HABILITATION THESIS
TEZA DE ABILITARE

RESEARCH AND CONTRIBUTIONS IN QUALITY MANAGEMENT AND ENGINEERING

DOMENIUL: INGINERIE ȘI MANAGEMENT

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2016

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ABSTRACT

The habilitation thesis presents the results of the scientific research and didactic activities performed at the “Petru Maior” University of Tirgu Mures and carried out after obtaining the scientific title of doctor (April 1996). As it is natural, the two central elements are related, therefore the didactic and research activities have focused especially on quality management and parallel mechanisms, but there have also been preoccupations in other domains specific for industrial engineering and management.

The habilitation thesis contains, in section I, SCIENTIFIC, PROFESSIONAL AND ACADEMIC ACCOMPLISHMENTS, ten sub-chapters dedicated to the presentation of the most relevant achievements in the above mentioned directions.

Therefore sub-chapter 1.1. “Quality assurance in higher education”, investigates the relationship between total quality management and strategic issues, of the way to implement quality management systems in universities. I have defined a strategy for integrating quality which has a central role in the competitive strategies, believing that the balance of determination is the opposite of the traditional. I have applied the model with its novelty aspects to a case study, showing how it is applied the defensive strategy.

Sub-chapter 1.2. “Quality assurance and sustainable assessment in the vocational education and training” demonstrate a new and innovative approach to assessing organizations institutional sustainability in terms of five key pillars: institutional capacity, environmental, economic, social, and training provision. In the five areas of the proposed new and original sustainability assessment framework, a total of 40 performance indicators are used to make the assessment. The assessment process is based on a novel approach for the couple values for performance and importance of the indicators, by using scales from 1 to 5 for both.

Sub-chapter 1.3. “Innovative tools and models for elearning in Romania” reports results from the Move-it project, examples from new, ongoing distance learning activities that utilize state of the art digital media, tools and methods. The design of video infrastructure in the video room is presented. The model for interactive distance learning as a natural extension of the traditional educational environment is developed as a new educational technology for the master degree in Quality Management.

Sub-chapter 1.4. “VET course design in quality management” presents some results of the project TIT-us. It addresses to the need of designing new Vocational Education and Training courses for training in quality management qualifications. I have shown that each activity in VET is a quality approach which consists of a number of decisions made within the five steps: plan, do, check, act and a certain methodology. The pedagogical methodology for training of quality professionals employs new developments of Activity Based Training (ABT) and Student Response System (SRS).

Sub-chapter 1.5. “Green methodology for evaluation” presents a pear learning approach as a result of the eQvet-us project, which creates a green learning arena by employment of peer assessment, a new methodological approach in 5 steps. The new eQvet-us training outcome evaluation model developed, consist in an improvement of the Kirkpatrick’s model by associating to the evaluation level the corresponding objectives. In this way two levels are deduced, that are following the PDCA cycle in opposite senses.

Sub-chapter 1.6. “Quality methods employed for product design” demonstrates application of quality function deployment (QFD) approach and knowledge management in order to understand the customer needs and to select suitable characteristics and their “weights”, for a new product design, in a mineral water company. This knowledge is used to develop a new product, enabling the company to enter the new markets successfully. The presentation shows how achieved experience and continuous improvement are parts of the knowledge management, which fits into the QFD project.

Sub-chapter 1.7. “Parallel mechanisms” presents the 6-PGK innovative structure of a spatial parallel mechanism with 6 degrees of freedom and a method to determinate a desired trajectory for the manipulated object, with an imposed velocity, when some vibration motions act in the prismatic motor joints. By using the Lagrangian approach the dynamic equations of motion of the parallel robot are deduced and the supplementary generalized forces that must be introduced in system in order to correct the trajectory errors are computed from these equations.

Sub-chapter 1.8. “Performance evaluation of the 6-PGK parallel mechanism” evaluates of the mechanism and aids the design process via the analysis of maximum force in all direction index and actuator force index. It allows all the actuators of the manipulator to be compared on the same dimensionless scale and to select it properly in the design process. Four sets of test are performed on the most common trajectories used in industrial applications consisting in linear and circular motions. The results and the developed software for numerical simulation assist the designer in the process of developing the parallel robot manipulator.

Sub-chapter 1.9. “ANN based inverse dynamic model of the 6-PGK parallel robot manipulator” presents an inverse dynamic model estimation based on an artificial neural network. By implementing feedforward artificial neural networks as a nonlinear autoregressive model with exogenous inputs, it is investigated the possibility of choosing the optimum parameters that characterize the neural network so that it approximates as better as possible the model of the 6-PGK prototype robot. Finally an innovative algorithm is developed for obtaining the optimal configuration parameters set of the feedforward artificial neural network.

Sub-chapter 1.10. “Parallel mechanism with six degrees of freedom for robots construction” presents the author invention which refers to a spatial parallel mechanism with six degrees of freedom that can be used for parallel robots construction, intended for handling or processing operations.

The second section PLANS FOR THE EVOLUTION AND THE DEVELOPMENT OF THE PROFESSIONAL, SCIENTIFIC AND ACADEMIC CAREER, based on the synthesis of the scientific and didactic achievements, presents a set of principles underlying the activity, the directions of the professional development as well as the concrete elements which contribute to their being carried out in future. The future development directions are detailed on concrete scientific domains, also presenting the expected results. Future plans related to international collaboration and the programs with national and international funding are highlighted.

Section III. REFERENCES include the list of associated bibliographical references used in the habilitation thesis.

REZUMAT

Teza de abilitare prezintă rezultatele cercetării științifice și a activităților didactice desfășurate la Universitatea „Petru Maior” din Tirgu Mures după obținerea titlului științific de doctor (aprilie 1996). Așa cum este firesc, cele două componente sunt conectate și prin urmare, activitățile didactice și de cercetare s-au concentrat în special pe de managementul calității și mecanismele paralele, dar au existat preocupări și în alte domenii specifice din ingineria industrială și management.

Teza de abilitare conține, în secțiunea I, REALIZĂRI ȘTIINȚIFICE, PROFESIONALE ȘI ACADEMICE, zece subcapitole dedicate prezentării celor mai relevante realizări în direcțiile menționate mai sus.

Prin urmare, sub-capitolul 1.1. „Asigurarea calității în învățământul superior”, investighează relația dintre managementul calității totale și aspectele strategice, a modului de punere în aplicare a sistemelor de management al calității în universități. Am definit o strategie de integrare a calității, care are un rol central în strategiile competitive, arătând că modul de determinare este opus celui tradițional. Am aplicat modelul, cu aspectele sale de noutate, într-un studiu de caz, care prezintă modul în care este aplicată strategia defensivă.

Sub-capitolul 1.2. „Asigurarea calității și evaluarea durabilă în educația și formarea profesională” prezintă o abordare nouă și inovatoare pentru evaluarea instituțională a sustenabilității organizațiilor, structurată pe cinci piloni cheie: capacitate instituțională, mediu, economic, social și furnizarea de formare. În cele cinci domenii ale noului cadru original propus pentru evaluarea sustenabilității, pentru a efectua evaluarea sunt folosiți 40 de indicatori de performanță. Procesul de evaluare se bazează pe o abordare nouă prin utilizarea de scale la 1 la 5 pentru fiecare din valorile cuplului format din performanța și importanța indicatorilor.

Sub-capitolul 1.3. „Instrumente și modele inovatoare pentru e-Learning în România” prezintă rezultate ale proiectului Move-IT, exemple de noi activități de învățare la distanță, care folosesc cele mai actuale medii, instrumente și metode digitale. Este prezentată proiectarea infrastructurii video în laboratorul video. Este dezvoltat modelul de învățământ interactiv la distanță, ca o extensie naturală a mediului educațional tradițional, care constituie o nouă tehnologie educațională folosită în cadrul masteratului în managementul calității.

Sub-capitolul 1.4. „Proiectarea cursului EFP în managementul calității” prezintă câteva rezultate ale proiectului Tit-us. Se adresează nevoii de proiectarea de noi cursuri de Educație și Formare Profesională în calificări de management al calității. Am arătat că fiecare activitate în EFP are o abordare legată de calitate, care constă dintr-un șir de decizii luate în cadrul celor cinci etape: planificare, execuție, verificare, acționare și o anumită metodologie. Metodologia pedagogică pentru formarea de profesioniști calitate folosește noile metode ale Activității Bazate pe Training (ABT) și Sistemul de Răspuns al Studenților (SRS).

Sub-capitolul 1.5. „Metodologia verde de evaluare” prezintă o abordare de învățare reciprocă care creează o arenă verde de învățare prin utilizarea evaluării reciproce, ce constituie o nouă abordare metodologică în 5 trepte, ca rezultat al proiectului eQvet-us. Noul model dezvoltat de evaluare a rezultatelor formării eQvet-us, constă într-o îmbunătățire a modelului Kirkpatrick prin asocierea la nivelul de evaluare a obiectivelor corespunzătoare. În acest fel, sunt deduse cele două niveluri, care urmăresc ciclul PDCA în sensuri opuse.

Sub-capitolul 1.6. „Metodele ale calității utilizate pentru proiectarea produsului” prezintă aplicarea metodei casa calității (QFD) și a managementului cunoașterii pentru a înțelege nevoile clienților și pentru a selecta caracteristicile adecvate și „ponderile” lor, pentru un design nou de produs, într-o companie de ape minerale. Aceste cunoştinţe sunt utilizate pentru dezvoltarea unui produs nou, care permite companiei să pătrundă cu succes pe noi pieţe. Prezentarea arată modul în care experiența obținută și îmbunătățirea continuă fac parte din managementul cunoașterii, care se încadrează în proiectul QFD.

Sub-capitolul 1.7. „Mecanisme paralele” prezintă structura inovatoare 6-PGK a unui mecanism paralel spațial cu 6 grade de libertate și o metodă de determinare a traiectoriei dorite pentru obiectul manipulat, cu o viteză impusă, atunci când acționează mișcări vibratorii la nivelul articulațiilor prismatice motoare. Sunt deduse ecuațiile dinamice ale mișcării robotului paralel prin utilizarea metodei Lagrange precum și forțele generalizate suplimentare care trebuie introduse în sistem, cu scopul de a corecta erorile de traiectorie, care sunt calculate tot din aceste ecuații.

Sub-capitolul 1.8. „Evaluarea performanțelor mecanismului paralel 6-PGK” evaluează mecanismul și facilitează procesul de proiectare prin analiza indexului de forțe maxime în toate direcțiile de acționare și a indexului forțelor motoare. Acesta permite ca toate dispozitivele de acționare ale manipulatorului să fie comparate pe aceeași scară adimensională și selecta lor corespunzătoare în procesul de proiectare. Sunt efectuate patru seturi de testare pentru cele mai uzuale traiectorii utilizate în aplicațiile industriale care constau în mișcări liniare și circulare. Rezultatele și software-ul dezvoltat pentru simularea numerică ajută proiectantul în procesul de dezvoltare a robotului paralel manipulator.

Sub-capitolul 1.9. „Modelarea dinamicii inverse a robotului paralel manipulator 6-PGK cu ajutorul rețelelor neuronale” prezintă o estimare a modelului dinamic invers bazat pe o rețea neuronală artificială de tip feedforward. Prin implementarea acestui tip de rețea neuronală artificială, ce se constituie într-un model autoregresiv neliniar cu intrări exogene, se investighează posibilitatea de determinare a parametrilor optimi care caracterizează rețeaua neuronală, astfel încât aceasta să aproximeze cât mai bine modelul prototip al robotului 6-PGK. În continuare este dezvoltat un algoritm inovativ pentru obținerea setului de parametri optimi de configurare ai rețelei neuronale artificiale de tip feedforward.

Sub-capitolul 1.10. „Mecanism paralel cu șase grade de libertate pentru construcția roboților” prezintă invenția autorului, care se referă la un mecanism paralel spațial cu șase grade de libertate ce poate fi utilizat pentru construcția roboților paraleli, destinați operațiunilor de manipulare sau de prelucrare.

A doua secțiune PLANURI PENTRU EVOLUȚIA ȘI DEZVOLTAREA CARIEREI PROFESIONALE, ȘTIINȚIFICE ȘI ACADEMICE prezintă pe baza sintezei realizărilor științifice și didactice, un set de principii care stau la baza activității viitoare, direcțiile de dezvoltare profesională, precum și elementele concrete care vor contribui la efectuarea lor în viitor. Direcțiile viitoare de dezvoltare sunt detaliate pe domenii științifice concrete, fiind prezentate și rezultatele așteptate. Sunt, de asemenea, evidențiate planuri de viitor legate de colaborarea internațională și programele cu finanțare națională și internațională.

Secțiunea III. BIBLIOGRAFIE include lista referințelor bibliografice asociate utilizate în cadrul tezei de abilitare.

Section 1

SCIENTIFIC, PROFESSIONAL AND ACADEMIC ACCOMPLISHMENTS

1.1. QUALITY ASSURANCE IN HIGHER EDUCATION

1.1.1. Relation between quality and strategy

There is very considerable variation both nationally and institutionally in the way quality issues are “managed” in higher education (Brennan and Shah, 1997). An international comparison of the extent of commonality or diversity in the main national external quality assurance frameworks for higher education shows that a “general model” of external quality assurance does not universally apply, but that most elements of it do apply in most countries. The “general model” provides a starting point from which to map deviations. In each country, there may be specific additions of elements or omissions from the model, but more usually there are modifications or extensions of elements. These variations are determined by practicalities, the size of the higher education sector, the rigidity/flexibility of the legal expression of quality assurance and the stage of development from the state control of the sector (Billing, 2004).

Strategies focused on quality, are positively related to the other competitive strategies adopted by the universities (Moldovan, 2012a). Through quality, competitive strategies can be developed. They describe how the university plans to gain advantage over competitors and are differentiated by the nature of guidance in order to ensure the competitiveness of the organization: Strategies aimed at differentiating curricula in various forms of education: day courses, part time courses, distance courses; Strategies focused on a demand of the market in a particular qualification; Strategies focused on technological advantage by using new educational technologies such as blended learning, learning management systems and video systems; Strategies focused on quality of the educational program, etc.

Strategies focused on the quality are among the competitive strategies, while being in dependence relationship on other competitive strategies adopted by the university. Quality mission is generally to meet competition, which is why there may be two types of strategies (Moldovan, 2012a):

- defensive strategy, keeping the market, that focuses on the quality assurance control of the educational and research processes in the university,
- offensive penetration strategy, which focuses on creating educational programs at technical and quality level located over or at least to the competitors.

The concept of Total Quality Management, EFQM Excellence Model and ISO 9001:2008 implementing a process-based approach to management are popular among European universities. Although the advantages of the process-based approach to quality management of any target-based organizations (e.g., universities) are vivid, there is still much room for improvement. It should be noted that universities' process management needs some improvement in the field of quality management of the results of scientific and educational activities (Chuchalin, and Zamyatin, 2011).

1.1.2._Quality defensive strategy

Quality defensive strategy must regard the two functions of the university: teaching and scientific research. Teaching quality emerged as a significant issue in higher education during the 90s. This led to the implementation of numerous quality controls, assurance and enhancement schemes as institutions attempted to stay abreast of demands from various stakeholders in a rapidly changing educational environment (Kulski and Groombridge, 2004). Education policy documents have recently placed great emphasis on teacher quality in the belief that "education of the highest quality requires teachers of the highest quality". Teachers are active voices in the policy-making process (Thomas, 2005). The higher education system is encouraged to improve and enhance creativity in accordance with the results so as to enhance innovation level and fulfil the national goal of efficiency (Chen and Chen, 2011). Institutions constraining this set of defensive innovation strategies on scientific research and reducing its deterring effects may increase the resources devoted to innovation and also the number of active scientific research race participants (Ledezma, 2010).

A support of quality defensive strategy is the implementation of quality management system (QMS) under the requirements of the standard ISO 9001, but also the specific requirements for educational mainframe systems in each country (Moldovan, 2012a). In Romania they are promulgated by the Emergency Ordinance no. 75/2005 of the Romanian Government on quality assurance in education and the Romanian Agency for Quality Assurance in Higher Education (ARACIS) which in 2006 had elaborated the "External assessment methodology, standards, reference standards and the list of performance indicators" (www.b).

1.1.2.1_Integrated quality strategy

Research on Total Quality Management (TQM) has examined the relationships between the practices of quality management and various levels of organizational performance (Kaynak, 2003). There is a paucity of in-depth research examining this complex relationship (Leonard and McAdam, 2001). The relationship between TQM practice and organizational performance is significant in a cross-sectional sense, in that TQM practice intensity explains a significant proportion of variance in performance. Some but not all of the categories of TQM practice were particularly strong predictors of performance. The categories of leadership, management of people and customer focus were the strongest significant predictors of operational performance (Samson and Terziovski, 1999).

There is a need for TQM to be considered from a philosophical level rather than simply as an operational tool (Leonard and McAdam, 2001). In universities there has been a change from informal "light-touch" quality control systems based on local practices and a significant amount of trust and professional autonomy in the early 1990s to a highly prescribed process of audit-based quality control today (Hoecht, 2006).

Before a quality management system implementation, quality strategy is dependent on the educational marketing strategies, the teaching strategy, the scientific research strategy, believing that quality strategy is a result of other competitive strategies (Fig. 1.1).

Thus, a strategy that integrates quality is elaborated (integrated quality strategy based on performance indicators), which has a central role in the competitive strategies, believing that the current approach of determination is opposite to the traditional one (Fig. 1.2) (Moldovan, 2012a).

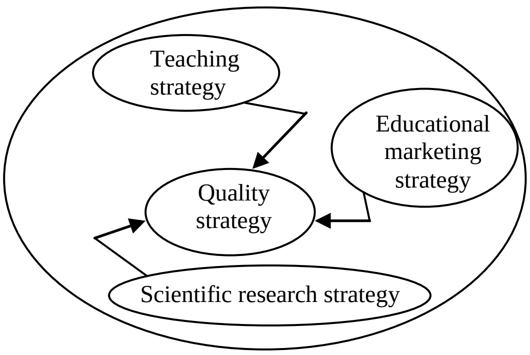


Figure 1.1. The traditional approach of the relationship between quality strategy and competitive strategies

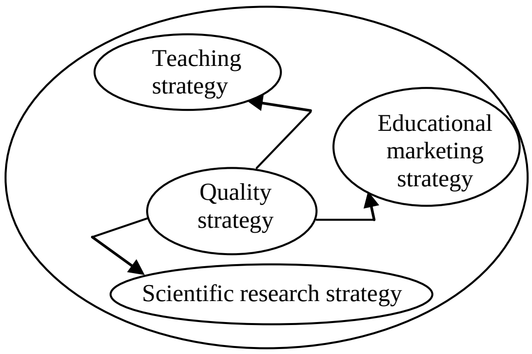


Figure 1.2. The current approach of the relationship between quality strategy and competitive strategies

My conclusion is that integrated quality strategy determines other competitive strategies (Moldovan, 2012a).

1.1.2.2._Performance indicators strategy

The application of performance indicators to higher education is a phenomenon that belongs to the nineteenth and twentieth centuries, although there are reverberations from an earlier period (Bruneau and Savage, 2002). The indicators are regarded as tools to support universities, to encourage and continue subsidizing public and private higher education. Most performance indicators, though, have had some kind of funding attached to them, even if "performance-related pay" was usually a very small fraction of total institutional income. Among jurisdictions that publish institutional performance indicators, institutional graduation rates appear to be the only key indicator that has universal acceptance as a measure of institutional performance. Beyond this core indicator, different jurisdictions use very different measures depending on local policy contexts. Employment indicators are widely used as are measures of graduates' satisfaction with their education. Financial performance appears just about everywhere, and is usually measured by having low administrative overhead. Less frequent are items such as faculty diversity, student default rates, fundraising performance, and quality data reporting (Finnie and Usher, 2005). The higher education effectiveness in preparing graduates for work and life can be evaluated by alumni research using the model designed by Delaney (2004). The rank data show that the specific measures and indices used by magazines are inconsistently related to each other and to the universities' final assigned rankings (Page and Cramer, 2004).

Governments and institutions are implementing strategies to ensure the proper performance of universities and several studies have investigated evaluation of universities through the development and use of indicator systems. There is a difficulty involved in establishing classification criteria for existing indicators, on which there is currently no consensus (Garcia-Aracil and Palomares-Montero, 2009). My conclusion is that performance indicators are tools achieving integrated quality strategy (Moldovan, 2012a).

The changes implied by quality assurance must start at local level, i.e., individual courses and programs of study. The task of documenting such changes and, thereby, recognizing the impact of quality assurance policies and practices (accreditation and evaluation or assessment) makes it necessary to use different metrics at different levels of a higher education institution (Gray and Patil, 2009).

In a first phase, a university may adopt a quality strategy to establish, document, implement and update operating procedures and activities, based on domains, criteria, standards and performance indicators, required by the national quality assurance agency, which in Romania is ARACIS. Thais path was followed also by the "Petru Maior" University of Tîrgu-Mureș (UPM).

In order to have a strategic advantage, in the second phase, UPM has established 22 own references for the performance indicators levels, among which we mention (www.a):

- University involved student organizations in audit activities,
- Admission is considered in the formulation of university policies focused on quality,
- Assessing the effectiveness of university-level research is conducted on the procedures and specific documentations of the Quality Management System,
- Concerns of the university to stimulate research,

– Structures to track and improve quality of education,
– Participation of independent evaluators in the country and abroad,
– University involvement in research projects with objectives to improve university curricula,
– Concerns for the university's own quality assurance procedures,
– Quality Management System is documented according to the ISO 9001:2008 standard and ARACIS requirements - university processes are documented and measured periodically, etc.

As a consequence of the last indicator, in the third phase UPM has reorganized the QMS, by following the new editions of the quality management standards ISO 9001:2008 and the requirements of ARACIS, with the strategic objective to benefit from the advantages of both implementations.

1.1.2.3. Organization of quality management system

Total Quality Management has much to offer to higher education but that is not just a case of translating ISO 9001 from a product-based to a service-based system. Sensible application of total quality management principles in higher education in order to show a realistic improvement takes time, commitment and considerable investment by top management. The starting point should be a better understanding of customer needs, which can then be addressed through a process of service quality improvement which permeates the organizational structure (Watkins, 2007).

The findings indicate that a key element for a successful implementation of the new system is the institutions' own understanding of the rationale behind the system. Internal evaluations, annual reports and quantitative institutional basic data must be considered and also used by the institutional leaders and the academic staff members as “tools” for meaningful internal quality work and not just looked upon as strange elements requested from “above”. The institutions' quality work must be considered a crucial “instrument” for strategic management of the entire institution.

According to ISO 9001, the quality management system involves all phases of the educational cycle and processes, from identifying the needs of customers to the final meeting of their requirements. In these activities the university has focused on educational marketing, on determining and defining customer needs and its requirements for educational programs (Moldovan, 2012a). To this end, UPM:
- has defined and documented activities that contribute directly or indirectly to the achievement of quality;
- has defined the general responsibilities and specific responsibilities in quality, as well as responsibilities and delegated authority for each activity affecting quality;
- has defined organizational structure related activities affecting quality.

1.1.2.4. Quality management system processes

A quality map that explicitly takes into account the environment, strategic planning and the internal processes of the organization, has been presented by Kettunen (2005). The quality map helps the management of the higher education institution to present an overview of the quality assurance system to the external evaluators, members of the organization, students and other stakeholders.

In UPM I had identified QMS processes and ordered them in four categories (Moldovan, 2012a):
- management processes to coordinate the work of the University,
- basic processes are the core of the quality management system,
- support processes necessary for sustaining basic activities,
- measurement, analysis and improvement processes for the effectiveness of QMS.

Starting from the process categorization, and the model of a quality management system based on processes (Fig. 1.3), in UPM I had drawn up a process map (Fig. 1.4). For each departmental process is named a process responsible - the executor or head of department; for interdepartmental processes, as well as for projects, there are process / project owners - they are responsible for controlling the interfaces and the achievement of performance indicators of the process (Moldovan, 2012a).

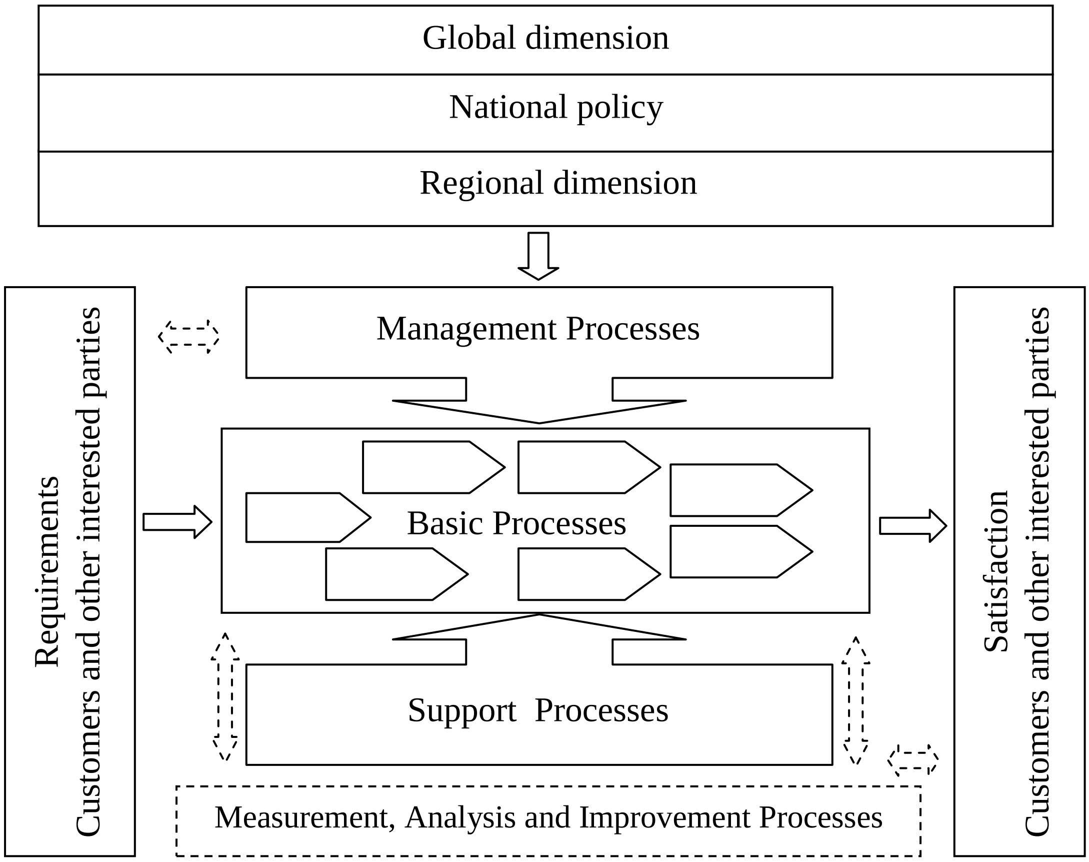


Figure 1.3. Model of a quality management system based on processes

Complying with ISO 9001 requirements, in UPM I had developed quality management system documentation, through interpretation and adaptation of ISO 9001 standard requirements to the university areas of activity: higher education and scientific research. In a first stage had been developed quality policy and quality objectives, followed by quality manual and 33 operational procedures describing the quality management processes (www.a).

1.1.2.5. Process matrix

According to the ISO 9001 standard requirement 8.2.3-*Monitoring and measurement of the processes*, the university has to apply adequate methods for quality management system process measurement, based up on process indicators.

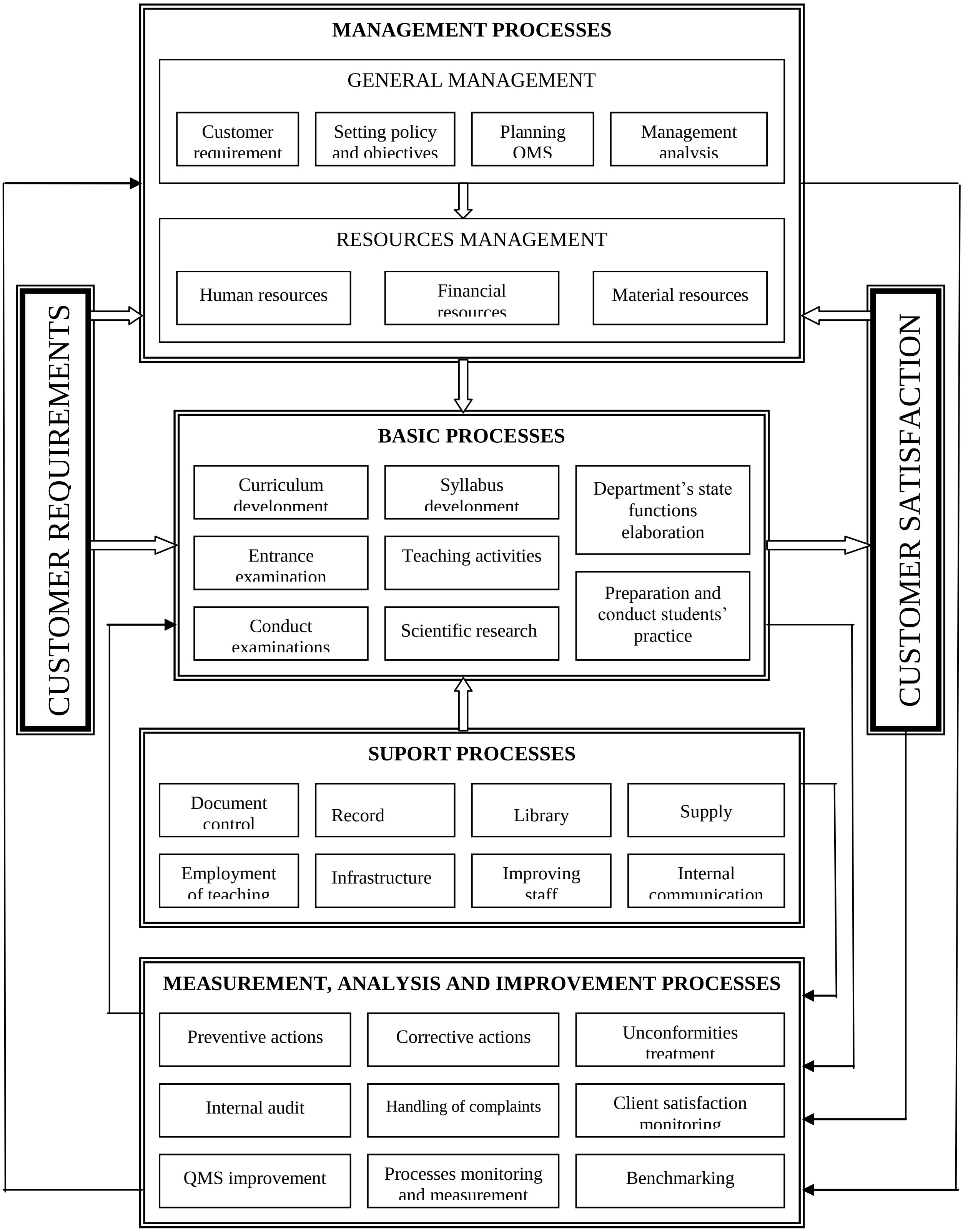


Figure 1.4. UPM's Process map

Table 1.1. UPM's Process matrix

Process name	Documented procedure	Process responsible	Input data	Output data	Measuring method	Meas freq.	ENQA Standard	Performance indicator	Specific objective
…………									
Curriculum development	Elaboration of new study programs	Head of department	● Specification of study programmes ● Ministry req. ● ARACIS req. ● Legislation ● Benchmarks in RO and EU	● The curriculum of the specialization	● Number of new programs / updated ● Number of nonconformities of the curriculum	Annual	Approval, monitoring and periodic review of programmes and awards	● Curricula structure ● Differentiation in implementting study programs	Ref. 1 Ref. 2
Scientific research	Management of scientific research	Scientific Vice-Rector	● Research plan of the faculty / department / ●Advertisements competitions / grants / scientific events	● Grants ● Articles / books / studies / research publication ● Patents ●Awards National /International	● Number of books / study / research published ● Score obtained in national evaluation	Semestrial		● Research programming ● Making research ● Turning research	Ref. 1 Ref. 2 Ref. 1
…………									

In UPM I had developed a system of process indicators that are similar to performance indicators, presented in the ARACIS methodology (www.b). Each procedure of the quality management system developed in the ISO 9001 system is applied to achieve ARACIS performance indicators, which are also process indicators measuring the performance, but also the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) (www.c). Criteria for selecting indicators refer to measurable quantities and are related to staff motivation system.

The documentation of the processes, the periodical measurement and the allocation of ARACIS indicators specific to each type of process are documented in the Process Matrix (table 1.1). It outlines a new element for quality management systems in Romanian higher education (Moldovan, 2012a).

Defining elements of matrix processes for two basic processes are exemplified in table 1.1. Following the allocations identified in the processes matrix, there are developed operational procedures that are applied in order to achieve ARACIS performance indicators. Complete documentation of processes ensures planning, operation and effective control of processes.

1.1.2.6._Implementation effects

UPM management appreciates that it has established, documented and implemented with success a quality system that meets both ARACIS national legal requirements and international ISO 9001 standard requirements. The latter is necessary due to market considerations but also because of some organizational advantage offered by ISO 9001 implementation. The standard provides some mechanisms which lead to organizational improvement, for example the treatment of nonconformities which ensures that the same nonconformity will not happen again if effective corrective actions are established.

UPM management appreciates that the challenge lies in maintaining and improving the system. In order to create a quality culture in the university it is necessary to have frequent trainings of the staff on different quality subjects (Moldovan, 2012a). The strong personality of many members of the academic community makes certain demands of the management systems to be highly disputed. Another obvious obstacle in implementation UPM has faced is the large volume of the reports and registrations demanded by the quality management system.

The main success in implementation is the result of UPM evaluation by ARACIS, which granted the university “high confidence”. With this result UPM ranks among top universities in Romania. This confirms the validity of quality defensive strategy adopted by the university whose main result is the clients' confidence: admittances, students, employers.

1.1.3. Conclusion

In this study I have presented the concept of *quality defensive strategy*, which emphasizes control of the university educational and scientific research processes.

A strategy that integrates quality I have defined (quality integrated strategy based on performance indicators), which has a central role in competitive strategies, demonstrating that the current approach of determination is opposite to the traditional one, so the quality strategy determines other competitive strategies. The implementation phases I have conducted in UPM are presented in synthesis below.

In Romanian universities, implementation of the quality management systems in accordance with ISO 9001 standard is not a legal requirement. The legal requirements for quality assurance in universities are formulated by the national accreditation body ARACIS in the "External assessment methodology, standards, reference standards and the list of performance indicators", organized in three domains with specific standards and performance indicators that can be fulfilled on different levels. UPM management has decided to implement the quality management system that meets both legal and ISO requirements, but also to develop own levels for the performance indicators.

In a first phase, UPM has adopted a quality strategy to establish, document, implement and update operating procedures and activities, based on domains, criteria, standards and performance indicators, required by ARACIS. In order to have a strategic advantage, in the second phase, UPM has established 22 own references for the performance indicators levels.

In the third phase, UPM has reorganized its QMS, by following the new editions of the quality management standards, ISO 9001:2008 and the requirements of ARACIS, with the strategic objective to benefit from the advantages of both implementations.

Starting from the process categorization, UPM has drawn up a process map that explicitly takes into account the environment, strategic planning and the internal processes of the organization. It is the support for the QMS documentation.

Each procedure of the quality management system developed in the ISO 9001 system is applied to achieve ARACIS performance indicators, which are also process indicators measuring the performance. The documentation of the processes, the periodical measurement and the allocation of ARACIS indicators specific to each type of process are documented in the Process Matrix. It outlines a new element for quality management systems in Romanian higher education.

The quality management system implemented by UPM has practical implications for practitioners from universities due to the establishment of the correspondences between the requirements for quality management systems formulated by ISO 9001 international standards and accreditation body for academic management systems ARACIS. The case study is an example for quality managers from Romanian universities. The contribution consists in the modality of documenting processes, the periodical measurement and the allocation of ARACIS performance indicators to each process that is documented in the Process Matrix. It establishes correspondences between the requirements of ISO 9001 standard and ARACIS performance indicators.

The adopted quality defensive strategy confirmation is appreciated through the immediate result of confident customers and through the outcome of UPM evaluation by ARACIS, which granted "high confidence" to the university.

1.2. QUALITY ASSURANCE AND SUSTAINABLE ASSESSMENT IN THE VOCATIONAL EDUCATION AND TRAINING

1.2.1. Sustainable development strategy

Organizations all over Europe are becoming increasingly aware of the need for, and benefits of, the triangular union of economically, ecologically and socially responsible behavior. The European Union sees sustainability as a key factor for financial systems and the economy as a whole (www.d.), while the International Organization for Standardization member bodies overlap these 21st century pillars and have reasons to consider that an organization's impact on the environment has become a critical part of measuring its overall performance and its ability to continue operating effectively (www.e.), as the economy is dependent on the health of the world's ecosystems.

In this context, the Vocational Education and Training (VET) system needs a paradigm shift and revision of its role in society from focus on delivering competences for a market economy towards delivering competences for sustainable development, in which the market is confined to social development, respecting the limits on growth (Jansen, 2008).

A first revision in the VET system is done by the curricular content, stressing the importance of education for all people to achieve sustainable development (Mayor, 2007), the competence-based model being the means of achieving educational and societal transformation towards sustainability (Mochizuki and Fadeeva, 2010), which is framed by a shared vision about quality education and a society that lives in balance with Earth's carrying capacity (Pavlova, 2013).

Environmental education—in whatever form—actually supports and promotes more sustainable development in practice; its development being accompanied by the implementation of a problem-based learning approach (Menet and Gruescu, 2013), environmental impact assessment (Foo, 2013), environmental protection rules (Nicole, 2008) and integration of knowledge management. This is supported by a framework (Chepkemei et al., 2012) that may also include the regulatory and operational requirements to adopt a Green Plan.

A second revision in the VET system can be done at the level of VET organizations that have competitiveness and sustainability on the agenda, by developing frameworks to improve their performance in regard to quality and sustainability issues (Dos Santos et al., 2012).

A range of different quality frameworks have been proposed for VET providers, but Shah and Stanford (Shah and Stanford, 2013) state that there is a need for institutions to develop a single framework to meet internal and external needs that are economical, sustainable, and morally responsible in order to improve academic quality and to monitor standards.

By reviewing the existing literature, I feel it is clear that, along with the environmental education that is commonly claimed to be at the center of efforts to achieve sustainable development, there is a need to develop adequate frameworks in organizations that may support sustainability policies.

Furthermore, implementation of a sustainability assessment framework in a VET organization is a strategic one, because it supports a sustainable development strategy, which ensures the competitiveness of the organization.

In my opinion, adoption of a sustainability assessment framework is the operational part of a strategy focused on sustainable development that is positively related to the other competitive strategies adopted by a VET provider. I consider that it has a central role in the competitive strategy of the organization, and I believe that it determines the other competitive strategies: marketing, training delivery, partnerships, etc., as illustrated in figure 2.1. Such strategies describe how the VET provider plans to gain advantage over competitors, for example with the support of technology by using new educational technologies such as distance training, blended learning, learning management systems and video systems for delivery of training with paperless support; strategies using the alternance model for training by working part-time with an employer; etc.

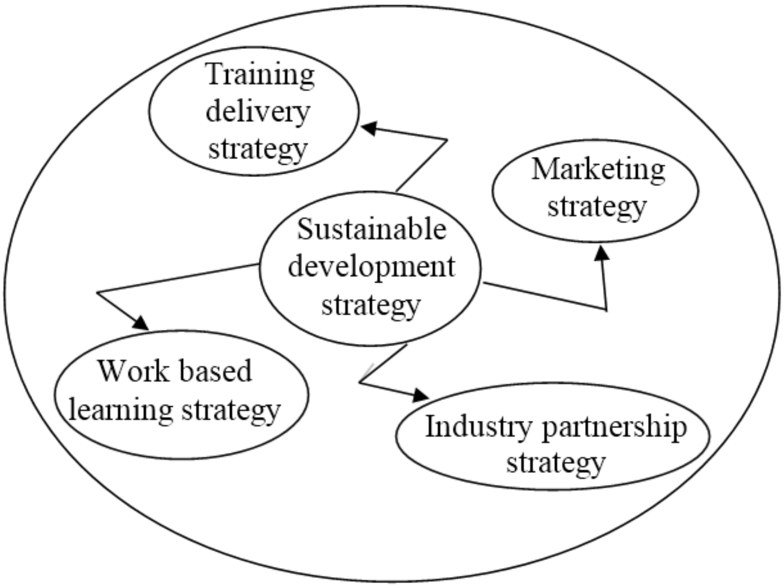


Figure 2.1. The relationship between the sustainable development strategy and other competitive strategies of the Vocational Education and Training (VET) provider

The scope of my research is to develop a framework for sustainability assessment of VET organizations, relying on a management system that is: socially fair, economically viable, and ecologically responsible.

The methodology of research started with the literature review in relevant scientific journals on sustainability, quality, and vocational education and training themes.

With this support, in the next step of the research methodology a qualitative study of five case study VET providers in the Mureș County was undertaken, which allowed us to identify the areas and performance indicators of a framework for sustainability assessment of VET organizations.

The new and innovative proposed framework integrates quality and sustainability in vocational education and training institutions (Moldovan, 2015a.). It is a starting point to help VET managers to create and manage their organizations towards high standards of sustainability.

1.2.2. Sustainability assessment framework

1.2.2.1. Selection of areas and performance indicators

I have developed the sustainability assessment framework as operational part of the sustainable development strategy with the support of performance indicators.

Application of performance indicators to VET is a phenomenon imported from the higher education sector. In the field of VET, it is employed by the European Quality Assurance in Vocational Education and Training (EQAVET) quality assurance reference framework (www.f), which operates by means of 10 indicators with the main objective to determine the impact of unemployment. In fact, this is the single framework operational for VET providers, which has one area and makes no reference to sustainable development.

In the research, I had to decide the areas of focus in the new proposed framework, the format for description of indicators as well as their content.

