions of the Industry-University collaboration in an Open Innovation context is shown next:

a) Knowledge map of the motivation factors.

The motivation factors were adapted from [5, 86, 111, 151] and they are depicted in figure 13 [59, p. 6284].

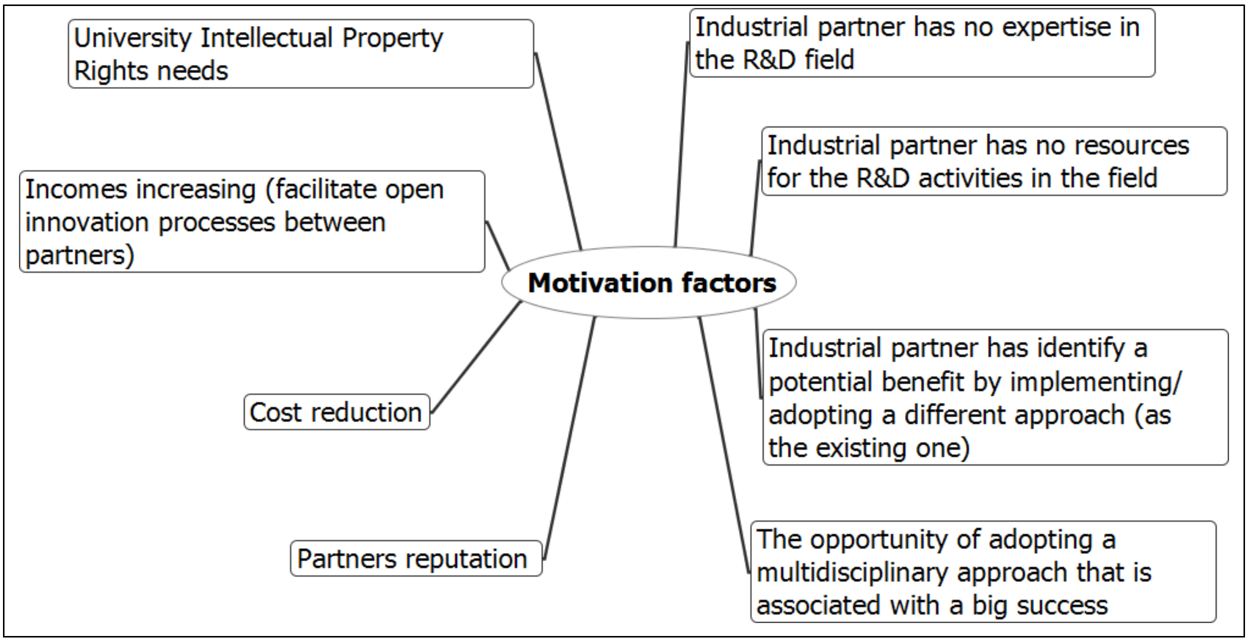


Figure 13. The knowledge map of the motivation factors of the Industry-University collaboration in Open Innovation [59, p. 6284]

b) Knowledge map of the barriers.

The items of the barriers were adapted from [40, 77, 152]. Figure 14 shows the knowledge map of the barriers [59, p. 6284].

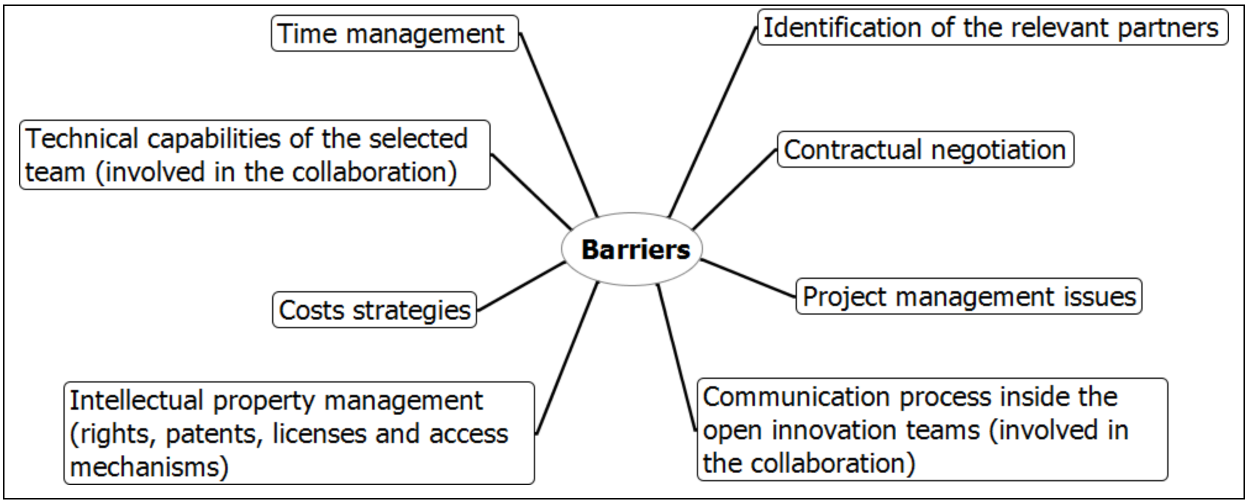


Figure 14. The knowledge map of the barriers of the Industry-University collaboration in Open Innovation [59, p. 6284]

c) Knowledge map of the channels of the knowledge transfer.

The channels of the knowledge transfer were adapted from [3, 40] and they are presented in figure 15 [59, p. 6284].

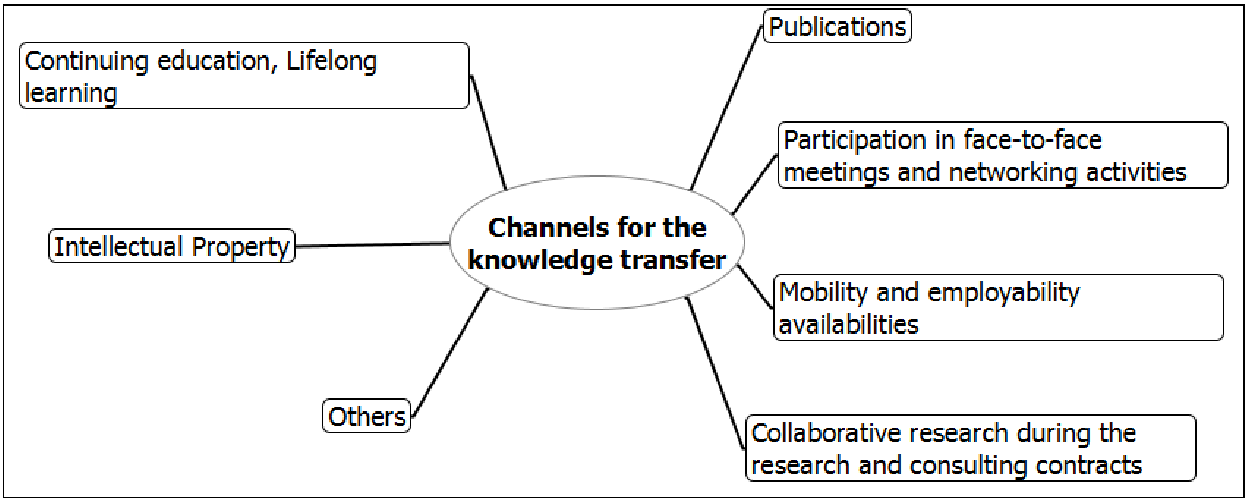


Figure 15. The knowledge map of the channels of the knowledge transfer between the Industry-University in Open Innovation [59, p. 6284]

d) Knowledge map of the benefits and disadvantages.