In the first phase of the development, I started with establishing the areas of the new framework by collecting relevant ideas from the literature review in order to keep a significant and causal positive relationship between a good institution and sustainability, as demonstrated by Stoever (2012).

In this stage, I have considered the synergies between quality and sustainable development in an organizational framework described by Isaksson (2006); the capital-based frameworks as part of the statutory responsibility that promote the social, economic, environmental and cultural well-being of their communities (Saunders and Dalziel, 2010); and the many perspectives for implementation described between the extremes of the ecological sustainability perspective described in the international standard for environmental systems (www.g) and the well-being perspective (Van Zeijl-Rozema et al., 2008).

Among the so-called three “pillars” of sustainable development, it is necessary to introduce a fourth dimension—institutional component, as demonstrated by Zdravkovic and Radukic (2012), due to the fact that sustainable development cannot be achieved without governance because of its nature: it is normative and requires collective action.

Having analysed the previous conceptual components of a framework evidenced in literature: quality, social, economic, environmental and institutional, in the new developed framework I considered merging institutional capacity with quality management, and adding a fifth component related to training as a core area of a VET organization. As a result, the new developed sustainability assessment framework for VET organizations helps orienting within the following five areas (Moldovan 2015a):

- institutional capacity and management;
- environmental responsibility;
- economic performance;
- social responsibility; and
- training provision.

These areas are seen as key pillars a VET organization will have to consider for both implementing and continuing a sustainable development approach, by interconnection of economics with environmental issues that are of great significance.

In the second phase of the development, I have selected performance indicators in order to cover as wide as possible areas, but also to have a limited number of indicators.

The criteria for selection of sustainable development indicators were built from the basic functionality of the indicator, which is to transfer relevant information from physical space to users through communicable data (Nathan and Sudhakara, 2011). For this purpose, a qualitative study of five case study VET providers was undertaken. The five VET providers represent the landscape types selected because each exhibited a cross-section of characteristics—such as declining, growing and stagnating—as well as differing levels of human capital.

Gathering quality and sustainability approaches developed by each organization was proceeded in a comparative analysis in order to achieve a common reference framework.

I examined how the VET providers implemented the quality assessment for sustainable development and discovered different approaches to help other VET organizations find a common way to implement sustainable management. The key aspects that informed the methodology are:

- The vision/mission/goal related to sustainability assessment;
- Previous experience of the organization;
- Institutional context;
- Key issues for “implementation to governance” of a sustainability assessment towards a sustainable quality development (this should describe how organization started, how they implemented it, how they run and manage it, who is involved when/why, what measures have been taken, *etc.*); and
- Key success factors.

In addition, from the literature review, in describing the performance indicators, I have used the integrative management concept elaborated by Jabareen (2008), but also the 16 elements contributing to the framework of sustainable technical and vocational education: creativity, innovation, networks and partnerships, staff development program, teaching methods, generic skills, industrial relations and internships, counseling, entrepreneurship, ICT skills, interest, recognition, knowledge, competency based training, articulation, and commitment of management revealed by Minghat and Yasin (2010).

Finally, the new and innovative sustainability assessment framework was designed, with the main objective to determine the impact on the environmental, economic, and societal quality of the training system.

The new developed framework (Moldovan 2015a) is composed of five key pillars: institutional capacity, environmental, economic, social, and training provision, which interact in the context of globalization of training, as presented in figure 2.2. Thus, all five areas are considered in their mutual interaction and dependency. In the five areas of the new sustainability assessment framework, a total of 40 performance indicators are used to make the assessment. They are designed to cover as wide as possible areas.

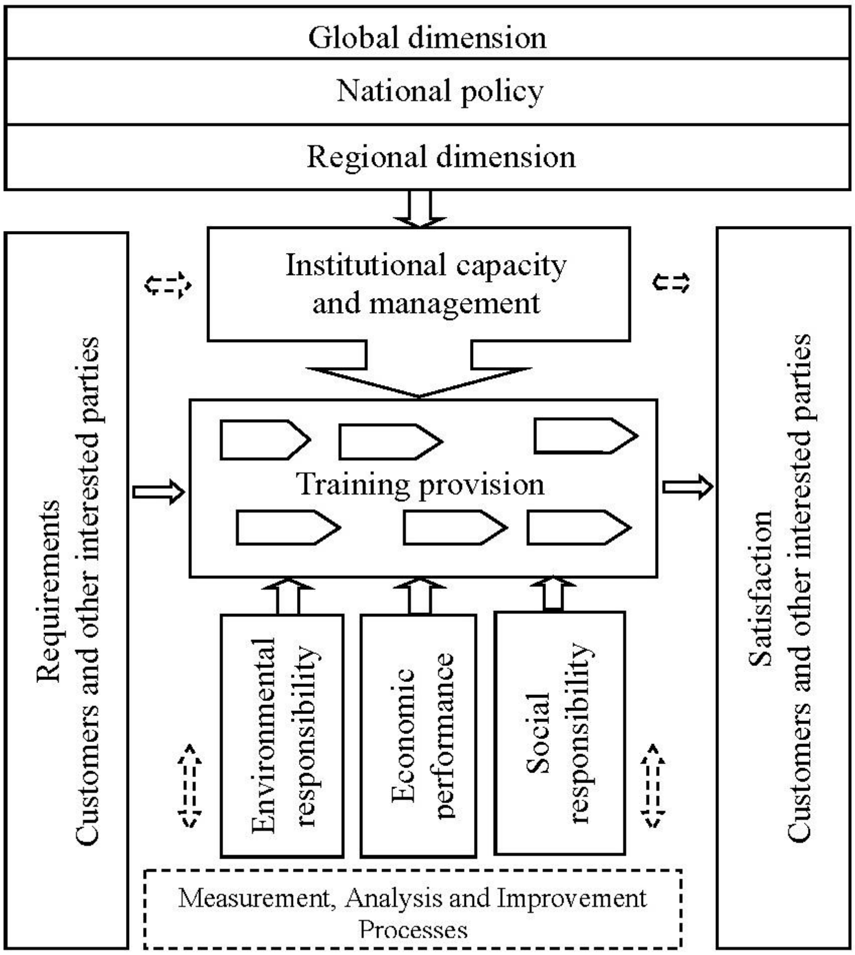


Figure 2.2. Interaction of the sustainability framework areas

1.2.2.2. Sustainability assessment framework content

The purpose of the innovative sustainability assessment framework is to assess VET organizations institutional sustainability in terms of the five key pillars (areas): institutional capacity, environmental, economic, social, and training provision.

The map comprising the areas of the sustainability assessment framework and the corresponding performance indicators are presented in table 2.1, in which the four phases of the continuous improvement cycle are bordered (Moldovan 2015a).

Figure 2.3 demonstrates the allocation of indicators from the five areas of the framework on the four phases of the continuous improvement cycle.

The sustainability assessment framework is based on the Plan-Do-Check-Act (PDCA) cycle and consists of four phases:

- setting of policy goals/objectives and planning phase;
- implementation phase;
- evaluation phase, which deals with the design of the mechanisms for evaluation and the assessment of achievements/outcomes at individual, provider and system levels; and
- review, based on a combination of internal and external evaluation results, processing of feedback and organization of procedures for change.

Table 2.1. Sustainability assessment framework areas and performance indicators

1. Institutional Capacity and Management	**2. Environmental Responsibility**	**3. Economic Performance**	**4. Social Responsibility**	**5. Training Provision**
1.1. Strategy and planning mechanism 1.2. Management system	2.1. Bio diversity	3.1. Design and development of VET delivery	4.1. Community involvement and development	5.1. Design of training provision
1.3. Responsibility 1.4. Internal and external communication 1.5. Facilities 1.6. Logistics 1.7. Staff participation 1.8. Participant access	2.2. Water consumption management 2.3. Non-renewable energy consumption 2.4. Consumption of raw materials	3.2. Policy of employment and wages 3.3. Marketing and sales of services	4.2. Equal opportunities 4.3. Social relation in organization 4.4. Fair operating practices	5.2. Training contents 5.3. Training delivery 5.4. Training resources
1.9. Relationship with stakeholders 1.10. Supply chain 1.11. Legislation awareness 1.12. Risk management	2.5. Water pollution 2.6. Soil management and pollution 2.7. Air pollution and greenhouse effect	3.4. Investment	4.5. Health and safety 4.6. Consumer issues	5.5. Citizenship and training
1.13. Fundamental rights 1.14. Internal audit	2.8. Waste	3.5. Economic performance	4.7. Training and education	5.6. Training review

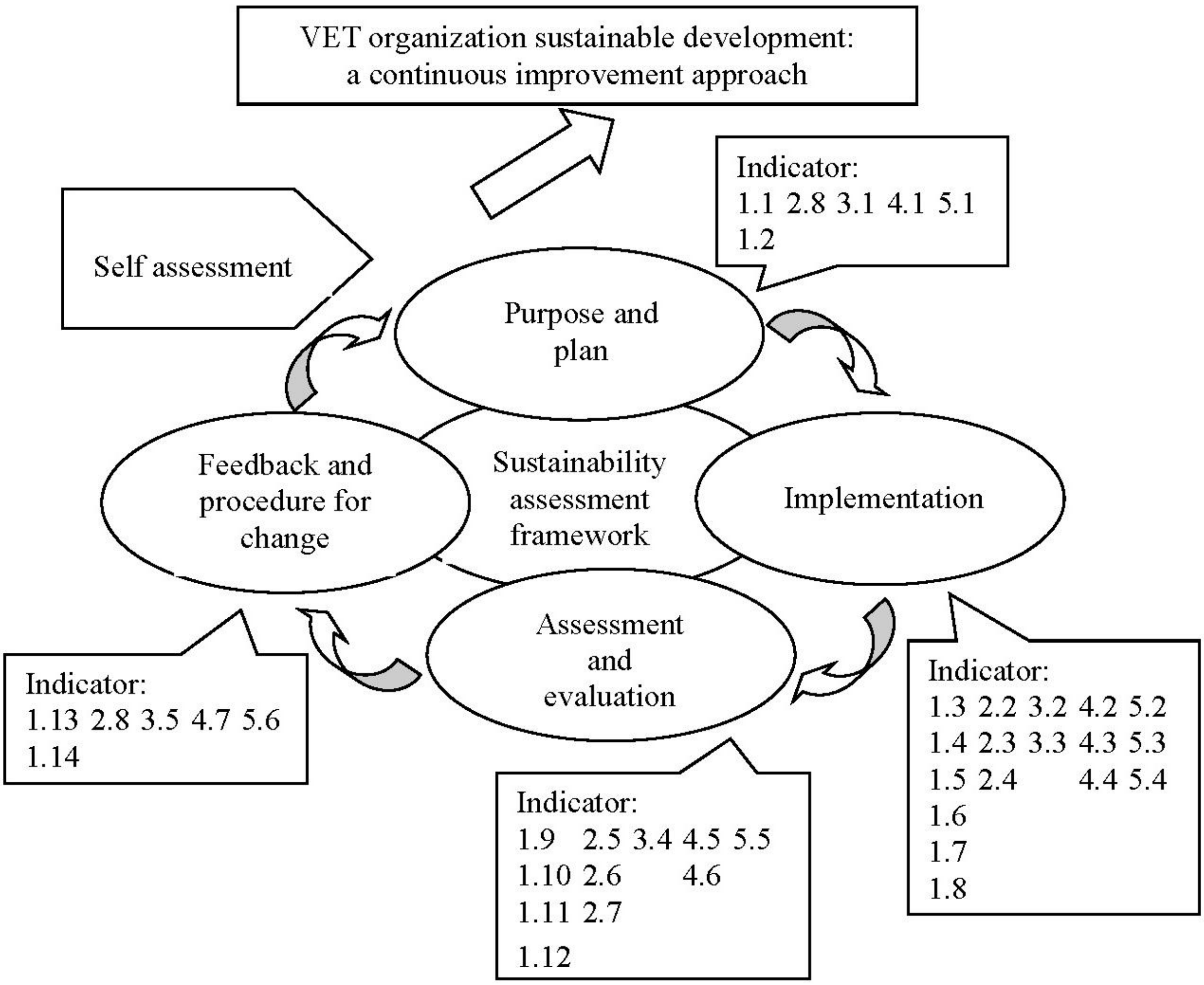


Figure 2.3. Continuous improvement cycle for the VET organization sustainable development

1.2.2.3. Performance indicators format

In order to enable assessment for each indicator, I have designed five performance categories: awareness, measures, action, innovation and excellence and five importance categories.

The assessment process is based on a novel approach of “couple values” of each indicator’s performance and importance, both evaluated on specific scales from 1 to 5.

To help understand the above-mentioned areas and indicators, the descriptions below in table 2.2 exemplifies the format in the case of the “Water consumption” performance indicator (code 2.2) from the environmental area, which is composed of “Indicator description”, “Environmental aspects to check” and the couple criteria (Performance.Importance).

For a more synthetic presentation of the other seven indicators from the “Environmental responsibility” area, the following is a summary of: the description, environmental aspects to check and performance criteria for the five rankings: (1) *Becoming aware*; (2) *Measures*; (3) *Setting up actions*; (4) *Incomplete mastery of innovations*; and (5) *Excellence/model behavior*.

Table 2.2. Performance indicator format

Indicator Code	**Water Consumption 2.2**	
Indicator description	Water has becoming such a rare good that it needs better consumption management by individuals as well as by organizations. To be able to observe better and more efficient consumption, an organization must know its level of consumption, types of use, the origin of water consumed, communication actions developed towards staff members and learners.	
Environmental aspects to check	What is the water resource origin; the water consumption and the amount of the invoice; the uses and sectors most concerned by water consumption; means to follow up water consumption; means and measures taken to reduce water consumption (“saving” taps, use of water rain, *etc.*); how the staff members and trainees awareness is raised about this subject.	
	Description	
Scale	Description criteria: **Performance**	Impact
1	*Becoming aware*: There is no management or control of water consumption.	Assessment result with concrete examples from VET provider organization
2	*Measures*: Control of water consumption without any optimization.	
3	*Setting up actions*: Optimization of water consumption and formalized follow up—optimized networks of used and consumption waters. Activities oriented towards staff members and training course participation in order to develop awareness.	
4	*Incomplete mastery of innovations*: Formalized action plan with a fixed quantitative objective for water consumption reduction and actions developed to reach the objective. Action plans for staff	

	member and participant awareness.	
5	*Excellence/model behavior*: Exclusive use of renewable water resources. Functioning is performed in close circuit. Mode of functioning that gives priority to recycling.	
Scale	Description criteria: **Importance**	Impact
1	The issue is of little consequence; dealing with it is not on the agenda, and it can be ignored for the moment.	Assessment result with concrete examples from VET provider organization
2	Not to master the issue could undermine or penalize—for a limited time and in a limited area—the operating process of the organization.	
3	Not to master the issue could jeopardize the success of the organization's projects. Mastering it is essential in order to accomplish projects.	
4	Not to master the issue could jeopardize the successful completion of all the organization's projects. Mastering it is essential for the successful completion of the whole body of projects	
5	Not to master the issue could put the very existence of the organization in jeopardy. It is essential for its survival that it should master the issue.	

Non-renewable energy consumption (code 2.3): Lightning and heating as well as specific training activities using energy are elements to be taken into account in energy consumption management. These elements are: information, by type of activity or by sector, and its own consumption; prevention actions and individual and collective sensitization towards staff and learners; being aware of energy needs regarding premises, transport, materials and other kind of electronic equipment and the actions developed in order to optimize them; and using renewable energies.

All organizations are concerned with this indicator; whatever we think of lighting, or heating for some of them, the control of energy consumption is a collective topic to think about.

Environmental aspects to check: information about the energy needs; the cost of the consumption; activity or uses that are the most important consumers of energy; follow up of energy consumption settled in the organization; decisions or measures taken in order to manage and control the energy consumption (control and reduction of heating, hot water temperature, lighting, double glass windows, *etc.*); and how the organization raises staff members and trainees' awareness.

Performance: (1) *Becoming aware*: No management nor control at all of energy consumption. None or very little knowledge about types of energy consumed; (2) *Measures*: Existence of a detailed report of consumption and evaluation of costs sharing by location and activity; (3) *Setting up actions*: Actions are implemented in order to reduce energy consumption. Actions are set up to raise and develop staff and trainees' awareness on saving energy; (4) *Incomplete mastery of innovations*: An action plan has been settled and formalized in order to reduce energy consumption (including a quantitative objective for consumption reduction). It has been communicated towards staff members and training participants. It includes measures/means that enable reducing consumptions but also optimizing needs (isolation of premises, using systems of low consumption, *etc.*). Surveys and analyses on premises allow considering what to do in order to optimize energy consumption and use renewable energies; (5) *Excellence*/*model behavior*: Building and construction of projects, purchasing or renting new premises taking into account energy consumption aspects (premises certified as being "low consumption"). Concerning type of energy, preference is given to renewable energies.

Consumption of raw materials (code 2.4): All raw materials have to be taken into account whenever they are common (used by everyone), such as ink or specific to an activity (e.g., food stuff for a catering and cooking course). It is relevant to know the level of consumption, the origin of products and to take them into account. The raw materials used for training courses provision are paper, ink, *etc*.

Environmental aspects to check: Disposal to identify and check permanently the raw materials consumption; how the organization raises staff members and trainees awareness.

Performance: (1) *Becoming aware*: No concern nor management at all of raw materials. None or very little knowledge of raw materials origin and types; (2) *Measures*: Measure of quantity of raw materials used by location and activity in relation with turnover or training activity level; (3) *Setting up actions*: Actions are set up in order to reduce raw materials consumption. Actions are implemented to raise staff members and participants' awareness in saving energy; (4) *Incomplete mastery of innovations*: An action plan aiming to reduce materials consumption (including a quantitative objective for consumption) is formalized and communicated to all staff members and trainees. Some materials come from recycling. Use of recyclable raw materials; (5) *Excellence/model behavior*: Consumption is permanently decreasing (for the same level of activity). Raw materials come from recycling. Preference is given to renewable energies when making the selection.

Water pollution (code 2.5): According to its activity, a training organization can produce waste that might have a risk of impacting water pollution. Being aware of this impact, measures taken to reduce it, awareness of staff and learners are points that can be observed to measure how this risk is managed.

Environmental aspects to check: Existence of a reflexion within the organization about environmental impacts on water and if these impacts are taken into account. If yes, how? How much is the water consumption in terms of quantity and costs; the impact of disposal on the environment; and how the organization raises staff and trainees awareness.

Performance: (1) *Becoming aware*: None or very little knowledge of the activity impact on rivers in the neighborhood and of the potential treatments of polluted waters rejected by the organization; (2) *Measures*: Quantitative and qualitative analyze of throwing (types and pollution risks); (3) *Setting up actions*: Treatment of waste; (4) *Incomplete mastery of innovations*: Limiting wastes and disposal at source. Staff members and trainees awareness; (5) *Excellence/model behavior*: Technological observation enables identifying, for one's activity and inherent risks of pollution, what are the most relevant and appropriate techniques for liquid waste disposal. Functioning is performed in closed circuit. Staff member and participants to trainings are developed on new technologies that enable better liquid waste disposal.

Soil management and pollution (code 2.6): Decisions and activities may have an important impact on urban and rural environment and its ecosystems. This impact can be, for example, associated with urban policy, buildings, construction, transport systems, waste, used water and to agricultural techniques.

Environmental aspects to check: The impact of the activities on soil and subsoil (underground).

Performance: (1) *Becoming aware*: No observations of impacts on soil or subsoil. None or very little knowledge about the impact produced by its activity on soil or subsoil; (2) *Measures*: Rough knowledge of soil pollution and geology; (3) *Setting up actions*: According to the law and regulations—storage in hermetic containers of all waste and equipment that may generate soil pollution. Organization of cleaning and decontamination of sites previously polluted; (4) *Incomplete mastery of innovations*: An action plan is set up and aims at reducing the organization impact on soil and subsoil. Soil geology is taken into account within the training organization activity. Research and implementation of new processes to limits impacts are organized; (5) *Excellence/model behavior*: The organization implements its staff, training participants, and partners' awareness on this topic.

Air pollution and greenhouse effect (code 2.7): Gas emissions, in particular greenhouse gas emissions, have an impact on climate evolution. Depending on the knowledge of the atmosphere, this pollution can be taken into account and actions implemented to limit it. The purpose is to identify types of disposal that cause air pollution, and they are quite numerous and depend on the activity: gas released by means of transport used by staff members and by persons attending courses has to be taken into account; and gas issued by training activities or production directly linked to training, and these are quite common.

Environmental aspects to check: The types of gas released into atmosphere; following up on gas released by the organization; how to take into account these emissions and what actions can be set up; and method for measuring the gas throwing out greenhouse effect; actions implemented to reduce these impacts.

Performance: (1) *Becoming aware*: No idea or very little knowledge of atmospheric emissions. No conformity with legislation or no knowledge of legislation obligations; (2) *Measures*: Identification of which gases are emitted. Measure and analyze emissions and their impacts (in particular for greenhouse gas). Conforming to legislative obligations; (3) *Setting up actions*: Setting up of punctual actions in order to reduce greenhouse gas emissions. Reduction of emissions (in particular through improvement of transport policy); (4) *Incomplete mastery of innovations*: An action plan in order to reduce all throwing out into atmosphere for any kind of activity (personnel's transport, trainees' transport, emissions directly linked to training activity) and on processes concerned with the training activity (e.g., purchase policy); (5) *Excellence/model behavior*: The organization organizes and develops staff members, trainees and partners' awareness.

Waste (code 2.8): It includes waste produced by all organizations (paper, ink, old IT material) and specific waste directly linked to training activity (oil, food, *etc.*). The identification (type, quantity) of the activities that produce waste, all the measures taken to reduce waste, reusing materials, recycling, and waste treatment, are elements to be taken into account by the organization in order to improve its waste management policy.

Environmental aspects to check: nature and volume of waste the organization is producing by type of activity or location; the types of use that produce the most waste; the impact of waste on the environment; how the organization deals with its waste; measures and means the organization sets up in order to reduce waste; and how the organization raise staff members and trainees awareness.

Performance: (1) *Becoming aware*: No idea about legislation or at least some knowledge but no application; no specific waste management; and everything is put into the dustbin; (2) *Measures*: Partly in conformity with laws and regulations; identification of volume and type of waste and location; (3) *Setting up actions*: Identification of the impact of waste on the environment; pre-treatment of waste (for example, selective waste sorting) organized on some sites; and actions are implemented in order to raise staff and trainees awareness on waste reduction; (4) *Incomplete mastery of innovations*: An action plan is set up with the aim of reducing waste by changing habits (for example, it could consist of reusing paper); organization of waste that is formalized and communicated to staff members and trainees; waste selection is systematically done; forthcoming waste is checked at "collector's" or "eliminator's" location; and when selecting waste "collectors" or "eliminators", the energy cost is taken into account (e.g., transport); (5) *Excellence/model behavior*: Volume of wastes decreases (for an equivalent activity); reducing raw material consumption; and agreements have been made with local partners in order to valorize materials when the organization cannot do it by itself internally.

Bio diversity (code 2.1): Biodiversity is life diversity in all its forms, at all levels, in any combination. It includes diversity among species and between species and ecosystems diversity. Knowledge of how the organization's activities impact fauna and flora, and actions developed to control and limit these impacts.

Environmental aspects to check: Information about the impact of the organization activity upon flora and fauna; existence of emissions into the atmosphere made by the organization; how they are taken into account and what actions are set up.

Performance: (1) *Becoming aware:* No conformity with legislation; none or very little knowledge about the impact of the activity upon flora and fauna; (2) *Measures:* Knowledge; (3) *Setting up actions:* Conformity with legislation; implementation of actions or disposals to correcting negative impacts on biodiversity; (4) *Incomplete mastery of innovations:* An action plan is set up in order to guarantee the consideration of the impact on biodiversity for any new activity; (5) *Excellence/model behavior:* The organization improves the awareness of staff members and trainees.

1.2.3. Experimental

Implementation of the new sustainability assessment framework for VET organizations is performed as a self-assessment tool.

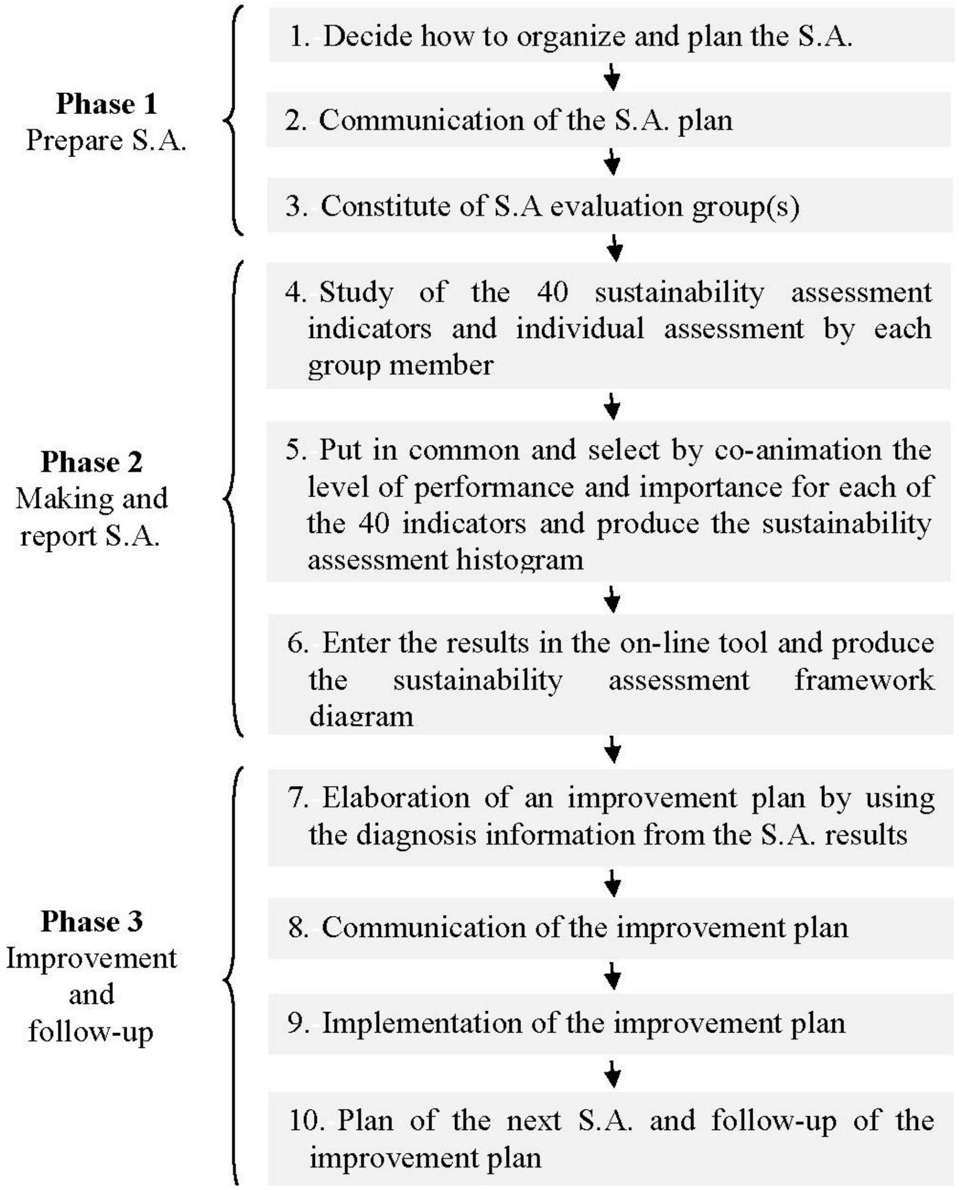


Figure 2.4. Self-assessment (S.A.) flowchart

A methodological approach for self-assessment in 3 phases and 10 steps is presented in figure 2.4 (Moldovan 2015a).

A pilot test implementation of the sustainability assessment framework and the self assessment tool have been performed at the VET provider Continuous Education Centre (CEC) from "Petru Maior" University, over one week by a group of five staff members with different jobs: executive, training coordinator in charge of relations with companies, administrative assistant, quality assurance, and trainer. The result of the evaluation for the performance indicators, the couple values (performance.importance), in the environmental area are presented in figure 2.5. The minimum value of 1 is for "Non-renewable energy consumption" performance indicator, while the maximum value achieved is 4 (four indicators).

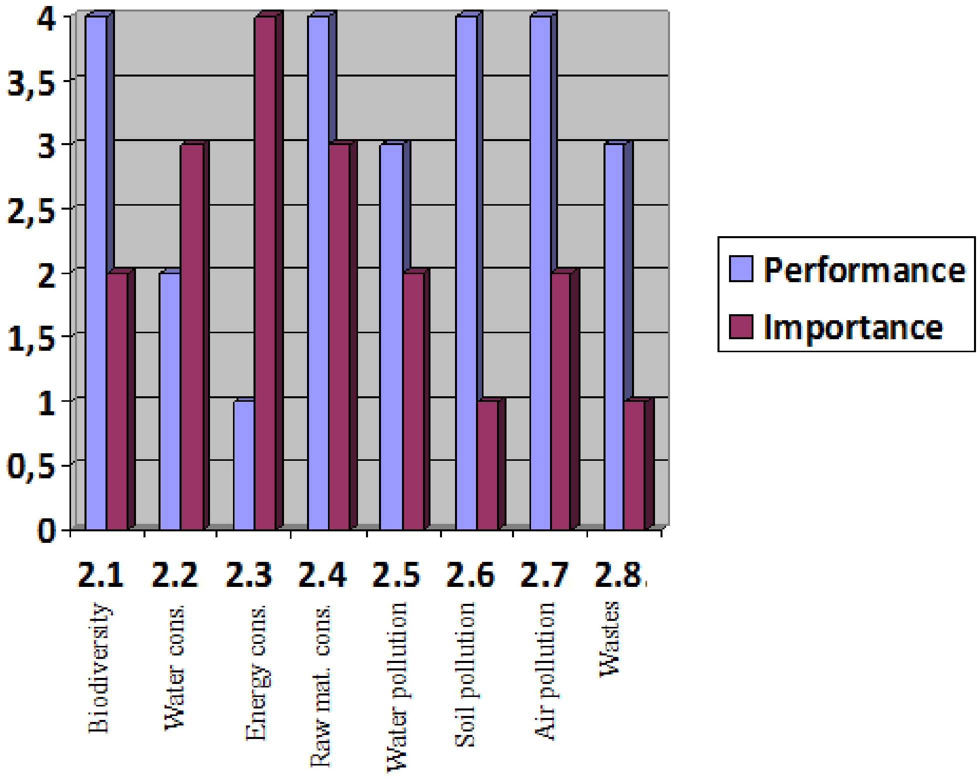


Figure 2.5. Sustainability assessment framework histogram for the environmental area

The result is transposed in the sustainability assessment framework diagram, which for environmental area is presented in figure 2.6. It is a useful "performance *vs.* importance" Eisenhower matrix that helps design activities for improvement (Moldovan 2015a).

At the end of the self-assessment and diagnosis, the information is used in a common meeting for an internal action plan proposal.

The self-assessment exercise reveals insufficient compliance with environmental duties imposed on the organization. For the restriction of negative influences on sustainable development assurance, some relevant measures are adopted, often joined with labeling activities that have as a task to inform, mobilize, and regulate an activity to limit or eliminate its influences (Rusko et al., 2014).

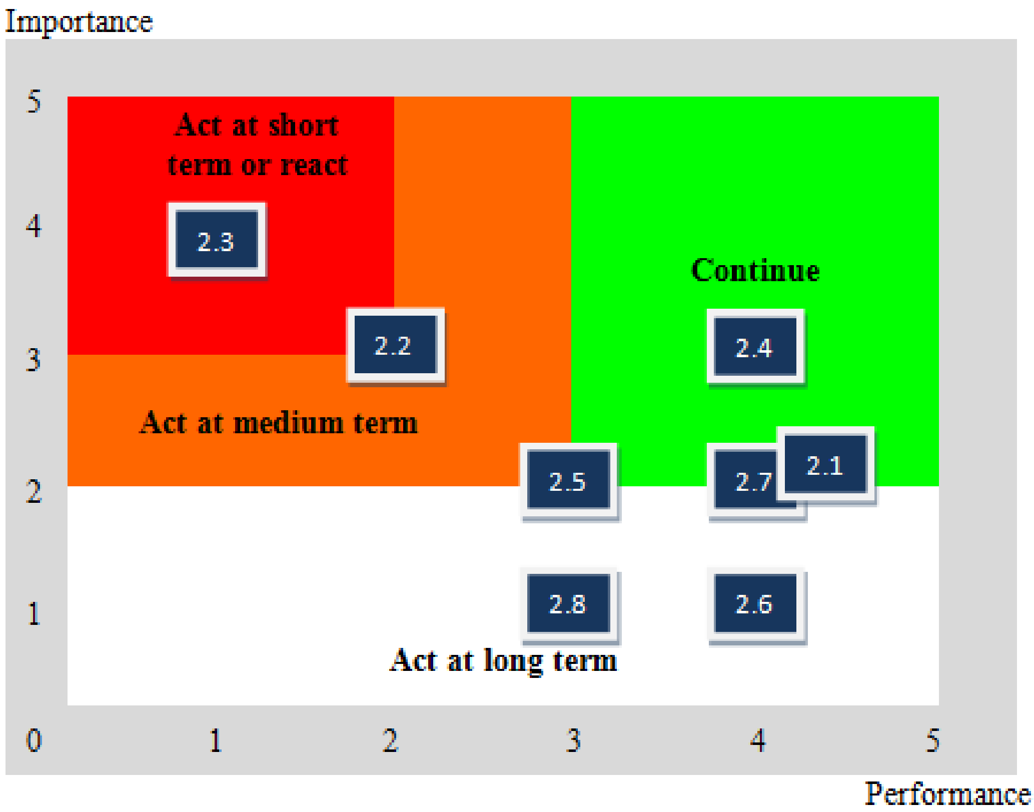


Figure 2.6. Sustainability assessment framework diagram for the environmental area

The water consumption is managed and the organization work to gradually decrease the consumption. Optimization is performed by developing awareness of staff members and training courses participations.

In regards to energy consumption, the organization works to gradually decrease the consumption of electricity, heat and cold through the use of energy efficient equipment: A-rated alternative fluorescent lamps and compact fluorescent H; motion detectors that control lighting in rooms/spaces rarely used, or “turn off the lights” signs; timers that control electrical equipment or electrical outlets; A-labeled appliances; timer control of ventilation, the heating system is based on heat pump; and low-flush taps in the sink; and a Decalogue for energy saving.

In regards to consumption of raw materials, the main issue is reduction of paper consumption thanks to immaterialized learning supports. The delivery of materials in electronic rather than paper-based format is encouraged, but also recycling of printed paper.

In regards to water pollution, the chemicals are envisaged by reduction in the use of environmentally hazardous products: the chemicals risk phases are written down in plain text on a chemical list; good laboratory safety and chemical management is ensured in order to reduce the risk of injury on the environment and human health; the partner cleaning and laundry firms have outlined their environmental policy and are committed to reporting their cleaning chemicals; and non-chemical cleaning methods are used where it is possible.

In regards to soil management and pollution, the use of products that respect the environment and have local origin is promoted and encouraged. By placing relevant environmental requirements on suppliers to reduce their environmental impact and encourage suppliers to improve the environment, CEC will promise to buy the products that cause as little environmental damage as possible, the eco-labels. The European Ecolabel (eco-label printing and copying paper and envelopes) is primarily looked for and can be trusted, the suppliers are informed about CEC environmental requirements: written environmental policy and a diploma or certification about the products. Rechargeable small batteries are used.

The goal is to buy organic and fair trade coffee and tea for staff, organic and fair trade or locally produced and cultivated fruit, food and beverages to staff and clients at meetings and events of various kinds.

In the advertising and marketing process, all externally produced printed materials, etc. are eco-label, which means an environmentally friendly printing process.

In regards to air pollution and greenhouse gas, the efforts are concentrated on transport related issues. Contacts, human encounters and communication are key elements of CEC business. Meetings can be implemented in different ways. Active selection of environmentally friendly transport and uptake IT as a supplement to travel can reduce the environmental impact. CEC promotes holistic travel and transport, including avoiding unnecessary travel by making use of various remote meeting systems: internet conference, Skype meeting, video laboratory meetings with codecs, *etc.*; leverage of own technology expertise to develop new ways of “remote working”; promoting and development of car-sharing practices; and increasing information regarding public transports; greater use of trains and buses instead of cars and planes.

In regards to waste, a “selective dustbin” is installed on the premises and the organization will work to increase the share of waste sorted at the source. The waste management and recycling is demonstrated by: discussion with suppliers for the opportunity to take back products that are suitable for recycling when they are used (toner cassettes to copiers printers and fax machines); reuse of boxes, packaging materials, printing and copying materials; recycling furniture/fixtures or giving away furniture, for example second hand; avoiding using disposables and reusable packaging and refill when it is possible; not using disposable crockery; not using small packets of milk, butter, *etc.*; and the garbage bags are made of recycled paper/plastic or composted materials source.

Training modules on environmental issues and sustainability are related to staff training. Staff and students/trainees should know that the organization publicly encourages concrete environmental measures that contribute to a more sustainable development. CEC ambitions in the field of environment must be understood and relevant to employees, students, participants and external partners.

The real internal action plan for sustainable development deduced in the experimental phase is the basis of the CEC environmental policy, which has two strands. The first one is related to the external work aimed at the general public who freely and voluntarily seeks knowledge. The second one relates to the internal work, addressing all employees and electing officials in their daily work.

With respect to the above, CEC aims are to promote sustainable environmental development and aim for greater environmental awareness, both internally and externally, by taking into account an action plan for the environment. It is specified at the organizational level but also in the departments’ annual action plans in the form of concrete actions, as presented in this paragraph.

1.2.4. Results and discussion

The pilot test implementation of the new sustainability assessment framework aimed to validate the methodology in action and to help prospective users.

The overall results of the self-evaluation activities at CEC are positive. In some cases there were intensive discussions and debates for some subcategories, but the sustainability assessment framework was able to create a positive atmosphere for quality discussions within the institution. In particular, whether performance indicators in some cases were put too generally was discussed. An additional glossary of definitions could be included to explain expressions and distinguish exact content of performance indicators.

The discovery of some working aspects of the organization that have never been approached before is one of the positive results. Furthermore, the decision to involve representatives of different jobs that can be found in the organization had a positive effect.

Sustainability assessment experience has been an opportunity “to change glasses”, at different levels of responsibility, from one monocular lens to a three-dimensional one: not just economic but environmental and social lenses. In all cases, it was clear that in order to improve sustainability assessment approach, we need a strong commitment from the director/manager of the institution and a “project manager” who lead the process in a working group.

The report showed various main important aspects: time is crucial, the need for planning and scheduling of activities; the team leader is very important; the collaboration in the organization enhances effectiveness and teamwork; and the importance of giving information and explanations to the target group to increase motivation for active participation.

The experience was an opportunity to improve: sustainability culture inside the organization, giving information, to have a better approach reducing energy in the building, managing paper/waste/recycling: it was a great opportunity to have a guide to face this problems and to have a practical approach for these; the culture of process; the culture of planning, in terms of defining/redefining resources and time; the culture of prevention, working adapting actions and scheduling prevention programs; the culture of working together and making decisions; the ability to invent new ways to do old or traditional duties/facilities according to the three-dimensional perspective of a sustainability assessment framework.

1.2.5. Conclusion

A new and innovative sustainability assessment framework for self-assessment of VET organizations institutional sustainability has been developed (Moldovan 2015a). The assessment is made in five areas: institutional capacity, environmental, economic, social, and training provision, by employing a total of 40 performance indicators. These are evaluated in a new and original format of a self-assessment tool for the “couple values” of performance and importance on scales from 1 to 5. The five rankings for performance are: awareness, measures, action, innovation and excellence.

The framework is different from others by its objective, which consists in impact determining and improvement on environmental, economic, social and quality of training system.

The assessment tool supports training providers in order to: (a) check the level of performance for each area within the framework; (b) identify improvement possibilities for all categories; and (c) make decisions and set priorities in relation to environment, activities and business projects.

With this support, another innovative aspect of the research is the development of a strategy based on performance indicators that integrates sustainable development. I have evidenced that sustainable development strategy has a central role in the competitive strategy of the organization and I believe that it determines the other competitive strategies of the VET provider.

In regards to the methodological approach of the new sustainability assessment framework, the multitude of indicators employed requires an assessment group of committed experts to accomplish the assessment.

The quality of the assessment depends on the availability of data at the assessed institution.

In optimal conditions, the results of the assessment have to be objective and precision may be an issue that facilitates the progress of evaluations.

Implementation of the new sustainability assessment framework is performed as a novel self-assessment tool, which in its application bridges theory and practice. Detailed application guidelines for the self-assessment tool are provided, which include a methodological approach flow chart for self-assessment, organized in three phases and 10 steps, that, together with the exact results presented from a case study carried out at CEC Tirgu-Mures, validate the methodology (Moldovan 2015a).

The results are used to establish a sustainability baseline, to identify possibilities for improvement, and to prioritize the implementation.

Furthermore, the results can be used to develop sustainability policies and action plans, establish performance guidelines and improve internal sustainability performance of institutions. This will have direct relevance to improved economic and social performance, institutional effectiveness and an enhanced image of the organization. Graduates of such institutions will naturally be sustainability driven.

1.3._INNOVATIVE TOOLS AND MODELS FOR ELEARNING IN ROMANIA

1.3.1._The scope of the pilot project Move-IT

The new information and communication technologies have an important impact on the society, obviously modifying it. The scientific, technologic and economic evolution lays its mark at all educational levels, being necessary new technologies of learning. People interested in the educational system must have permanent access to the scientific and technological information provided by institutional interconnection (universities, companies, administration) in an information network (Zhang and Nunamaker 2003). Long-distance learning represents a modern way of learning, characterized by high flexibility, meant to provide the students with superior accessibility and applicability of the traditional learning methods used in the educational institutions (Farazmand, 2005). The new form of computer based knowledge involves a different approach to didactics, through the learning object practice, and, in particular, a careful reflection on technological equipment intended to: 1) assure accessibility to every user, 2) grant for the fruition of a useful product to all recipients, 3) assure a perfect integration between the knowledge content and the different devices employed (Penna et al., 2006).