The benefits and disadvantages were adapted from [5]. Figure 16 depicts the knowledge maps of the benefits and disadvantages [59, p. 6284].

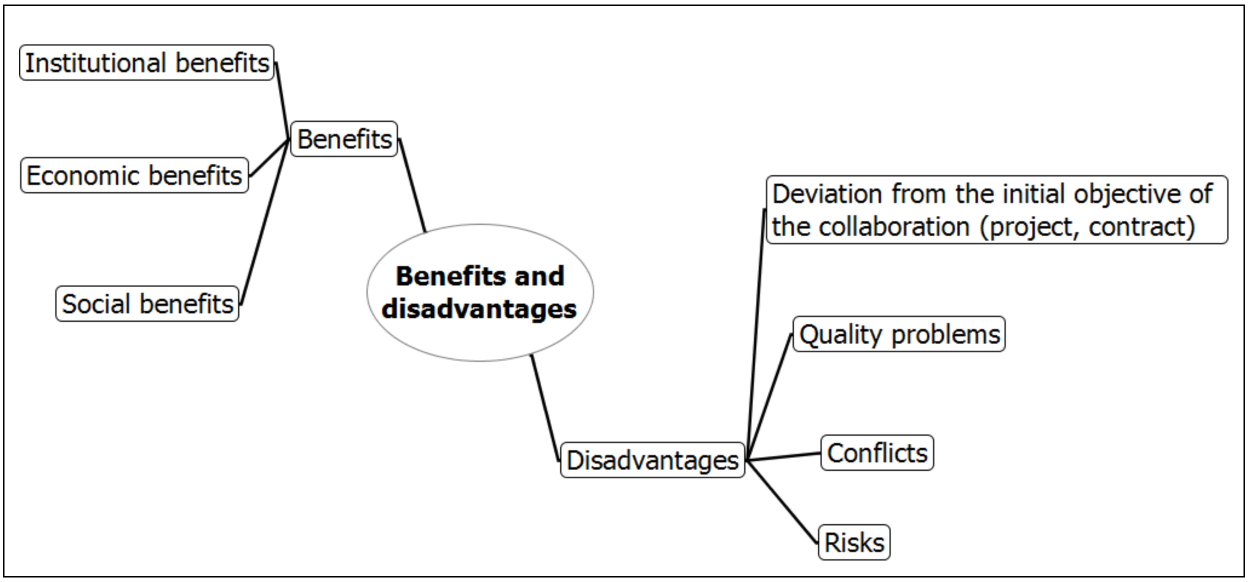


Figure 16. The knowledge map of the benefits and disadvantages of the Industry-University collaboration in Open Innovation [59, p. 6284]

Specific knowledge maps of the competencies that must be achieved to carry out the activities in the departments of a simulated enterprise in the automotive maintenance and repair field were presented in [21]. A knowledge map approach will be also used in the next sections for the knowledge representation of the author's research.

II.3.2. Knowledge management in higher education: an overview

We operate within the global society, a dynamic world where knowledge is seen as a highly valuable resource for sustainable competitive advantage and serves institutions to achieve their vision, mission and goals [10, 56]. Therefore, organizations are now motivated to manage knowledge in more effective and efficient ways. Universities are knowledge-creating organizations that build many complex relationships both within and external to their boundaries to accomplish their main missions of teaching, research, and service to society [89]. However, the knowledge-based society provides higher education institutions with new roles and new challenges. The growing rate of new knowledge generation and the transformation of their main functions based on emerging information and communication technologies are among the main challenges which universities are facing [6, 61, 83, 110]. Globalization, massification and diversity [9, 85, 112, 123, 130] as well as an increasing requirement for accountability and performance measures [72, 80, 95, 96, 103] are also presented as challenges for universities.

Therefore, the higher education institutions have to respond to their changing role in the present-day society [102, 119]. As it was suggested in [98], [102] or [127], the use of knowledge management may be a solution for universities to deal with both economic and social changes of our society. Guidelines for the implementation of knowledge management in these organizations were described in [135] and the impact of knowledge management in universities was reviewed in [4]. While the idea that knowledge management might be a response of higher education to coming challenges has attracted growing attention, only a few examples of knowledge management employment in higher education institutions have been presented so far in the literature [13, 70, 143].

Nonaka and Takeuchi [109, p. viii] describe the two forms of human knowledge as explicit and tacit knowledge. They are developed by people, exist in work teams and are incorporated in all components of an organization [90]. The management of knowledge also requires an adequate infrastructure. Considering that one of the most important demands is to have the right knowledge when and where is needed [90, p. 29], organizations have developed practices and systems for simple to complex knowledge management activities [98, p. 205]. As Cronin [48, p. 133] and Geng [67, p. 1032] have indicated, the academic and operational knowledge are the two main knowledge domains in universities. The two major knowledge areas include explicit as well as tacit knowledge. The academic and scholarly knowledge is discovered through research and development, is transferred by teaching and learning, and is disseminated in academic journals or conferences. The operational or administrative knowledge is used in different domains, like student and alumni networks, financial and human resources, or planning services. Therefore, higher education institutions seem to be well placed to embrace knowledge management practices as their environments are based on knowledge discovery, sharing and application [98]. Moreover, the development of an organization focused on such knowledge management activities is likely to be a promising solution for its success in today's society [102].

According to Townley, knowledge management in higher education "can be defined as a set of organizational processes that create and transfer knowledge supporting the attainment of academic and organizational goals" [145, p. 9]. The opportunities that higher education institutions have in employing knowledge management practices to achieve their mission and goals, are illustrated in [90]. Some possible applications and benefits of knowledge management for different processes and services of a university, including the research and academic processes, as well as several operational services are presented by Kidwell et al. [90, p. 32-33]. Representative applications of the management of knowledge associate with the two main knowledge domains are also depicted by Cronin [48, p. 134].

The challenges of higher education institutions in applying knowledge management are explored by Rowley [124]. Based on Davenport et al. four categories of knowledge management objectives [53], Rowley [124] found significant advance of universities for the first two objectives, which are the development of knowledge repository and improvement of knowledge access. However, Rowley suggested that much progress is expected for the other two objectives: in developing the knowledge environment and in valuing knowledge as an asset. Rowley came to the conclusion that an "effective knowledge management may require significant change in culture and values, organisational structures and reward systems" [124, p. 332]. Townley [145] pointed out that knowledge management has been slowly embraced in higher education. Nevertheless, in his opinion, academia can learn to manage their knowledge and "knowledge management can improve academic effectiveness and accountability if campuses can overcome their constraints" [145, p. 8].

According to Geng et al., the management of knowledge in higher education "is a complex and subtle process that involves priorities, needs, tools, and administrative support components" [67, p. 1033]. One of their recommendations is to develop additional research about the relationship between knowledge management dimensions and nationwide environmental contexts.

II.3.3. Identifying Knowledge Management Dimensions in Romanian higher education context

Although knowledge management in higher education has lately attracted attention to Romanian academics [38, 49] and some work has been done in implementing knowledge management in higher education institutions [118], very few studies have been carried out on how the Romanian national environmental realities affect the knowledge management activities in universities. The project "Comparative research concerning knowledge management in the Romanian engineering education-UNIKM" [22], aimed to fill the above gap and investigated the influence of the Romanian environmental realities on the practices of knowledge management in higher education institutions. The UNIKM project was developed in the Romanian Partnerships in Priority S&T Domains Programme of the Romanian National Authority for Scientific Research. It brought together within a consortium academics from University of Oradea, University Politehnica of Bucharest, Technical University of Cluj-Napoca and Politehnica University Timisoara, and researchers from IRECSON Institute in Bucharest. Each of the universities within the UNIKM consortium has more than 12,000 students, with bachelor, master and doctoral programs, as well as research activities. Within this framework, the four universities were considered in the project as large Romanian universities. The UNIKM research consortium has been intended to become a research center of excellence, contributing to the development of knowledge management towards increasing higher education and research competitiveness. One of the most important objectives of the UNIKM Project has been to find out how the universities of the consortium address the management of their knowledge, developing the major knowledge management dimensions in concordance with the Romanian national realities. The results of the UNIKM Project activities were published in different studies [20, 24, 25].

A perspective on how the Romanian universities involved in the UNIKM consortium have developed knowledge management priorities to address their organizational vision, mission and goals is presented in [20]. The study was based on a survey employed by Geng et al. [67], which addresses both explicit academic and operational knowledge. As Geng et al. noted, their survey format "is based on a survey of U.S. government knowledge workers conducted as part of the 2000 Knowledge Management Conference sponsored by the Foundation for Electronic Government" [67, p. 1035]. All the same, the Likert scale was employed based on a five-point scale. The survey format was also employed in the research of several UNIKM academics [42, 60].

In [20] the survey was conducted among the academics involved in the UNIKM Project. The same academics were also involved in the survey presented in [24]. The UNIKM consortium has been developed based on the academic qualifications of each member and his/her participation in different knowledge management initiatives (involvement in projects or in writing articles on knowledge management, etc.). Their willingness and availability to participate in the project were also considered. All of these could explain the high response rate of each survey. The characteristics of the participants are presented next in terms of education, years performed in higher education and academic positions at the time when the survey was completed [20, 24]. The UNIKM respondents had different education background and experience, with degrees in engineering, economics, management, sociology, education science, philosophy, mathematics and statistics, and informatics. All participants were involved in teaching and followed an academic career for many years. Most of UNIKM academics hold a PhD degree and more than half of them hold a position of professor or associate professor. All participants were involved in research projects, both at international (FP7, FP6, Fulbright, etc.) or national level (Partnerships in Priority S&T Domains Programme, CEEX, CNCSIS, ANSTI, etc.) and they collaborated in some of these projects. Therefore, the project's objectives and activities were accomplished with a multidisciplinary team characterized by a high level of specialization and complementary, where researchers with different disciplinary backgrounds collaborate across the knowledge of their fields in a tightly integrated manner.

In [20] the survey was open to all the academics involved in the UNIKM consortium, starting in 2010 and all of them responded to the survey. The team members of the research institute partner were not involved in this survey since they are not involved in knowledge management in higher education. The respondents were asked to rank each of the five priorities of knowledge management at their university. Such knowledge management priorities have been documented in previous studies [90, 97] and have been employed by Geng and al. [67, p. 1036]. In our study, the five items of knowledge management priorities were adapted to the Romanian nationwide realities from Geng et al. [67, p. 1036] and Kidwell et al. [90,

p. 32-33]. The knowledge map of the knowledge management priorities is shown in figure 17.

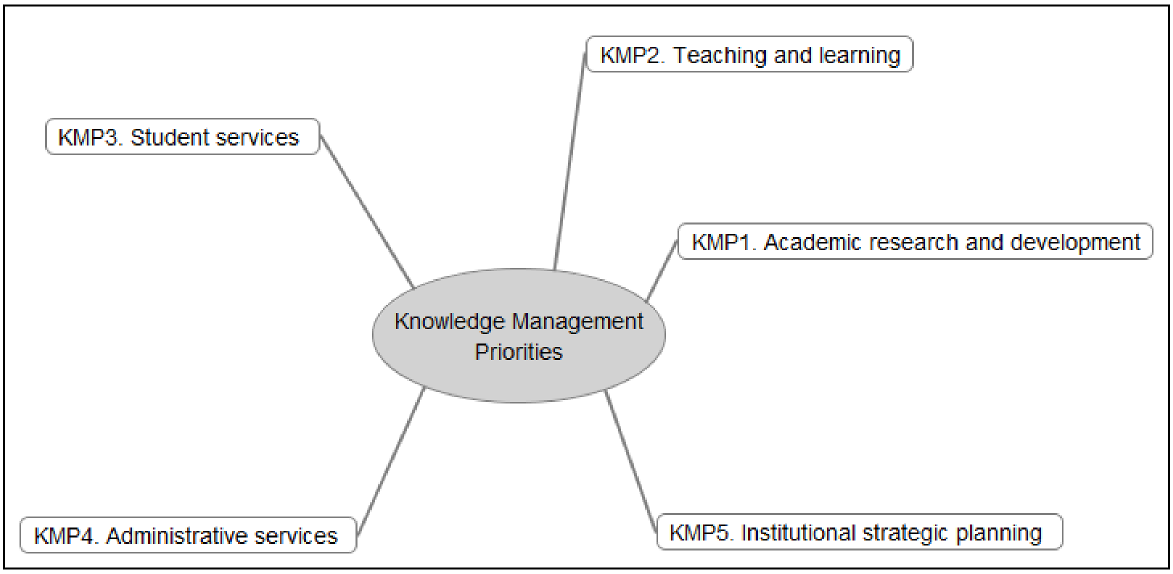


Figure 17. The knowledge map of the knowledge management priorities

The rank order of each knowledge management priority was established on the basis of the mean for each item. The importance of these five knowledge management priorities was presented in [20, p. 2] and is depicted in figure 18.