One prototype of collaborative virtual geographic education environment has been developed using Java and Java 3D. It provides one immersive 3-dimensional environment and many virtual teaching methods including virtual geographic environment, virtual geographic process. Teachers and learners can discuss with each other in a social way by combination virtualization and reality (Li et al., 2007).

How to design learning environments leading to learning, thinking, collaboration and regulation skills which can be applied to transferable, knowledge oriented learning outcomes is still controversial (Zitter et al., 2010).

Established roles, resources and locations of learning are extended, changed and replaced in current vocational training education. The rapidly changing knowledge-based economy puts pressure on vocational training education to extend, change and replace established roles, resources and locations of learning and deliver flexible, employable, high qualified professionals (Zitter et al., 2010). The massification and diversification of the higher education system, economic globalization, novel modes of knowledge production, new professional requirements and the establishment of new vocational higher education system in many countries have challenged higher education to develop new forms of collaboration with working life. They state that learning environments in which learners work collaboratively on actual (or simulated) real-life problems are good examples of forms of collaboration between education and working life (Tynjälä et al., 2003). There is a need to develop teaching strategies and approaches that can be used by technology and vocational education teachers to achieve effective classroom practices (Pavlova, 2009).

In-company training is indeed one of the critical skills and key constraints to economic growth and development in Central and Western Romania, and a range of new international standards developed support immediate needs for skills development in industrial applications and practices.

In the pilot project Move-IT - "Innovative Tools and Models for Vocational Education and Training in Central and Western Romania" (***Project Move-IT) I have developed and managed this challenging problem have tried to solve by disseminating and deploying successful state of the art large-scale skills upgrading solutions from Norway to Romania (Moldovan, 2010a). This includes developing a technical infrastructure that supports the application of quality assurance services for institutions dealing with vocational training. Thus, it promotes the establishment and development of quality control culture that targets the technical infrastructure, the pedagogical methods, the teaching quality management, and the administrative level in industrial training. Teachers may from host institution jointly guide the student by use of video conferencing through the training process (Moldovan, 2012b).

1.3.2. The vocational training network

A high definition video network is constructed in the Central and Western parts of Romania, and organizations in 4 different towns can utilize the infrastructure to provide vocational education and training with the support of the European EEA Program which financed the Move-IT project I have conducted (*** Project Move-IT). It is an innovative project that developed and established a regional network of vocational education and training centres in Central and Western parts of Romania (Moldovan, 2010b), in which “Petru Maior” University of Târgu-Mures (UPM), is the hub in the video network. The results have improved the inter-institutional partnership between existing vocational training centres and UPM in the Targu-Mures region in Central Romania, by stimulating and improving the quality, accessibility and supply of vocational education and training services for further development of human resources (Moldovan, 2010a).

The vocational schools are located in the towns Oradea (Agora University), Alba Iulia (1 Decembrie 1918 University) and Sighisoara (Mircea Eliade National College) as shown in figure 3.1. The distances from the hub (“Petru Maior” University) and to the sites are from 60 to 225 km.

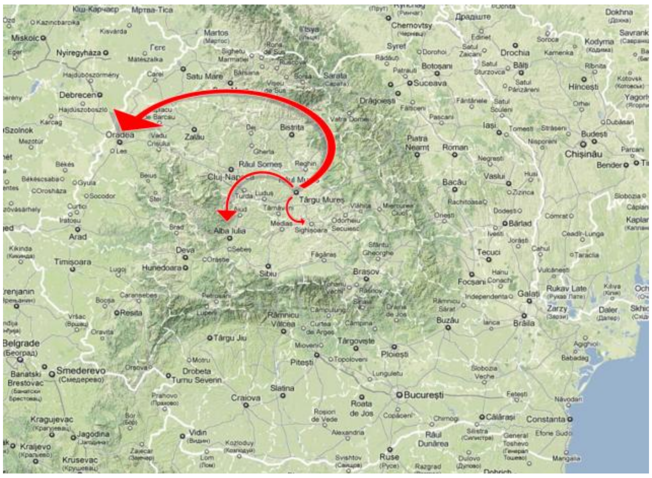


Figure 3.1. Geographical position of the institutions participating in the Move-IT project

The video network is containing the following main components:

- A high standard dedicated video room at UPM, for delivery and distribution of vocational training to external partner sites by use of two-way videoconferencing and digital blackboards,
- Video rooms at 3 different vocational schools in the region that is dedicated to receiving training from UPM or another organization that utilizes video in training,
- Construction of one digital classroom, as well as two state of the art computer laboratories at UPM,
- The state of the art digital classroom infrastructure, include transfer of required knowledge transfer and the practical organization of training delivery,
- Design and establishment of a state of the art vocational education and training infrastructure based up on best video practices from Scandinavia,
- Development and deployment of instructor training through a dedicated instructor training program,
- Delivery of vocational training courses that may utilize blended learning methods mixing (i) on-site training, (ii) inclusion of learning management systems, (iii) deployment of streaming video solutions, and (iv) effective use of videoconferencing, into distance learning environments,
- Evaluation of training methods and technical solutions for easy transfer of results and achievements,

– Dissemination of project results for effective transfer of knowhow to a pan European audience.

1.3.3. Methodology

The methodology consists in selecting technical solutions that are adapted to available bandwidth, and establish training solutions that are accommodated to the telecommunication costs. The training solutions identify good practises that underpin the capacity for innovation, as well as expansion of capacity, in vocational training. The participating training organisations and industrial companies may utilize the new training environment to offer and receive a broad range of specialized courses.

The network integrates development and professional planning and testing of the ICT- and video infrastructure, in combination with instructor training and pilot training offered by the instructors. The dedicated ICT and video infrastructure, services and training solutions improve the learning environment by enabling teaching of quality management through: i) activation of prior experiences, ii) demonstration of skills, iii) application of skills, and iv) inclusion of skills into real-world descriptions. Also, it provides the management of vocational training in industry with Quality Assurance tools, such that VET schools, instructors, students or professionals select and obtain the most time and cost-efficient training methods and processes.

UPM act as a hub in a “good circle” towards a set of vocational schools acting as regional study - and competence centres in Central and Western Romania. Courses are available at upper secondary and tertiary vocational education level. The network provides modern teaching methods in the form of net based follow-up, videoconferencing, recording of lectures and digital materials.

The network emphasis ICT-supported working methods, such as self study, teaching content communicated via Internet portals and videoconferencing, partly supported with recorded lecture material. This gives participants access to tutorial support when required, and enables them to have as many repetitions as they wish or need. For instance, the recording of specially-adapted lectures, with no participants present, appears highly effective and useful. This is obtained by using advanced equipment which is still simple for the teacher to use.

I can illustrate the process with the following example: Industry approaches UPM and/or the local school with its competence development needs. If the school cannot exactly meet these requirements through its existing courses, a training programme will be tailor made. The development costs are met by the network of schools and UPM. The course is conducted and industry pays a lower price which still leaves the teachers and UPM with an operating profit. Part of this surplus is then returned to the vocational schools in the form of new technical equipment, funding for continuing education and competence development for the teachers, study grants, etc. Enhanced teaching competence and modern technical equipment in the school also bring increased benefit to the regular day students. In brief, we find ourselves in a “good circle”.

1.3.4. Implementation

The implementation of the infrastructure which creates the network has been realised in a period of 2 years to (Moldovan, 2011b):

a) Deploy state of the art tools and services that provide a new infrastructure and improve existing training materials and study paths, in combination with extension of new pedagogical methodologies;
b) Establish a sound and vivid training system that brings teachers, regional schools and UPM in closer association with local businesses, such that they become the preferred provider of vocational education;
c) Offer easy access to the best cost-efficient training process solutions that may significantly expand the regional capacity for vocational training, by establishing and organising a training solution that in an easy way stimulates teachers, the vocational schools and UPM to provide new courses to the market;
d) Maintain good practices and experiences from Sør-Trøndelag University College in Trondheim Norway partner in the project, in combination with utilization of the latest R&D achievements from international EU-founded projects.

Implementations of the network design consist in:

1) Modernize the existing ICT infrastructure at UPM by developing 2 state of the art computer technology labs, 1 digital classroom, and 1 video laboratory and instalment of necessary ICT servers;
2) Install modern technical ICT and video equipment at 3 regional vocational schools that will act as regional study - and competence centres. The equipment may be used by their regular day students, local vocational training of staff in industrial companies, and transfer and/or export of training within the network consisting of UPM, the vocational schools and industry;
3) Deliver instructor training targeting use of technology and new pedagogical methods;
4) Enhance training delivery through regional seminars at the vocational schools;
5) Deliver vocational training at each of the 3 vocational schools sites;
6) Develop a “good circle” for tailor made training programmes providing vivid and cost efficient distribution of income and expenditure between the teachers, the regional schools, and UPM;
7) Improve and simplify administration of training activities by extending existing Learning Management Solutions for effective deliverance of educational material from teachers to students.

1.3.5. Design of the video infrastructure

The Video room at UPM has three usage scenarios with the following functionality (Moldovan, 2012c):

- Transmission of courses by internet to three external locations; to retrieve images using two high definition cameras, each positioned optimally for the position in which the user is located, and transmitted in external locations, which are displayed on control screens, simultaneously are transmitted images taken from the computer (also by using interactive board connected to it), notebook PC, document camera, DVD / BD player or other auxiliary equipment;
- Production of training material for distribution on offline web platform by acquiring images using high definition video camera and training materials from PC, document camera, etc., and preparing the final form of dissemination material using graphics studio editing stations;

• Video conferencing sessions with three other foreign locations simultaneously.

In figures 3.2 and 3.3 the furniture placement in the video room and editing room is presented (Moldovan, 2012b).

Equipment used in the video room is: high-definition video cameras, display screens in two positions in the room, PC with monitor, interactive board connected to PC, document camera, DVD / BD player with the included audio system, sound system microphones and fixed wireless placed in different areas of the video room.

Equipment used to run the integrated system is:

– video codec;
– control system for easier use of equipment;
– automatic control system used with detection devices;
– video converters, scaled, amplifier / distributor;
– array audio / video sources to connect audio and video conferencing studio video.

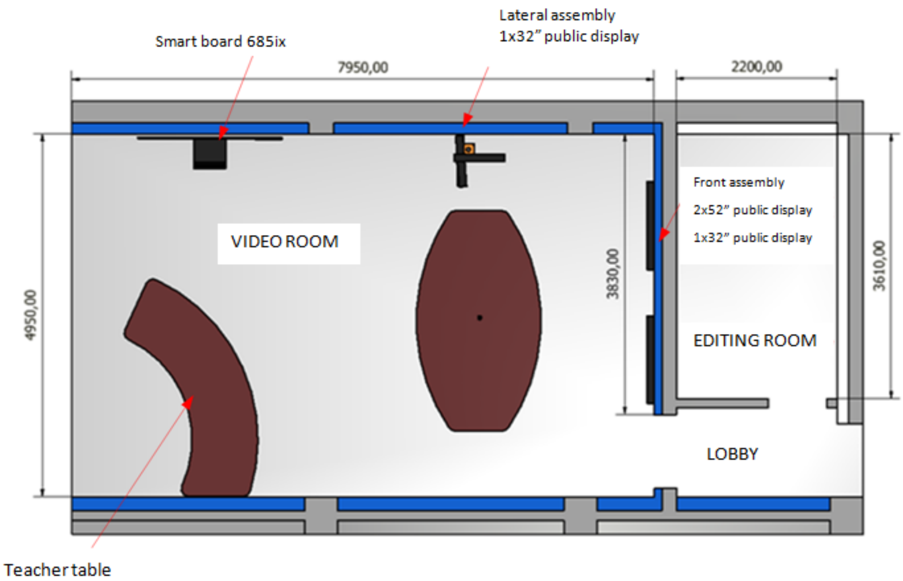


Figure 3.2. Furniture placement in the video room and editing room (2D view)

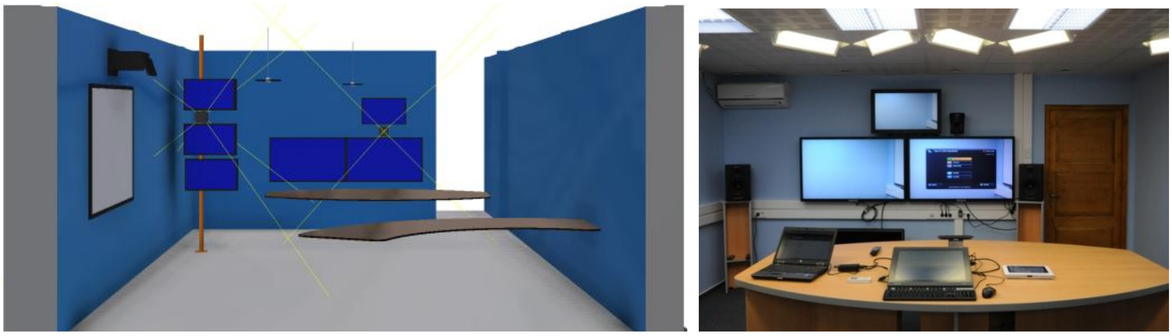


Figure 3.3. Furniture placement in the video room and editing room
(3D view and picture)

The studio space dedicated to video conferencing is calculated according to (Moldovan, 2012b):

- optimal range of employment in the visual field of high-definition camera of the participants are sitting at the table (calculated according to the maximum angle of vision of HD 55.2 degrees, opening the front table meetings), the viewing

angle participants to maintain contact with the apparent HD camcorder even if you follow the images on screens (Fig. 3.4);
- 55.20 degrees – the maximum visibility angle camera;
- 2700-3000 mm - required table length for video conference;
- 2600 mm - minimum distance required between camera and video participants.

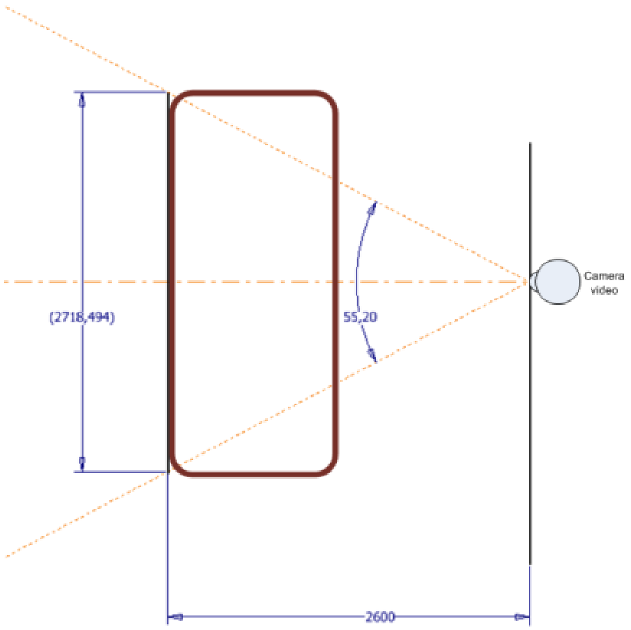


Figure 3.4. The width of the visual field to determine the length of the table

In a broadcast by video conference (Moldovan, 2011a), is impossible to have a 100% direct visual contact between the two participants in different locations (Fig. 3.5), therefore, is indicated to achieve a maximum angle α = 10 °, adjustable depending on the distance between camera and eyes on the screen play participant and the distance between viewer and screen (Fig. 3.6).

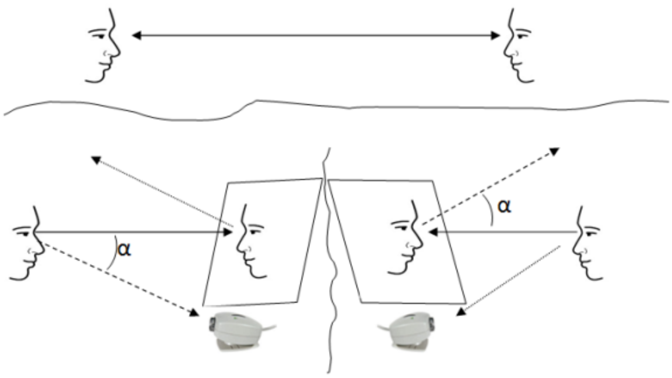


Figure 3.5. Direct eye contact and apparently directly

In calculating optimum distance between the participant and the video camera we have considered:
- 450 mm - the distance calculated between the centre of the screen (52") and video conference room;
- 1300 mm - the height of the participant;

- 2600 mm – resulting distance between the camera and the nearest video conferencing participant in maintaining an apparent contact angle below 10 °.

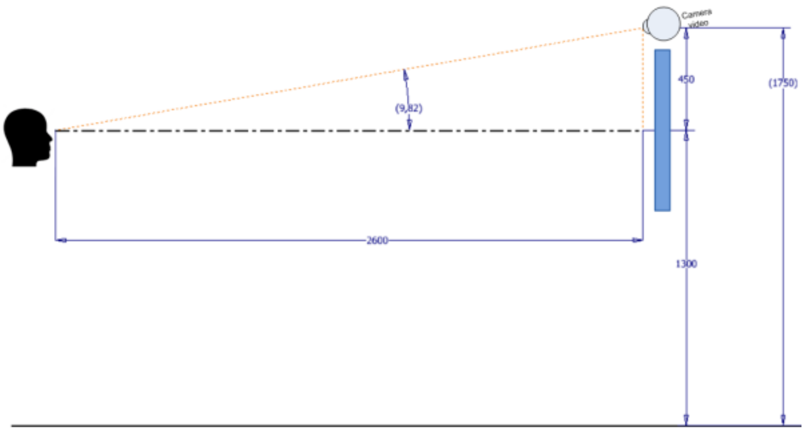


Figure 3.6. Calculating optimum distance between the participant and the video camera

In dimensioning videoconferencing room also takes into account the following:
- meeting table dimensions;
- teacher table dimensions;
- additional space for traffic.

The studio design has been conducted in the following stages: acoustic design and acoustics measurement; cover windows; system walls, floors and ceilings built within the current structure.

Lighting (Fig. 3.7) was designed and executed so that it meets the following requirements: - CCT (Correlated Colour Temperature) for all sources of light in the camera is 3200 3500K range. CRI (Colour Rendering Index) is at least 82 (the value of CCT of 3200K), the maximum level of illumination gives even coverage across the room, over 550 lux - oriented light directly to the person must have a value of 75 lux measured in an 45^{o} angle (Moldovan, 2011b).

Values to be achieved in terms of lighting levels are as follows:
- the participants, an average of between 200-500 lux, vertical illumination of the face (take the value 450 lux);
- the walls, an average of between 200-400 lux, lighting by 40% -60% level of diffuse reflection (300 lux at the height of the target to which the participants eyes are situated);
- ceiling light level should not exceed 850 cd/m2 at any point of the surface, but not more than 15 cd/m2;
- at the smart board surfaces, the value of residual lighting (spill light) is less than 50 lux, and the screens are less than 200 lux.

All lighting sources are no blinking effect (flicker-free) by using frequency electronic ballast sites; with all the lights turned on, there is a higher contrast ratio of 3:1 between the brightest and darkest area of the room and not more than 1.5 to 1 a contrast between the lighting on the faces of two persons side by side.

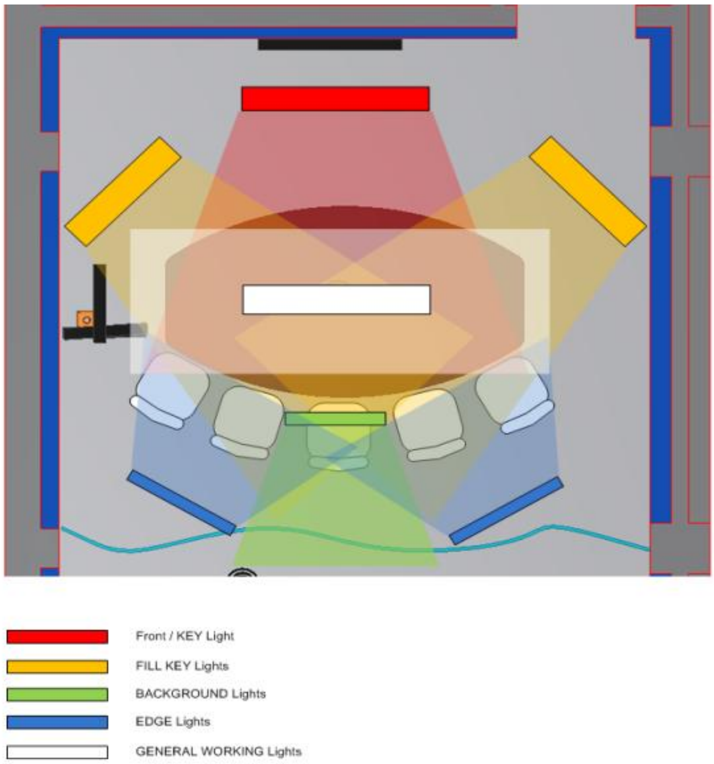


Figure 3.7. Location of lights - the whole scheme

Lighting system is based on individual control of five areas with the option of continuous dimming (not stepped). All areas are controlled from the control system. Also, there is the possibility of on / off manually (without control system) of general lights.

Video room camera lights specifications are the following:

- Front light (KEY LIGHT) - the main light source facing downward at an angle of 30^o.. 45^o, directly to the person;
- Fill (FILL KEY LIGHTS) – oriented light sources, also by the person under a lower angle, or a wider angle of dispersion of light;
- Lights outline (EDGE HAIRLIGHTS) – light source located behind /above the person, face down at the subject in order to separate the subject from the background;
- back lighting (BACKGROUND LIGHTS) - source / sources of light located above or behind the person, face down to the background to achieve uniformity of the background;
- general lighting to be used in normal working conditions, such as local meetings, presentations, etc. General lighting sources produce a diffused light if these are suspended at some distance from the ceiling. These have a distribution of 60% light projected toward the ceiling (to avoid reflections / lighting displays and smart board residual).

Light sources can adjust the inclination angle, spin respectively, and the distance of fixing to the ceiling. All light sources are individually controlled on / off and dimming, with the possibility of grouping (e.g. control of all lights FILL KEY type in a given scenario).

The light positioning rule is the following: the horizontal distance between the light source and the person should be about (1.2) x (distance from the person at the ceiling). In order to reduce the need for light sources used for each working position, the light sources can be placed so that, by turning / tilting them to be able to use the same sources in different usage scenarios.

Because of the size and construction of the room and the large number of equipment located therein, has been fitted with a ventilation system intake fan located in the server room and free outlet across the room (Fig. 3.8) (Moldovan, 2011b).

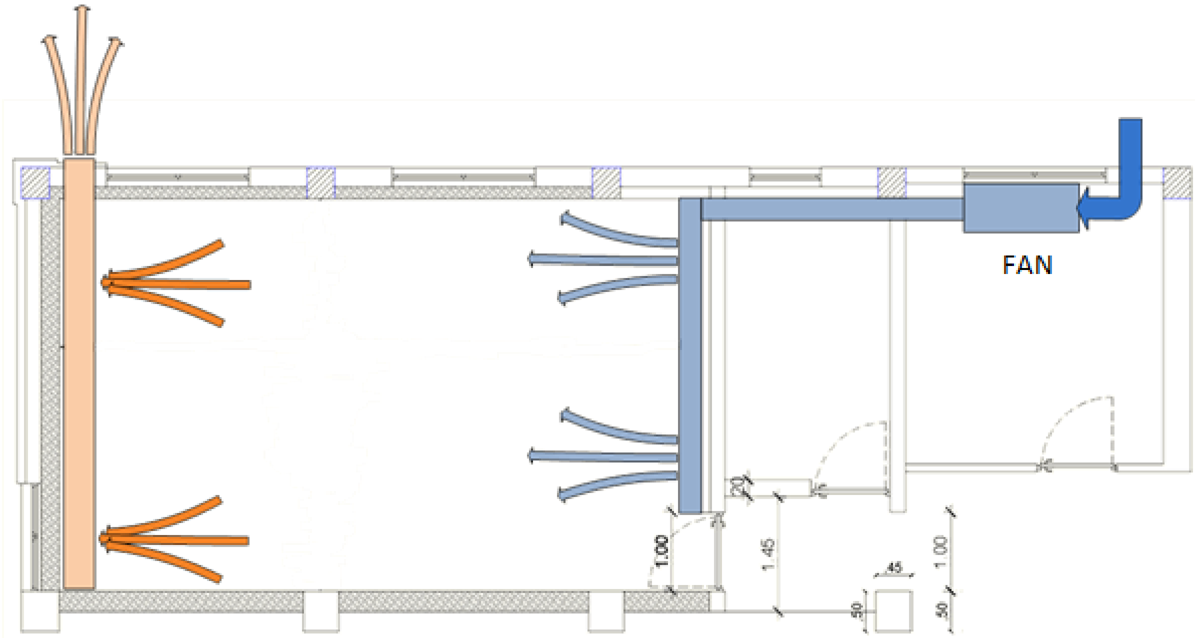


Figure 3.8. The ventilation system of the camera

Editing equipment installed in the studio are workstations with two monitors, video capture cards and audio production, software, audio: active studio monitors, microphone, headphone type monitors, graphics tablet, laser colour printer, leverage optical media; indoor air-conditioning unit.

1.3.6. Blended learning

Instructional development in higher education has become an important topic in recent years. Instructional development can be described as any initiative specifically planned to enhance course design so that student learning is supported (Taylor and Rege Colet, 2009). Contemporary youth makes intensive use of interactive media, although young people appear to have intermediate media skills (Van den Beemt et al., 2011). Although student-centred learning environments stimulate students towards the use of deeper approaches to learning (Baeten et al., 2010).

Successful training courses mediated from digital classrooms, contain some common characteristics that are independent of the various types of courses. This includes constraints on the design of the infrastructure, e.g. location and orientation of cameras, screens, projectors, selection of cables, various additional equipment, etc. It also involves quality assurance systems offering train-the-trainer courses to teachers, tutors, and administrators, as well as information services describing the role that the ultimate end-user like students and learners have during a training session. The last point is important since video mediated training will always have some technical limitations that make it impossible to compete with the quality offered by ordinary classroom based training. It may, however, if operated properly be very close by; whereby it offers a very good alternative if we include the costs of travelling and lost working time into the economical calculations (Stav et al., 2006).

It is usually the blended approach that works best, i.e. a mixture of some traditional teaching, e-learning and video communication mediated solutions. Blended learning training methods help promoting reduced training related costs. This includes travel expenses and time away from work. Time away from work includes the disruption to the work schedule pre and after training related travel. It also includes the disruption to the lives of professionals as it may take a couple of days to get into the normal work rhythm. Finally, it promotes training solution to take place intra- and inter-company.

The validation of the infrastructure built at UPM is done by delivering a number of vocational educations and training courses. This enables UPM and the vocational schools to offer and validate state of the art vocational education and e-learning adapted training to staff from industry in Central and Western parts of Romania. The developed blended learning solutions constitute of the following training elements (Moldovan, 2012c):

- Traditional classroom structured instruction with face-to-face training where the trainer(s) and the students meet when the course starts. Digital blackboards are often used;
- Self-paced learning through Learning Management Systems (LMS);
- Hands-on practical training and collaborative laboratory work;
- Inclusion of video streaming and videoconferencing services that offer high quality multipoint two-way real time communication to groups of students. The principal steps were followed for setting up of a web educational video-clips exhibition.

1.3.7. Design strategies for distance learning program in quality management

“Petru Maior” University has adopted an interactive distance learning model that is a natural extension of the traditional face to face learning environment (Moldovan, 2002a). This model combines both asynchronous and synchronous learning and connects students, teachers and educational content in online learning communities (Moldovan, 2002b).

In general, about 80% of a student's time is spent for study of online materials (that can be also read off line after unloading from internet) and about 20% in interactive, synchronous learning sessions with the teacher and other students. These percentages are of course flexible and the optimal allocation of time to synchronous and asynchronous components is a function of several variables including the nature of the course content, teachers personality, students participation etc.

The main drawback of distance learning courses is the lack of interaction. Starting in the early '80s, a number of researchers began to add asynchronous computer communications and synchronous interaction to traditional distance learning technologies (Lister et al., 1999). Unfortunately, these technologies were often extremely expensive and technically challenging to implement. While the majority of a student's time is spent in asynchronous activities, the synchronous portion of a distance learning course is crucially important.

The learning outcomes and student retention rates in purely asynchronous, based courses are often disappointing for all age groups, and especially for younger learners.

From this point of view, a design strategy for distance learning courses is to create the social construction of an interactive, face-to-face classroom and capture all the benefits of a hands-on learning environment. The main technology I have used to implement the synchronous portion of UPM distance learning courses are the Lotus LearningSpace Forum and Moodle software system for interactive distance learning (Moldovan, 2007a).

By definition, the asynchronous portion of our distance model is not coordinated in space or time so students are studying “on their own”. Teachers do not put structure to this learning, they only indicate to study module number in the following period of time of two weeks. The asynchronous portion of the distance learning technology looks more like the traditional classroom meeting.

I have revisited some important concepts of learning (Kolb, 1994), (Parker 1996) and the learning cycle used at Rensallaer Polytechnic Institute USA (Lister et al., 1999), than I have adopted a design strategy for the distance learning program (Moldovan, 2003a) by developing the Interactive Distributed Learning (IDL) Cycle that is applicable to any asynchronous type of course.

Figure 3.9 shows the cyclic nature of the design, indicating that all elements should be considered for each and every learning experience, regardless of length (Moldovan, 2002a,b).

- Step 1: The Interactive Distance Learning (IDL) Cycle starts with an introduction of the objectives and a statement of the necessary bibliographic material for the course module. It tries to “humanize” the learning environment by making the student feel a part of a learning community.
- Step 2: Following the motivational introduction, students are exposed to a concrete example (Concrete Experience CE) of what they are about to study.
- Step 3: Students are then asked to think about this experience (Reflective Observation RO) and share those thoughts with other students. This is all done asynchronously.
- Step 4: Abstract Conceptualization (AC) presents principles or theories and requires feedback on performance.
- Step 5: Active Experimentation (AE) is an activity that requires the student to go beyond regurgitating the content presented in Step 4.
- Step 6: The student is prepared to transfer this new knowledge to future learning experiences after Evaluation.

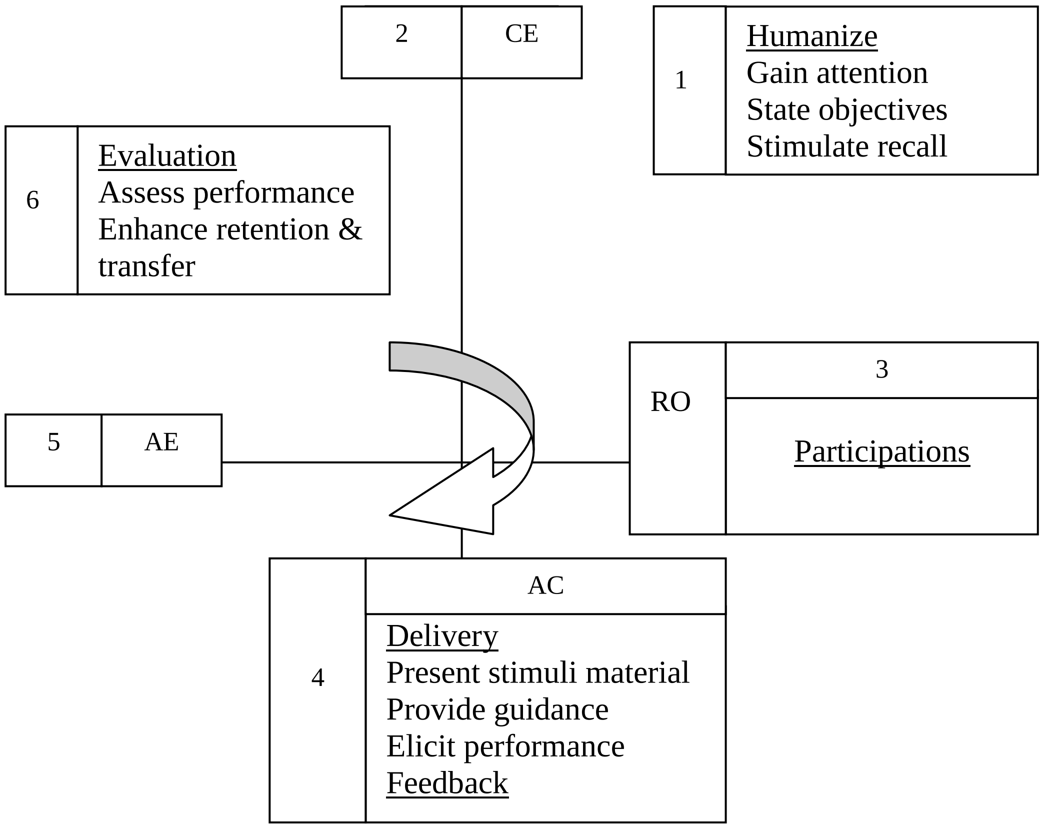


Figure 3.9. Interactive distributed learning cycle

This Cycle serves as a template for the asynchronous learning experience. Teachers can implement this cycle in any number of ways, depending on their specificity.

The learning modules lack personality, so it needs to be humanized. Among other things, we need to motivate students, orientate them and give them direction. Students seldom read a lot of text on the web. Hence, we need something more than text to add this personality.

For this purpose I have used a second window with streaming video just near the text window. It gives the illusion of the instructor talking directly to the learner. The effect adds warmth to the learner's experience. Video streaming can be used at major transition points. Elsewhere in the module, streaming audio can be used to provide direction to the learner as well as support and encouragement.

As a conclusion I consider that there is no single way to implement the cycle and also, asynchronous learning is not for everyone. Much depends on the learner's maturity and motivation.

Considerations for selecting the media for delivering courses are the costs of the technology, time required to prepare materials, potential learning curve for students, and the human resources required (system engineer, administrator).

The media chosen to deliver distance courses has to be pedagogically effectual, accessible to students, receptive to different learning styles, and sensitive to the time and place limitations of the students.

In the implementation of the distance learning course I have looked at different issues regarding (Moldovan, 2006a):

- the support infrastructure that currently exists in the University for traditional courses;
- how we do transition from traditional courses to the distance learning courses;
- enhanced course development support, including instructional design support and the use of a team approach to course development;
- technical support for students;
- on-line student services: downloadable forms for admissions, on-line registration, 24 hour on-line access to individual student, registration.

As concluding remarks, the master education in Quality Management at "Petru Maior" University in Tîrgu-Mureş has been transformed by use of interactive distance learning, which is a natural extension of the traditional educational environment (regular courses face to face). The cyclic nature of the course design and all elements has been considered for each and every learning experience.

1.3.8. Sustainability of Move-IT project results

During the Move-IT project we have developed and deployed instructor training through a dedicated instructor training program. The objective was delivering a set of state-of-the-art training courses for trainers and teachers. This activity acknowledges that the key person to motivate the students is the teacher itself and this activity creates guidelines and examples on how to implement the new pedagogical training principles in education. These courses are of generic nature and have a cope of use far beyond vocational training itself.

During the project the following courses were delivered: a) Introduction to training delivery that utilize video communication and Learning Management Systems for organizing course material, in vocational education; b) Pedagogical methods and use of video in vocational education and training; c) Blended learning methods and optimisation of video in vocational education and training (Stav and Moldovan, 2010). The training consisted of a combination of theoretical and practical tasks in class, and that it is followed up by mentoring and guidance of the instructors/teacher by utilizing videoconferencing (Moldovan, 2012b). Videos of the training sessions are available on the project website (*** Project Move-IT).

Instructor training courses, which target use of video technology and new pedagogical methods in order to deliver vocational training at each of the 3 remote sites, supports the deployment. The new pedagogical methods utilize face-to-face training, e-learning solutions, digital blackboards and high quality video.

The project results are developed in 3 different economic areas (Moldovan, 2009a):

- UPM and the network of vocational schools have got access to modern ICT and video technologies, and knowledge associated to these technologies. This allows the organizations to exploit this knowledge in the forthcoming years for their own development of courses and services at different technical levels. Additionally, they are able to exploit new market opportunities both nationally as well as internationally.
- The know-how and technology obtained through the project has a generic nature and can be applied to all kind of vocational education. UPM may also exploit new business by transferring their obtained knowledge to other players in the educational sector in Romania or abroad, thus strengthening their income.

- The growing need for personnel with technical education within the industry in Romania creates a new opportunity for business services, which can be exploited by UPM. These services can be course development of general nature. The need for bespoke course development will increase drastically as the industry is becoming more specialized. The internationalization of industry in Romania fosters a differentiated course development in order to meet the needs. UPM's unique position with its international cooperation, quality assurance services, and knowledge make them to be the natural contact points for such activities.

1.3.9. Conclusion

A dedicated video network infrastructure is constructed in Central and Western parts of Romania during the period 2009-2011 with the support of Move-IT project I have developed and managed (Moldovan, 2011a). The teachers, students at campus, and external students participating through videoconferencing, should manage using a well-designed video network. Three levels of use must be adapted to the selected pedagogical methodologies:

- Inclusion of AV tools into ordinary training/education as they offer convenient services for recording and tracking of educational events that use digital blackboards;
- Videoconferencing based education where the digital classroom receives training from an external part;
- Videoconferencing adapted education where the digital classroom transmits the training to multiple endpoints.

The educational framework may be used in different training environments and skills upgrading contexts. The training methodology has not been designed for a special delivery method. It is possible to use a highly structured and rigid structure, whereby the instructor may control and verify all the training steps of the student. The instructor must plan for a number of activities, and must make up a plan for how to add the theoretical elements as well as how to present and initiate cases and practical tasks into the course. The instructors may select among a number of educational resources, including selection of video elements or multimedia material that will be used for presentation of a problem or a case. Thus, the delivery of the educational content will as a consequence not be very dependent of the technological infrastructure like limitations in bandwidth and hardware.

1.4. VET COURSE DESIGN IN QUALITY MANAGEMENT

1.4.1. Quality design of VET courses

The Technical Working Group “Quality in Vocational Education and Training” of the European Commission has developed a Common Quality Assurance Framework (CQAF) for Vocational Education and Training (VET) aimed at supporting VET providers in the development, evaluation and improvement of Quality Assurance systems and practices throughout Europe (Visscher, 2009).

In Romania, the National Authority for Qualifications ANC (www.h) has developed three occupational standards in the field of quality assurance, so Vocational

Education and Training (VET) providers may accredit courses for three occupations: Manager of Quality Systems, Specialist in Quality Systems, and Auditor in Quality. Requirements of these standards are input elements for designing courses by VET providers.

The basic approach I have considered for designing VET courses in the project "Transfer of Innovative Training and Ubiques learning Solutions for quality professionals" (***Tit-us project) that I have managed, is the classic Deming PDCA cycle augmented with description of methodology. My approach for quality design of VET courses is to add to the normal Deming cycle PDCA an additional step, the methodology (Moldovan, 2013a). In fact, each activity in VET is a quality approach which ensures quality design of VET courses. It consists of a number of decisions made within the following five steps (Fig. 4.1): 1-(PLAN) to elaborate a purpose and a plan; 2-(DO) to implement the plan; 3-(CHECK) to assess and evaluate activities from the implementation step; 4-(ACT) to collect feedback and transmit to procedure for change; 5-to follow a certain methodology.

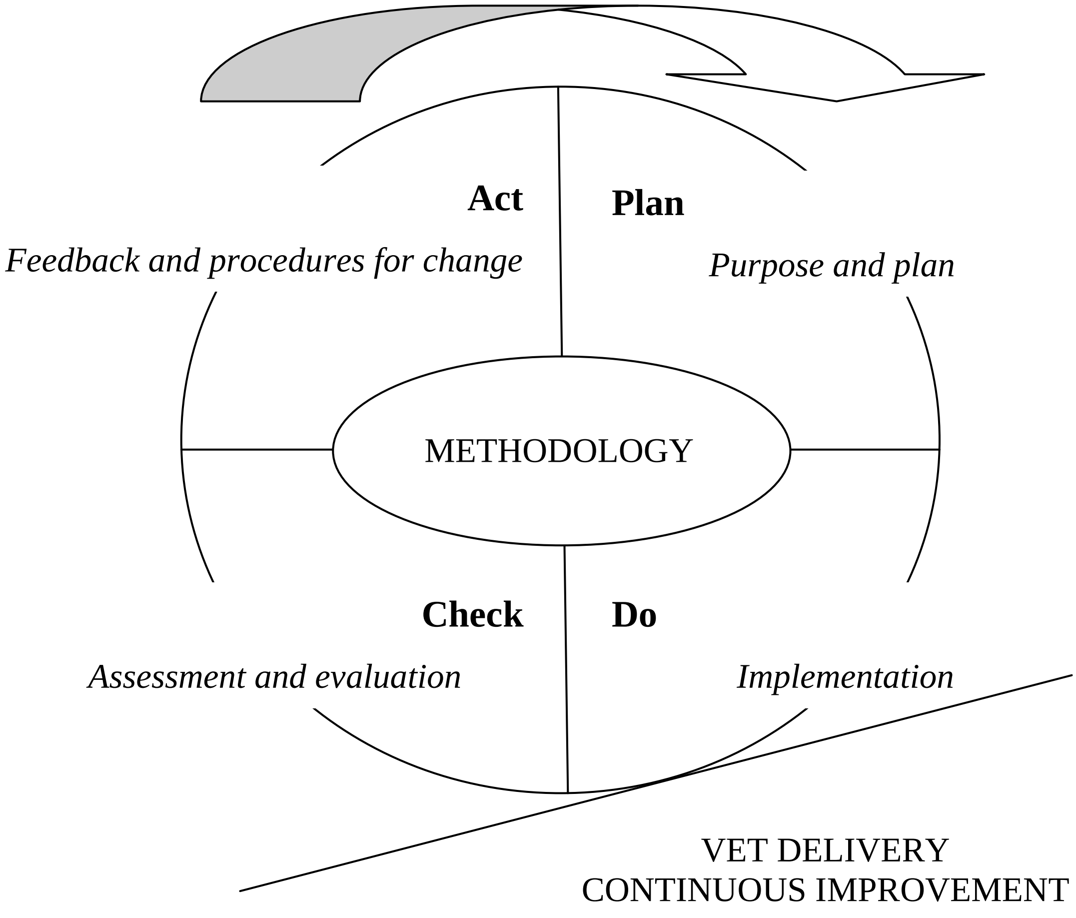


Figure 4.1. Quality circle in VET

The characterization of the five steps and particularization in the TIT-us project, (Moldovan, 2013a) consist in:

Step 1: (PLAN) Purpose and plan – characterised by clear purpose and consistent planning addressed to achieve the set aims. It consists in establishing objectives and processes required to deliver the desired results. In the VET schools there are a number of processes that are interrelated. As an example: the administrative routines for creating/starting new courses, improvement of existing curricula, the administrative routines for the trainees, maintenance and purchase of equipment, etc.