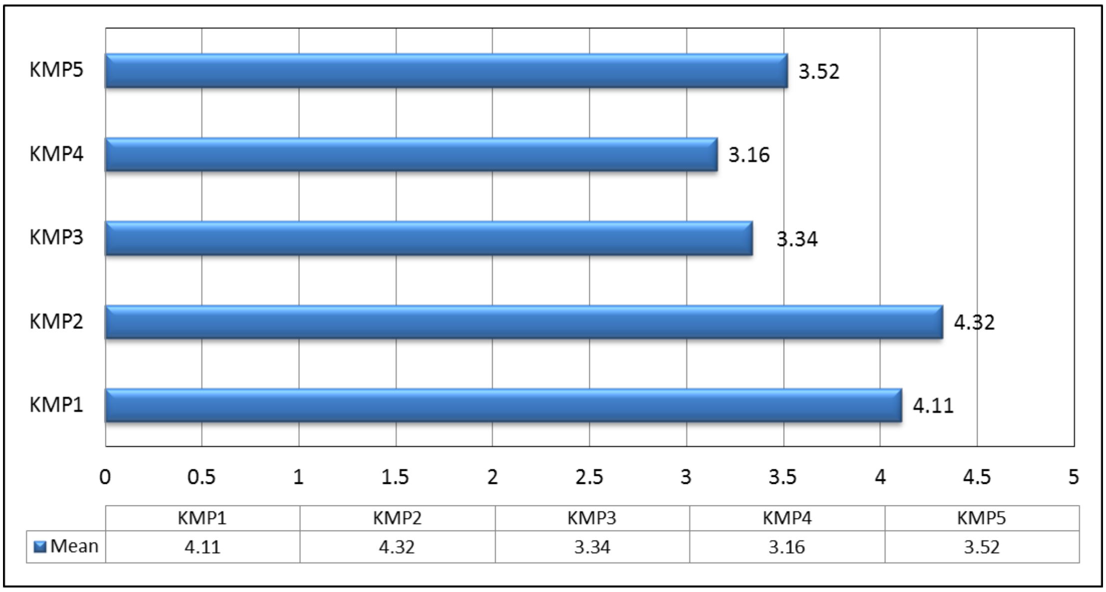


Figure 18. The importance of the knowledge management priorities [20, p. 2]

The one-way ANOVA [75] was used for testing differences among the means of the knowledge management priorities. If the hypothesis of equal mean was rejected using the ANOVA F-test the Tukey's honestly significant difference (Tukey HSD) post-hoc test, which is one of the most conservative post hoc test, was employed to find a statistically significant difference between any two pairs of means of the knowledge management priorities [75]. Within the members of the UNIKM academic community the higher ranks were reported for the KMP2 and KMP1 priorities. The lower rank was reported for KMP4 priority, which included services such as human resources, finance, procurement and contracting. The results of the one-way ANOVA show a clear evidence that at least one of the means of knowledge management priorities statistically significantly differs from the other means (at the 0.05 significance level). The matrix of differences between the means of knowledge management priorities is presented in [20, p. 3]. We found a statistically significant difference between the mean of the KMP2 priority and the means of the operational service priorities (KMP3, KMP4 and KMP5). The mean of the KMP1 priority was also found significantly different from each one of the operational service priorities (KMP3, KMP4 and KMP5). The means of the other priorities cannot be distinguished and we cannot claim that the means of KMP3, KMP4 and KMP5 priorities significantly differ from each other. In addition, the means of the KMP1 and KMP2 priorities remain indistinguishable and cannot be considered significantly different.

With European Union membership, Romanian universities operate in a more stable environment, but they are facing the challenges of nowadays society. Considering the results of our study, the universities within UNIKM consortium should be focused on the management of knowledge that is enhancing teaching and learning activities as well as academic research and development research opportunities. Cronin [48] and Kidwell et al. [90] presented different applications for both research and teaching priorities and they can be used by the UNIKM academic community to address these knowledge management priorities.

On the other hand, implementing knowledge management initiatives is difficult without an adequate support of technology [76]. There are many choices in employing tools for knowledge management [18, 99, 150], which can be grouped in: "business intelligence, collaboration, content and document management, e-learning, knowledge base, portals, customer relationship management, data mining, workflow, and search" [99, p. 85-86]. Knowledge management tools used in universities have been presented in previous studies [67, 120, 134]. According to Geng [67], similar universities from different countries may employ different knowledge management tools to better respond to their changing needs.

Within this framework, the study [31] investigated the knowledge management tools used in Romanian higher education institutions. This research was based on a survey conducted among academics from Romanian universities, in which the employment of knowledge management tools was explored. The survey was sent to 25 members of the academic community interested in the field of knowledge management and 12 completed questionnaires were returned, resulting in a response rate of 48 %. The respondents ranked each of the five knowledge management tools at their university based on the five-point Likert scale. All five knowledge management tools were adapted to the Romanian nationwide realities from Geng et al. [67, p. 1038]. Citing the research of Lighthouse Consulting Group [97], Geng et al. [67, p. 1038] mentioned that each item of these knowledge management tools has been documented in previous studies. The knowledge map of the five knowledge management tools is presented in figure 19. The mean was used to establish the rank order of each knowledge management tool.

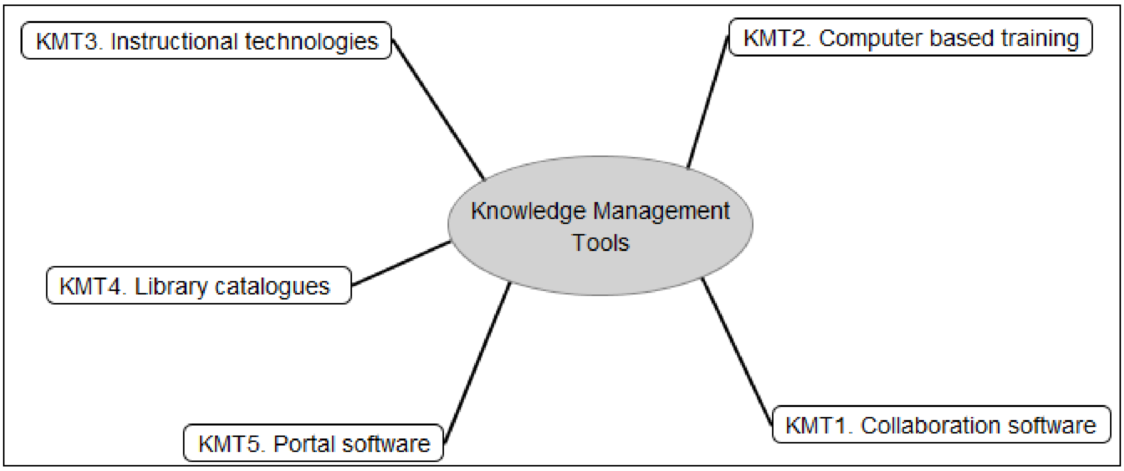


Figure 19. The knowledge map of the knowledge management tools

The importance of each of the five knowledge management tools within the UNIKM research consortium was presented in [31, p. 107] and is depicted in figure 20. The higher means were reported for the KMT1 and KMT4 tools, while KMT3 and KMT5 tools received the lower means.

II.3.4. Knowledge management practices in Romanian higher education context

An effective management of knowledge resources in universities requires appropriate knowledge management practices. Recent studies have presented different knowledge management practices and initiatives in higher education institutions [13, 70, 90, 128] and knowledge sharing was identified among the most important of them [13].