In order to have an effective planning process, there are some actions the VET provider has to solve: to establish the goals/objectives of the organisation in relation to VET; to provide goals/objectives clear and measurable; to include in the goals of the organisation the European VET goals and objectives; to provide a measurement/assessment method for the degree on which the organisation/system fulfil the goals/objectives; to have a procedure for the planning process within the quality approach in use.

In the Tit-us project planning consist in: the European and national goals or purposes for VET are known throughout society in each partner country; we have systematic procedures to identify future needs of participants in training; we have a number of minimum objectives/standards; results on specific indicators are systematically collected.

Step 2: (DO) Implementation - characterised by existence of an implementation plan; allocation of resources and clear responsibility. It consists in implementation of the process developed. This means that a number of processes must be implemented. Each process must have an owner/responsible entity that are clearly defined. The implementation requires that the organizational structure is clearly defined with responsibilities and authorities to carry out the actions that are needed.

In order to have an effective implementation process, there are some actions the VET provider has to solve: to establish how to implement a planned action; to describe the key principles in the procedure of the implementation process.

In the Tit-us project implementation consist in: legislation demands a quality approach at provider level; contribution of the social partners; work of the VET providers; giving the full responsibility for implementation to VET-providers; setting up a number of minimum criteria the providers have to meet; given a specific quality approach to be used by all providers; involving different stakeholders in the work.

Step 3: (CHECK) Assessment and evaluation - characterised by existence of a well-described assessment system and a systematic evaluation strategy, but also for use of a consistent and accountable methodology for both assessment and evaluation. Monitor and evaluate the implemented process by testing the results against the predetermined objectives. The processes and objectives can be monitored in a quantitative way. It also consequently means that the objectives must be clearly defined so they can be monitored. Objectives of a general nature cannot be used.

In order to have an effective assessment process, there are some actions the VET provider has to solve: to describe the procedure for assessing - the input, the processes, the output, the outcome results; to ensure that the assessment and evaluation process is relevant and systematic; to nominate stakeholders that participates in the assessment and evaluation process; to define roles the stakeholders play; to establish the assessment and evaluation frequency.

In the Tit-us project assessment and evaluation consist in: the process of assessing is using self-evaluation; external inspection; internal quality control; the actual results compared to the expected results; results of teaching and learning; staff-oriented results; key performance results; societal results; the systematic feedback is collected by asking the users; stakeholders participating in assessment are: managers, teachers, students, parents and the employers of the students; the stakeholders participate in a broad range of activities e.g.: initiatives, decisions, evaluation, certification, the link to the labour market; assessment is performed: after completing education, during the period when the students attend school.

Step 4: (ACT) Feedback and procedures for change - characterised by visible and documented connection between feedback mechanisms and planning process. Apply necessary actions for improvement if the results require changes.

In order to have an effective acting process, there are some actions the VET provider has to solve: to organise feedback and procedures for change in the organisation/system; to ensure systematic feedback; to make transparent the feedback on quality in VET; to ensure that the results of the assessment/evaluation are used; to relate the goals/objectives to the assessment and evaluation.

In the Tit-us project feedback and procedures for change consist in: feedback and the procedures for change are an integral part of the provider's own learning organization; each department has to report to management in accordance with a fixed plan; the results of the assessments are used by a combination of control and development meetings with the different departments and by the participation of many different stakeholders in the work; relation between goals/objectives to the assessment and evaluation are established at meetings in of the VET provider as a systematic part of the decision-making structure.

Step 5: Methodology - characterised by description of methodology.

In order to have an effective methodological process, there are some actions the VET provider has to solve: to establish the way of employing the systematic quality approach; to nominate stakeholders that is involved in the different steps of the quality approach and in which roles; to establish tools and procedures to be used for data collection, measurement, analysis, conclusions and implementation; to check the tools for accountability and consistency; to motivate participants to play their roles properly; to define strategies for the implementation of change; to use external assessment in a proper way.

In the Tit-us project methodology consist in: we have decided to use quality approach based on the ISO standard quality system; a number of different actors - from social partners, to students - are involved; external consultants participate in some parts of the activities; we develop common questionnaires, instruments for measuring quality, benchmarking, etc. together with a selected group of other VET-providers; the external participants are motivated by their influence over the VET providers, as board members. Internally, the main motivation is personal development, but also consideration for the image/results of the institution; the systematic structure of our quality system includes clear strategies for change; audit is following our plans.

Based on user requirements specifications, the implementation strategy for the stakeholder groups (QA personnel) consist in:

1) Format of courses, that are used by instructors during courses delivery: Quality Auditing in manufacturing; Quality Management in manufacturing; Quality Assurance in manufacturing;
2) Pedagogical methodologies, Student Response Systems (SRS) technology and Activity Based Training (ABT) learning environment that are used by instructors during training.

In the TIT-us project the innovative educational are Activity Based Training and Student Response System, that are adapted in this project to the specific context of education in quality assurance (Moldovan, 2014a). The ABT methodology is used for QA courses in VET, according to ISO 9001. Evaluation of theoretical achievements is done with SRS.

1.4.2. Activity based training

Activity Based Training has in theory a lot in common with *Learning by doing* (Chang et al., 2011), which improves capability of people in execution of tasks by repeating the same type of action very regularly and *Problem based learning* (De Graaff, 2003), which enables trainees to apply their knowledge to solve matters that are directly related to their jobs, but when it comes to the practical implementation there are differences in the methodology.

The core idea behind ABT is that trainee should produce something related to their activity, which can be a physical product or a service (Cattell, 2008). The exemplified industrial process must be clearly defined so that each step in the process represents an added value to the process itself. The process consists of a number of defined production steps, each adding a value to the product.

To be able to actively participate in collaborative creation of knowledge objects, trainees are expected to take control of their learning, to go beyond individual efforts and to engage in productive collaboration with peers.

The idea of collaboration is central and a key element in ABT. Collaborative learning stimulates the ability to cooperate in order to full-fill the activities that is a part of the production process. The collaboration efforts are in many cases, more important than the results.

The collaborative learning can be stimulated through the learning process by establishing a group of trainees that shall work together as a work group. Each class will then consist of two or more work groups. These work groups will work in parallel with the same activity through the production process.

At the end of each activity these work groups are going to exchange their results of activities at that stage. This means that for every activity in the production process the work groups are starting with a result from another work group, they will add a certain value to the final product during the activity and at the end they deliver their result to another work group. Through this result exchange they will experience the dependencies of other groups to perform their task in order to be able to full-fill their own task. This is a very important element of the ABT, because this is quite similar with the normal production in real life.

The result exchange is a way of letting the trainees be aware of their dependencies of other groups in order to full-fill their own tasks. It also will make them aware of that they have to deliver the correct quality as defined in the task. If the quality is not acceptable or the delivery time or scope of delivery is not correct, negative consequences will occur.

ABT may be used in any vocational training for physical products or services. Since the idea is not targeting special products then it can be used with products that may be available through cooperation with local industrial companies or other sources. Through such cooperation additional practical knowledge and competence can be accessed during education and training. Activity based training is a concept suitable to apply also in quality management VET (Moldovan and Stav, 2011).

Following principles presented above, I have developed 3 training course supports that are employing ABT and are evaluated by means of SRS: Quality Management in manufacturing; Quality Auditing in manufacturing; Quality Assurance in manufacturing.

The core idea behind the ABT is that the student shall fallow the main steps of the real quality management issues from an enterprise during the training course. The base processes of the enterprise can be anything that is related to industrial fabrication or services.

During the course the quality management will be produced by going through a sequential process that consists of a number of steps that can be identified and be treated as standalone training elements.

It should be noticed that local industry needs can be used to define the object of the study, or local community needs for products could be utilized in the training process.

1.4.3. Activity based training employed in quality management in manufacturing

In figure 4.2, I considered the idea of training with the ABT methodology by simulating quality management issues in an organization. The main steps of the ABT training are evaluated with the SRS methodology (Moldovan, 2015b).

The study modules for quality management in manufacturing, ABT activities, ABT practical things explored by students during training, the moments of SRS evaluation are represented in table 4.1.

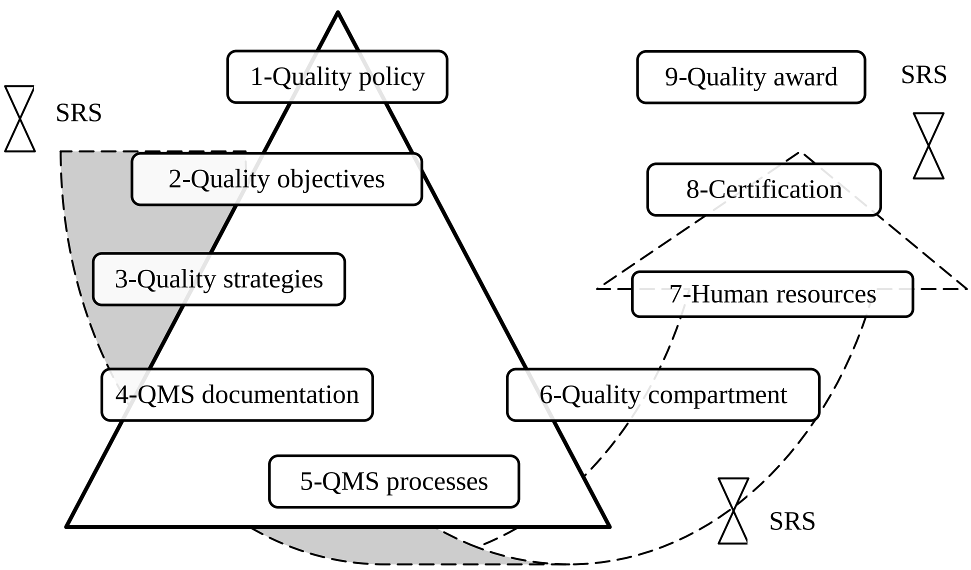


Figure 4.2. The sequential structure of the quality management training by means of ABT and SRS evaluation

Table 4.1. The ABT modules for quality managers training evaluated by means of SRS

Module	Module title	Quality management process – ABT activities	Quality management process – ABT practical exemplifications	SRS evaluation
1	Quality policy	The way to elaborate the quality policy, and the quality plan for an enterprise	• Quality policy declaration • Quality plan for a work	8 questions
2	Quality objectives	The elaboration of quality objectives and ensure the adequate quality for the product	• Quality objective of the enterprise • Quality objective of individuals	5 questions
3	Quality strategies	The main types of strategies in quality	• Continuous improvement strategy • Methods and techniques of Kaizen strategy	11 questions
4	Quality management system documentation	Main steps of QM system implementation and structure of documentation	• Quality manual • Quality procedures • Work instructions	10 questions
5	Quality management system processes	Identification of processes in a company	• Process matrix • Process map	10 questions
6	Quality compartment organising	Global image of the quality compartment organising	• Organizing chart of the company • Organizing chart of the quality compartment	26 questions
7	Human resources – competence, awareness, training	Selection, training and awareness of the personnel	• Evaluation of personnel • Training • Job description	5 questions
8	Quality management system certification	Main steps of the QMS certification	• Documents for certification	10 questions
9	Quality awards	Main quality awards and methodology to select companies	• Criteria for quality awards • Steps in quality awards	22 questions

1.4.4. Activity based training employed in quality audit in manufacturing

In figure 4.3, I considered the idea of training with the ABT methodology by simulating of a quality management system audit in an organization. The main steps of the ABT training are evaluated with the SRS methodology.

The study modules for quality audit in manufacturing, ABT activities, ABT practical things explored by students during training, the moments of SRS evaluation are represented in table 4.2.

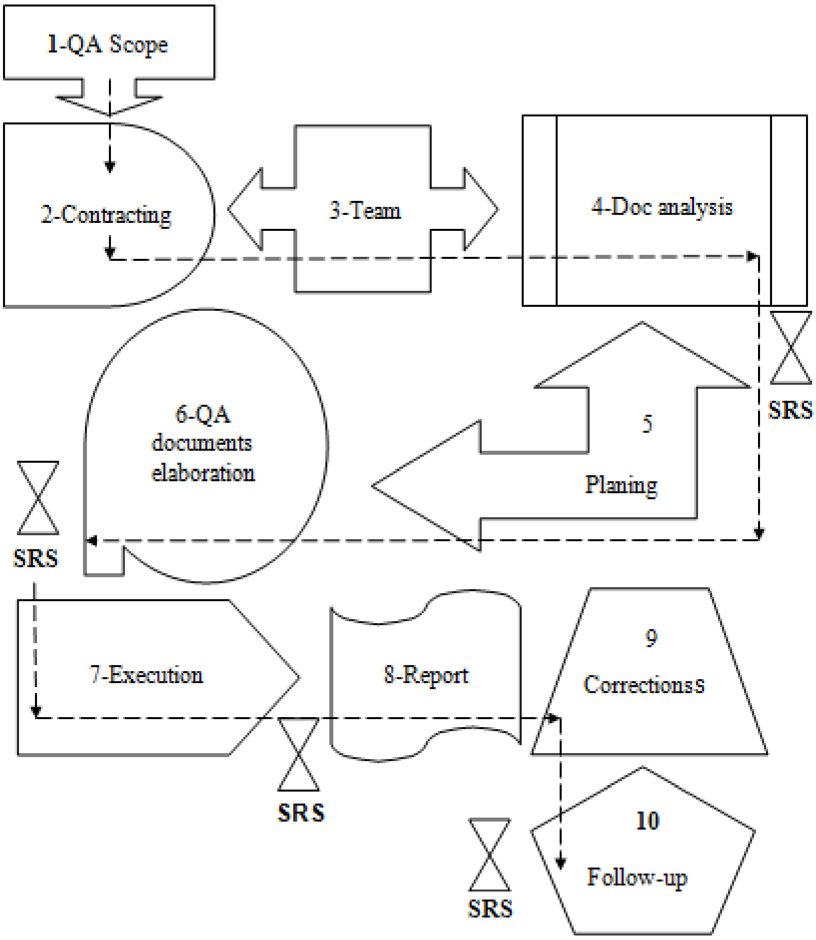


Figure 4.3. Quality audit training by means of ABT and SRS evaluation

Table 4.2. The ABT modules for quality auditors training evaluated by means of SRS

Module	Module title	Quality audit process – ABT activities	Quality audit process – ABT practical exemplifications	SRS evaluation
1	Quality audit scope and domain defining	Establish of the audit scope and domain of application	Quality manual (Chap. 1) ISO9001	10 questions
2	Contracting the audit	Delivery of contractual documents according to the domain and criteria of audit	Contract review	8 questions
3	Establishing the audit team	Nomination of chief auditor, selection of auditors	Documents for qualification of auditors, Criteria for chief auditor	10 questions
4	Analysis of quality management system documentation	Analysis of QMS documentation	QMS documentation ● Quality manual, ● System procedures, ● Operational procedures	9 questions
5	Audit planning	Elaboration and delivery of audit plan – agreements between auditors and audited organization	Audit plan according to organisational chart and system documentation	11 questions
6	Elaboration of documents for audit	Creating the format of the documents employed by the auditor in the execution and report phases	Elaboration of: ● Audit questioner, ● Nonconformities report, ● Audit report ● Meeting documents	12 questions

7	Audit execution	Examination of organization; objective proofs for audit: registrations, observation, discussions	Registration of: ● Audit questioner, ● Nonconformities report ● Meeting documents	17 questions
8	Audit report elaboration	Filling the audit report and delivery to the audited organisation	Registration of: ● Audit report	11 questions
9	Corrections - Follow up corrections and corrective actions	Establish corrections, corrective actions Evaluation of corrections and corrective actions	Registration of: ● Nonconformities report ● Corrective actions report Proofs for: ● Nonconformities report ● Corrective actions report	9 questions

1.4.5. Activity based training employed in quality assurance in manufacturing

In figure 4.4, I considered the idea of training with the ABT methodology by simulating of a quality assurance process in an organization. The main steps of the ABT training are evaluated with the SRS methodology (Moldovan, 2014b).

The study modules for quality assurance in manufacturing, ABT activities, ABT practical things explored by students during training, the moments of SRS evaluation are represented in table 4.3.

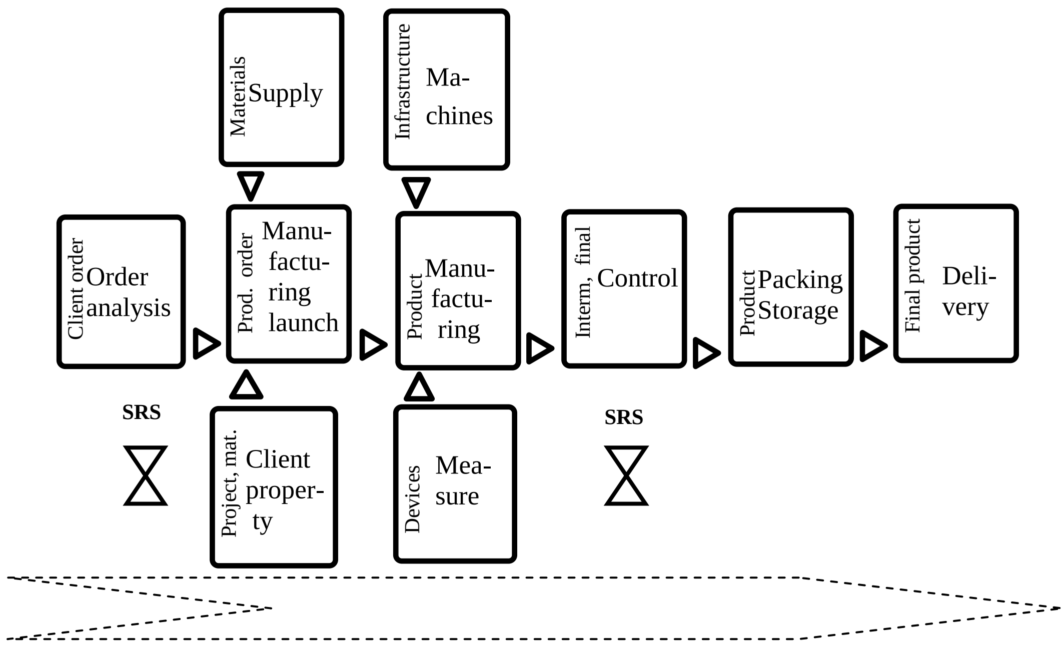


Figure 4.4. Quality assurance training by means of ABT and SRS evaluation

Table 4.3. The ABT modules for training in quality assurance evaluated by means of SRS

Module no	Module title	Quality assurance process – ABT activities	Quality assurance process – ABT practical exemplifications	SRS evaluation
1	Client order analysis	Determination and analysis of requirements for the product ordered by the customer	• Product specifications • The supply contract	8 questions
2	Client property control	Customer property incorporated into the final product analysis and acceptance	• Intellectual property • Physical property	8 questions
3	Supply	The supply of raw materials required product execution	• Criteria for selection of suppliers • Procedures for selection of suppliers	8 questions
4	Manufacturing launch	Technical and operational records in the manufacture of the product launch	• Documents launching and tracking manufacturing • Traversing launch	8 questions
5	Machinery control	Infrastructure and working environment for production	• Scheme of location • Equipment fact • Featured lists	8 questions
6	Measure devices control	Production measuring equipment assurance	• Register EMM • Data EMM • Calibration plan EMM	8 questions
7	Product manufacturing	Carrying out the production	• Procedures for work execution • Work instructions • Special processes	8 questions
8	Manufacturing / product control, intermediate and final	Production process and product monitoring	• Production control procedures • Nonconforming product control	8 questions
9	Product packing and storage - Delivery	Identification, traceability, packaging, storage and delivery of the product assurance	• Identification and traceability • Keeping product-handling, packaging, storage, protection	8 questions

1.4.6. The ABT resources from the production flow

The ABT resources from production flow used in the three courses from the Tit-us project, I developed in video format in two companies from the Mureș County: Matricon Tîrgu-Mureș (producer for automotive parts) and Hirschmann Vidrasău (producer for automotive cables). A sample of it is presented in figures 4.5a,...,m.

Figure 4.5a. The ABT resource: Collection of product defects - The ABT resource presents the collection of product defects in the manufacturing sector

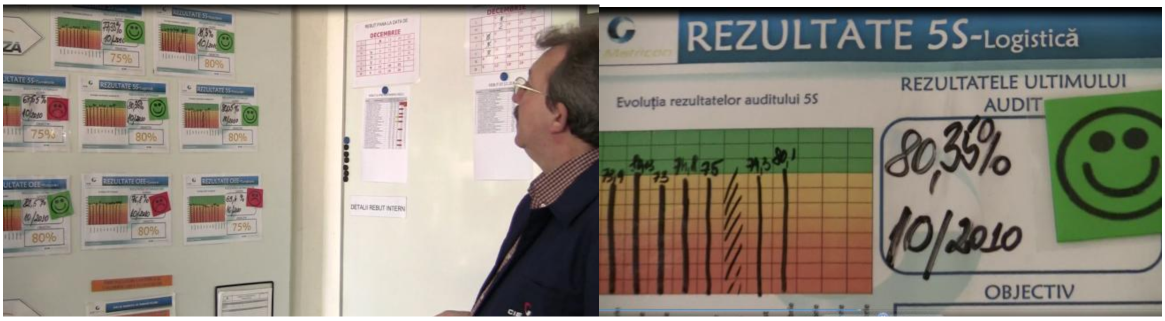


Figure 4.5b. The ABT resource: 5S - presents the 5S the method, part of the continuous improvement strategy

Figure 4.5c. The ABT resource: Product external inspection - presents the external inspection of the product, used when the product cannot be controlled during production

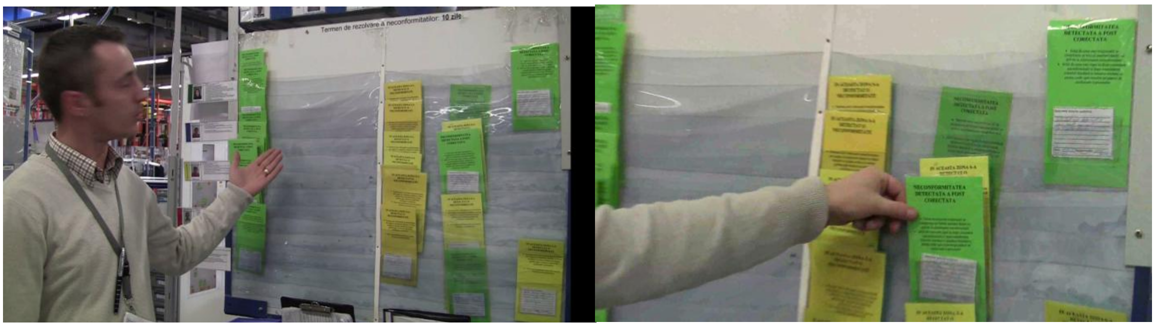


Figure 4.5d. The ABT resource: Compartment audit panel - presents information displayed on a production sector audit panel

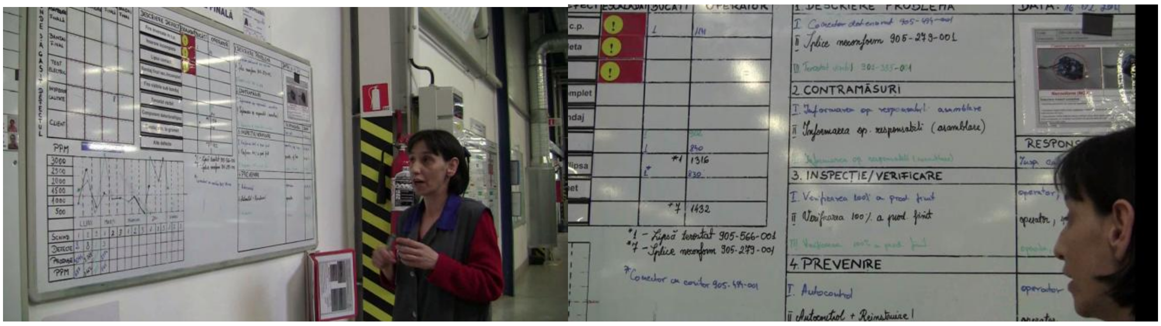


Figure 4.5e. The ABT resource: Quality panel - presents information displayed on a production sector quality panel

Figure 4.5f. Verification and calibration of measuring and monitoring equipment - presents the calibration certification status of the measuring and monitoring equipment

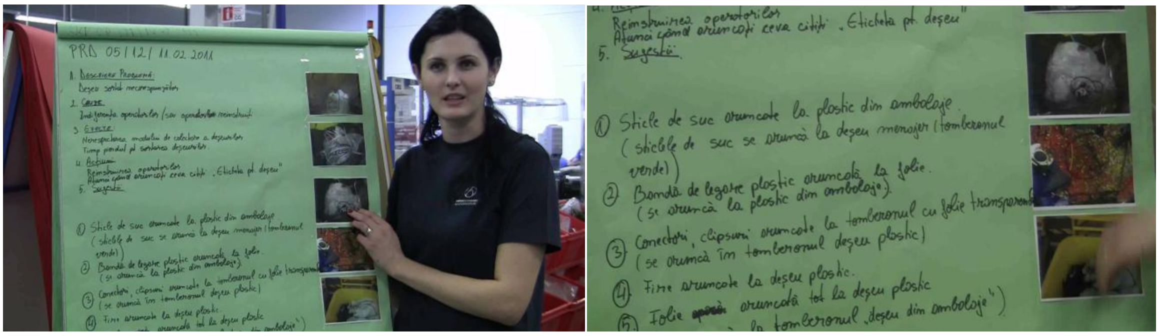


Figure 4.5g. Production sector quality panel - The ABT resource presents information displayed on a production sector quality panel

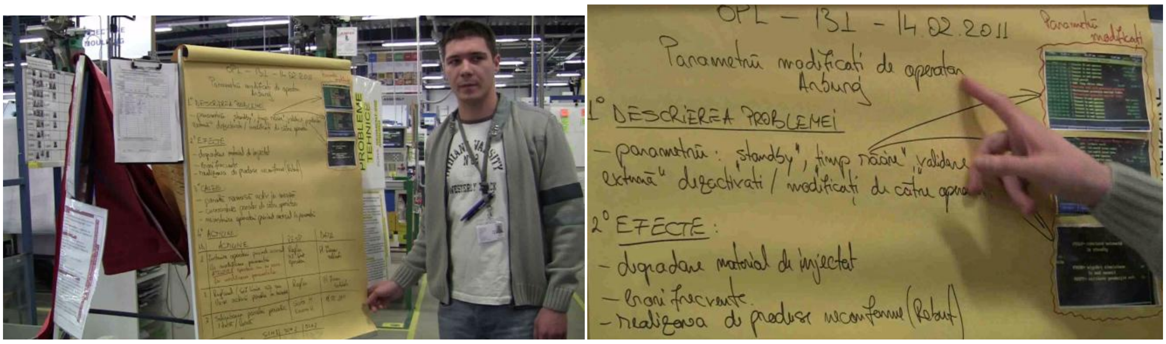


Figure 4.5h. Production sector technological flow panel - The ABT resource presents information displayed on a production sector technological flow panel

Figure 4.5i. Rewarding continuous improvement ideas - The ABT resource presents how to reward the best ideas coming from employees' continuous improvement

Figure 4.5j. Optimization of production flow by eliminating losses - The ABT resource presents how to restructure the flow analysis and to optimize its manufacturing

Figure 4.5k. Statistical process control - The ABT resource presents aspects of manufacturing statistical process control

Figure 4.5l. Equipment maintenance - The ABT resource presents how to ensure the manufacturing sector equipment maintenance

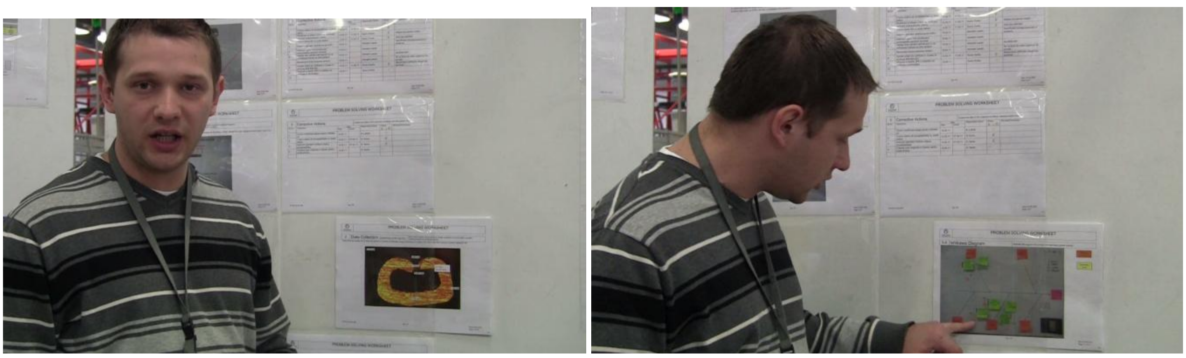


Figure 4.5m. 7 steps problem solving - The ABT resource presents how to solve the problems relating to quality in seven steps

1.4.7. Student response systems for mobile learning

Student Response Systems or SRS have been used for many years, typically in large classes to increase the level of trainee's engagement and learning. SRS technology generally includes a receiver, a collection of mobile devices and dedicated software. Through a wireless connection the clickers enable trainees to answer a number of questions, or quizzes, during a lecture. Because the trainees use their keypads instead of raising hands to submit answers, individual responses stay confidential from the rest of the trainees while result overviews are available on the classroom screen.

In literature SRS may have many different names, such as clickers, personal response systems, audience response systems, and classroom response systems. SRS are technology products designed to support communication and interactivity in classes (Barnett, 2006). Technology allows an instructor to present a question or problem to the class, and receive answers from the trainees through a response device. A summary of all answers is presented to the instructor and the trainees to see. In other words, SRS is a communication system that allows the instructor to collect and analyze large amount of data and on behalf of these investigate whether learning has taken place.

SRS has the ability to collect and display data instantly rather than waiting days to present the outcome as with a test, essay or project. The value of SRS comes from instructors analyzing information quickly and then devising real-time pedagogical solutions to maximize trainee learning (Beatty and Gerace, 2009).

Student Response Systems or SRS technology generally include a receiver, a collection of keypads (transmitters or "clickers") and dedicated software. Through a wireless connection the clickers enable students to answer a number of questions, or quizzes, during a lecture. Because the students use their keypads instead of raising hands to submit answers, individual responses stay confidential from the rest of the students while result overviews are available on the classroom screen.

The iPhone/iPod Touch solution for SRS used in Tit-us project is more flexible than existing on-site technological solutions, since it uses the wireless network to provide responses from students (Pein et al., 2010) (Fig. 4.6).

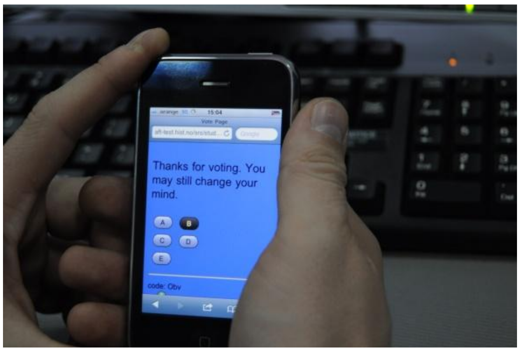


Figure 4.6. The interface for voting sessions on an iPod Touch

The teacher gives the students a task, for instance a question or a problem. The students solve the task and responds anonymously by using the SRS either on their laptop or through their mobile handheld device, whereby the teacher get a "knowledge map" of the class (Fig. 4.7) (Moldovan, 2011c). Finally, the teacher must decide how will provide the feedback to the class.

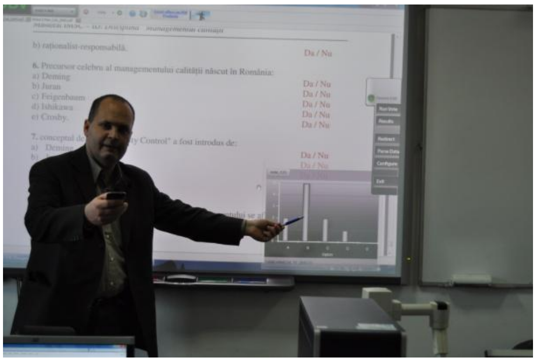


Figure 4.7. The response of a SRS vote is shown at the Smart board

In the TIT-us project SRS have been used for evaluation of quality managers training by making technical and methodological preparations.

The technical preparations have been conducted weeks ahead of first-time use of the SRS to ensure a successful implementation, by:

- Checking that the classroom in which the SRS is to be used has sufficient wireless network coverage in terms of signal strength, the number of simultaneous connections, and bandwidth;
- Making sure the SRS interface is properly installed and tested on the instructor's computer;
- Making sure that the handheld mobile devices distributed to the trainees are fully charged and properly configured (e.g. set up for wireless network access, passwords etc.);
- Setting up bookmarks/home screen shortcuts on the mobile devices (this can be done either by technicians or by the trainees themselves).

The methodological preparations have consisted in:

- Have a one or more instructor colleagues check that the quiz questions are clear and unambiguous;
- When the class starts, hold a 15-minute introduction to the SRS, during which the purpose of the SRS is explained, and the trainees are made familiar with the interface on the devices used for casting votes.

A timeline of a typical SRS session, consist in:

- Mobile devices are distributed to the trainees (preferably before the class starts), or trainees may use their own devices (mobile phones, laptops);
- The trainees are presented with a multiple-choice quiz question, where one or more alternatives are correct. The quiz questions can been displayed in several ways depending on the facilities available in the classroom: whiteboard/blackboard, flip over chart, overhead projector/ document camera, video projector;
- The trainees are given time to discuss between themselves (in the peer instruction paradigm, they are given time to think through the question individually first);
- From the SRS interface, the instructor starts the voting session (a timer/countdown mechanism can be used);
- Each trainee casts a vote as to what the correct answer is, using the handheld unit.

The vote closes and the results are shown to the trainees in the form of a histogram;
- The instructor comments the various alternatives and highlight the correct one – explaining thoroughly why it's the correct one and why the other ones are incorrect;
- The lecture proceeds as normal.

The SRS can be used within a multitude of methodical and educational approaches. Two approaches are of particular interest, both of which I have tested in during the quality management courses:
1. "Classical" approach: letting the trainees discuss 2-3 minutes between themselves in groups before doing a voting session;
2. Peer instruction: each trainee first has to think individually through the quiz question before casting a vote. Once the vote is cast (and the result of the vote is shown to the trainees), a group discussion ensues, during which each trainee has to argue his or her position to the rest of the group. After the group discussion another vote is held, and the results between the two voting sessions can be compared.

To illustrate the difference between the two approaches, a side-by-side timeline is described in table 4.4.

Table 4.4. The differences between the classical approach and peer instruction in using SRS

"Classical" approach	Peer instruction
The quiz question is shown to the trainees	The quiz question is shown to the trainees
The trainees discuss between themselves for 3 minutes	The trainees think for themselves individually for 1 minute
A vote is held	A first vote is held without the instructor commenting on the results
The results are shown and commented by the instructor	The trainees discuss between themselves for 3 minutes
	A second vote is held
	The results are shown and commented by the instructor (who may or may not comment on the possible differences between the two voting results)
Total time used: 5-6 minutes	

The evaluation has shown that classroom technology can support active discussion learning. Based on observations so far, however, on a purely qualitative basis, it appears that the peer instruction approach (in which each trainee is given time to think through the question before the group discussion) engages the trainees to a greater extent than going directly into a group discussion before the vote is cast.

With the goal to increase the amount of interaction, classical approach and peer instruction have different strengths, the last one being superior to class-wide discussion. The smaller numbers in the peer groups makes it easier for all trainees to participate in discussion and trainees report that this method is more beneficial than class-wide discussion. From this viewpoint, a key strength of peer instruction is that trainees are encouraged to construct their understanding of core concepts in discussions with others.

Another observation is the combination of peer instruction followed by instructor explanation that improved average student performance substantially when compared with either alone.

Departing from the traditional mobile phone, the number of devices that can be used wirelessly is also the subject of considerable innovations: smart phones, tablet computers, lap-tops, plus many "fixed" devices.

Thus, the SRS provide new pedagogical methods that enhance interactive teaching models by using instructional feedback loops.

The SRS technology may be used for in-class, laboratory, but also for distance training purposes, the latter being an entirely new option in SRS technology.

SRS have the potential to facilitate classroom processes such as: participation, collaboration, physical activity, cognitive involvement, self-evaluation (Stav et al. 2010; Thorset and Stav, 2011).

On the other hand if SRS is not used correctly, it can affect negatively the lectures (Barber and Njus, 2007). Focusing only on the SRS technology instead of focusing on how students think and learn, it will not automatically improve the lectures (Mayer, 2005).

1.4.8. SRS evaluation for quality management in manufacturing

The results for participants' evaluation, for SRS method, course and instructor evaluation after employing SRS in the quality management courses demonstrate that SRS has the potential to (Moldovan, 2014a):

- Break the monotony of a lecture and allow the students to actively take part in the lecture,
- Increase teacher-student interaction,
- Give both teacher and students "real-time" feedback on learning effect,
- Use modern and cheap and widely available devices that start fast (within 2-3 seconds).

The students provide positive feedback with respect to increased engagement and motivation. Many students feel it become fun to attend the lectures. They also point out that the SRS has become an integrated part of the teaching practices (Fig. 4.8).

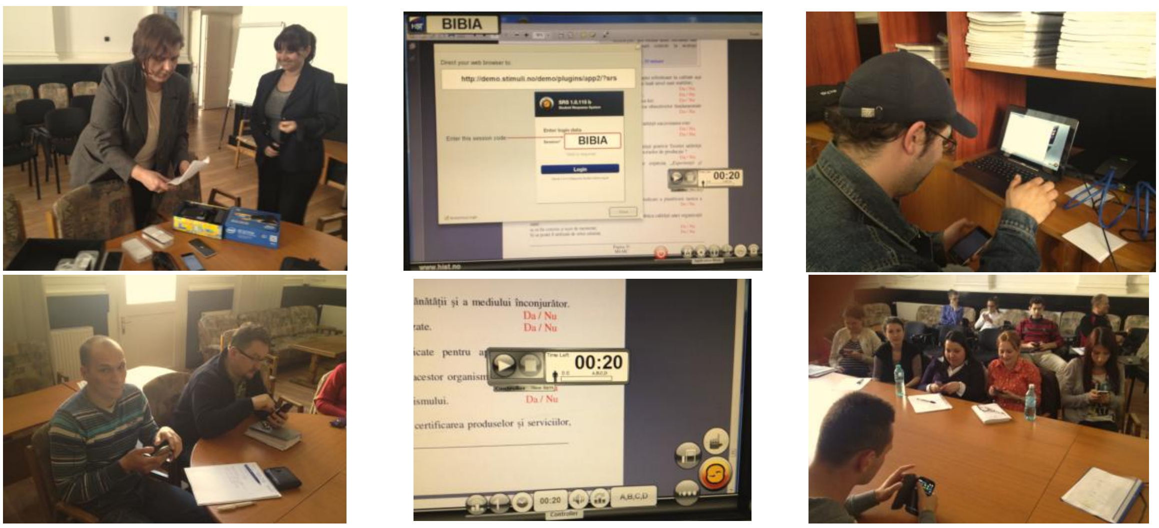


Figure 4.8. Pictures during course delivery and evaluation with SRS

1.4.9. Discussion and conclusion

In this section I highlight some research results and practical issues deduced from the implementation phase of ABT and SRS during the quality assurance VET courses delivered during the Tit-us project in the interval 2013-2014, which can be relevant to those who might wish to implement the interactive methods described in this paper.

The behaviours and skills required to solve a quality assurance problem are always multi-dimensional. Most of the VET programs for quality managers are linear in nature, being useless when a trainer interacts with the audience in one direction with a frightening array of slides useless. This mismatch between the real world and the training world makes it a certainty that industrial organisations are wasting their financial training resources and trainees learn nothing at all when subjected to this kind of training.

Training developed in a classical fashion, does not deliver the depth of learning required by trainees to actually change behaviour. In industrial companies, the objective of training is usually not the technical knowledge but to change behaviour. A good example comes from the aviation industry for pilots that are trained on simulators. There is no linear path in their training and are supposed to complex situations. Very often they fail but they learn in every situation by reflection. In this way their further knowledge is higher and they become much better prepared for different future complex situations.

Starting from these observations I have developed the content of the quality managers training programme in order to help trainees to learn from activity based examples that are making training experiential, allowing for periods of reflection. It employs the four steps process of learning structured in: concrete experience, observation and reflection, formation of abstract concepts, testing in new situations. The developed ABT learning model for quality managers reflect similar patterns of activities in a circular series.

As a conclusion after delivery of training I observed that practical modules, combined with classroom training, have significantly improved the learning retention and application, the ABT is more fun; trainees learn more also from their mistakes when they are in a relaxed atmosphere.

As regards SRS the first issue is the added value provided by classroom communication technology, the unique contribution consisting in the quality of feedback that it enables.

A second issue concerns the effectiveness of the different discussion methods. This evaluation has shown that classroom technology can support active discussion learning. However, it has also shown that peer instruction is more beneficial than class-wide discussion. The peer discussion has to be followed by instructor explanation.