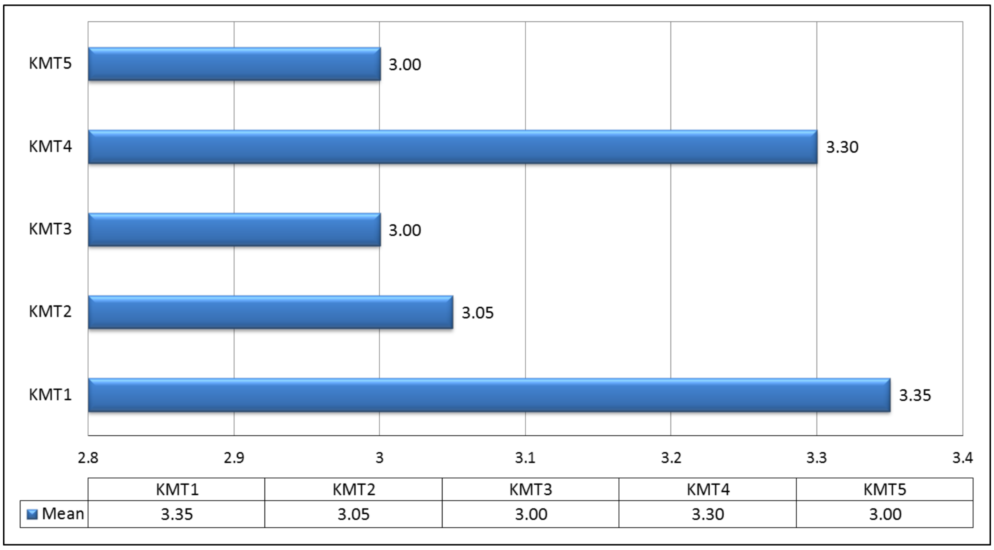


Figure 20. The importance of knowledge management tools [31, p. 107]

Since knowledge is viewed as one of the most important assets of universities, a knowledge sharing approach is needed for their organizational success [132] and initiatives to share knowledge are required for the achievement of their business objectives [90]. However, knowledge sharing is a challenging process and difficulties in sharing of knowledge are underlined in [41, 144].

Although knowledge management practices in universities have received an increased attention in the last time, the research in this field is scarce in Romanian higher education. Therefore, an exploratory study on universities involved in the UNIKM Project used knowledge management practices in their national environment is presented in [24]. This research was based on a survey that included practices of knowledge management in the main processes and services of universities. Knowledge management applications in such areas were documented in prior studies [48, 90]. The questionnaire of the survey included knowledge management practices in both research and teaching processes, and in student services. Possible responses to the survey questions included: "yes/no" or "never/seldom /frequent", while the values employed for the analysis of data were: "no=1, yes=2" or "never=1, seldom= 2, frequent=3". The survey was distributed to all the academics involved in the UNIKM consortium in the fall of 2009 and 93% of them responded to the survey. The team members of the research institute partner were not involved in this survey since the academic processes and student service are not among their main activities.

The respondents were asked to specify if they were involved in the management of research projects or in doctoral activities (conduct doctoral dissertations or participate in doctoral dissertation committees). The results are shown in [24, p. 159-160] and are described next. We found that in the past five years from the time of the survey, the UNIKM academics had conducted 23 national or international research projects, 28 doctoral dissertations and took part in more than 100 doctoral dissertation committees. The respondents were asked to respond with Yes/No to the three knowledge management practices in research. The knowledge map of these practices is shown in figure 21.

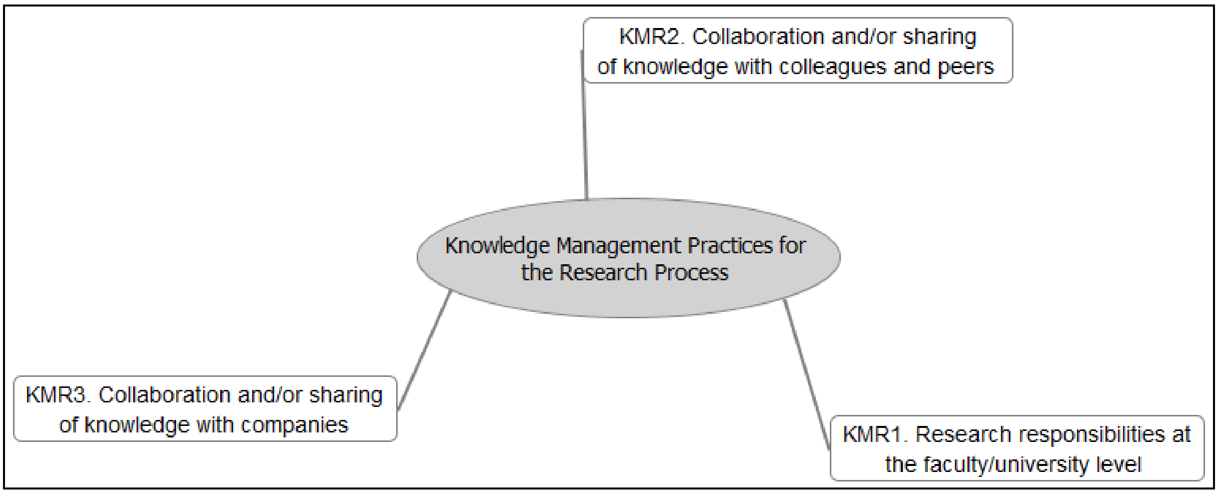
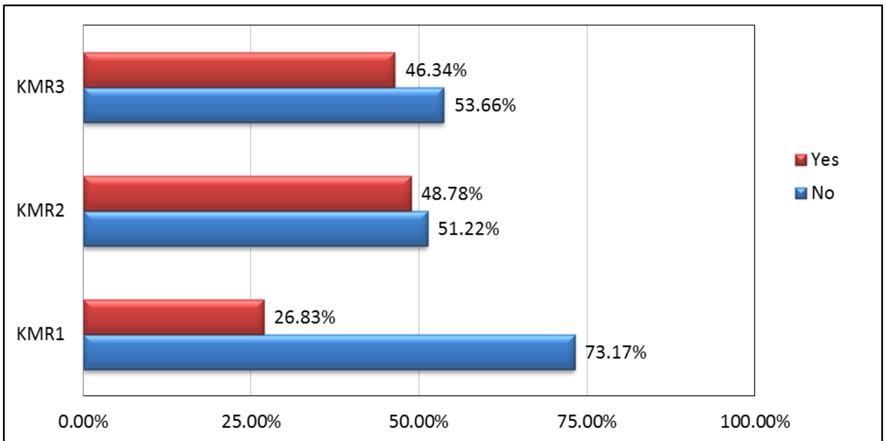


Figure 21. The knowledge map of the knowledge management practices in research

Figure 22 depicts the responses to these questions [24, p. 159]. As it is shown in figure 22, more than a quarter of the respondents have had different research responsibilities such as scientific secretary, head of research centers or member of different scientific committees at their faculty or university level. Almost half of the UNIKM academics were involved in some types of collaboration and/or sharing of scientific knowledge with colleagues and peers as well as with companies.



	KMR1	KMR2	KMR3
Yes	26.83%	48.78%	46.34%
No	73.17%	51.22%	53.66%

Figure 22. Knowledge management practices for the research process [24, p. 159]

The knowledge management practices in teaching and learning were also investigated. The knowledge map of these practices is depicted in figure 23.

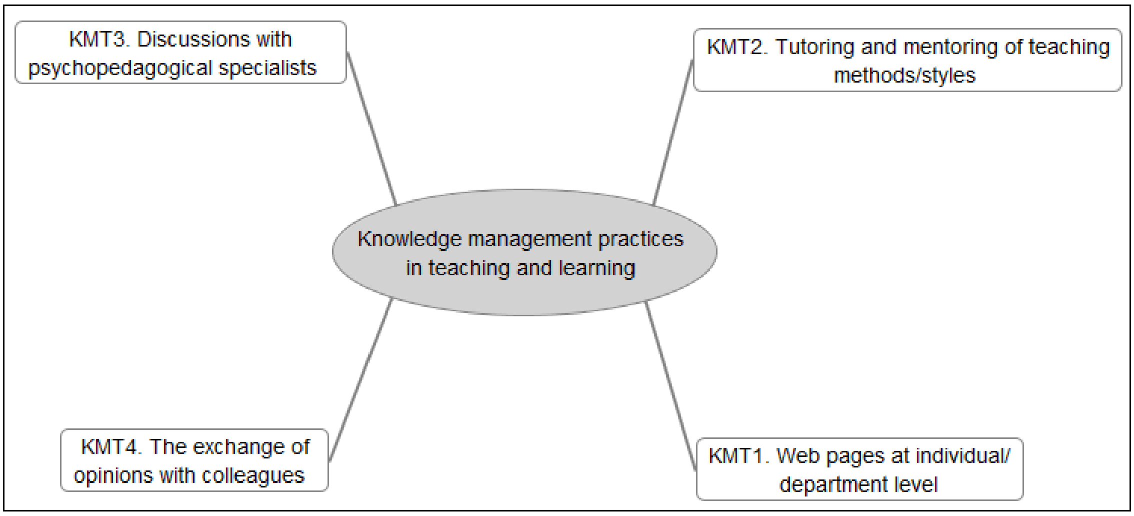
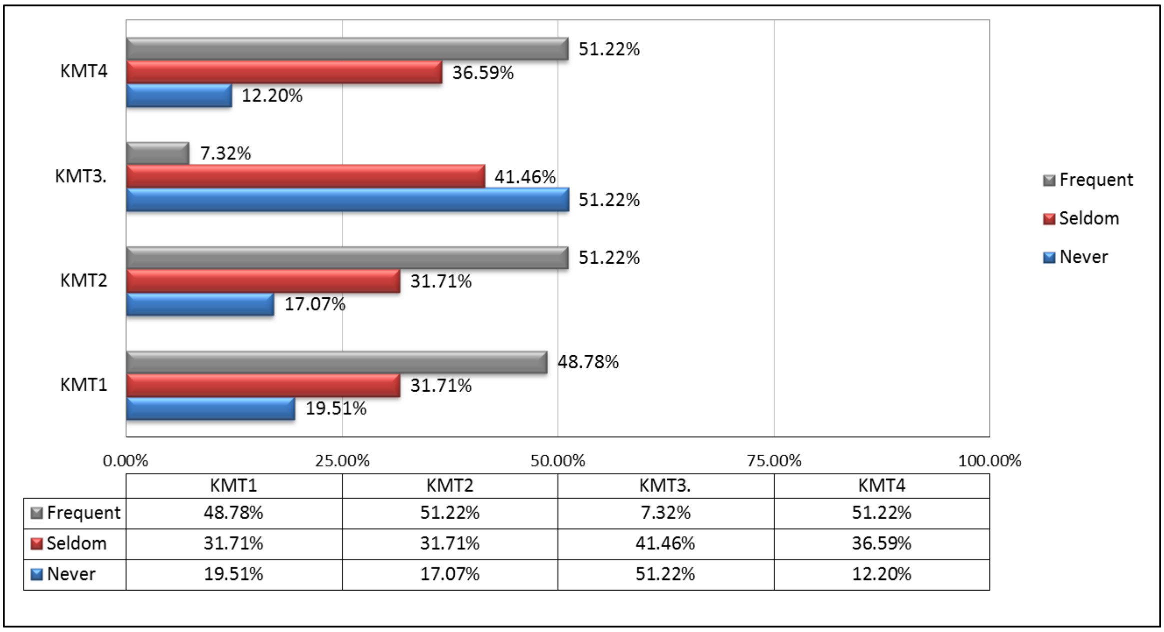


Figure 23. The knowledge map of the knowledge management practices in teaching and learning

The respondents were asked to respond with never/seldom/frequent about four collaboration/sharing possibilities regarding the teaching and learning methods. Figure 24 shows the responses to the KMTi questions ($i=\overline{1,4}$) [24, p. 159].



	KMT1	KMT2	KMT3.	KMT4
Frequent	48.78%	51.22%	7.32%	51.22%
Seldom	31.71%	31.71%	41.46%	36.59%
Never	19.51%	17.07%	51.22%	12.20%

Figure 24. Knowledge management practices regarding the teaching and learning methods [24, p. 159]

Two knowledge management practices were frequently used by more than a half of the UNIKM academic community for the collaboration/sharing possibilities in the teaching and learning methods. They are the exchange of opinions with their colleagues, respectively tutoring and mentoring of teaching methods/styles. The Web pages at individual/department level are also frequently employed by almost half of the respondents. On the other hand, very few respondents used frequently discussions with psychopedagogical specialists.

The UNIKM academics were asked to respond with never/seldom/frequent about eight knowledge sharing practices regarding student services. The knowledge map of these practices is presented in figure 25. The responses to the KMSi questions ($i=\overline{1,8}$) are shown in figure 26 [24, p. 160].