The third issue concerns some logistical considerations because the SRS is designed to be used in large classes, and the server/client infrastructure is very scalable. However, the simple task of handing out mobile devices for dozens of trainees can present a logistical challenge.

The most efficient way to distribute a large number of mobile devices is to have the trainees pick up a unit as they enter the classroom, and hand it back as they leave the class.

Alternatively, handheld units can be given on loan to the trainees at the start of a term, on the condition that the unit is handed back in at the end of the term. In this scenario, each trainee would be individually responsible for his or her unit – making sure it's charged; bringing it to classes and so on.

The fourth issue consists in exploration of the timed versus non-timed voting sessions. The SRS is designed to be used in large classes, and maintaining order and discipline is a priority. After a group discussion, the instructor will want to start a voting session. But it can be challenging to restore order and attention in a class in which hundreds of trainees have been engaged in serious discussion. In particular, to make all the trainees, some still fiercely involved in the discussion, aware that a voting session is about to begin.

To aid the instructor in restoring order for the voting session, the SRS can be set to play back a "ticking clock" sound during the countdown.

My experience shows that using such a sound is invaluable in shifting the trainees' attention away from the discussion, and over to the voting session in progress. A 20-second countdown is sufficient – any longer than that and the trainees quickly lose patience. When the vote starts, the trainees have already completed their discussions and made up their minds. Therefore, 20 seconds should be enough to let everybody press the button on their mobile device corresponding to the alternative they think is correct.

The fifth issue refers to the instructor's role that is critically important for the trainees to thoroughly explains what the correct alternative is, and why, but also to put a lot of effort into stimulating the discussion between the trainees. This problem is exacerbated if the trainees don't know each other very well.

After a 3 year employment of SRS, Nielsen et al. (2013), shows that most criticism from trainees shifted towards the way SRS was used by different instructors, by dividing results into the sections: consistency when using SRS; differences in instructors' SRS experience level; time usage; commitment: a two-way street; preparation of the questions; and voting results as a false image of understanding.

On the other hand I have challenged with some problems that in some situation may become drawbacks of the evaluation system:

- Time spent to prepare relevant questions to the course is consuming resources. It depends also on the nature of the taught subject. The evaluation system is most suitable for descriptive sciences, and less for exact sciences. The instructor has to appreciate what kind of questions to ask: factual or conceptual questions. He has to read up on existing articles on multiple-choice questions. I appreciate that in general is preferable to have multiple-choice questions;
- For questions projecting the instructor needs technology support (lap-top, projector, smart board, etc.), so the classroom has to be adequate;
- If the trainees do not have own Smartphone the instructor has to distribute mobile devices (clickers like iPods) and there is a time spent to distribute/receive it;
- There are some browsers that don't run properly the application;
- Not all the instructors allow the use of mobile phone in classes, because it can be a distraction.

The trainees provide positive feedback with respect to increased engagement and motivation, many of them feeling that it becomes fun to attend the lectures. My SRS experience is in general a very positive element in trainee lectures and a valuable tool for both the instructor and trainees. In the 2013-2014 survey on 94 trainees, 91.5% of the trainees answered that they would want SRS to be used in their future education if they had the chance.

My approach consists in designing a very modern pedagogical methodology for training of quality professionals. The new learning environments Activity based Training (ABT) and Student Response System (SRS) are used at for VET of quality professionals (Moldovan, 2014a). The training follows the main professional challenges of a quality professional from an industrial organisation.

I have demonstrated a professional training by means of Activity Based Training (ABT) learning environment, in a modular structure, employing a generalised quality assurance process in an organization that can be tailored to any industrial application, which is relevant for the target group.

The findings are the generic training sequences employing the ABT learning environment that are not related to any specific product. Various technological processes, from very different industries can be employed for delivery of learning material, thus creating an attractive, flexible, engaging and motivating blended educational training environment (Moldovan, 2015b).

The main steps of the ABT training are evaluated with the SRS methodology. The ABT and SRS have been designed such that it helps instructor to: break the monotony of a lecture and allow the trainees to actively take part in the lecture; Increase instructor-trainee interaction; Give both instructor and trainees "real-time" feedback on learning effect; Use modern and cheap and widely available mobile devices which trainees have access to through their mobile phones.

Pedagogical challenges related to the new roles of the instructor and the trainees in the educational process have been demonstrated, by linking of theoretical training with practice and increased trainee-instructor but also trainees' interaction.

1.5. GREEN METHODOLOGY FOR EVALUATION

1.5.1. Green learning arena

Development of "e" mobile technology can be done by means of new educational methods that are based on Peer learning processes, where trainees learn from their peers (Moldovan, 2014b). Peer-assessment is used to help trainees develop assessment criteria learn from viewing peers' work by using mobile device (Lai et al., 2015).

In the "European Quality Assurance in VET towards new Eco Skills and Environmentally Sustainable Economy " project (*** Project eQvet-us) that I have developed and managed, it is proposed a new evaluation model, where the assessment results from several tests and/or the final exam (summative assessment) in a class can be turned into an active, creative and collaborative peer learning process by the use of immediate feedback.

The system consists of three main parts (Fig. 5.1): a) Controller interface, used by the trainer; b) Assessment interface, used by trainees or people filling the questionnaire; c) Server, controlled by gmail administrators, which is a public free service.

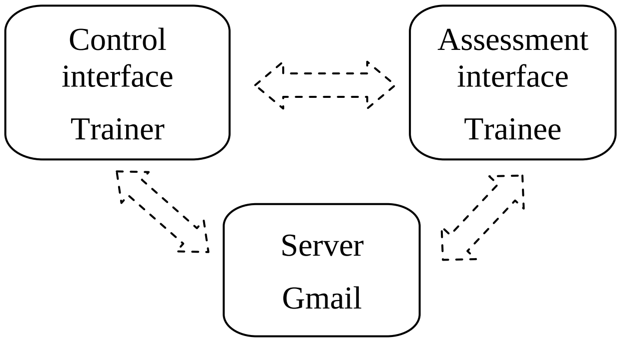


Figure 5.1. The two actors in the assessment process, connected via internet

The peer learning processs for trainees is created by employment of mobile technology and regulate assessment of the course material as a result of the symbiosis between training and assessment, both being represented in figure 5.2 by the vizual design element Taijitu (Moldovan and Moldovan 2015d).

In subsidiary, by employing the instant feedback, there is created a green learning arena, on which inputs come also from trainer after the evaluation process.

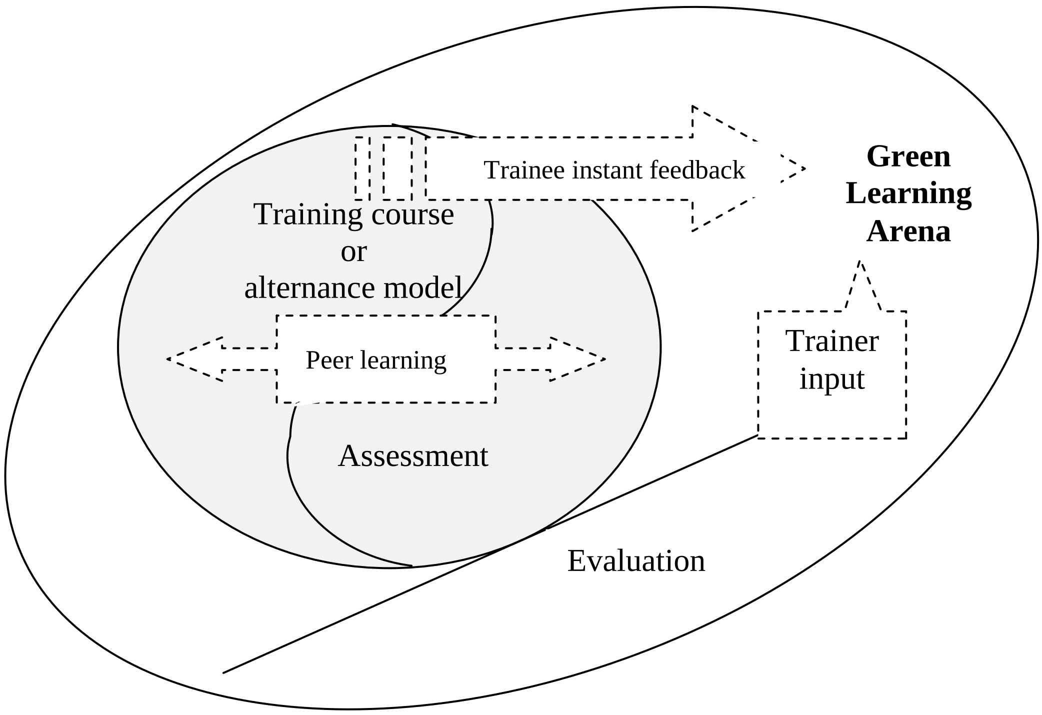


Figure 5.2. Assessment employment for the creation of a green learning arena

In this way by employment of mobile technology assessments and evaluations can now be done in class or outside of class, using computers, laptops, tablets or smart phones. This is a green initiative that completely eliminates reams of paper used in the past for bubble sheets and comment sheets, and associated printing and scanning.

If the information from an assessment system to the trainer is correct, dependent upon the results, the teacher can organise teaching in many different ways. With this assessment solution the target is to provide the teacher with instant feedback on the status of the assessment. Teacher analyses what questions did the students solve correct and what questions caused more problems.

The trainee might have spent time on parts of the assessment but have just not found or understand the right answer. Dependent upon the nature of the subject being thought, there might be just a hint from a peer student or a teacher that might solve the problem. The entire idea here is to make the assessment a *green arena for learning* by employment of mobile technology (Moldovan and Moldovan, 2015d).

There are many methodologically questions rising in such an arena, regarding: how the teachers will use the system; how the students will like to respond electronically; how the immediate feedback will change the view on assessment; the frequency and dimension of the assessments; the focus of the learning culture more on learning than on assessment; the relevance of continuous evaluation during a course in comparison with the final exam result; the category of students that benefit from the change in the assessment, etc.

1.5.2. The assessment

Very different methods and contexts for the use of peer assessment in classes, supported by different learning software tools: Student Response System (Almeida and Moldovan, 2014), WebPA Peerwise software tool (Denny et al., 2008), Virtual learning environments, are reported. The key issue in this approach is to provide a set of tools that the instructor can use and feel free to apply different educational path in the learning activity.

My development employs free available software Google Forms (www.i). The methodological approach of Peer Learning Assessment by employment of Google Forms includes several steps:

- *Step 1:* Creation of a gmail account by the trainer and development of a test before the course starts. The test can be done with questions answered in multiple ways: text, paragraph text, multiple choice, check boxes, choose from a list, scale, grid, date, time.
- *Step 2:* Starting a typical assessment session consists in giving/sending de address of the test to the trainees, where from they may access it. Teacher may project de short URL address of the questionnaire and trainees access it, or submit by email. The duration of the assessment can be limited by using the form limiter function.
- *Step 3:* Trainees have to connect to internet address provided by trainer and they may see the test and answer it. The access can be done from computers in the class, laptops, tablets or touchsensitive mobile phones. At the end of the test they submit it.
- *Step 4:* The result consideration phase is after the test submission, when the trainees get a short break. Instructor uses this phase to obtain a complete overview of the results submitted by the trainees.
    a) Individual response result
    b) Response result in synthesis

The post-assessment activities can be done by the instructor as effectively as possible due to the software interface that is designed as a tool which ensures that. A question with a high proportion of incorrect answers from trainees is highlighted, so that the instructor may spend more time on it when reviewing the test. The instructor uses this information to select the problematic questions in order to prepare the most important part, from a learning perspective: the post-assessment activities.

- *Step 5:* In the post-assessment phase, new questions are elaborated, in connection with the problematic questions from the testing phase. They are used by the instructor to provide verification or elaborative feedback in order to enhance new learning activities. In this way, the assessment system is used to reveal the test results and promote and enhance the peer-learning process. The instructor engages the trainees in a process where they learn from the problematic questions they have just spent time trying to solve.

Use of mobile technology doesn't require any reconstruction of classrooms or other infrastructure at the campus, due to the portability and availability of mobile tools (smartphones, tablets and laptops) among the students. Due to this, it is possible to apply this evaluation method in any classroom that is connected to the WI-FI network, thus reducing the costs for carrying out advanced and improved evaluations in large scale training environments with thousands of students.

If the information from an assessment system to the instructor is correct, dependent upon the results, the instructor can organise teaching in many different ways. With the eQvet-us assessment solution the target is to provide the instructor with instant feedback on the status of the assessment (Moldovan and Moldovan, 2015d). Instructors analyses what questions did the trainees solve correct and what questions caused more problems. Than the instructor can apply the following scenarios:

a) Continue as usual and only give the results;

b) Give the trainees verifying feedback and explain what has been misunderstood;

c) Give the trainees a hint of what might be the problem for this question, but not the actual solution;

d) Give the trainees the results, "this is what you voted" and allow the trainees the possibility to discuss the problem;

e) Or to find other ways.

In case of c) and d) the trainees could be allowed to take part of the test again, or could be after a group / peer discussion be able to renegotiate their response.

The main advantage of entering the test subject just after the test is the problem is fresh in mind since the trainee has just been working with it. The trainee might have spent time on parts of the assessment but have just not found or understand the right answer. Dependent upon the nature of the subject being taught, there might be just a hint from a peer trainee or an instructor that might solve the problem. The entire idea here is to make the assessment an arena for learning.

There are many methodologically questions rising in such an arena, regarding: how the instructors will use the system; how the trainees will like to respond electronically; how the immediate feedback will change the view on assessment; the frequency and dimension of the assessments; the focus of the learning culture more on learning than on assessment; the relevance of continuous evaluation during a course in comparison with the final exam result; the category of trainees that benefit from the change in the assessment, etc.

The key issue in this approach is to provide a set of tools that the instructor can use and feel free to apply different educational path in the learning activity.

1.5.3. 4 level evaluation methodology

Kirkpatrick described four levels of evaluation in which the complexity of the behavioural change increases as evaluation strategies ascend to each higher level. According to the Kirkpatrick methodology, by employment of mobile technology the teaching innovation of the eQvet-us project (Moldovan, 2014b) is evaluated at levels of (Fig. 5.3):

(1) *Reaction evaluation*: measure how trainee thought and felt about the training and learning experience during the training course or by using the alternance model;
(2) *Learning evaluation*: measure the increase in knowledge or capability before and during the course, in order to provide corrective actions at the end of the course;
(3) *Behaviour evaluation*: measure the extent of applied learning back on the job (implementation of knowledge);
(4) *Result evaluation*: investigate the effects on the business or environment resulting from the trainee's performance, and try to assess and validate the Return of Investment in VET programs by using the extended Kirkpatrick`s evaluation model.

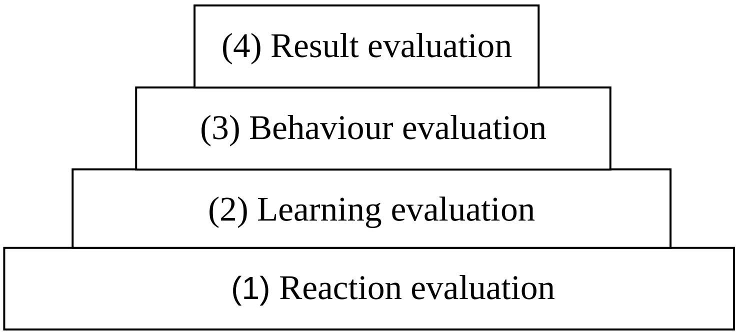


Figure 5.3. Kirkpatrick's hierarchy of evaluation levels

eQvet-us training evaluation is used to measure information about trainee and course in various moments, as depicted in figure 5.4 (Moldovan, 2015e).

Reaction is measured from just before the course starts, and these data will be collated with immediate feedback from tests offered towards the end of the course, collecting information from trainees about their impression, what they felt, course content, teacher ability to deliver training, handouts, infrastructure, etc;

Learning is measured after the beginning of the course using intermediate and final assessments and exams.

Behavior evaluation is performed after 2-3 month the course is ended with information from graduates and employer. The objective is to explore the usefulness of the course for the graduate and enterprise.

The result evaluation is performed 4-6 month after the course is completed with information also from graduates and mainly from employer in order to explore the return of investment of the course.

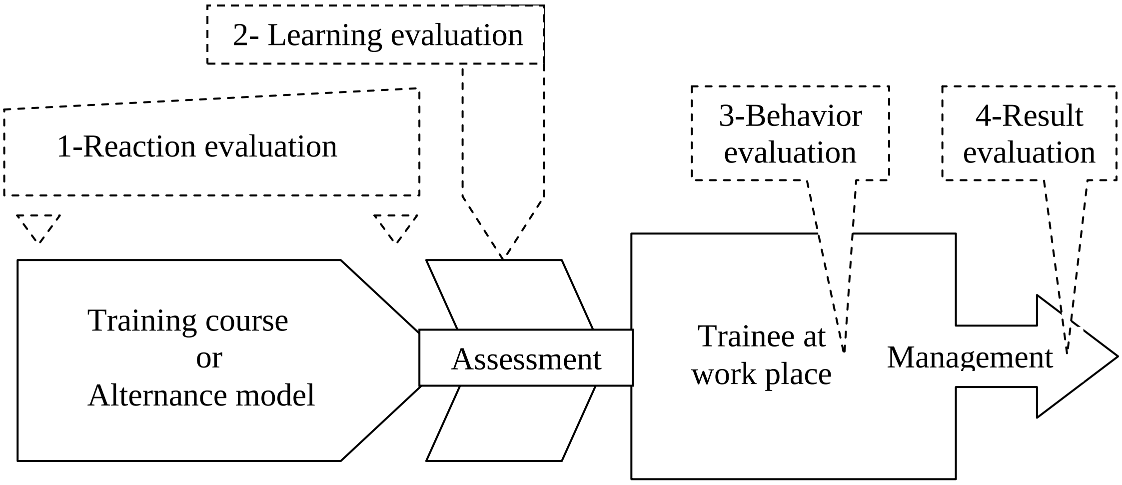


Figure 5.4. The process of training evaluation

The data gathered before and after the course are then merged into an interactive learning and evaluation activity. The learning approach targets short, intense training courses and applies the pedagogical method to environmental courses.

Complexity of evaluation increases as evaluation of intervention ascends the hierarchy, as demonstrated in figure 5.5. At the first two levels the trainee evaluation is dominant in relevance, while at the last two levels the employer evaluation is dominant in relevance.

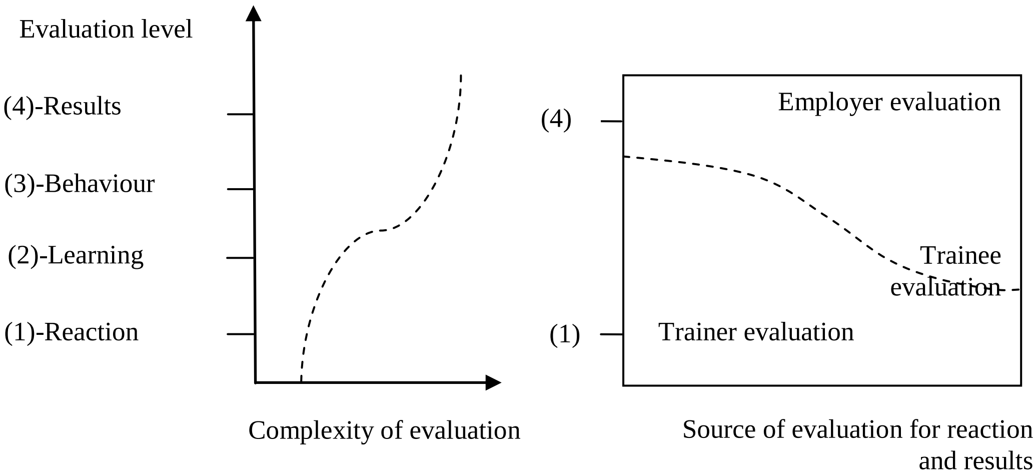


Figure 5.5. Complexity of evaluation hierarchy

During the design and development phase, trainer should thinking about the post-training evaluation of the trainees and evaluation of the training materials themselves:

- Determine if it's appropriate to provide a pre-test that would allow the trainee to skip the training if he/she can pass the pre-test and, if so, to develop the pre-test;
- Determine how the trainees will be evaluated post-training;

- Determine what the trainee must do to successfully complete the evaluation;
- Create procedures for helping or retraining workers who do not successfully complete the evaluation.

Than trainer should turn the attention to the nature of effective evaluations.

- First, the evaluation of the trainee should be based on the trainee's ability to satisfy the learning objectives for the training.

In addition, the evaluation should be both "reliable" and a "valid measure":

- Reliable: Gives consistent results over time,
- Valid measure: Reflects the knowledge, skills, abilities, or attitudes specified in the learning objective.

Next, evaluations must comply with all applicable regulations, like for example, the minimum acceptable level of training, where trainees can at least meet that minimum, or exceed the minimum acceptable level of training.

After this, the evaluation should include one, and may include all, of the following approaches:

- *Learner reaction*: Surveys or other methods to get the trainees feedback about the training, including how well they learned, how well the training materials were designed, and how well the trainer performed.
- *Knowledge, skill, ability evaluation/test*: This can include a written test, oral exam, a demonstration of a real-life job skill in the real or simulated work environment, the completion of a project, or other forms of evaluation. The test should align with the learning objective and the type of test will be influenced by the learning objective. Pre-tests and post-tests may be used as a way to determine how much the trainees learned. Technology, including online or computerized assessments, may be used.
- *On-the-job performance observation*: Observing the employee's real on-the-job behavior at the workplace to see if the employee is correctly applying the knowledge, skills, abilities, or attitudes the training was intended to convey. This may include a comparison of observations made before and after training, and can include observations from customers, co-workers.
- *Effect of training on organization as a whole*: Analyzing data to determine the effect of the training on key performance indicators such as safety behaviors; safety records; implementation of preventive measures; increased use of personal protective equipment; reduction of environmental incidents; increased regulatory compliance; and higher revenues and return of investment.
-

1.5.4._eQvet-us evaluation model

The eQvet-us evaluation model - is used for establishing:

- objectives (Table 5.1 - left column; Figure 5.6 – the inner circle) and
- evaluation level (Table 5.1 - right column; Figure 5.6 - the outside circle).

Table 5.1. Evaluation model stages

Stage of the objective	Objective	Evaluation level	Stage of the evaluation level
Act	Motivation: What must the trainees perceive in order to learn and perform?	Reaction: Are the trainees motivated to learn?	Plan
Check	Knowledge: What new knowledge, skills and resources do trainees need in order to perform?	Learning: Did the trainees learn the needed skills and use the resources they were given?	Do
Do	Performance: What must the trainee be able to perform in order to achieve the organizational objective?	Behavior: Did the trainees transfer the skills to the workplace?	Check
Plan	Outcome: What is the organizational goal to improve the business?	Result: Is the desired organizational impact being felt?	Act

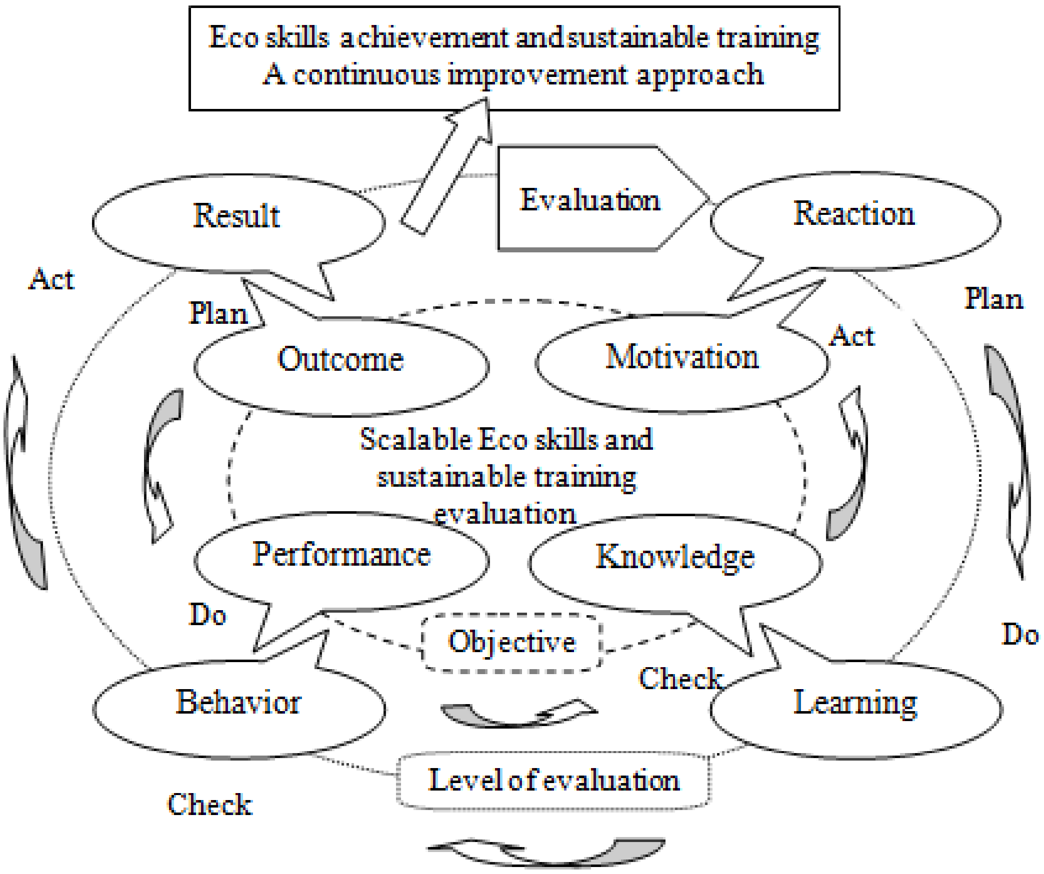


Figure 5.6. Evaluation model

In addition, it aids the troubling-shooting process. For example, if you know the trainees learned their skills but do not use them in the work environment, then the two more likely troublesome areas become apparent as they are normally in the cell itself (in this example on figure 5.6, the Performance cells) or the cell in relation with it (Behavior):

- there is a process in the work environment that constrains the performers from using their new skills, or
- the initial premise that the new skills would bring about change is wrong.

The diagram in figure 5.7 shows the environment of evaluation, and inclusion of the evaluation processes in order to fit together.

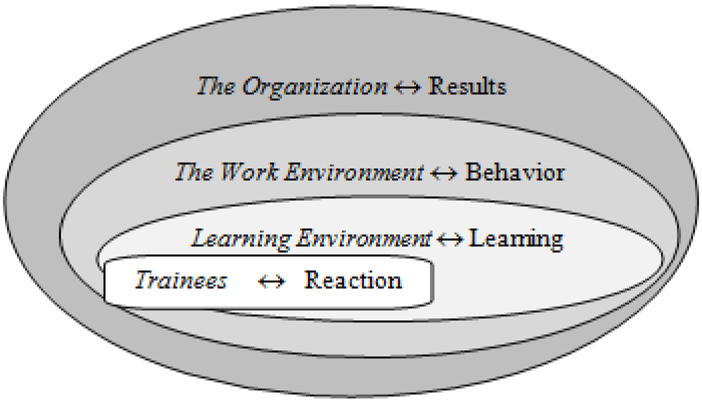


Figure 5.7. Learning and work environment

As the diagram shows, the Results evaluation is of the most interest to the business leaders, while the other three evaluations (Behavior, Learning, and Reaction) are essential to the training designers for planning and evaluating their training processes; of course the Results evaluation is also important to them as it gives them a goal for improving the business.

1.5.5._Discussion and conclusion

In order to validate the proposed methodology I have tested the model in a short duration VET course for quality professionals working in services industry delivered by UPM.

In the “Objective” level the questions and problems addressed in the 4 phases of the PDCA cycle, were developed according to descriptions in table 5.1.

The outcome in the “Plan” phase consist in the organizational goal to improve the business by increasing of services with 30%, increased profits, member satisfaction, satisfied customers, frontline staff that can identify needs, recommend solutions.

In the “Do” phase the performance consist in what must the trainee be able to perform in order to achieve the organizational objective. Frontline staff identify members’ needs by reviewing their client profile and asking questions during each transaction. Once a need is identified, staff makes a recommendation, usually a product or service that will meet the need. Staff also highlight the benefit of the solution by showing how it saves time, money and/or provides peace of mind.

In the “Check” phase the new knowledge, skills and resources trainees need were established in order to perform: quality services, client consultation, identify the gaps between what clients expect or need from the organization and the service they feel they are actually receiving; measuring client satisfaction. With this information the training content was designed, consisting in client consultation process: client consultation as a way of doing business; client consultation in the decision-making process; client consultation in implementing new initiatives.

In the “Act” phase the trainees’ motivation was analyzed. In order to ensure that trainees perceive the value of what is presented in the course, they must see training as an opportunity, as a way to address a need they have, and as a way to achieve valued outcomes. Trainees must perceive the organization and their immediate work environment as a supporting participation in training.

In the next level of “Evaluation” it was developed four questionnaires for each kind of evaluation that are exemplified with selected questions:

Reaction: How valuable have you found the program to be?

Learning: How much effort have you made to apply your learning? How much support have you received when applying your learning?

Behavior: As a result of the program, how would you rate you attitude towards your job? What are your changes to job behavior? What level of practical application have you been able to achieve?

Result: Have you noticed any changes in the behavior of those around you? How strongly do you believe that your company is committed to the objectives of the program?

At the end of the pilot testing it was appreciated the utility of the proposed methodology and observed that once the initiative has been rolled out, it is important to gather relevant quantitative and qualitative data to make sure that value is being added all along the way, and that the required leading indicators levels 3 and 4 are pointing the way to ultimate mission and business success.

Kirkpatrick’s model has many adaptations to various fields of training, by using 4 level evaluations. The new eQvet-us training outcome evaluation model developed (Moldovan, 2015e), consist in an improvement of the Kirkpatrick’s model by associating to the evaluation level the corresponding objectives. In this way two levels are deduced, that are following the PDCA cycle phases in opposite senses. The objectives’ level consists in outcome performance, knowledge, motivation, that is associated to the classical evaluation level compost of reaction, learning, behavior and result evaluations. To evaluate the effectiveness of the proposed approach, an experiment was conducted for a VET course for quality professionals in services industry. The course was designed and evaluated according to the proposed methodology. It was demonstrate that the methodology not only help the training professional plan the intervention, but help the trainees employers understand the factors that facilitate training transfer and produce business results. By using the tool, it was demonstrated post-training value for stakeholders.

1.6. QUALITY METHODS EMPLOYED FOR PRODUCT DESIGN

1.6.1. General presentation

Quality Function Deployment (QFD) has been practiced by leading companies around the world since 1966. Its two-fold purpose is to assure that true customer needs are properly deployed throughout the design (Akao and Mazur, 2003). An empirical study about QFD in UK conducted by Martins and Aspinwall (2001), considered the method to be a design tool for attaining better quality products, processes and/or services, but also considerable lack of knowledge about the methodology expressed by many respondents from top companies and universities.

QFD method is used in many selection processes, for example supplier evaluation in a pharmaceutical company (Alinezad et al, 2003); the crucial logistics requirements and supply chain management strategies for the dairy industry (Ayağ et al., 2012). QFD could be successfully applied in the housing projects as a strategic tool to facilitate marketing decisions (Dikmen et al., 2005).

Some researchers have applied fuzzy theory to quantitatively formulated problems for optimizing the improvements of design requirements. Fung et al. (1998) proposed a fuzzy approach for customer requirements in order to map out product attributes. A decision system for product design optimisation was presented by Moskowitz and Kim (1997) and later Kim et al. (2000) used the fuzzy theoretical modelling to QFD. Such systems require professional knowledge in order to model and simulate the real market conditions and formulate practice applicable results. Wolniak and Sedek (2009) have used QFD for selecting activities that are crucial for fulfilling ecological requirements and improvement of life quality.

Current management interests are also focused on knowledge management as a major determinant of business excellence and competitive advantage. Empirical findings suggest that management of both endogenous and exogenous knowledge through IT applications significantly enhances dynamic capabilities (Sher and Vivid, 2004).

According to Alavi & Leidner (2001), the objective of knowledge management is to support creation, transfer, and application of knowledge in organizations. Tiwana (2000) has described the knowledge management toolkit composed of techniques and tools for making knowledge management happening in a company, that is build on existing intranet, data warehouse, and project management investments (Rezayat, 2000).

Andrew et al. (2001) have shown that knowledge infrastructure consisting of technology, structure, and culture along with knowledge process architecture of acquisition; conversion, application, and protection are essential organizational capabilities or “preconditions” for effective knowledge management. Also organizational creativity is critical for improving performance (Lee and Choi, 2003).

1.6.2. Continuous improvement and knowledge management

Bottled products at Natural Aqua Company are the result of capture and bottling processes of mineral water in the Biborteni area. The quality management system of the company is a complex set of processes that produces consistently reliable in making products with qualitative characteristics, customer satisfaction and other stakeholders in all stages of the product development, from marketing activities on which company relates with market and customer for determining requirements relating to natural mineral water drinks, purchase of technology for preparation and bottling, product processing under controlled conditions to their after-sales support (Fig. 6.1).

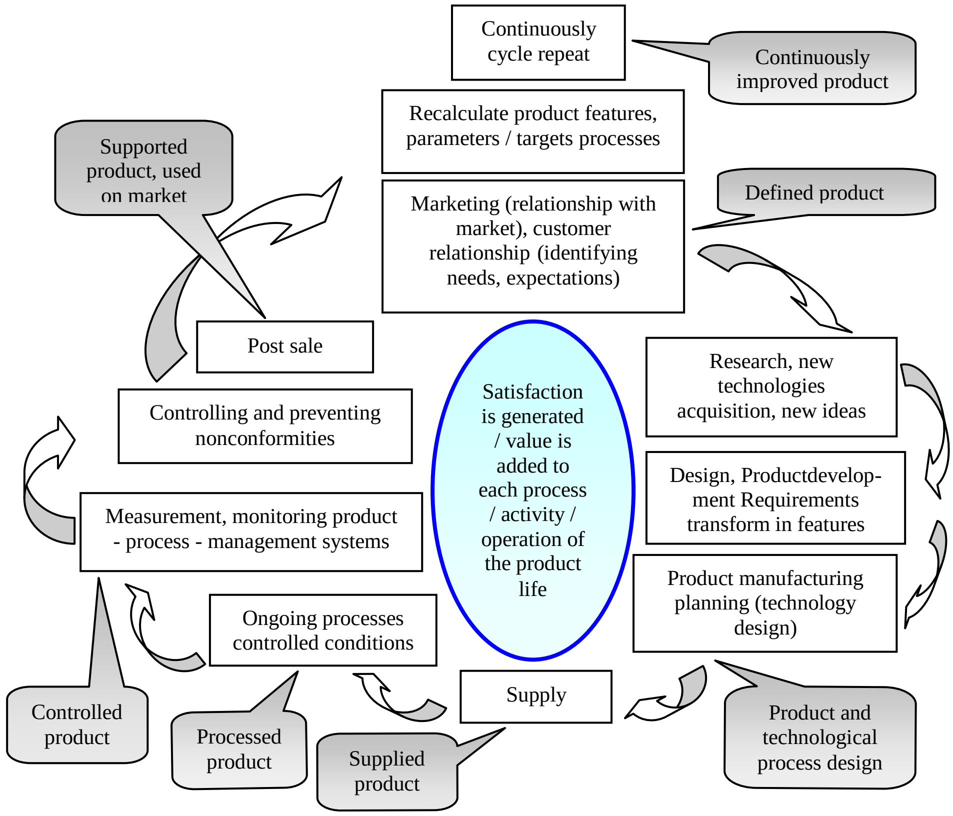


Figure 6.1. Continuous improvement support for knowledge management

The organisation adopted the principle of the continuous improving, with the goal that all the technical requirements which contribute to the requirements of the client should be improved functions. Whole process of planning, implementation and support of products is continually repeated resulting in continuous improvement of products by adding accumulated experience brought every product realization process, in the knowledge management with the view for quality that matters consisting in added value and joy for stakeholders. In this way by creating a nurturing and “learning-by-doing” kind of environment, an organization can sustain its competitive advantages (Bhatt, 2001).

According to Rezayat (2000), effective reuse of enterprise knowledge is a key strategic component of creating a distributed design and manufacturing environment that enables integrated product, processes, and protocols development. To reuse the knowledge, however, we must first capture and maintain it in a persistent manner and then disseminate and share it in a practical manner throughout the development cycle.

Knowledge management operational planning includes issues from outside the company, such as identifying customers and establishes their needs, but also issues within the company, referring to the transposition of customer requirements in quality characteristics of the product and process development, which make it possible to achieve these characteristics.

Strategies and practices have been used to identify, create and enable adoption of insights and experiences, regarding products characteristics. Such insights and experiences are appreciated as knowledge management, embodied in company's engineers and transferred to organizational processes and products that are leading to intended and sometimes to unintended results (Fig. 6.2).

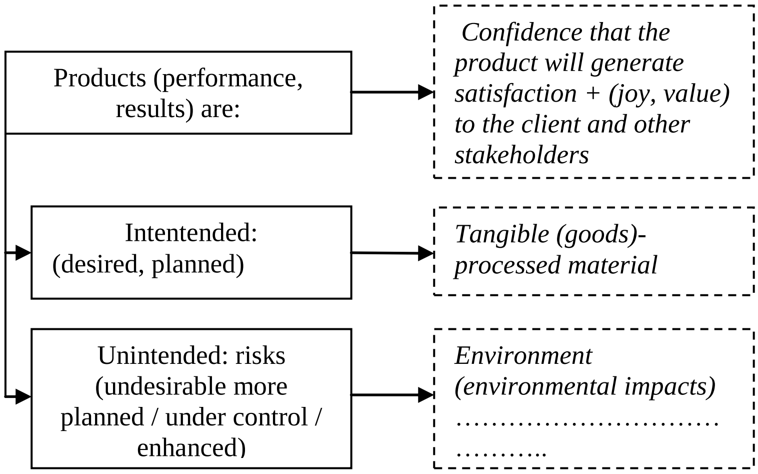


Figure 6.2. Company results

The knowledge management model used in Natural Aqua Company consists in collaboration, trust, learning, centralization, formalization, and information technology support.

At Natural Aqua Company the diversifying of soft drinks product range, by development of new products such as "Limio", is a main objective, where the customer needs, are transposed in quality planning, product development, production planning and verification. Quality Function Deployment method is applied for different stages of the soft drink Limio in cascade for the following phases: marketing, product development, planning and production, by a team of specialists from various departments in which I was involved. Input data formulation process for the new product is summarized in figure 6.3 (Moldovan, 2014c).

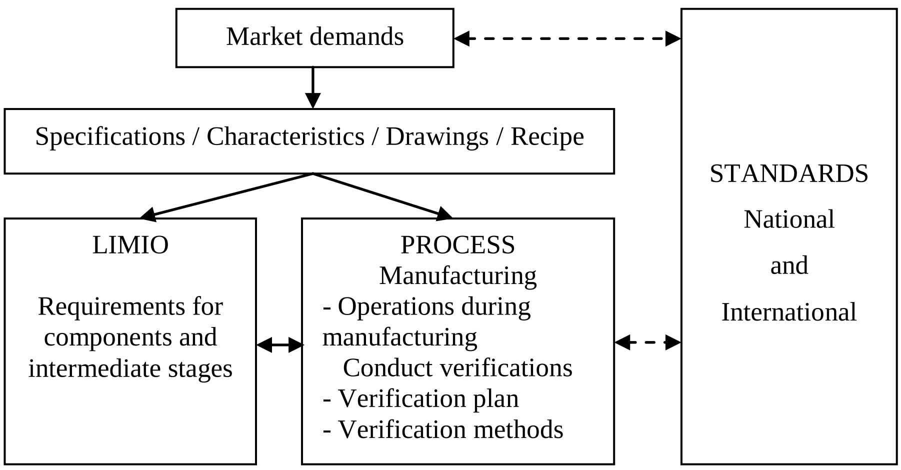


Fig. 6.3. Input data for the soft drink Limio

In the first phase the marketing team analyzed the market, using various methods of market research, competition assessment, surveys, etc. One of the practices that become part of the company's knowledge management is development of a questionnaire to listen the voice of the client. It provides: the requests and the expectations of the customer for the product; the importance that customers gives to accomplish different requests and expectations; information regarding the competitiveness of the product perceived by the clients.

The customer requirements are: sour taste, small amounts of sugar, more fruit pulp and natural ingredients. Also their requirements are the product to be packaged in several types and volumes of packaging, with low price and absence of E numbers (dyes, additives, chemicals, etc.).

The information collected from customers are input elements in QFD (Fig. 6.4) which helped in establishing the product characteristics, improvement of the product function, the priority granted by the client to the characteristics in order to accomplish his requests. As seen from the results the highest requirements weights are accorder by the customer to: the content of natural ingredients, lack of E (colour) and low price.

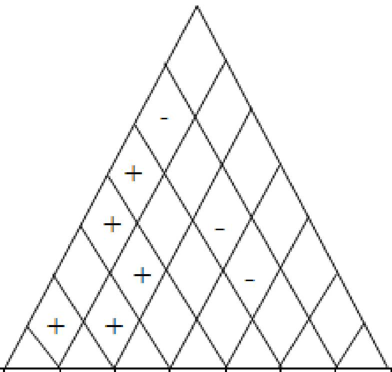
The technical requests comprised in product characteristics have been established as an analysis of the knowledge management data of the mineral water company. Then, the quality correlations between the technical requests and the client's requests are analyzed. Also the assessment by the clients of the competitiveness of products realised by the Natural Water Company in comparison with the competitors' products: Romaqua Group Borsec, Europen Drinks, Coca Cola, and Perla Harghitei are investigated. Depending on the result it is established the proportion for improving the level at which the company will action so as to accomplish the client's requests through the target value and the effect foreseen for the product.

The team translated in the QFD matrix consumers' claims in measurable quantities in order to obtain the desired quality of the product that is prescribed by the following characteristics: Acidity - 8.5 ‰; Soluble substances - 11% refractometric degrees; Citrus pulp content - 1.7%; Natural ingredients: natural mineral water "Biborteni"- 75%; No dyes; Maximum delivery price: 4.0 ron; Different capacity bottles: 0.5 l, 1.5 l.