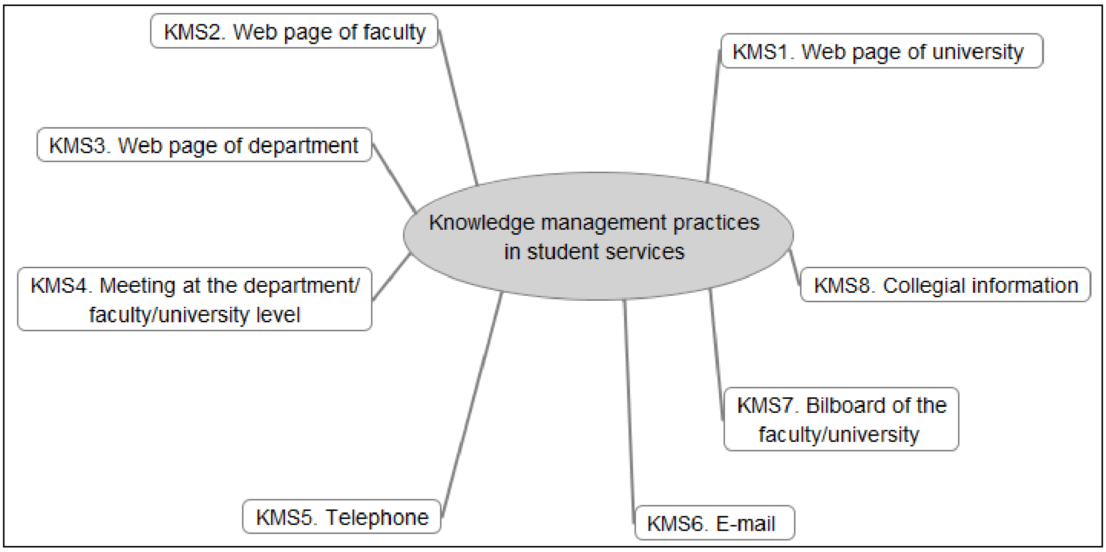
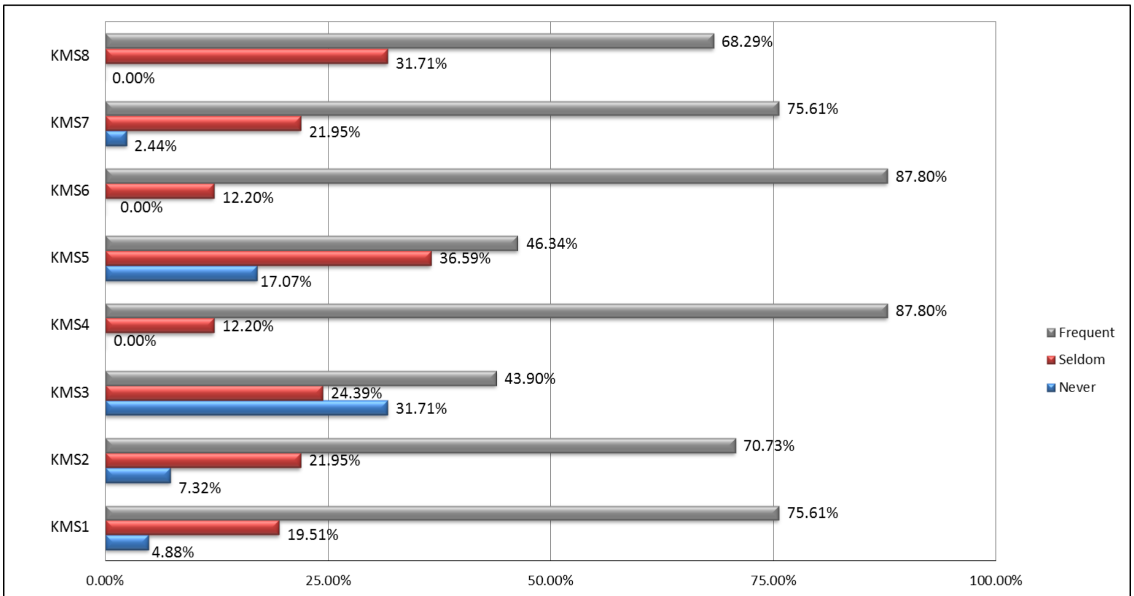


Figure 25. The knowledge map of the knowledge management practices in student services



	KMS1	KMS2	KMS3	KMS4	KMS5	KMS6	KMS7	KMS8
Frequent	75.61%	70.73%	43.90%	87.80%	46.34%	87.80%	75.61%	68.29%
Seldom	19.51%	21.95%	24.39%	12.20%	36.59%	12.20%	21.95%	31.71%
Never	4.88%	7.32%	31.71%	0.00%	17.07%	0.00%	2.44%	0.00%

Figure 26. Knowledge management practices regarding student services [24, p. 160]

Among the knowledge management practices in student services, meeting at the department/faculty/university level and E-mail are extensively used. The Web pages of university and faculty, the billboard of the faculty/university as well as the collegial information are also very frequently employed.

II.3.5. Concluding remarks

There is an important value for organizations which used knowledge management to achieve their vision, mission and goals, and the development in higher education of initiatives based on knowledge management principles may be a solution to success. However, knowledge management in universities is an emerging field, where experiments are just at the beginning and the author's studies are among the first studies in Romanian higher education institutions.

The studies [20, 24, 31] sustain the view of Geng et al. [67], which consider the management of knowledge in universities as complex and multifaceted process sensitive to the nationwide context and realities. The results also support the conclusion of Geng et al. [67] that similar universities in different national environments may address somewhat different knowledge management components. The Romanian academics involved in the studies [20, 24, 31] are considered to have the right explicit knowledge in their academic processes and knowledge management tools are available to make the explicit knowledge easily accessible.

According to Rowley [124, p. 332], the development of the knowledge environment is one of the major areas where much advance is expected. Although universities are regarded as communities of knowledge sharing and dissemination through teaching and research, the reputation and opportunities of participating in knowledge creation and dissemination significantly rely on individual performances. Universities reward their faculty members for creating new knowledge, teaching students and services to society, based mainly on individual achievement and performance [124, p. 331]. This situation may determine more an academic competition than a knowledge sharing environment. Moreover, the academic staff is less likely to be rewarded for developing new ways of knowledge sharing, and especially for sharing of tacit knowledge. The results of the study [24] support the assumption of Rowley regarding the development of a knowledge environment, showing that there is still room for more improvement in the sharing of knowledge.

Therefore, one area that needs future research work is related to the development of appropriate initiatives to encourage the development of the knowledge sharing environment, for a better sharing of the existing knowledge and generation of new knowledge in both teaching and research. As a result, the organizational efficiency and effectiveness of higher education institutions is expected to be improved. In addition, only the explicit knowledge was addressed in [20, 24, 31]. Since the tacit knowledge is considered to offer an important competitive advantage to organizations that are capable of capturing and using it effectively and efficiently [100], future research should be conducted to explore the management of such knowledge.

On the other hand, our research provides one of the first perspectives into the Romanian realities. Moreover, only the universities within the UNIKM consortium were involved in the studies [20, 24], even if they are large universities in the number of students enrolled, teaching and research. In addition, the studies [20, 24] were based on the responses of the academics involved in the UNIKM Project, while in [31] the respondents were among an academic community interested in the field of knowledge management. Therefore, the studies [20, 24, 31] should be considered exploratory approaches and additional research must be performed to generalize their results to the Romanian universities. Future research should also identify if there are significant differences of the knowledge management dimensions and practices between the academics and the management of Romanian universities. In this way, the use of knowledge management to achieve the vision, mission and goals of the Romanian universities is expected to be better carried out.

III. ACADEMIC AND PROFESSIONAL ACHIEVEMENTS

After receiving his doctoral degree, the author continued his didactic activities as lecturer at the University of Oradea. He became associate professor in 2000 at the Faculty of Management and Technological Engineering and since 2004, he is professor at the same faculty of the University of Oradea. Both positions were obtained following the legal steps, through open competition. During his academic career, the author remains devoted to the field of his doctoral thesis and has taught disciplines such as Reliability or Quality Management at the bachelor level, and Total Quality Management at the master level. The author also started to teach a new course in the field of knowledge management at the master level, which is the Knowledge Management and Engineering Creativity. Currently he is teaching the courses of Quality Management, Total Quality Management, Data Management and Information Systems in Engineering and Management, and Knowledge Management and Engineering Creativity. The author published several books, textbooks and practical work/application textbooks in his fields of interest.

The author has been the president or a member in the committees of the public presentation of 3 doctoral thesis in the field of Engineering and Management/Industrial Engineering and the coordinator of numerous diploma projects, both at undergraduate and master level.