In the next stage the new product Limio has been analyzed. The product features were quantified and in order to improve the physic-chemical dry powder, the recipe has been modified, by reducing the amount of sugar in soft drink Limio composition.

In the last stage actions have been taken such as the new product to satisfy all customer requirements. In the analysis of the new product, it is clear that the most important issue is the price. Meanwhile, a demand among consumers' claims was that the soft drink sugar content to be lower. By reducing the amount of soluble solids in the stage of preparation of syrup as raw material was obtained concomitantly with lower price.

Thus at Natural Aqua Company was obtained the first Limio carbonated soft drink with 10% lemon juice content and 1.7% citrus pulp, made from natural mineral water wells Biborteni F7 and F9. It is supplied to the domestic market since 2010 and was very successful with competing products because of sour taste, as a natural drink that satisfies customers' expectations.



	Product characteristics / Customer requirements	Requirements weight	Acidity 1	Soluble solids 2	Citrus pulp content 3	Carbonated mineral water 4	Without dies 5	Cost 6	Bottle volume 7	Competition assessment: Romaqua Group Borsec 1	European Drinks Izv. minunilor 2	Coca Cola HBC Dorna 3	Perla Harghitei 4	Average	Competition status 5: Better	Competition status 5: Worse	Market goals 6
	Optimisation directions		X	[-]	[+]	[+]	X	[-]	X						Bet ter	Wo rse	
1	Have sour taste	4	3	1	2	1		1		4	2	3	3	3,0			
2	Low in sugar	3	1	2				2		4	3	3	4	3,5			Dec sug
3	More fruit pulp	4	1		3			2		2	1	1	1	1,2			
4	With natural ingredients	5		1	3	3	3	2		4	1	2	2	2,2			
5	Lack of E (colour)	5	1	1	1		3	1		2	1	1	1	1,2			
6	Low price	5	1	2	3	1		3	2	3	4	4	4	3,7			Dec price
7	Varied packaging	3						1	3	2	3	3	2	2,5			
	Soft drink Limio		8,5	12	1,7	75	No Col.	4,0	Dif. cap.								
1	Quantification		gac ‰	dr %	%	%	%	lei	litri								
2	Function significance		29	34	55	24	30	51	19								
3	Function significance in %		12	14	23	10	12	21	8								
4	Difficulty of optimisation		2	3	2	1		4	1								
	Competition assessment																
1	Romaqua Group Borsec		8,6	12	1,6	80	Con Col.	4	Dif. cap.								
2	European Drinks Izv . M		8,4	10	1,5	70	Con Col.	3,6	Dif. cap.								
3	Coca Cola HBC Dorna		8,5	10	1,5	75	Con Col.	3,6	Dif. cap.								
4	Perla Harghitei		8,5	12	1,5	75	Con Col.	3,6	Dif. cap.								
5	Media		8,5	11	1,5	75	Con Col.	3,7	Dif. cap.								
6	**Competition assessment** – Bet ter																
	Competition assessment – Wo rse																
7	Optimum values (target)		8,5	11	1,7	75		3,8									

Figure 6.4. QFD for the Limio soft drink

1.6.3. Discussion and conclusion

Quality function deployment (QFD) and knowledge management are suitable ways to understand the customer needs to select suitable characteristics and their “weights” for a new product design. A way to collect information for a new product design is to ask an orientated group, which uses similar products with the studied one.

In such situations the interviewed subjects give the answers in their own language. In order to avoid information dispersing it is recommended to use close questions with multiple choices. Collected information has been organized and structured by specialists in the field as part of the knowledge management.

With the help of questionnaire the obtained information is: requests and expectations of the client and importance accorded but also client perceive of the product competitiveness. The investigated company (Moldovan, 2014c), adopted the principle of continuous improving, and all the technical requests that contribute to the requests of the client are added to the company's' knowledge management. The achieved experience and continuous improvement are parts of the knowledge management which fits into the QFD project.

Then, this knowledge was used to develop a new soft drink, enabling the company to enter the new markets. The soft drink product characteristics in measurable quantities in order to obtain the desired quality of the product have been prescribed: Acidity - 8.5 ‰; Soluble substances - 11% refractometric degrees; Citrus pulp content - 1.7%; Natural ingredients: natural mineral water "Biborteni"- 75%; No dyes; Maximum delivery price: 4.0 ron; Different capacity bottles: 0.5 l, 1.5 l. The product was released into the Romanian market with great success.

For some objectives the research can be continued with another method, interpreting the technical requests that must be improved as effect and the secondary causes as a plenty of the directions for amplifying the effort.

1.7. PARALLEL MECHANISMS

1.7.1. General presentation

Parallel robots manipulators are mechanisms which are constituted by a number of links arranged in parallel. The synchronized motion of these links produces the desired motion of the end-effector.

The six controlled degrees of freedom (DOF) parallel robot configuration is a structure proposed by Stewart used as a flight simulator and widely referred as Stewart platform.

In robotics, the class of parallel robots represent a constructive solution suitable for many industrial, medical or domestic applications, like micromanufacturing (Uzunovic et al., 2013), tool machine (Abdellatif and Heimann, 2010), pick and place operation (Yang et al., 2008), laparoscopic surgery (Ibrahim et al., 2012), assembly work (Ageli and Nestinger, 2014), flexible manufacturing (Coppola et al., 2013), piezoelectric transducers (Palmer et al., 2004), etc.

The limitations encountered with serial robots are well known, because they are built with only one kinematics chain between the base and the end-effector and their stiffness is very bad (Ceccarelli and Ottaviano, 2008).

Even if parallel robots have a reduced workspace (Moldovan, 2008a), their benefits over their serial counterparts are various: stability and rigidity of contacts during haptic interaction (Constantinescu et al., 2005), high positional accuracy, high stiffness, high payload capability, low moving inertia (Le et al., 2013), good dexterity, compact size, large power to weight ratio (Lu and Li, 2014), small error, and so on.

Currently, many industries generally use serial robots in operations. Results are good, but both accuracy and throughput could be significantly improved by using parallel robots (Ider and Korkmaz, 2008).

The parallel robots are a solution when the stiffness is of more importance than the size of the workspace.

Performance is a critical topic for the further improvement of parallel robot manipulators. Improving the overall performance of parallel robot manipulators is the bridge to connect the academia and industry for the great development and real-world application.

1.7.2. Kinematic scheme

In papers (Moldovan, 1996a,b) the 6-PGK parallel mechanism structure was presented (Figure 7.1) which can be employed for construction of robot manipulators. The movable platform is supported above the stationary base platform by six serial kinematics chains. At the first level there are six prismatic motor joints, at the second level there are six spherical joints, at the level III each link of length R_i is mounted to the superior platform by a cardan coupling.

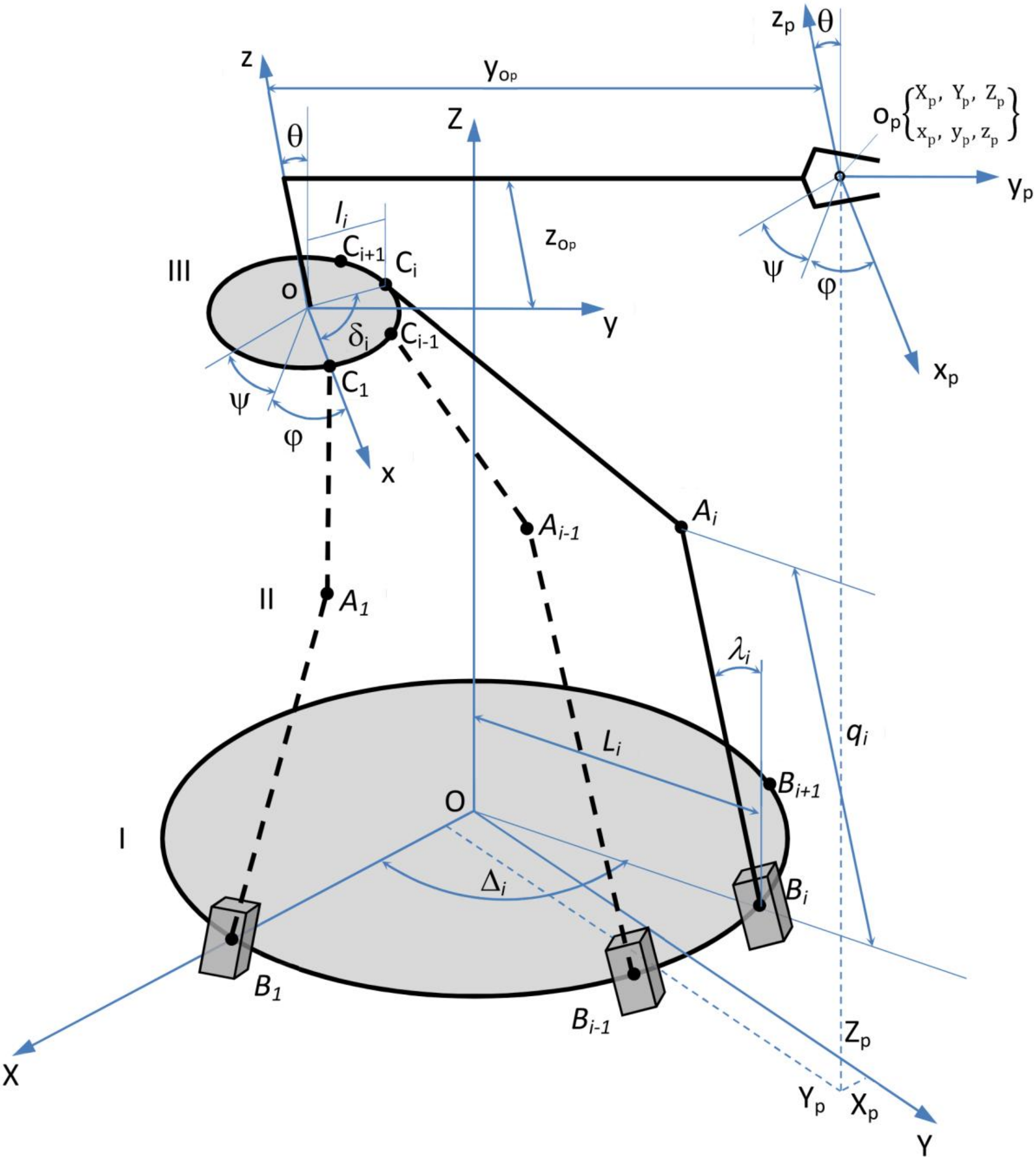


Figure 7.1. The structure of the 6-PGK parallel robot (Moldovan, 2008)

The lengths q_i (i=1,2,...,6) of the motor joints are the generalized coordinates of the robot.

The three linear coordinates of a point of the manipulated object X_p, Y_p, Z_p and the Euler angles: Ψ, φ, θ are the generalized coordinates of the manipulated object. A gripper is attached to the movable platform.

This mechanical design provides a basis to control all six degrees of freedom of the manipulated object in space.

1.7.3. Kinematics

The position problem of manipulators, both with serial and parallel architectures, consists of determining the position and orientation of the end-effector as a function of the manipulator configuration that is given by the link position, defined by the joint variables.

The in-out equations of the mechanism, that relate the generalized coordinates of the robot to the generalized coordinates of the manipulated object, are a system of six second order equations in q_i (Moldovan, 1996a):

$$q_i^2 - 2b_i q_i + c_i = 0, \qquad (i=1,2,...,6) \tag{7.1}$$

where $\alpha',...,\gamma'''$ are terms of the rotational matrix that relates the coordinates fixed in mobile frame to the base coordinates in:

$$\begin{aligned} b_i = {} & \left[X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i)\alpha'' - z_p\alpha'''\right] S\lambda_i S\Delta_i - \\ & \left[Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' - (y_p - l_i S\delta_i)\beta'' - z_p\beta'''\right] S\lambda_i C\Delta_i + \\ & \left[Z_p - (x_p - l_i C\delta_i)\gamma' - (y_p - l_i S\delta_i)\gamma'' - z_p\gamma'''\right] C\lambda_i \end{aligned}$$

$$\begin{aligned} c_i = {} & \left[X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i)\alpha'' - z_p\alpha'''\right]^2 + \\ & \left[Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' - (y_p - l_i S\delta_i)\beta'' - z_p\beta'''\right]^2 + \\ & \left[Z_p - (x_p - l_i C\delta_i)\gamma' - (y_p - l_i S\delta_i)\gamma'' - z_p\gamma'''\right]^2 - R_i^2 \end{aligned} \tag{7.2}$$

with the solution:

$$(q_i)_{1,2} = b_i \pm \sqrt{b_i^2 - c_i} \qquad ,(i=1,2,...,6) \tag{7.3}$$

that means for the same location of the mobile platform there are two possible configurations of the robot′s legs. When a prismatic motor joint reach one of the limiting devices, a vibration motion of low amplitude and high frequency is induced and the corresponding generalized coordinate of the robot becomes.

1.7.4. Instantaneous kinematics

The inverse instantaneous kinematics problem of the robot is to compute the motor joints velocities given the manipulated object generalized velocities as follows:

$$[\dot{q}_p] = [J][\dot{q}] \tag{7.4}$$

where $[\dot{q}] = [\dot{q}_1, \dot{q}_2, \dot{q}_3, \dot{q}_4, \dot{q}_5, \dot{q}_6]^T$ is the generalized velocities coordinates vector of the robot, $[\dot{q}_p] = [\dot{q}_{p_1}, \dot{q}_{p_2}, \dot{q}_{p_3}, \dot{q}_{p_4}, \dot{q}_{p_5}, \dot{q}_{p_6}]^T = [\dot{X}_p, \dot{Y}_p, \dot{Z}_p, \dot{\psi}, \dot{\varphi}, \dot{\theta}]^T$ is the generalized velocities coordinates vector of the manipulated object, and [J] is the Jacobian matrix. In error analysis, error sensitivity is represented by the Jacobian matrix (Cui et al., 2008).

Differentiating equations (7.1) with respect to time, we have:

$$\dot{q}_i = \frac{2\dot{b}_i q_i - \dot{c}_i}{2(q_i - b_i)} \qquad ,(i=1,2,...,6) \tag{7.5}$$

where:

$$\begin{aligned}\dot{b}_i = {} & [\dot{X}_p - (x_p - l_i C\delta_i)\dot{\alpha}' - (y_p - l_i S\delta_i)\dot{\alpha}'' - z_p\dot{\alpha}''']S\lambda_i S\Delta_i - \\ & [\dot{Y}_p - (x_p - l_i C\delta_i)\dot{\beta}' - (y_p - l_i S\delta_i)\dot{\beta}'' - z_p\dot{\beta}''']S\lambda_i C\Delta_i + \\ & [\dot{Z}_p - (x_p - l_i C\delta_i)\dot{\gamma}' - (y_p - l_i S\delta_i)\dot{\gamma}'' - z_p\dot{\gamma}''']C\lambda_i\end{aligned}$$

$$\dot{c}_i = 2\left\{\begin{array}{l}[X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i)\alpha'' - z_p\alpha'''] \\ {[\dot{X}_p - (x_p - l_i C\delta_i)\dot{\alpha}' - (y_p - l_i S\delta_i)\dot{\alpha}'' - z_p\dot{\alpha}''']} + \\ {[Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' - (y_p - l_i S\delta_i)\beta'' - z_p\beta''']} \\ {[\dot{Y}_p - (x_p - l_i C\delta_i)\dot{\beta}' - (y_p - l_i S\delta_i)\dot{\beta}'' - z_p\dot{\beta}''']} + \\ {[Z_p - (x_p - l_i C\delta_i)\gamma' - (y_p - l_i S\delta_i)\gamma'' - z_p\gamma''']} \\ {[\dot{Z}_p - (x_p - l_i C\delta_i)\dot{\gamma}' - (y_p - l_i S\delta_i)\dot{\gamma}'' - z_p\dot{\gamma}''']}\end{array}\right\} \tag{7.6}$$

Equations (7.4) and (7.5) are in the form:

$$\dot{q}_i = l_{i1}\dot{X}_p + l_{i2}\dot{Y}_p + l_{i3}\dot{Z}_p + l_{i4}\dot{\psi} + l_{i5}\dot{\varphi} + l_{i6}\dot{\theta} \qquad ,(i=1,2,...,6) \tag{7.7}$$

where l_{ij} are terms of the inverse Jacobian matrix. Due to the small amplitudes, the influence of the vibration motions on the generalized coordinates of the robot is neglected. This influence cannot be neglected upon the generalized velocities of the robot $\dot{q}_i$ and so these become: $\dot{q}_i + \dot{\zeta}_i$. In this state, equations (7.7) become:

$$\begin{aligned}& \dot{X}_p[q_i S\lambda_i S\Delta_i - X_p + L_i C\Delta_i + (x_p - l_i C\delta_i)\alpha' + (y_p - l_i S\delta_i)\alpha'' + \\ & + z_p\alpha''' + z_p\beta'''] + \dot{Y}_p[-q_i S\lambda_i C\Delta_i - Y_p + L_i S\Delta_i + (x_p - l_i C\delta_i)\beta' +\end{aligned}$$

$$
\begin{gathered}
+(y_p - l_i S\delta_i)\beta'']+\dot{Z}_p[q_i C\lambda_i - Z_p + (x_p - l_i C\delta_i)\gamma' + (y_p - l_i S\delta_i)\gamma'' + z_p\gamma''']+ \\
+\dot{\psi}\left\{\begin{array}{l}
[-q_i S\lambda_i S\Delta_i + X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i)\alpha'' - z_p\alpha'''] \\
[(x_p - l_i C\delta_i)(-S\psi C\varphi - C\psi C\theta S\varphi) + (y_p - l_i S\delta_i)(S\psi S\varphi - C\psi C\theta C\varphi) + \\
z_p C\psi S\theta] - [-q_i S\lambda_i C\Delta_i + Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' - (y_p - l_i S\delta_i)\beta'' \\
- z_p\beta'''][(x_p - l_i C\delta_i)(C\psi C\varphi - S\psi C\theta S\varphi) + (y_p - l_i S\delta_i)(-C\psi S\varphi - \\
S\psi C\theta C\varphi) + z_p S\psi S\theta]
\end{array}\right\} - \\
-\dot{\varphi}\left\{\begin{array}{l}
[-q_i S\lambda_i S\Delta_i + X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i) \\
\alpha'' - z_p\alpha'''][(x_p - l_i C\delta_i)(C\psi S\varphi + S\psi C\theta C\varphi) + (y_p - l_i S\delta_i) \\
(C\psi C\varphi - S\psi C\theta S\varphi)] + [q_i S\lambda_i C\Delta_i + Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' \\
- (y_p - l_i S\delta_i)\beta'' - z_p\beta'''][(x_p - l_i C\delta_i)(S\psi S\varphi - C\psi C\theta C\varphi) + \\
(y_p - l_i S\delta_i)(S\psi C\varphi + C\psi C\theta S\varphi)] + [-q_i C\lambda_i + Z_p - (x_p - l_i C\delta_i)\gamma' \\
- (y_p - l_i S\delta_i)\gamma'' - z_p\gamma'''][(x_p - l_i C\delta_i)S\theta C\varphi + (y_p - l_i S\delta_i)S\theta S\varphi]
\end{array}\right\} + \\
+\dot{\theta}\left\{\begin{array}{l}
[-q_i S\lambda_i S\Delta_i + X_p - L_i C\Delta_i - (x_p - l_i C\delta_i)\alpha' - (y_p - l_i S\delta_i)\alpha'' \\
- z_p\alpha'''][(x_p - l_i C\delta_i)S\psi S\theta S\varphi + (y_p - l_i S\delta_i)S\psi S\theta C\varphi + \\
z_p S\Psi C\theta] - [q_i S\lambda_i C\Delta_i + Y_p - L_i S\Delta_i - (x_p - l_i C\delta_i)\beta' - \\
(y_p - l_i S\delta_i)\beta'' - z_p\beta'''][(x_p - l_i C\delta_i)C\psi S\theta S\varphi + (y_p - l_i S\delta_i) \\
C\psi S\theta C\varphi + z_p C\Psi C\theta] - [-q_i C\lambda_i + Z_p - (x_p - l_i C\delta_i)\gamma' - (y_p - \\
l_i S\delta_i)\gamma'' - z_p\gamma'''][(x_p - l_i C\delta_i)C\theta S\varphi + (y_p - l_i S\delta_i)C\theta C\varphi - z_p S\theta]
\end{array}\right\} = \\
=\left(\dot{q}_i + \dot{\zeta}\right)\left\{\begin{array}{c}
- S\lambda_i S\Delta_i[X_p - L_i C\Delta_i - (x_p - l_i S\delta_i)\alpha' - (y_p - l_i C\delta_i)\alpha'' - z_p\alpha''' \\
- q_i S\lambda_i S\Delta_i] + S\lambda_i C\Delta_i[Y_p - L_i S\Delta_i - (x_p - l_i S\delta_i)\beta' - (y_p - \\
l_i C\delta_i)\beta'' - z_p\beta''' + q_i S\lambda_i C\Delta_i] - C\lambda_i[Z_p - (x_p - l_i S\delta_i)\gamma' \\
- (y_p - l_i C\delta_i)\gamma'' - z_p\gamma''' - q_i C\lambda_i]
\end{array}\right\} \\
,(i=1,2,...,6) \quad (7.8)
\end{gathered}
$$

If the manipulated object is moved from an initial position and orientation $X'_p, Y'_p, Z'_p, \psi', \varphi', \theta'$ to a goal position $X''_p, Y''_p, Z''_p, \psi'', \varphi'', \theta''$ in certain amount of time between t' and t'' when the motion starts and stops at rest, for each generalized coordinate of the manipulated object, these constraints are satisfied by a polynomial of third degree. Consequently the generalized velocities of the manipulated object are:

$$
\dot{q}_{p_i}(t) = \frac{6\left(q''_{p_i} - q'_{p_i}\right)}{t''^2} t + \frac{6\left(q'_{p_i} - q''_{p_i}\right)}{t''^3} t^2 \qquad ,(i=1,2,...,6) \qquad (7.9)
$$

1.7.5. Dynamics

The reason for examining the dynamics of the robot is to determine the generalized forces that are required of the actuators to balance the supplementary forces applied to the robot. The dynamic model of the parallel manipulators is a kind of non-linearity with characteristics of time-varying and coupling (Yang et al., 2008). The Lagrange method describes the dynamics of a mechanical system from the concepts of work and energy. This method enables a systematic approach to the motion equations of any mechanical system (Lopes and Almeida, 2008). The dynamic analysis presented here is based on the Lagrangian approach:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_{p_j}}\right) - \frac{\partial L}{\partial q_{p_j}} = Q_j \qquad ,(j=1,2,...,6) \tag{7.10}$$

where:

$$L=E_C-E_P \tag{7.11}$$

is the Lagrangian, which is the difference between the kinetic energy and the potential energy:

$$E_C = \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} J_{kl}\omega_k\omega_l + \frac{1}{2}\sum_{k=1}^{3} M\dot{q}_{p_k}^2 + \frac{1}{2}\sum_{i=1}^{6} m_i\dot{q}_i^2 \tag{7.12}$$

$$E_p = m_o g(Z_p - \gamma' x_p - \gamma'' y_p - \gamma''' z_p) + m_p g Z_p + \sum_{i=1}^{6} m_i g(q_i - l_i)C\lambda_i \tag{7.13}$$

where g is the gravity acceleration, m_i are masses of the motor links and J_{kl} are the elements of the inertia matrix of the end-effector of mass m_o and manipulated object of mass m_p, ($M=m_o+m_p$).

After some mathematical computations, the following motion equations of the parallel robot are obtained:

$$\begin{aligned}
&\left\{\frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} J_{kl}\left(\frac{\partial\omega_k}{\partial\dot{q}_{p_j}}\dot{\omega}_l + \dot{\omega}_k\frac{\partial\omega_l}{\partial\dot{q}_{p_j}}\right) + M\sum_{k=1}^{3}\ddot{q}_{p_k}\frac{\partial\dot{q}_{p_k}}{\partial\dot{q}_{p_j}} + \sum_{i=1}^{6} m_i\ddot{q}_i\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}\right\} + \\
&\left\{\begin{aligned}
&\frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\dot{J}_{kl}\left(\frac{\partial\omega_k}{\partial\dot{q}_{p_j}}\omega_l + \omega_k\frac{\partial\omega_l}{\partial\dot{q}_{p_j}}\right) - \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\frac{\partial J_{kl}}{\partial q_{p_j}}\omega_k\omega_l + \\
&\frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} J_{kl}\left[\frac{d}{dt}\left(\frac{\partial\omega_k}{\partial\dot{q}_{p_j}}\right)\omega_l + \omega_k\frac{d}{dt}\left(\frac{\partial\omega_l}{\partial\dot{q}_{p_j}}\right) - \frac{\partial\omega_k}{\partial q_{p_j}}\omega_l - \omega_k\frac{\partial\omega_l}{\partial q_{p_j}}\right] + \\
&\sum_{i=1}^{6} m_i\left[\dot{q}_i\frac{d}{dt}\left(\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}\right) - \dot{q}_i\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}\right]
\end{aligned}\right\} + \\
&\left\{Mg\frac{\partial Z_p}{\partial q_{p_j}} + \sum_{i=1}^{6} m_i g\frac{\partial q_i}{\partial q_{p_j}}C\lambda_i - m_o g\left(x_p\frac{\partial\gamma'}{\partial q_{p_j}} + y_p\frac{\partial\gamma''}{\partial q_{p_j}} + z_p\frac{\partial\gamma'''}{\partial q_{p_j}}\right)\right\} = Q_j
\end{aligned}$$

$$,(j=1,2,...,6) \tag{7.14}$$

where the generalized forces due to the non-conservative forces are:

$$Q_j = \sum_{i=1}^{6} l_{ij} Q_{m_i} \tag{7.15}$$

and Q_{m_i} are the generalized motor forces.

The inverse dynamic model is useful for the robotic system control. It consists in determination in real time of the generalized motor forces Q_{m_i} from equations (7.15), by solving the positional problem from equation (7.1), the kinematic problem from equation (7.5) and the dynamic model from equation (7.14).

Parallel robots with a high number of degrees of freedom, in particular six degrees like the 6-PGK parallel robot, are modelled by complex dynamic equations, comprising a large number of parameters. Solving them requires crossing a high number of iterations and selection of admissible real solutions. The complexity of the program, the large number of loops, testing all solutions, selecting the nearest current configuration solution, can induce errors in configuration identification. Therefore in current industrial exploitation, parallel robots control requires the use of simple and effective control methods.

1.7.6. Trajectory errors of the 6-PGK parallel mechanism

Manufacturing tolerances, installation errors and link offsets cause deviations with respect to the nominal kinematics parameters of the robot system. As a result, if the nominal values of these parameters are used within the robot system control software, the resulting pose of the system will be inaccurate. Link and joint flexibility has a significant impact on robot performance and stability. Link gravity and external payload cause the deflection of links and flexible joints, and therefore degrade the robot performance (Zhaocai and Yueqing, 2008).

In recent research (Cui and Zhu, 2008), trajectory tracking control of parallel manipulators is aimed in the presence of flexibility at the joint drives and joint structural damping is considered in the dynamic model.

In the case of the 6-PGK parallel robot, when the supplementary motions are induced, the dynamic equations (14) become:

$$\left\{ \begin{array}{l} \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3} J_{kl}\left(\frac{\partial \omega_k}{\partial \dot{q}_{p_j}}\dot{\omega}_l + \dot{\omega}_k \frac{\partial \omega_l}{\partial \dot{q}_{p_j}}\right) + M\sum_{k=1}^{3}\ddot{q}_{p_k}\frac{\partial \dot{q}_{p_k}}{\partial \dot{q}_{p_j}} + \\ \sum_{i=1}^{6} m_i\left(\ddot{q}_i + \ddot{\zeta}_i\right)\frac{\partial\left(\dot{q}_i + \dot{\zeta}_i\right)}{\partial \dot{q}_{p_j}} \end{array} \right\} +$$

$$\left\{\begin{array}{l} \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\dot{J}_{kl}\left(\frac{\partial\omega_k}{\partial\dot{q}_{p_j}}\omega_l+\omega_k\frac{\partial\omega_l}{\partial\dot{q}_{p_j}}\right)-\frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}\frac{\partial J_{kl}}{\partial q_{p_j}}\omega_k\omega_l+ \\ \frac{1}{2}\sum_{k=1}^{3}\sum_{l=1}^{3}J_{kl}\left[\frac{d}{dt}\left(\frac{\partial\omega_k}{\partial\dot{q}_{p_j}}\right)\omega_l+\omega_k\frac{d}{dt}\left(\frac{\partial\omega_l}{\partial\dot{q}_{p_j}}\right)-\frac{\partial\omega_k}{\partial q_{p_j}}\omega_l-\omega_k\frac{\partial\omega_l}{\partial q_{p_j}}\right]+ \\ \sum_{i=1}^{6}m_i\left[\left(\dot{q}_i+\dot{\zeta}_i\right)\frac{d}{dt}\left(\frac{\partial\left(\dot{q}_i+\dot{\zeta}_i\right)}{\partial\dot{q}_{p_j}}\right)-\left(\dot{q}_i+\dot{\zeta}_i\right)\frac{\partial\left(\dot{q}_i+\dot{\zeta}_i\right)}{\partial q_{p_j}}\right] \end{array}\right\}+$$

$$\left\{Mg\frac{\partial Z_p}{\partial q_{p_j}}+\sum_{i=1}^{6}m_i g\frac{\partial q_i}{\partial q_{p_j}}C\lambda_i-m_o g\left(x_p\frac{\partial\gamma'}{\partial q_{p_j}}+y_p\frac{\partial\gamma''}{\partial q_{p_j}}+z_p\frac{\partial\gamma'''}{\partial q_{p_j}}\right)\right\}=Q_j+Q_{j_{suppl}}$$

$$,(j=1,2,...,6) \qquad (7.16)$$

The differences between equations (14) and (16) are the supplementary generalized forces that must be introduced in system to correct the trajectory errors:

$$Q_{j_{suppl}}=\sum_{i=1}^{6}m_i\left[\left(\ddot{q}_i+\ddot{\zeta}_i\right)\frac{\partial\dot{\zeta}_i}{\partial\dot{q}_{p_j}}+\ddot{\zeta}_i\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}+\left(\dot{q}_i+\dot{\zeta}_i\right)\frac{d}{dt}\left(\frac{\partial\dot{\zeta}_i}{\partial\dot{q}_{p_j}}\right)\right.$$
$$\left.+\dot{\zeta}_i\frac{d}{dt}\left(\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}\right)-\left(\dot{q}_i+\dot{\zeta}_i\right)\frac{\partial\dot{\zeta}_i}{\partial\dot{q}_{p_j}}-\dot{\zeta}_i\frac{\partial\dot{q}_i}{\partial\dot{q}_{p_j}}\right]$$

$$,(j=1,2,\ldots,6) \qquad (7.17)$$

where $\dot{\zeta}_i$ are deduced from the system obtained by equalizing the two different shapes of $\dot{X}_p,\dot{Y}_p,\dot{Z}_p,\dot{\psi},\dot{\varphi},\dot{\theta}$ from equations (7.8) and (7.9).

The method (Moldovan, 2008a) allows obtaining a desired trajectory for the manipulated object of the 6-PGK parallel robot, in real work situations, when some vibration motions act in the prismatic motor joints. The method is different in comparison with other research (Ider and Korkmaz, 2008) where dynamic model is first converted into an open-tree structure by disconnecting a sufficient number of unactuated joints and the closed loops are then expressed by constraint equations.

1.8. PERFORMANCE EVALUATION OF THE 6-PGK PARALLEL MECHANISM

1.8.1. Performance index

In order to evaluate the performance of a parallel mechanism suitable for robot applications, various indexes are used: the force polytrope, out-of-plane stability (Seriani and Gallina, 2015), performance visualization, finite element analysis (Zhang and Gao, 2015), genetic algorithms and artificial neural networks as an intelligent optimization tool for the dimensional synthesis of the spatial six degree-of-freedom

(Gao et al., 2015), performance atlases (Liu et al., 2015), the performance index defined as the maximum acceptable distance between the mobile platform geometric center and the center of mass of the set consisting of the platform and a payload (Gouttefarde et al., 2015), etc. For the efficient computation of the solution set diverse software packages which implement various algorithms are used. An example is the algorithm based on homotopy continuation (Abbasnejad and Carricato, 2015).

The performance of the 6-PGK parallel mechanism is studied using the maximum force in all direction index and the actuator force index as indexes of robot performance, on various set of parameters and to provide some insight to the dynamic behavior that is useful in the design process. The objective of the study is to use the conservative estimates of parameters in order to obtain the worst case actuator requirements.

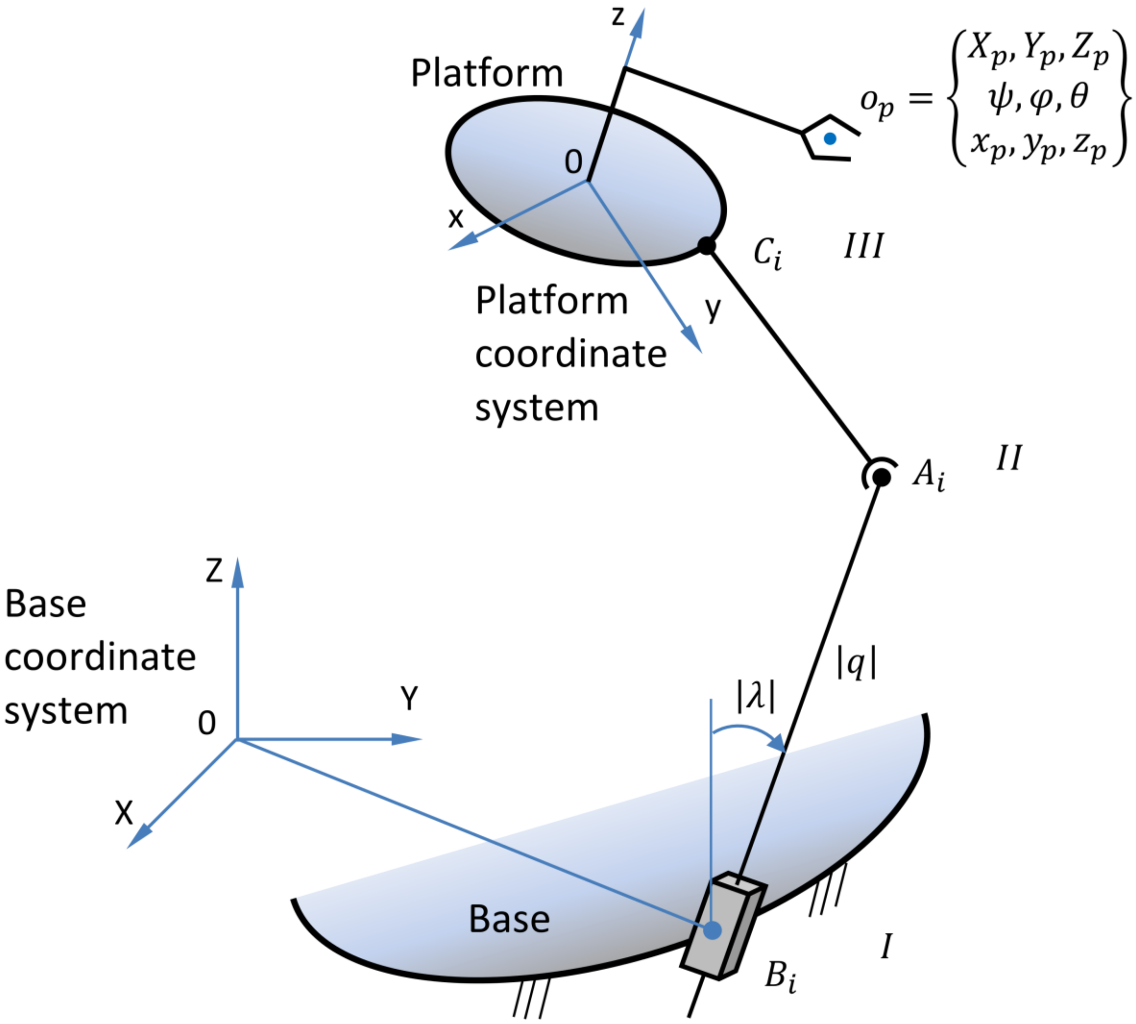


Figure 8.1. A kinematic chain of the 6-PGK parallel mechanism

In the construction of the 6-PGK parallel mechanism, six legs connect the platform to the base. Each leg (Fig. 8.1) has an actuated translational kinematic pair at level I and a spherical kinematic pair at level II. The translational kinematic pairs form the angles λ_i with the vertical axis in points B_i. The location (position and orientation) of the end-effector and of the manipulated object are expressed in the base coordinate system OXYZ by the generalized coordinates of the manipulated object X_p, Y_p, Z_p, ψ, φ, θ denoted q_{pi} (i=1,2,…,6), and in the platform coordinate system oxyz by the x_p, y_p, z_p coordinates.

The displacements in the actuated translational kinematic pairs (actuators displacements) are the generalized coordinates of the parallel robot q_i (i=1,…,6).

The dynamic equations of motion obtained by Lagrange method are composed of three terms: inertial, centrifugal and Coriolis, gravitational, that are grouped in the three large brackets (7.14).

1.8.2. The dynamic simulation software

The dynamic simulation software allows the designer to determine the actuator requirements for a manipulator performing a desired task or motion. The first goal of testing this software is to gain some understanding of the dynamic behavior of parallel manipulators. The actuator requirements (forces, power and frequency response) are a function coupling wrench and therefore a function of the geometry, the system parameters such as masses, desired motion or task.

The test results help to gain some understanding of the dynamic behavior of the system. Since the equations of motion are a function of so many different parameters, it is very difficult to assess the effect of all the possible parameters variations. This is why only some combinations are tested, enough to understand the dynamics of the system and help identify some relevant factors affecting such behavior.

The tests are conducted to understand some of the relationship between the geometric parameters, motion planning and inertial properties of the parallel manipulator and the dynamic behavior of the system.

Another objective is to demonstrate the usefulness the computational software as integrated part of a Computer Aided Engineering tool for the design of parallel manipulators. By evaluating the effect of different parameters on the dynamic behavior of the system, this software will assist the designer in the process of developing the parallel manipulator.

The detailed steps of the proposed computational algorithm are as follows:

Algorithm: Determination of the robot actuator forces

Input: the structural characteristics of the parallel mechanism consisting of base and platform dimensions, the masses of the elements, the initial and the final point of the manipulated object trajectory.

Output: the generalized actuator forces.

*Step 1.*Set the generalized coordinates of the manipulated object in the initial and final point of the trajectory; set the time interval of the trajectory movement and the time interval Δt for kinematic parameters of the trajectory determination.

*Step 2.*Compute the intermediate points of the planed trajectory C_p.

*Step 3.*Determine the intermediate computation time $t_{kinitial}$ and t_{kfinal}. Select the intermediate initial and final generalized coordinates pair X_{pstart}, X_{pstop}.

---

*Step 4.*Compute the robot inverse kinematics at time *t*.

*Step 5.*Solve the motion system of equations with respect to generalized actuator forces.

*Step 6.*Compute the generalized motor forces Q_m and moments M_i, i=1,…,6.

*Step 7.*Increment the time *t* and then check if $t>t_{ifinal}$. If Yes then go to Step 8 else go to Step 4.

*Step 8.*Check if $t<t_{final}$. If Yes go to Step 3 else go to Step 9.

*Step 9.*Stop.

1.8.3. Motion and task planning for testing

Two different types of motions or tasks are used for testing the dynamic simulation software. The platform will be used in a machining process to support and move a workpiece. A full groove is cut with a four tooth end mill. The workpiece is to be taken through rectilinear and curvilinear motion as explained below.

The first motion to be used for machining the workpiece is a rectilinear motion parallel to the XY plane at a distance Z_p from the base, as shown in figure 8.2a, along the axis of translation w which is at an angle α with the X axis, as shown in figure 8.2b. The platform starts moving from point C_{start}, moves distance ΔS along the direction of motion in a period of time T and completes its motion at point C_{stop}. The workpiece is machined through the complete motion.

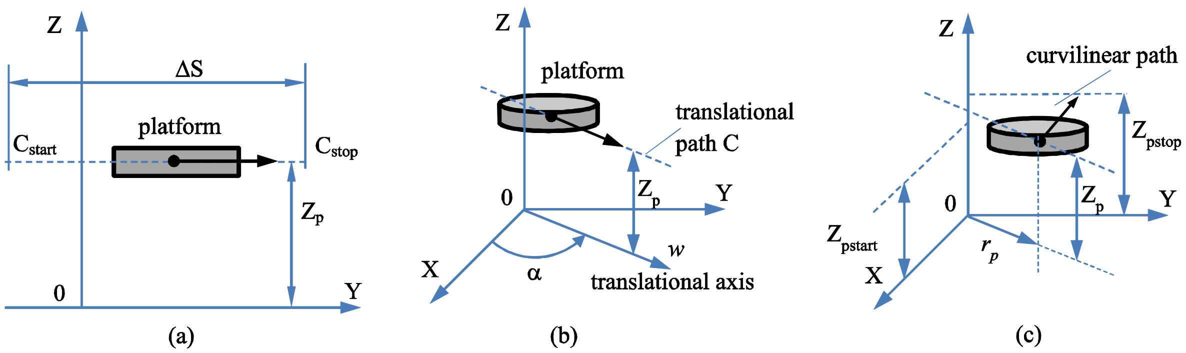


Fig. 8.2a. Rectilinear motion for machining; b. Axis of translation for the platform; c. Curvilinear motion for machining

The second motion to be used for machining the workpiece is a curvilinear motion. The radius of curvature is r_p, the axis of rotation is the OZ axis, starts at the height Z_{pstart} and and stops at Z_{pstop}, as shown in figure 8.2c. The initial orientation of the platform is 0°, and it rotates 180° in a period of time *T* to end. The workpiece is machined through the complete motion and the cutting forces are tangent to the path at all times.