The author has been involved in the implementation of several projects for the development of the students' competencies. He has been responsible for developing different departments of the simulated enterprises in the projects: POSDRU/22/2.1/G/29349 (responsible for the Quality Assurance department), POSDRU/109/2.1/G/ 81459 (coordinator of the Spare Parts Stock Management department) and POSDRU/161/2.1/G/133930 (coordinator of the Manufacturing and Quality of Products Obtained Through Reverse Engineering department). The author was the responsible for the LEONARDO da VINCI RO/2003/PL91231 project ”The development of competencies in the management and exploitation of logistic systems”, in which he coordinated the elaboration and implementation of the project, both at the technical and financial level.

After successfully finalizing the doctoral program, the author has been involved in many research projects and fellowships. He was the director of the Fulbright Research Grant no. 333/2005, the Partnership in Priority Domains Programme grant no. 337/2014 and 92074/2008, the CNCSIS grant no. 253/2005, the ANSTI grant no.

6144/2000 and the research fellowship no. 3740/2002. He is currently the director of the Partnership in Priority Domains Programme grant no. 337/2014, which is scheduled for the period 2014-2016. He also participated as a member in both international (FP6 ERANET project) and national projects (CEEX, Partnership in Priority Domains Programme and PN II Capacities). The results of these projects have been disseminated through articles published in the mainstream journals as well as in international and national conference proceedings. Some of the results obtained in the projects have been published in the author's books.

Between 2000-2008 the author was the vice-dean of the Faculty of Management and Technological Engineering in charge with the study and educational activities. Since 2012, he also served as vice-dean of his faculty, in charge with both education, and research and development activities. Between 2003-2005, he was co-chairholder UNESCO in Information Technologies at University of Oradea.

The author is editor of the Annals of the Oradea University. Fascicle of Management and Technological Engineering, and member of the editorial board of the Optimum Q Journal. He is also a member of the Scientific Committees of the Annals of the Oradea University. Fascicle of Management and Technological Engineering and of the Annual Session of Scientific Papers IMT Oradea as well as scientific reviewer for both publications. The author was an expert evaluator for the Program IDEAS, the subprogram "Complex Exploratory Research Projects" (http://cncsis.gov.ro/articole/1632/Procesul-de-evaluare.html). He was also an expert evaluator for the Partnerships in Priority R&D Domains Programme, subprogram "Joint Applied Research Projects" (http://www.cnmp.ro:8083 /pncdi2/program4/ evaluatori2008.php). The author is included in the Romanian National Portal of R&D experts (http://www.experti-cdi.ro/search_results.php). The author is a member of different professional associations and societies, such as the Romanian Managers and Economic Engineers Association (AMIER), Association for Integrated Engineering and Industrial Management (AIIMI) or the International Association of Engineers (IAENG).

PART II. CAREER DEVELOPMENT PLAN

The author's scientific development plans are heading towards the same fields previously described. Taking into account the results obtained until now, the author will continue with the advancement of his research that will complement the already presented research, as follows:

(i) The failure detection methods have no universal application, so that specific method must be used for the different processes or equipments. Vibration and temperature monitoring were more recently used in the author approach for failure detection. Future research will address the employment of other techniques for monitoring the state of the technical systems as well as for the condition-based maintenance.

(ii) Since the structure of the actual technical systems is based on non-homogenous components with both an increasing degree of complexity and a higher degree of intelligence, their behavior is inevitable affected by uncertainty. Therefore, the development of adequate mathematical models for the reliability prediction of such complex technical system will remain one of the main research topics of the author. However, the validation of such models requires high and largely accepted reliability data that should be collected through widespread database systems. The development of databases with the times-to-failure data for different complex systems are essential in the advance of the reliability models in practice and will be an important issue in the future studies of the author.

(iii) The fuzzy logic was successfully used for the planning of maintenance activities. Beside fuzzy logic, other techniques of soft computing, such as neural networks and evolutionary algorithms represent useful approaches and their combination could represent an important step forward for the planning of the maintenance activities. Therefore, future research will address the use of different combinations of soft computing techniques to improve the planning of maintenance activities.

(iv) Various practices of knowledge management are in place in higher education institutions, but there is still room for more improvements in different areas. Using knowledge management practices which support what the employees can do the best needs suitable policies and procedures. The aim of all these policies and procedures is to create a framework where knowledge is effective and efficient used in teaching, research or operational services of a university. Therefore, developing such policies and procedures will represent an important topic for future research, as well as the development of a suitable tool to evaluate their application efficiency.

Although universities are seen among the most important partners with whom firms can cooperate, from the existing literature on Industry-University relations, quantitative empirical evidence regarding the development, evolution and sustainability of these relationships in Open Innovation is still very scarce. Therefore, the project 337/2014 "Knowledge Management-Based Research Concerning Industry-University Collaboration in an Open Innovation Context" has been launched in 2014 aiming to fill this gap. With the implementation of this project, new research perspectives are emerging. They are related to the specific objectives of the project and will represent future research directions as follows:

(i) Capitalization and formalization of knowledge concerning Industry-University collaboration in Open Innovation, using specific methods of knowledge management;
(ii) The establishment of the main dimensions of Industry-University collaboration in Open Innovation;
(iii) The development of a maturity model to assess the level of Open Innovation adoption between Industry-University;
(iv) The development of an Open Innovation environment between Industry-University;
(v) The evaluation of the efficiency of Industry-University collaboration in Open Innovation.

The publication of the future research results in mainstream journals indexed in international recognized databases, and especially in ISI journals with significant impact factor, will continue to be one of the main objectives to increase the international visibility of the research activity. The publication of chapters of books or books in international recognized publishing houses will be another important objective. The development of new research projects at both national and international levels, especially within the frame of the Horizon 2020 program, represents another main objective.

The dissemination of all research results will be accomplished together with the teams involved on each topic of interest. In all his projects, the author has been using an interdisciplinary approach, where researchers with different disciplinary backgrounds collaborate across the knowledge of their fields in a tightly integrated manner, based on knowledge management principles. The author will remain dedicated to such approach. Moreover, the aim of the author to contribute at the development of competitive young researchers will be achieved by including in the teams of an increase number of both master and doctoral students, including the PhD students the author is expecting to enroll and advice (1-2 doctoral students in each year). Including the research results in the teaching programs, mainly for master and doctoral studies will directly contribute to achieve this goal and will also link the research and didactic activities.

Using new teaching and learning technologies, which are focused on interactivity and cooperation, will complete the author's methods of teaching. They will contribute to the development of new teaching and learning tools, which will be designed based on the multimedia application for the general description of the course/laboratory, self-education application and practice application. These new didactic tools are expected to increase the quality of teaching and learning.

Knowledge management in higher education is a new area, where experiments are just beginning, so the implementation of a knowledge management environment in the author's faculty may be a challenging objective. Nevertheless, it will represent a major topic in his future work, which can prove evidence the academics are able to manage their explicit and tacit knowledge, with considerable benefits in improving research competitiveness, enhancing teaching and learning or offering better opportunities for cooperation with industry.

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