1.8.4. Test cases results and discussion

There are many combinations of parameters that can be used when testing the dynamic simulation software. One of the objectives of the testing is to gain some insight of the dynamic behavior of the platform, not to test as many combinations of parameters as possible. The effect of geometric variations is explored by changing the height Z_p and the angles λ_i, than variations of the motion planning parameters is examined by reducing the time period T required for completing the motion, and finally the effect of variations in the system parameters is evaluated by increasing the mass and moment of inertia of the mobile platform and manipulated object.

The required actuator forces are calculated for each test by the simulation program and displayed. One important condition is that the actuator forces requirements must not exceed the maximum force capacity. When this happens, the system is operating in a condition known as an actuator singularity and the desired motion cannot be produced by the manipulator. The possibility of this condition happening is monitored using the actuator force index:

$$AFI = [(Q_{max} - Q_m / Q_{max})]x100 \tag{8.1}$$

where: Q_{max} is the maximum force capacity of the actuator and Q_m is the required actuator force.

The above equation is similar to the definition of some performance indices used in the area of control theory. The use of the actuator force index AFI allows all the actuators of the manipulator to be compared on the same dimensionless scale which might be somewhat difficult by just using the actuator force plots. The force index simplifies identifying actuator saturation; the smaller the force index, the closer the actuator is being saturated. This index also allows the designer to avoid overdesigning or understanding when selecting the actuators.

1.8.4.1. Test cases with geometric variations

The first test cases involve a rectilinear motion of the platform as discussed in figure 8.2a, 8.2b. In the group of tests the height of the platform Z_p was increased from Z_{p1}=0.3m, Z_{p2}=0.5m up to Z_{p3}=0.7m.

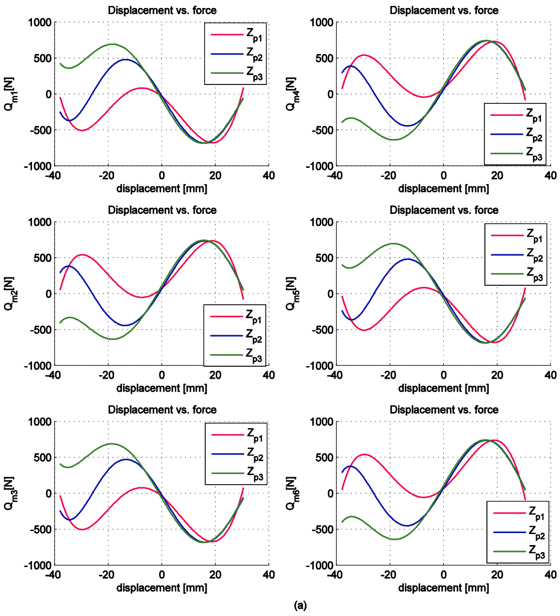
For the rectilinear motion it can be seen that as the height is increased there is an increase in module of the force requirements for all the actuators (Fig. 8.3a). This is seen more clearly in the actuators force index plots when *AFI* is nearest to 0 that happens for the extreme values of the actuator forces (Fig. 8.3b).

This suggests that the general force requirements increase with the height. The lower the height, the grater horizontal force components which are desirable for balancing the effect of an external load, such as the cutting force.

The second test case uses the curvilinear motion described in figure 8.2c, and the reference height of the platform is increased between 0.3m, 0.5m up to 0.7m, the angle λ is zero and the time period T is 20 seconds. The results of these tests are shown in figures 8.4a, 8.4b.

The effects of changing the height for the curvilinear motion are similar with the results obtained for the rectilinear motion. For the curvilinear motion as the height is increased, the overall force requirements are higher.

The next set of tests consist of changing the angle λ_1=0°, λ_2=30°, λ_3=60° while keeping the platform at a fixed height of Z_p=0.3m and the time period T equal to 20 seconds. The results of the rectilinear and curvilinear motions are shown in figures 8.5a, 8.5b and 8.6a, 8.6b respectively.



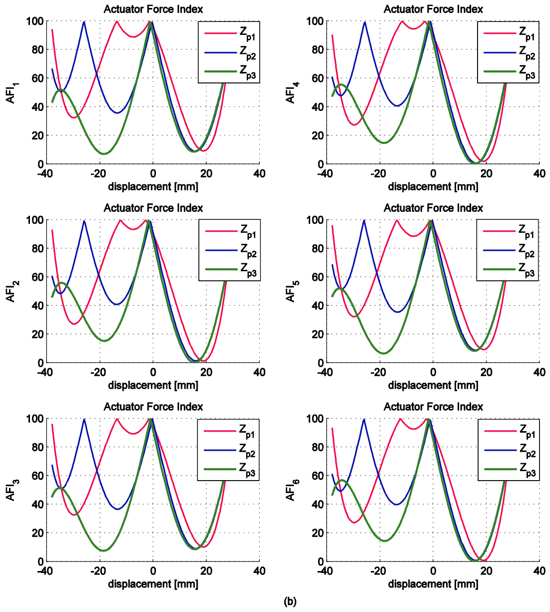
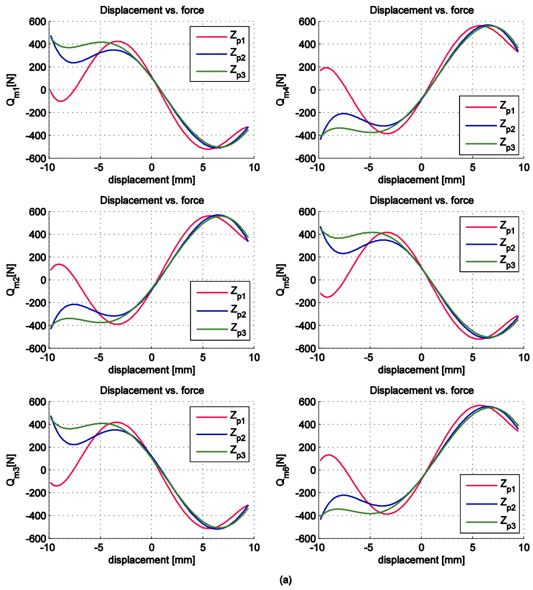


Fig. 8.3a. Effects of the platform height on the actuator forces, rectilinear motion

Fig. 8.3b. Effects of the platform height on the actuator force index, rectilinear motion



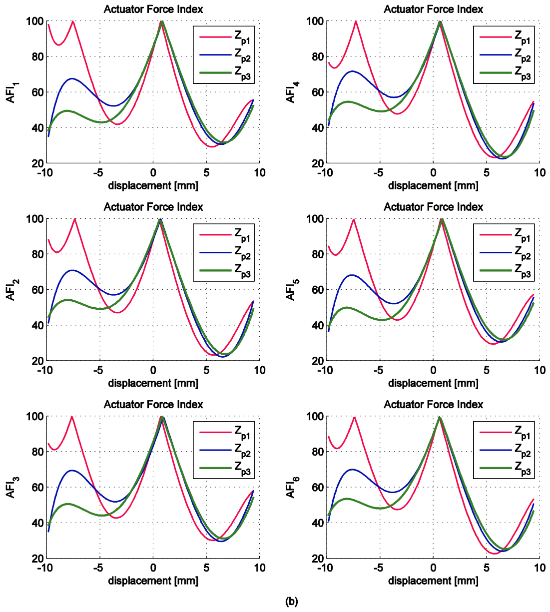


Fig. 8.4a. Effects of the platform height on the actuator forces, curvilinear motion

Fig. 8.4b. Effects of the platform height on the actuator force index, curvilinear motion

These plots indicate that the greater angle λ between the actuators and the normal to the base platform, the greater general actuator force requirements. The increase of angle λ increases the force components for the actuators in the higher plane.

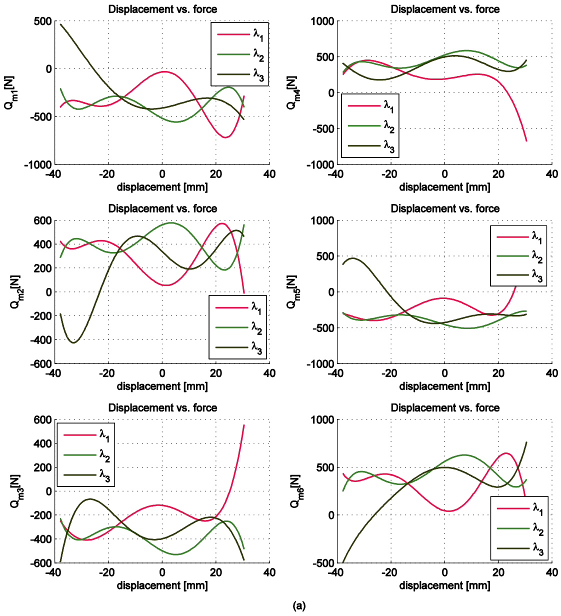


Fig. 8.5a. Effects of the angle λ on the actuator forces, rectilinear motion

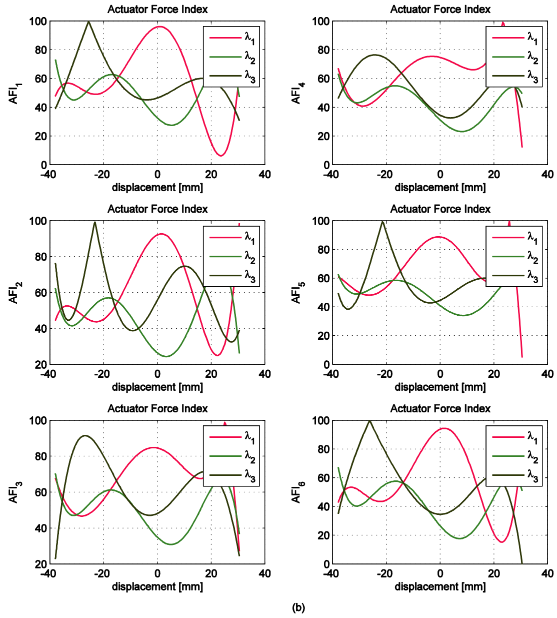


Fig. 8.5b. Effects of the angle λ on the actuator force index, rectilinear motion

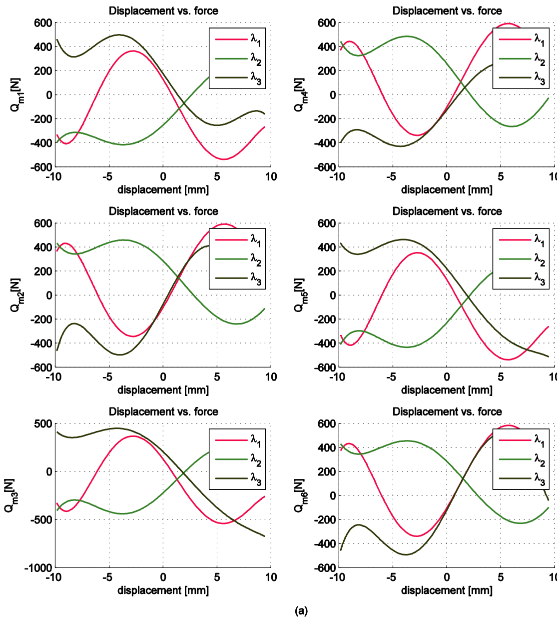


Fig. 8.6a. Effects of the angle λ on the actuator forces, curvilinear motion

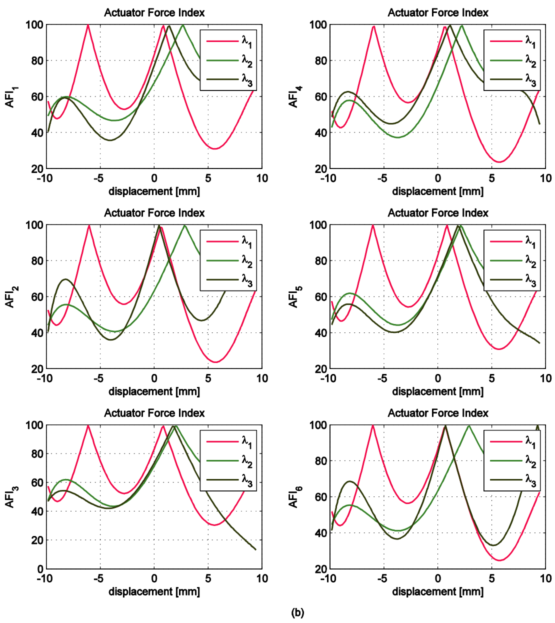


Fig. 8.6b. Effects of the angle λ on the actuator force index, curvilinear motion

1.8.4.2. Test cases with variations of motion planning parameters

The effects of variations of the motion planning parameters is examined by reducing the time period T required for completing the motion, and by changing the type of motion (rectilinear and curvilinear) used. The third set of tests is conducted using variations of the time period T. The shorter the time period, the faster the platform moves.

The results of the tests for the rectilinear and curvilinear motions are shown in figure 8.7a, 8.7b and 8.8a, 8.8b respectively. It can be seen that the reduction of the time period from 20 sec., 10 sec. and 1 sec. does not produce any noticeable changes in the force requirements.

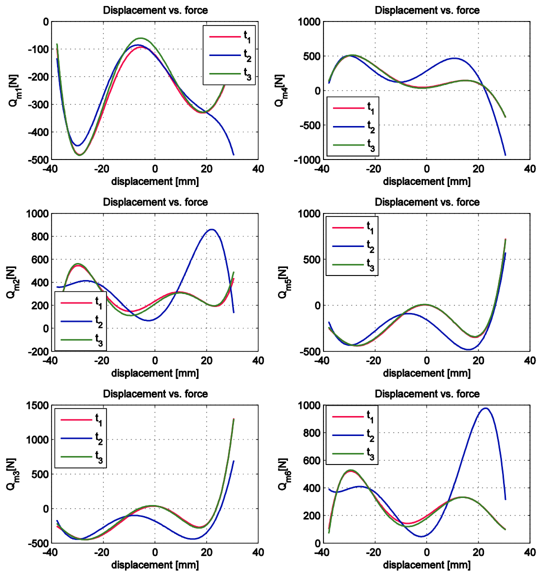


Fig. 8.7a. Effects of the time period on the actuator forces, rectilinear motion

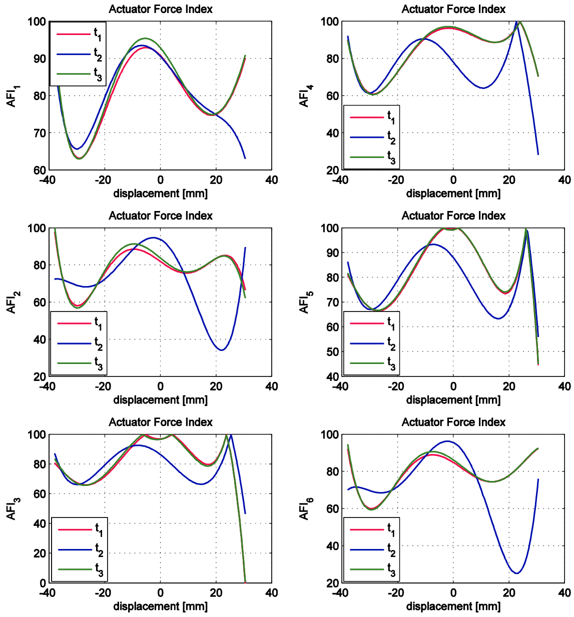


Fig. 8.7b. Effects of the time period on the actuator force index, rectilinear motion

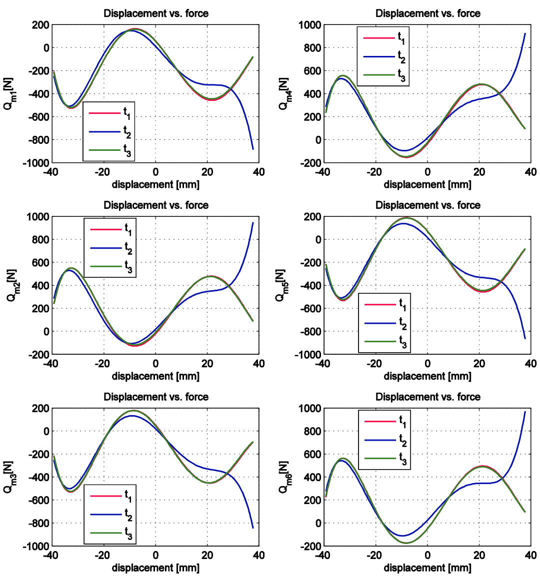


Fig. 8.8a. Effects of the time period on the actuator forces, curvilinear motion

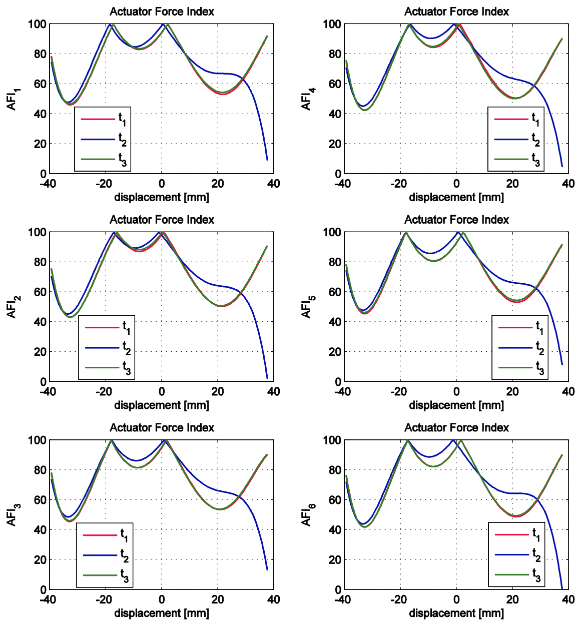


Fig. 8.8b. Effects of the time period on the actuator force index, curvilinear motion

The platform moves faster as the time period used is shorter, and the velocity and acceleration of the connectors will increase. This will increase the magnitude of the tangential, Coriolis and centrifugal coupling wrenches of the actuators since they are functions of the kinematic state of the system among other sings. Since these wrenches are a function of the kinematic state, one would expect a noticeable increase in the actuator force requirements as the platform moves faster. In the test results this trend in not observed. One possible explanation is that the magnitudes of the angular velocities and acceleration vectors are small for the motions tested.

1.8.4.3. Test cases with variations of inertial properties

The effects of the mobile platform masses and moments of inertia on the dynamic behavior are explained in the last set of tests. The platform height is set to Z_p=0.3mm, the angle λ is zero and the time period is 20 seconds. The masses and inertias are multiplied by a factor of 1, 3 and 5. The results of the rectilinear motion and curvilinear motions are shown in figures 8.9a, 8.9b and 8.10a, 8.10b respectively.

It can be seen that as the inertial properties are increased, the general actuator force requirements increase. The greatest increases for force requirements register more than a 100% increase. This suggests that the inertial parameters have a significant effect on the dynamic behavior of the system. All the coupling terms in the equations of motion are functions of these inertial parameters. Since for the motions used for testing generate small values for the connector angular velocity and accelerations vectors, the only numerically significant coupling term left is the gravitational wrench. This term is a function of the gravitational acceleration and the geometry of the system. These results indicate that the gravitational terms are relevant in the dynamic behavior of the system regardless of the speed of the platform and should be considered when designing and controlling a parallel manipulator.

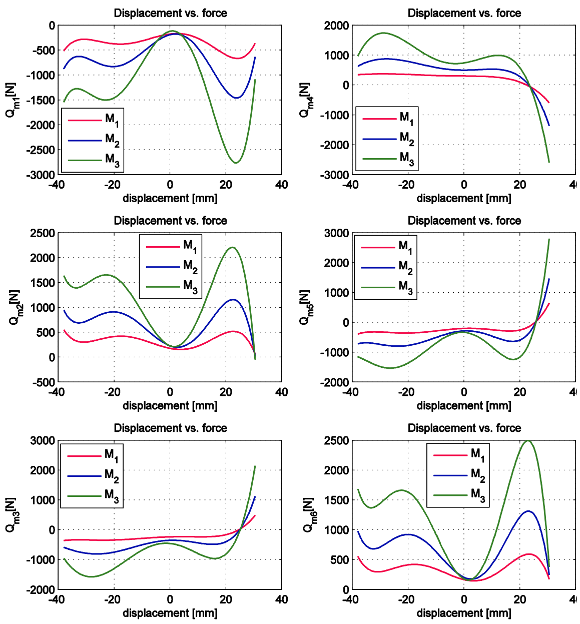


Fig. 8.9a. Effects of the mass and inertial parameters on the actuator forces, linear motion

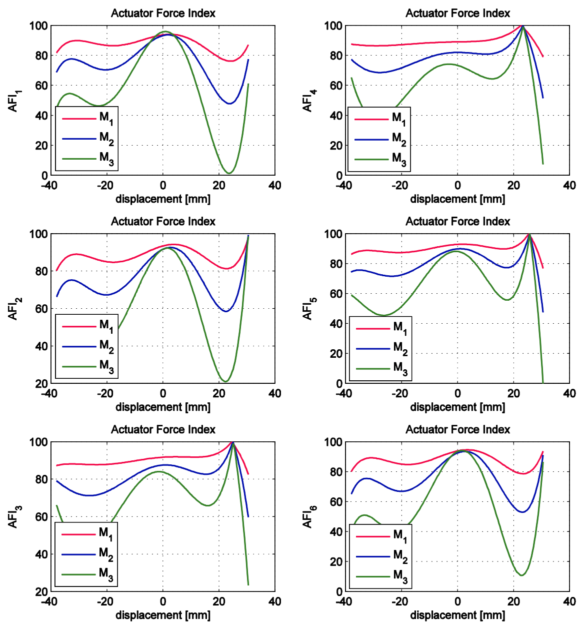


Fig. 8.9b. Effects of the mass and inertial parameters on the actuator force index, linear motion

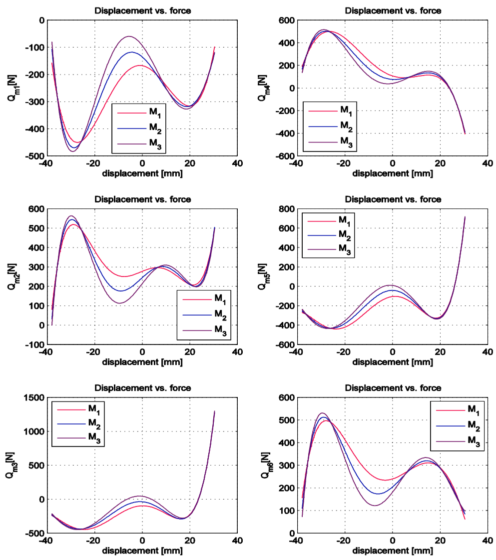


Fig. 8.10a. Effects of the mass and inertial parameters on the actuator forces, curvilinear motion

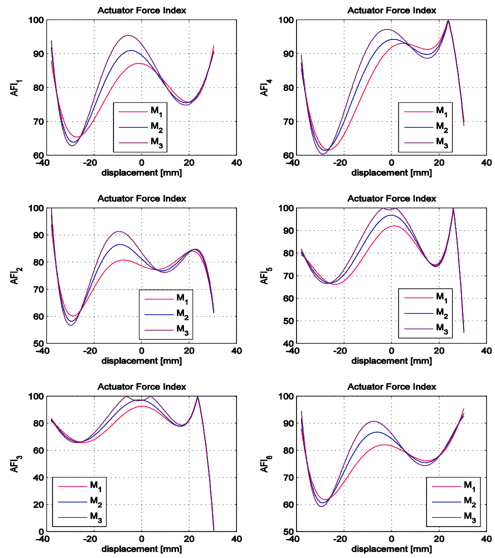


Fig. 8.10b. Effects of the mass and inertial parameters on the actuator force index, curvilinear motion

1.8.4.4. Conclusion from the test cases

In order to evaluate the 6-PGK spatial parallel mechanism and aid in the design process, a complete dynamic model based on the Lagrange method was defined. The model takes advantages of analytical and numerical investigations, carried out with the Matlab software.

The numerical evaluation phase is carried out by exploiting the concepts of maximum force in all direction index and actuator force index which allows all the actuators of the manipulator to be compared on the same dimensionless scale which might be somewhat difficult by just using the actuator force plots. The actuator force index simplifies identifying actuator saturation, the smaller the force index, the closer the actuator is being saturated. This index also allows the designer to avoid overdesigning or understanding when selecting the actuators.

Tests are done on two different trajectories consisting in a rectilinear motion and then a circular motion, which are most common in industrial applications.

In a first set of tests it is demonstrated for the both trajectories that the general force requirements increase with the height Z_p on which the task is performed. The lower the height, the parallel robot manipulator has batter capacity to balance the effect of external load.

The next set of tests consists in changing the angle λ between the actuators and the normal to the base platform. The results indicate that the greater angle λ the greater general actuator force requirements. The increase of angle λ increases the force components for the actuators in the higher plane.

The third set of tests was conducted using variations of the time period T for the same task. It is demonstrated that the reduction of the time period does not produce any noticeable changes in the force requirements.

In the fourth set of tests the effects of the mobile platform masses m_0, manipulated object m_p and moments of inertia on the dynamic behavior is explained. When the inertial properties are increased, the general actuator force requirements increase and the inertial parameters have a significant effect on the dynamic behavior of the system.

These observations are based on simple test cases, and in order to study general trends much more testing is required. If the gravitational coupling is found to a sole significant coupling factor, the manipulator can be designed to reduce this effect through mass balancing. The equations of motion are functions of a great set of factors that can be changed. This underlines the great importance of extensive testing with different sets of geometric parameters, system parameters, motions and tasks in order to carefully study the effects of coupling. These results provide some insight to the dynamic behavior of a platform system and how it is affected by different factors.

1.9. ANN BASED INVERSE DYNAMIC MODEL OF THE 6-PGK PARALLEL ROBOT MANIPULATOR

1.9.1. Robot control

A classic approach in controlling robots consists in the employment of the dynamic model. Various methods have been proposed to derive the dynamic model of the parallel manipulator, like the generalized momentum approach (Lopes, 2010), principle of virtual work (Staicu, 2007) screw theory (Gallardo et al., 2003) and Hamilton’s principle (Miller, 2004), the recursive matrix method (Staicu, 2006) or the Lagrangian approach (Le et al., 2013), which describes the dynamics of mechanical system from the concepts of work and energy (Lopes, 2010).

All these approaches are equivalent as they are describing the same physical system, and lead to equivalent dynamic equations, which present different levels of complexity and associated computational loads.

The analytical calculus involved in the dynamic equation is very tedious, thus presenting an elevated risk for errors. Furthermore, the duration of numerical computations is getting longer when the number of mechanism’s degrees of freedom is increased.

The dynamic model based control arises numerous difficulties because of the time-varying and coupling of the equations. Unfortunately, the present-day commercial controllers cannot provide satisfying performance for control.

In recent years an important credit in obtaining new enhancements is granted to the support offered by artificial intelligence techniques.

The role of artificial intelligence related to the parallel robots aims with predilection the modeling and control domain in terms of kinematics or dynamics. Moreover these strategies are designed to improve the classical control strategies, in terms of increasing the current performances, to add new properties such as robustness and improvement of the real-time behavior using fuzzy systems or different types of neural networks (NNET).

Compared to the mathematical model of the kinematics, neural networks provide significantly better mapping between manipulator’s task space and joint space, as demonstrated by Uzunovic et al., 2013.

Achili et al. (2012), proposed an adaptive force/position controller for parallel robot with constrained motions based on multi-layer perceptron neural network. The solution presents the major advantage of obtaining the control law without the prior knowledge of the inverse dynamic model and being able to take into account the endogenous disturbance (uncertainties and nonlinearities related to the robot dynamics) and to compensate exogenous disturbances.

Peng et al., (2010), design a control system for a parallel mechanism consisting from a combination of linear controllers and two neural networks. The aim of this control system is to compensate the nonlinearities from the model of the system and the dynamic model estimation for improved accuracy of trajectory.

Le et al. (2013), investigate the enhancement of the classical nonlinear PD torque controller by using neural networks for on-line self gain tuning. The proposed solution consists in a self gain tuning control law for minimizing the error in tracking trajectories of the parallel manipulators characterized by simple structure suitable for low computation effort in real-time implementations.

Yu and Weng (2014), propose a robust control structure for parallel manipulators based on H_∞ tracking adaptive fuzzy integral sliding mode control scheme mainly able to handle the nonlinear unmodeled dynamics and to compensate external disturbances.

All these solutions benefit from the advantages of various artificial intelligence techniques, but underline the difficulty of implementing them, starting from the structure, the different parameters values or choice of training methods, and finally reaching the problem of required computational effort.

Recent research in the field of robot control is conducted in new directions based on bio-inspired approach that proved their efficiency on other fields of robotics, like the simplified fuzzy controller using neural network based on genetic algorithm learning for mobile robots (Obe and Dumitrache, 2012), the communications and social structure of whale pods applied to cooperative robot structures (Resceanu et al., 2012) or fast genetic algorithm for robot soccer and planet exploration citelee. We consider that this direction of research may find applicability in the case of parallel robots, for the potential offered in solving many complex problems such as those in the case of parallel robot control discussed in this paper.

From the above explored literature I conclude that in the case of parallel robots there is a need to find adequate solutions for the real time control which involve increasing the trajectory following performance and low computational effort.

The objective of my research is to build and implement an artificial neural network based on the inverse dynamic model estimation of the parallel mechanism 6-PGK.

1.9.2. FANN based dynamic model of the 6-PGK parallel mechanism

1.9.2.1. FANN Structure for robot dynamic modelling

For the 6-PGK parallel mechanism modelling a feed-forward artificial neural network (FANN) with one hidden layer has been designed (Moldovan et al., 2016). The FANN is implemented as a nonlinear autoregressive model with exogenous inputs (NARX) model. The NARX model is based on the linear ARX model, which is commonly used in time-series modelling (Demut et al., 2007).

The numbers of the inputs of the used FANN is determined by the numbers of the generalized coordinates of the mechanism, the number of the generalized forces and the number of theirs considered past values. The numbers of the outputs of the used FANN is given by the numbers of the generalized forces from the dynamical model of the mechanism.

By using the compact structure of an artificial neuron presented in (Grif, 2014) I can summarize the mathematical processing that occurs inside of an artificial neuron from the used FANN as:

$$a = F\left(\sum_{j=1}^{n} \omega_j x_j + \theta\right) \tag{9.1}$$

where are denoted by: x_j ($j = 1, \ldots, n$) – the inputs of the neuron, ω_j ($j = 1, \ldots, n$) – the weights of the inputs x_j, θ – the weight of the offset input, n – the numbers of the inputs of the neuron, F is the activation function, a – the activation of the neuron.

The type of the activation function and the numbers of the inputs corresponding to each neuron depend on the layer to which it belongs. For the neurons from the hidden layer are used two types of the activation function: the hyperbolic tangent function (HTF) type and the radial basis function (RBF) type (Demut et al., 2007). The numbers of the inputs of the neurons from this layer is given by the maximum lags associated with robot output (n_Q) and input (n_{q_p}) signals described by relation $6\left(n_{q_p} + n_Q\right)$, which also represents the number of the inputs of the FANN. The activation function of the neurons from the output layer is the linear type function and the number of the inputs of these neurons equals the number of the neurons from the hidden layer of the FANN. For the training of the FANN the gradient descent back propagation algorithm was used (Demut et al., 2007). The training of the used FANN was achieved by presenting to their inputs and outputs the training set of the *N* pairs of the vectors:

$$\left\{\left(\underline{x}^i(1), \underline{a}_d^o(1)\right), \left(\underline{x}^i(2), \underline{a}_d^o(2)\right), \ldots, \left(\underline{x}^i(N), \underline{a}_d^o(N)\right)\right\}$$

where $x^i(k)$ is an input training vector ($k = 1, \ldots, N$) with $6(n_{q_p} + n_Q)$ elements and $a_d^o(k)$ is the desired target output vector (with 6 elements) of the FANN corresponding to the input training vector $x^i(k)$.

1.9.2.2. FANN optimal parameters determination

Analytical determination of the FANN parameters is an uncommon task, thus the empirical approach is more often used. The optimum determination however is a more complex task, so in this section a tested methodology for determination of these parameters is proposed.

Usually, the investigation of a system starts from the searching of the parameters that influence the behavior of the studied system. The same approach was established for the present work. In the case of the proposed structure of neural network the following four parameters were considered: learning rate (γ), the number of the neurons on the hidden layer (n_h), the number of the past values of the generalized forces (n_Q) and the number of the past values of the generalized coordinates (n_q). In order to study the influence of these parameters on the neural network behavior for building the FANN training data sets the generalized coordinates trajectory of the robot and the corresponding trajectories for generalized motor forces will be used.

An adequate solution for the process of searching through the experimental set can be performed by visual analysis of all the available results (large sets of plotted trajectories). But this approach presents a major drawback from time needed for analysis and required storage resources. In order to facilitate and automatize the evaluation process, quality measures can be used. An option is represented by the mean squared error or the mean absolute error. However, both measures present major difficulty in the case of establishing of a threshold value to aid in deciding the quality of the robot model identification. In order to overcome the mentioned drawbacks for the evaluation process the authors propose an automated method and the usage of a quality measure based on signal-to-noise ratio (SNR). For the 6-PGK prototype robot the SNR is given by the following equation:

$$\mathrm{SNR}_i = 10 \cdot \log_{10} \frac{\sum_{j=1}^{N} \left(Q_{m_i}(j)\right)^2}{\sum_{j=1}^{N} \left(Q_{m_i}(j) - Q_{m_{iFANN}}(j)\right)^2} [\mathrm{dB}], \ (i=1,...,6) \qquad (9.2)$$

where Q_{m_i} represents the generalized motor trajectory forces given by the inverse dynamical model of the robot, $Q_{m_{iFANN}}$ represents the generalized motor trajectory forces given by the FANN and *N* is the number of the trajectory samples.

The proposed SNR quality measured was derived from the signal-to-noise ratio used for evaluation of unidimensional electrical signals.

The algorithm for FANN optimal parameters determination is presented below.

General algorithm for choosing the structure of the FANN

Let us consider the following parameters which influence the behavior of the FANN: learning rate (γ), the number of the neurons (n_h) from hidden layer, the number of the past values for the input (n_{q_p}) and output (n_Q) variables employed to build the robot regressors vectors (input vectors of the FANN) used in training and simulation of the FANN. These parameters are referred as “FANN parameters”. The steps of the proposed algorithm for choosing the structure of the FANN are (Moldovan et al., 2016):

- *Step 0.* Select (experimentally): the number of the initial sets of values for the FANN weights and the corresponding weights values (that are random real numbers in the range $[-0.5, 0.5]$), having built a collection of initial sets of values for the FANN weights, the signal-to-noise ratio threshold SNR_{thold}, the sets of values for the FANN parameters. To each set of values of the FANN parameters is attached a set of counter variables of the same size as the size of the value of the considered set. Thus for a FANN parameter to each value (from the set of values of the considered FANN parameter) it corresponds a counter variable. The value of the counter variables is initialized with zero;

- *Step 1.* Set the following values of the FANN parameters with start values $n_h = n_{hStart}$, $n_Q = n_{QStart}$, $n_{q_p} = n_{q_p Start}$. These values are drawn from the sets of the FANN parameter values;
- *Step 2.* Keeping constant the values of the FANN parameters $n_h = n_{hStart}$, $n_Q = n_{QStart}$, $n_{q_p} = n_{q_p Start}$ establish the optimal learning rate γ_{opt} based on the Algorithm for Evaluation and Determination of the Optimum Value for the FANN parameters;
- *Step 3.* Keeping constant the value of the parameters $\gamma = \gamma_{opt}$, $n_Q = n_{QStart}$, $n_{q_p} = n_{q_p Start}$ establish the optimal number of hidden layer neurons (n_{hopt}) based on the Algorithm for Evaluation and Determination of the Optimum Value for the FANN parameters;
- *Step 4.* Keeping constant the value of the FANN parameters *gamma* = γ_{opt}, $n_h = n_{h\,opt}$ establish optimal values of the number of the past samples for the input and output variables of the robot model (n_{Qopt}, $n_{q_p opt}$) based on the Algorithm for Evaluation and Determination of the Optimum Value for the FANN parameters to which the following changes are made corresponding to the steps *Step 4”*, *Step 6”* and *Step 7”*;
- *Step 5.* Keeping constant the value of the FANN parameters gamma = γ_{opt}, $n_h = n_{hopt}$ and $n_q = n_{qopt}$ it is tested the estimation and identification algorithm considering other trajectories for input and output variables of the robot (or model of the robot).

Algorithm for evaluation and determination of the optimum value for the FANN

For each value from the set of values corresponding to the FANN parameter set to be evaluated, the following steps will be executed separately for the each set of the initial weights:

- *Step 1’.* Initialize the weights of the FANN with the corresponding initial selected set of weights;
- *Step 2’.* Run the estimation and identification algorithm calculating the signal-to-noise ratio (SNR) based on the relation (6) for each output path (trajectory corresponding to a generalized forces), thus corresponding to each set of initial weights, a set of six values of the noise-to-signal ratio will be obtained;
- *Step 3’.* Compute the average of the signal-to-noise ratio SNR_{med} as mean value of the six signal-to-noise ratio determined in *Step 2*;
- *Step 4’.* Compare the value of SNR_{med} with the threshold value SNR_{thold}. If the average is greater than the threshold then increment the counter variable corresponding to the current value of the FANN parameter and go to *Step 5’*;

- *Step 4”.* Compare the value of the SNR_{med} with the threshold value SNR_{thold}. If the average value is greater than the threshold value, then increment the counter variable corresponding to the current values combination for the two FANN parameters;
- *Step 5’.* If the sets of initial values for weights are not exhausted select a new set of values for weights and jump to *Step 1’*. If the sets of initial values for weights were exhausted continue with *Step 6’*;
- *Step 6’.* Using the values of the counter variables, the success rates corresponding to each FANN parameter value is computed by

$$SR_i = \frac{counter_i}{mo.\ of\ the\ initial\ weights\ sets} \cdot 100[\%]$$

where i = 1, …, no. of the FANN parameter values. Go to *Step 7’*;

- *Step 6”.* Using the values of the counter variables, the success rates corresponding to each combination of the FANN parameters values are computed and go to *Step 7”*;
- *Step 7’.* Choose the FANN parameter value for which the success rate is the largest. Finally this value will be considered as the optimal value for the evaluated FANN parameter;
- *Step 7”.* Choose a pair of values of the two FANN parameters for which the success rate is the largest. Finally the values of the selected pair will be considered as the optimal for the two parameters of the FANN evaluated.

1.9.3. Experimental results and discussion

For the implementation and testing of the parallel robot modeling, Matlab platform and its Neural Network Toolbox were used. In order to investigate the performance of the FANN based modeling the model of the parallel robot based on equations (7.3), (7.4) and (7.14) was implemented.

In Figure 9.1 six desired trajectories are presented for the generalized coordinates of the manipulated object (X_p, Y_p, Z_p, ψ, ϕ, θ denoted q_{p_i}, i = 1, …, 6). These trajectories are placed in parallel surfaces having the same 3D spatial shape at different elevation. These trajectories represent the input trajectories for the Inverse Dynamic Model of the 6-PGK Parallel Robot Manipulator.

In order to study the influence of the FANN parameters on the neural network behavior for building the FANN training data sets, one of the spatial generalized coordinates trajectory was used, which has the red Z_p line from Figure 9.1 and the corresponding red trajectories for generalized motor forces from Figure 9.2.

In Figure 9.2 six desired trajectories for the generalized motor forces (Q_{m_i}, j = 1, …, 6) are presented. These trajectories represent the output trajectories of the Inverse Dynamic Model of the 6-PGK Parallel Robot Manipulator corresponding to the input trajectories from Figure 9.1.

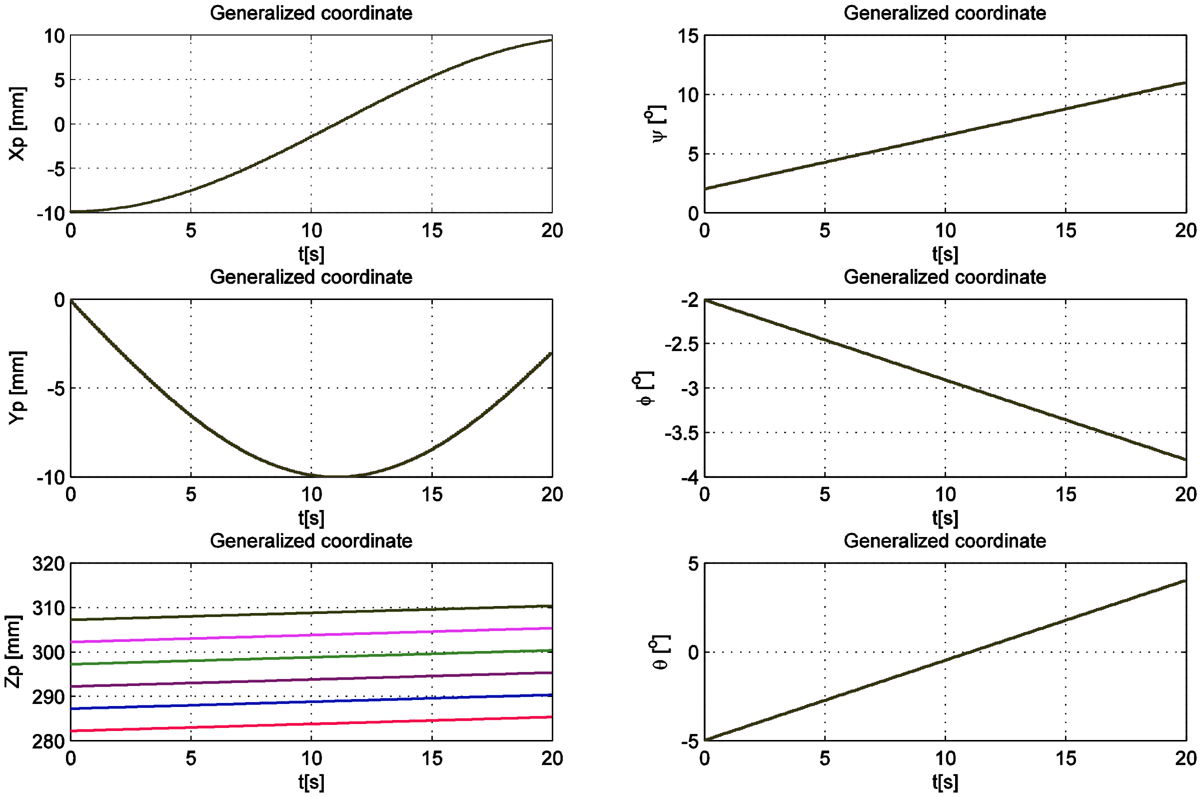


Figure 9.1. The generalized coordinates trajectories of the 6-PGK parallel robot

The estimation and identification algorithm is applied in each time step and consists of two phases:

- the estimation phase - based on the current input vector, the FANN computes the current estimated vector of generalized forces;

- the identification phase - based on current input/output training vectors the FANN is trained.

An input training vector $(\underline{x}_i(k), k = 0,..., N-1)$ and an output training vector $(a_d^o(k), k = 0,..., N-1)$, from the training vectors set, are constructed as follow:

$$\underline{x}^i(k) = \left[x_1^i(k-1) \ldots x_6^i(k-1) \ldots x^i_{6(n_{q_p}+n_Q-1)+1}(k-n_Q) \ldots x^i_{6(n_{q_p}+n_Q)}(k-n_Q)\right] = \\ = \begin{bmatrix} X_P(k-1) \ldots \theta(k-1) \ldots\ldots X_P\left(k-n_{q_p}\right) \ldots\ldots \theta\left(k-n_{q_p}\right) \ldots \\ \ldots Q_{m1}(k-1) \ldots Q_{m6}(k-1) \ldots Q_{m1}\left(k-n_Q\right) \ldots Q_{m6}\left(k-n_Q\right) \end{bmatrix} \tag{9.3}$$

$$\underline{a}_d^o(k) = \left[a_{d1}^o \quad a_{d2}^o \quad \ldots \quad a_{d6}^o\right] = \left[Q_{m1}(k) \quad Q_{m2}(k) \ldots Q_{m6}(k)\right] \tag{9.4}$$

The order of the vectors in the vectors training set corresponds to the order of the time sample from the time axis. Taking into account this observation, the input training vector from (9.3) and the training output vector from (9.4) can be expressed in relation with time:

$$\underline{x}^i(t) = \left[x_1^i(kT-T) \ldots x_6^i(kT-T) \ldots x^i_{6\left(n_{q_p}+n_Q-1\right)}\left(kT-n_Q T\right) \ldots x^i_{6\left(n_{q_p}+n_Q\right)}\left(kT-n_Q T\right)\right] \quad (9.5)$$

$$\underline{a}_d^o(t) = \underline{a}_d^o(kT) = \left[Q_{m1}(kT)\, Q_{m2}(kT) \ldots Q_{m6}(kT)\right] \quad (9.6)$$

where T is the sampling time.

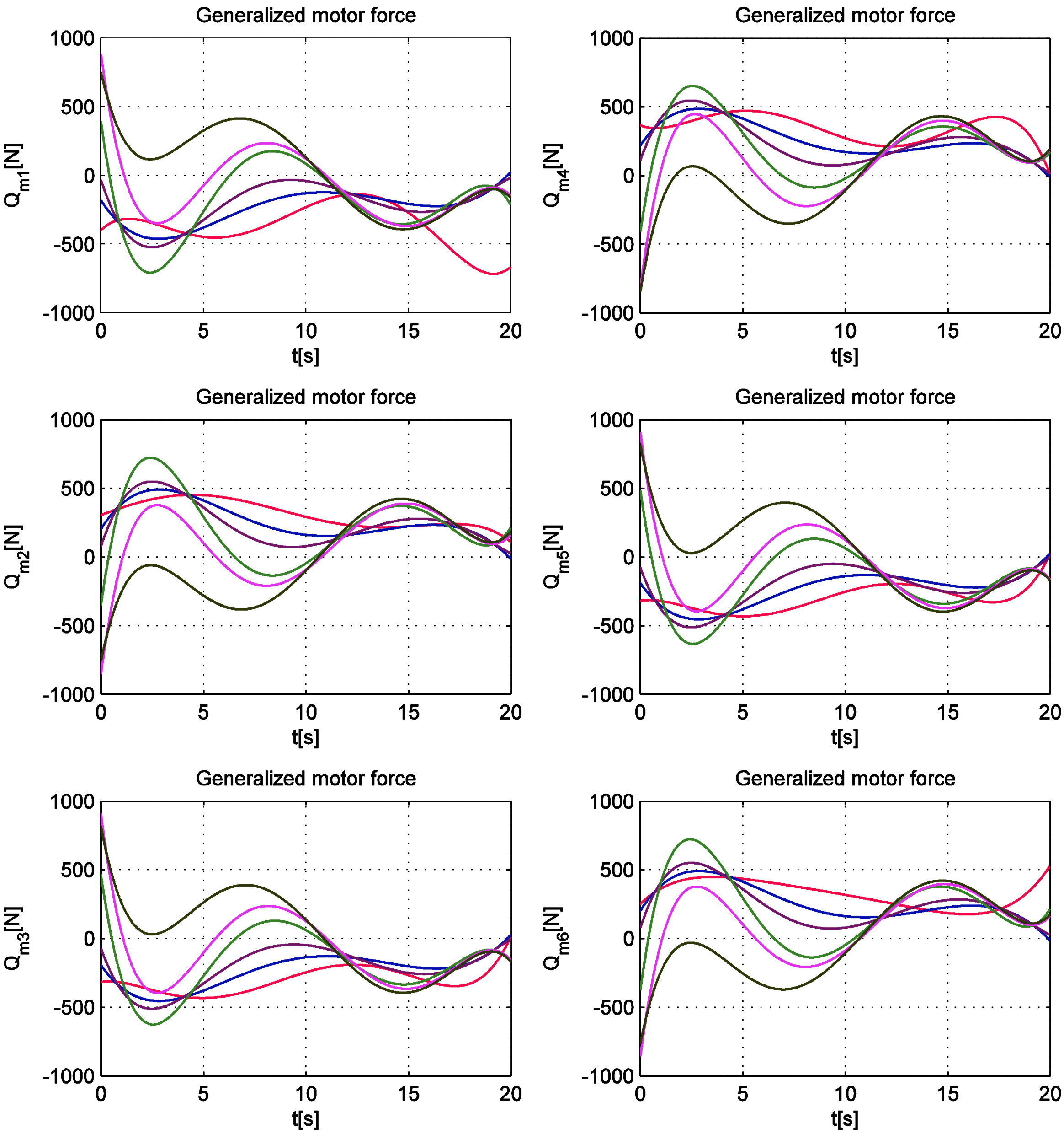


Figure 9.2. The generalized motor forces of the 6-PGK parallel robot

The results obtained by using the above algorithms are presented as follows. The experimental study was started from the following FANN parameters values: $n_h = 5$, $n_Q = 1$, $n_{q_p} = 1$, 20 initial weights sets values, $SNR_{thold} = 44.5$[dB], $\gamma = 0.01, 0.05, 0.1, \ldots, 0.98, 1$. During the *Step 2* of the general algorithm the success rates of γ were computed and then synthesized in figure 9.3. The analysis of figure 9.3 led to the selecting of the value of 0.25 as the optimal value for the γ parameter.

During *Step 3* the success rates of n_h were computed and then synthesized in figure 9.4.

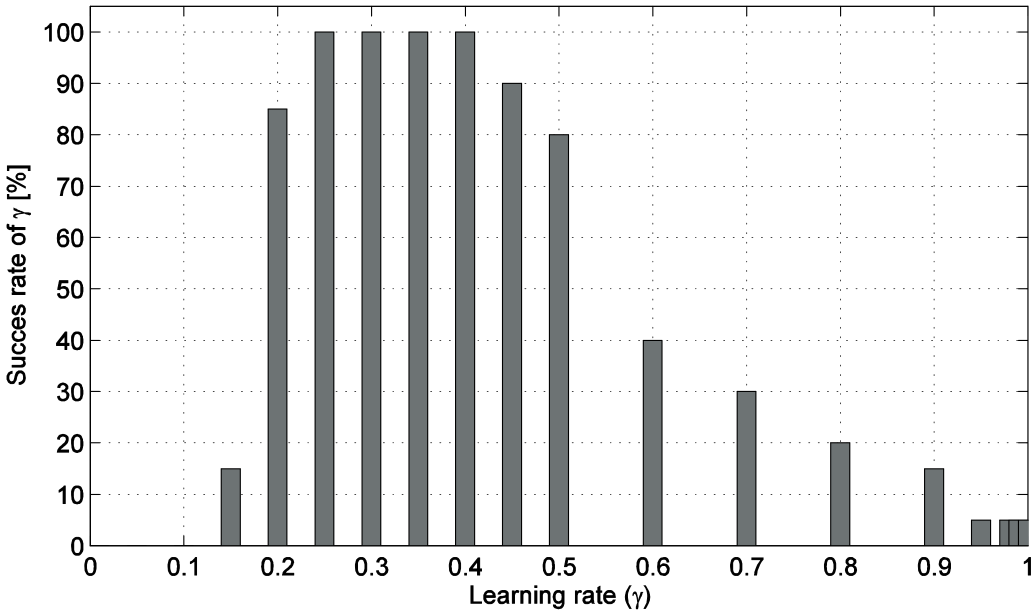


Figure 9.3. Success rates of γ parameter in case of using HTF in hidden layer

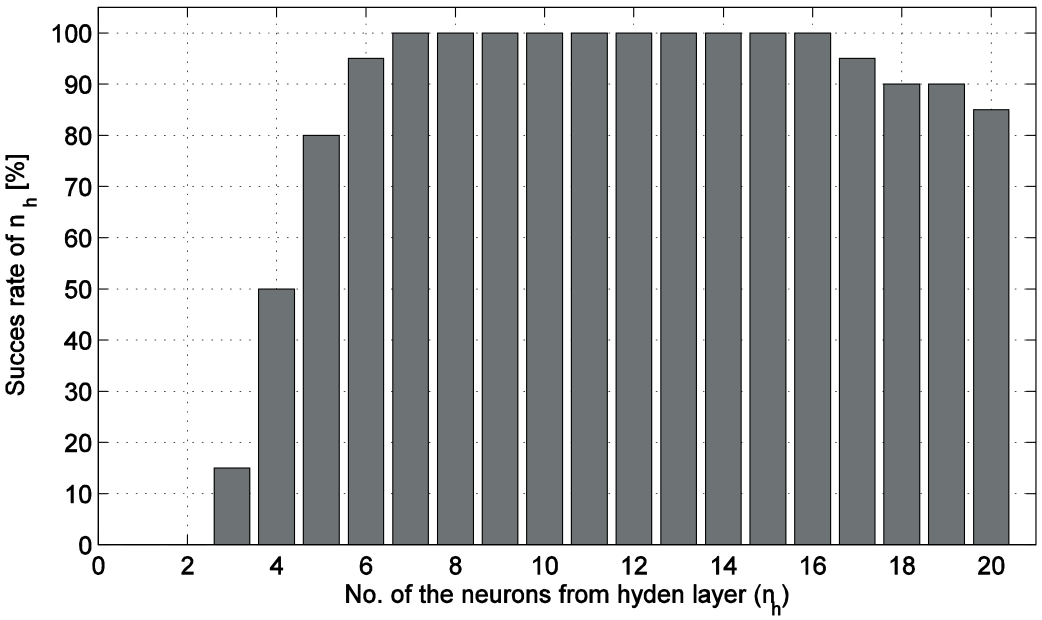


Figure 9.4. Success rates of n_h parameter in case of using HTF in hidden layer (γ = 0.25)

The analysis of figure 9.4 led to the selecting of the value of 7 as the optimal value for the n_h parameter. Further, after the evaluation of *Step 4* the results are synthesized in table 9.1. The values of the lag for n_Q are taken successively from 1 to 5. The values for n_{q_p} are taken successively from 1 to n_Q.

Analyzing the experimental results presented in table 9.1 were selected as optimal values $n_{q_p} = 1$ and n_Q = 1.

In case of the FANN with RBF the proposed algorithm generates the following parameters: $\gamma = 0.25$, $n_h = 6$, $n_Q = 1$ and $n_{qp} = 1$.

Table 9.1. The success rates corresponding to (n_Q, n_{q_p}) (FANN: HTF, $n_h = 7$, $\gamma = 0.25$)

Success rates [%]		n_{q_p} 1	2	3	4	5
n_Q	1	100	-	-	-	-
	2	100	75	-	-	-
	3	90	70	35	-	-
	4	60	55	15	20	-
	5	45	35	20	20	10

Table 9.2. The success rates corresponding to (n_Q, n_{q_p}) (FANN: RBF, $n_h = 6$, $\gamma = 0.25$)

Success rates [%]		n_{q_p} 1	2	3	4	5
n_Q	1	100	-	-	-	-
	2	95	85	-	-	-
	3	85	85	65	-	-
	4	75	70	45	40	-
	5	60	65	40	30	15

Comparing data from table 9.1 and table 9.2, figures 9.3, 9.4, 9.5 and 9.6 shows that FANN with RBF offer a better chance of achieving a good estimation even if the learning rate hasn't a 100% success rate.

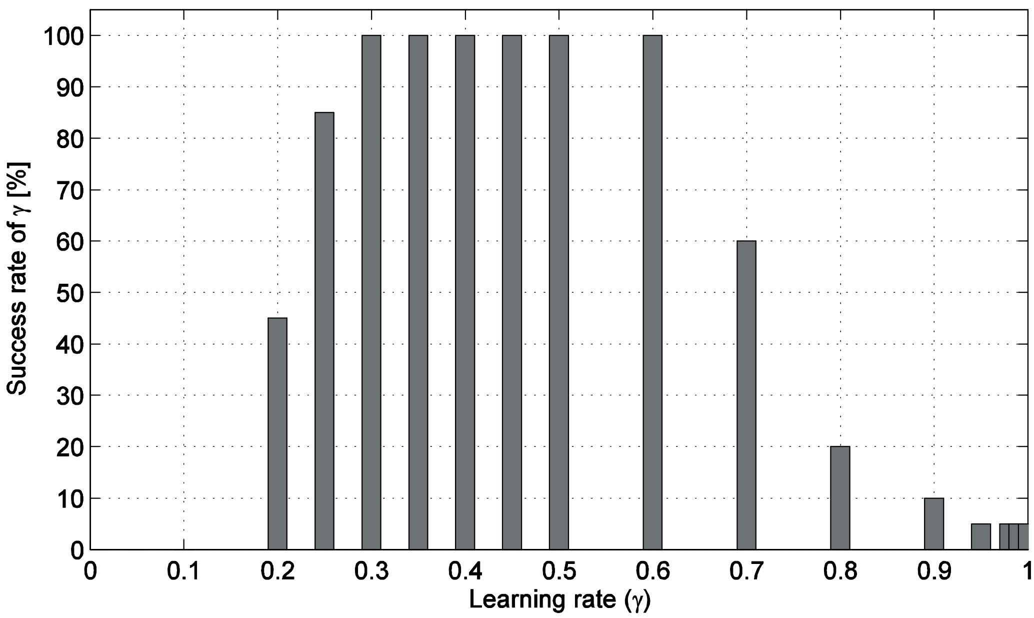


Figure 9.5. Success rates of γ parameter in case of using RBF in hidden layer

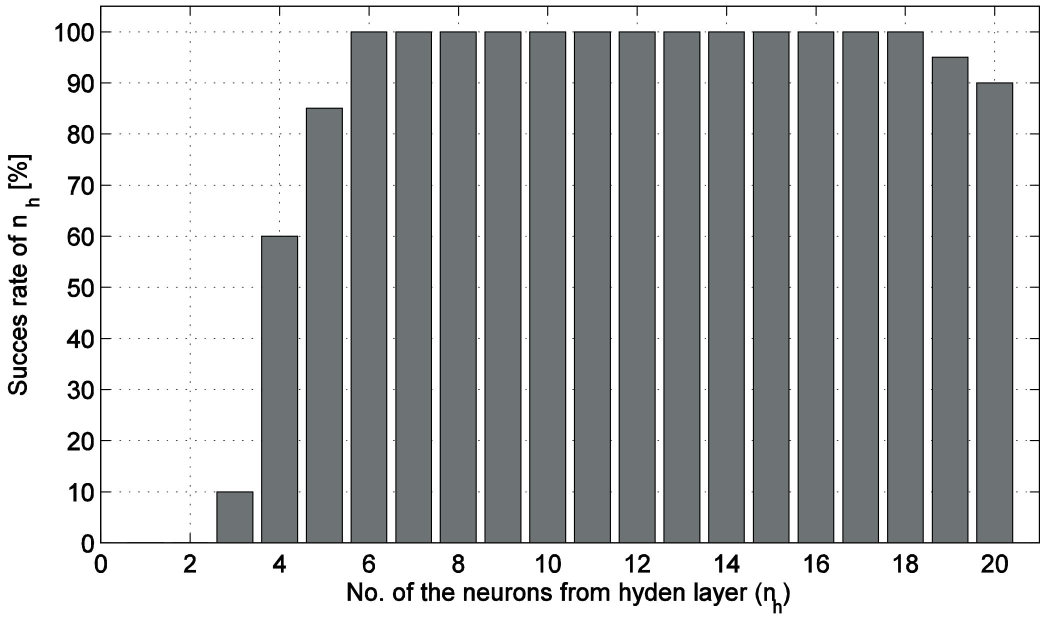


Figure 9.6. Success rates of n_h parameter in case of using RBF in hidden layer ($\gamma = 0.25$)

In order to evaluate the behavior of the built FANN, in figure 9.7 a test motor forces trajectories of the parallel robot and the estimated trajectory generated by the FANN are presented comparatively.

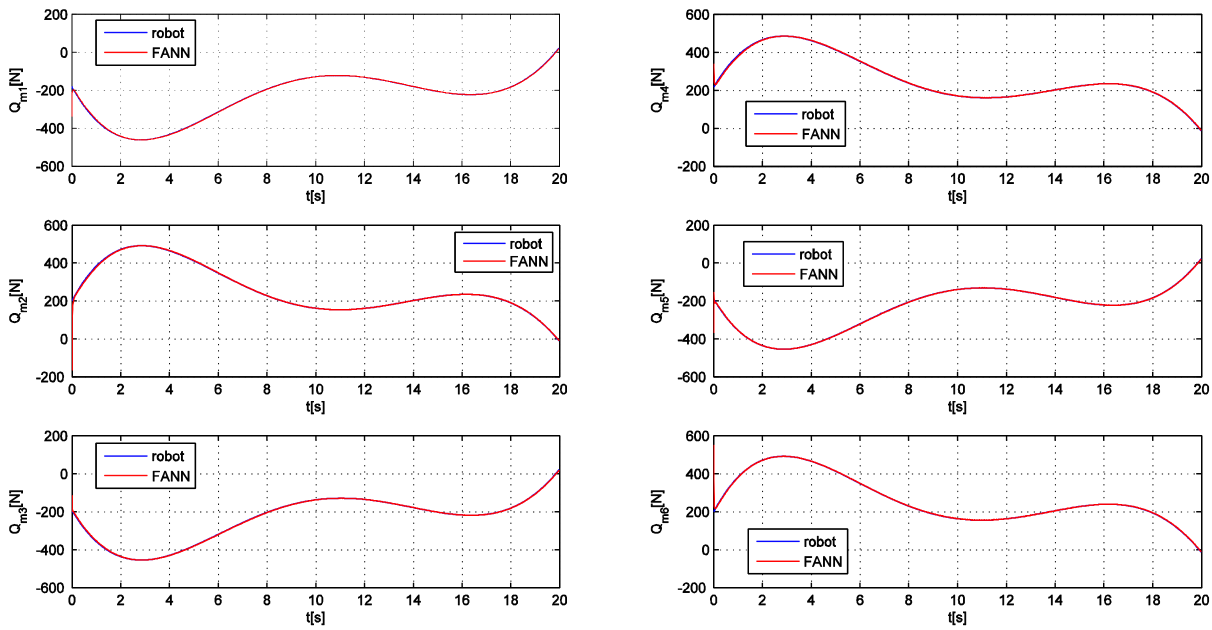


Figure 9.7. The FANN estimated motor forces trajectory and the motor forces trajectory of the 6-PGK parallel robot (FANN: RBF, n_h = 6, γ = 0.25)

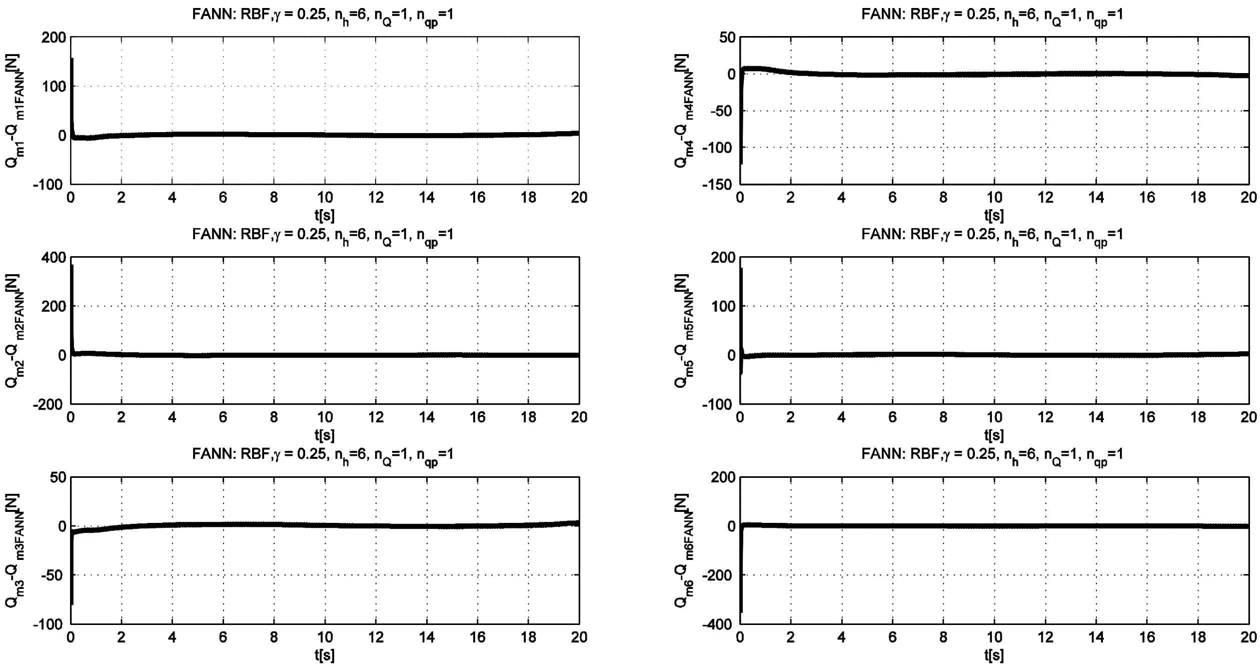


Figure 9.8. Estimation error trajectory corresponding to figure 9.7

In figure 9.8 the estimation error trajectories related to the trajectories from figure 9.7 is shown. The experimental results demonstrate a good approximation related to the studied system which is characterized by nonlinearities and high complexity.

This paper proposed to build an on-line feedforward artificial neural network with the aim of estimating the inverse dynamic model of the 6-PGK prototype parallel robot.

The presented solution was adopted in order to perform an on-line parametric identification of the inverse dynamic model of the robot. The chosen solution was adopted mainly for the use when the robots are characterized by the nonlinearities and high mathematical model complexity.

The implementation of the feedforward artificial neural networks allowed obtaining a nonlinear autoregressive model with exogenous input behavior, for which a new method for finding optimum parameters that approximate as better as possible the model of the 6-PGK robot was obtained. In addition, the proposed solution offers, with the best estimation results, the minimal computational load structure of the neural network.

Even if the FANN has a minimal internal structure, a slower training learning method, it offers a robust and efficient estimation method of the parallel robot motor trajectories, despite its complex and nonlinear mathematical model.

1.10. PARALLEL MECHANISM WITH SIX DEGREES OF FREEDOM FOR ROBOTS CONSTRUCTION

1.10.1. Mechanical design

The invention “Parallel mechanism with six degrees of freedom for robots construction", patent RO 128 018 (Moldovan, 2016b) refers to a spatial parallel mechanism with six degrees of freedom, that can be used for parallel robots construction, intended for handling or processing operations.

As it is known, parallel mechanisms are driven by motors arranged on the frame in parallel, which has the effect of reducing the weight of the mechanism in motion and its rigidity increase giving it the ability to execute highly accurate shifts at high speeds and accelerations. The main disadvantage of parallel mechanisms is the limited working space.

In order to build parallel robots are known more spatial linkage mechanisms, which have up to six degrees of freedom.

Such a mechanism is described in US Patent 5333514, "Parallel robot" (Toyama et al., 1993), which consists of a fixed platform, three kinematic chains jointed to the base at a predetermined distance about the center of the fixed platform and a mobile platform the three kinematic chains are jointed and on which is mounted a fastening system. Each kinematic chain is driven by a pair of rotary engines mounted in hole released platform places. Kinematic chains consist of two pairs of bars jointed between them. The downside of this mechanism is that it has a small working space.

It is also known from patent US 8442677 B2, "Verification system for robot pose" (Shoham, 2013) a parallel programming positioning mechanism having a base plate, a movable plate and six linear actuators with six degrees of freedom and extending between the two plates by means of actuators. Linear actuators are attached to the plates by universal joints. The ends of the actuator are paired in a triangular pattern in each plate and the actuators do not cross each other. The two actuators associated with one end to the base plate are each associated with an opposite end to another actuator of the movable plate. The actuators are screw unit for changing the length of each actuator in a programmable manner. Also, the actuators can be mechanically coupled to reduce the degrees of freedom and number of engines and control steps.

It is also known the document US 2010/0122602 A1 (Marcroft et al., 2008) which relates to an apparatus for positioning during the assembly operation having a base plate, a movable plate and six linear actuators with six degrees of freedom, elements which extend between the two plates by means of actuators. Linear actuators are attached to the plates by universal joints.

The technical problem solved by the invention "Parallel mechanism with six degrees of freedom for robots construction" (Moldovan, 2016b) is to provide a spatial parallel mechanism with six degrees of freedom that provides a larger workspace and a simple kinematic structure.

According to the invention (Moldovan, 2016b), the parallel mechanism with six degrees of freedom for robots construction, eliminates the disadvantages of the known mechanisms in that the assembly of variable length are connected, through a ball joint, rods connected by universal joint to the mobile platform, and the electric rotary-motor is mounted under the hexagonal fixed platform for each set of variable length.

According to the invention, the parallel mechanism has the following advantages:

- It has a simple kinematic structure;
- Workspace is bigger than existing parallel mechanisms that can be modelled by different inclinations of kinematic motor chains;

- Has high rigidity because the engines are attached to the base, which gives the ability to execute high-precision movement;
- Has reduced weight, which helps to reduce energy consumption during operation and manufacturing costs;
- Can execute movements with high accelerations and speeds.

In figures 10.1,..,10.3 is exemplified the construction of the parallel link mechanism. The parallel mechanism for robot construction, according to the invention (Fig. 10.1) consists of a flat hexagonal platform 1 located at the base (frame) and a movable upper platform 9. The two platforms are connected by six kinematic chains articulated to the two ends of the two platforms. The upper platform can attach a gripping mechanism. Mobile platform has six degrees of freedom.

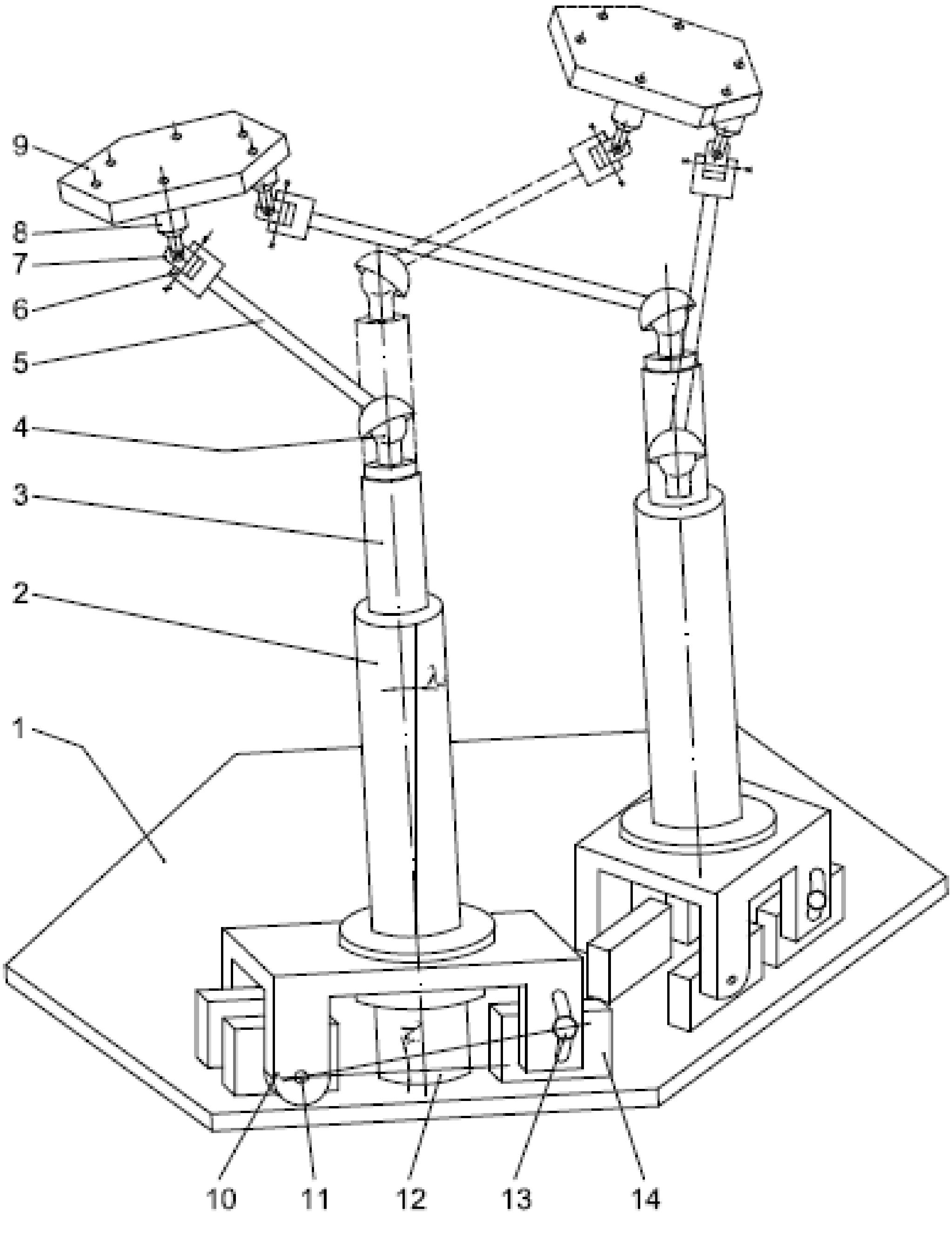


Figure 10.1. The kinematic chain of the mechanism

Kinematic chains (Fig. 10.2) are each formed by two elements articulated together by ball joints 4. The first element consists of variable length assembly 2-3 and the second element is the fixed-length bar 5. By means of the assembly 2, 3 at the lower end, the kinematic chains form a translational coupler. At the upper end the bars 5 are connected to the mobile platform by cardan joints (6-7-8), that the input shaft 6 by screw-fasten the rods 5 and the output shaft 8 by screwing to fasten the upper platform 9. The two axle 6, 8 of the cardan are cylindrical jointed by the cardan cross 7.

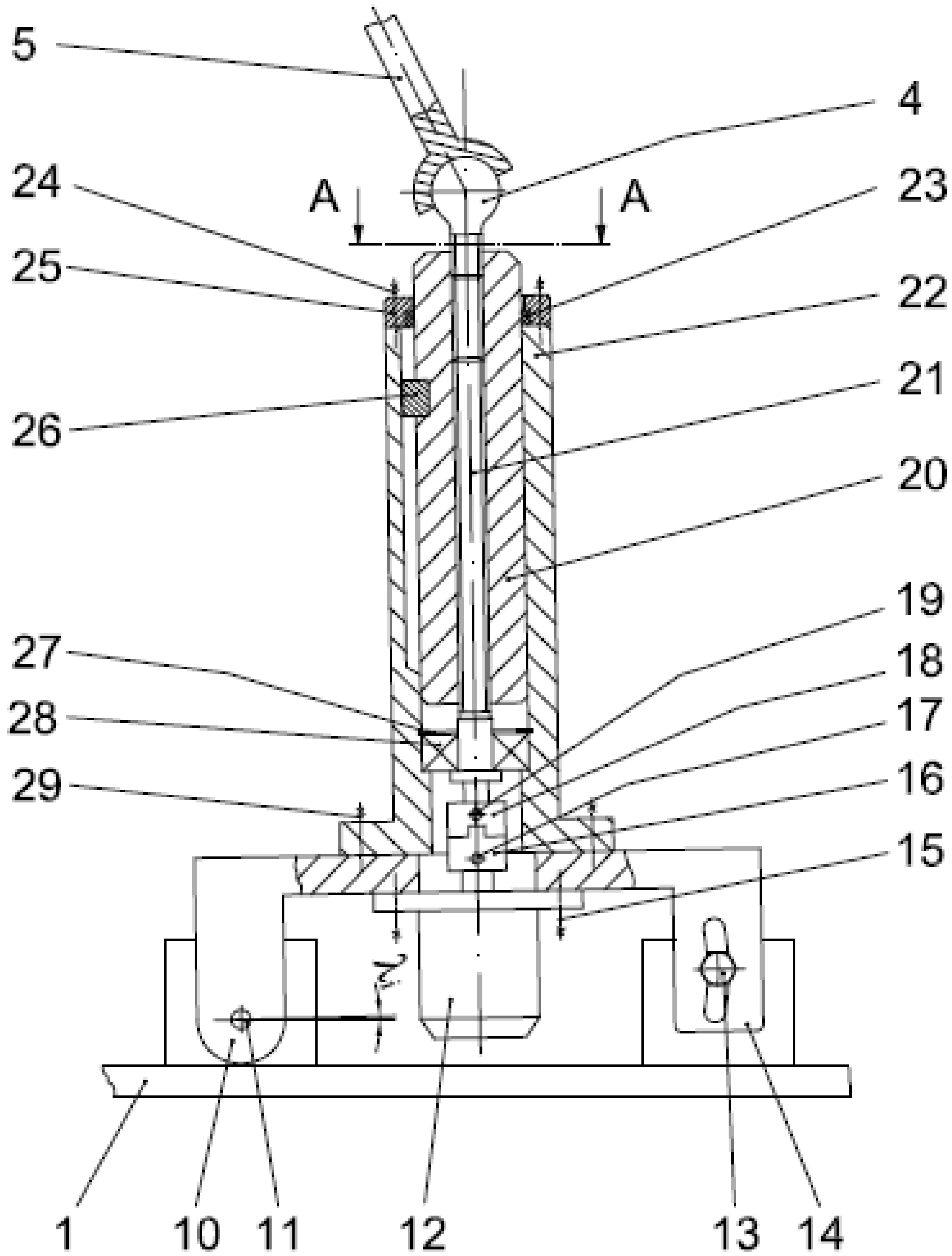


Figure 10.2. A sectional view of the drive system of the kinematic chain

The parallel mechanism is actuated by means of the six translational coupling, with the rotary electric motors 12, which in this way control the lengths of the kinematic chains. The angle of inclination of the translation couplers λ_i varies in the plane normal to the fixed platform, situated parallel at a predetermined distance from the side of the homologous hexagon, by tilting the support 10 which rotates around the cylindrical joint 11, with the angle λ_i to parallel at the fixed platform to the base. Setting the angle of inclination of the surface 10 takes place by the screw 13 of the support 14, which is integral with the fixed platform 1.

Operating kinematic chain (Fig. 10.2) is achieved by rotating the electric motor 12, fixed to the support 10 by screws 15. The movement is transmitted from the engine 12 to the lead screw 21 by elastic coupling 16, 18 fixed to the motor shaft and the lead screw by screws 17, 19. The lead screw clamp 21 is mounted on the inner ring of double row ball bearing 28, which is fixed in the housing 22 by the snap ring 27.

The rotational movement of the lead screw 21 is converted into rotation of the nut 20, which is set to 26, which translates the linear channel of the housing 22, fixed to support 10 by screws 29. The housing 22 is fixed to the cover 25 by screws 24. On the housing orifice is mounted the felt ring 23.

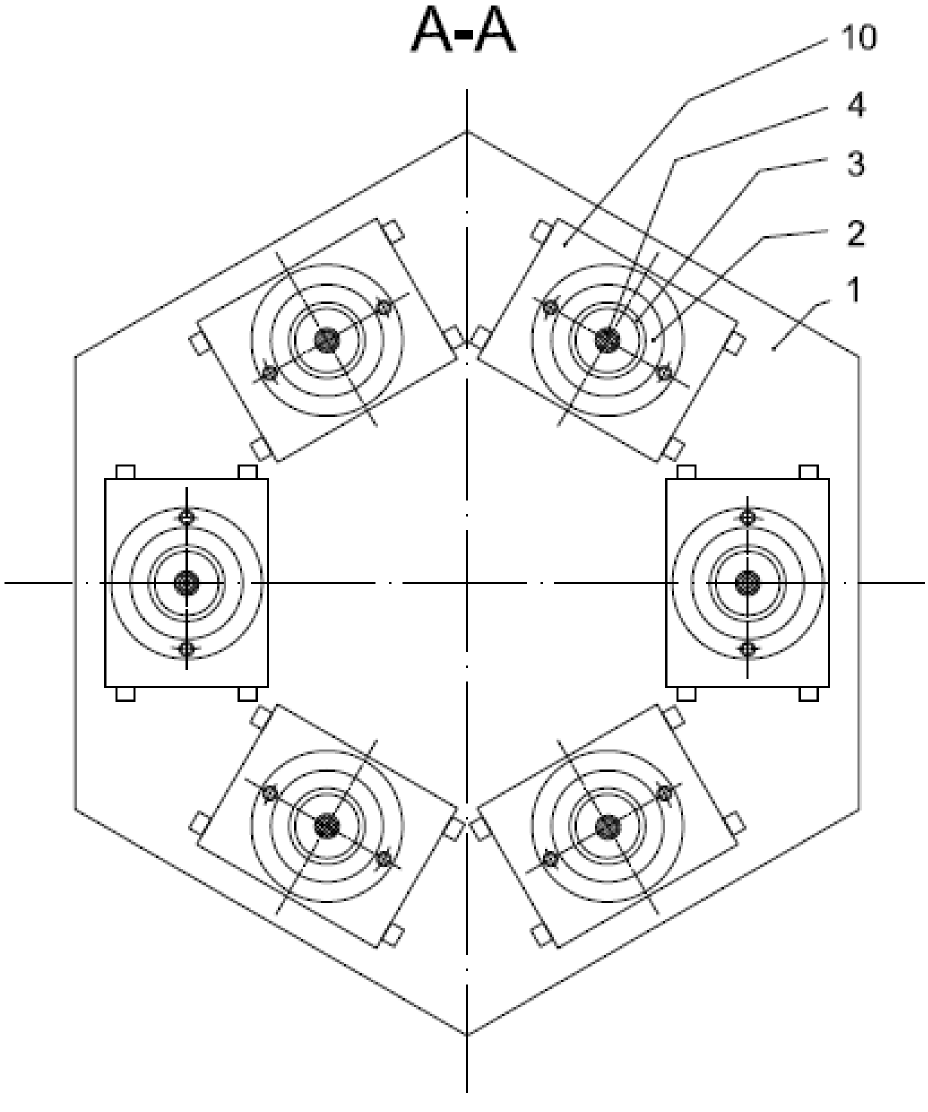


Figure 10.3. A section along A-A plane in figure 9.2

As shown in figure 10.3, the six kinematic chains are arranged in a hexagonal shape, fixed on the base platform 1.

The degree of mobility of the mechanism is calculated using the following formula:

$$M = 6\,n - 3\,C3 - 2\,C2 - C1 = 6 \cdot 7 - 3 \cdot 6 - 2 \cdot 6 - 6 = 42 - 36 = 6 \qquad (10.1)$$

where n = 6 + 6 + 1 = 13 is the number of mobile elements 3, 5, 9; C3 = 6 is the number of spherical couplings 4; C2 = 6 is the number of cardan couplings 6-7-8; and C1 = 6 is the number of prismatic couplings 2-3.

1.10.2._The workspace

The workspace of a parallel robot has a complex shape and is difficult to model. The workspace of the parallel robot may have separated "islands", where the centre of the manipulated object can be located (Moldovan, 2008b). This has consequences when planning the path for the parallel robot, because in this case a linear motion in a z plane, from one "island" to another is not possible. Hence verifying if an arbitrary trajectory lies entirely within this workspace is a complex issue.

The workspace of the 6-PGK parallel robot is bounded because of the limits on links lengths but also because of the mechanical limits on the kinematics pairs and links interference. The manipulated object reaches the workspace boundary, when one of the generalized coordinates of the parallel robot q_i (i=1,2,...,6), reaches the minimum q_i^m or the maximum value q_i^M.

The boundary of the workspace is determined by fixing four of the 6 DOF to get planar cross-sections. Then a discretisation method is used. The in-out equations of the 6-PGK parallel mechanism (7.1) are in the form (Moldovan, 2008b):

$$X_p^2 + Y_p^2 + Z_p^2 + K_{xi} X_p + K_{yi} Y_p + K_{zi} Z_p + K_{oi} = 0, \text{ (i=1,2,...,6)} \qquad (9.2)$$

Substituting $Z_p = d$, these are in the form

$$X_p^2 + K_{xi} X_p + K'_{oi} = 0, \qquad \text{(i=1,2,...,6)} \qquad (9.3)$$

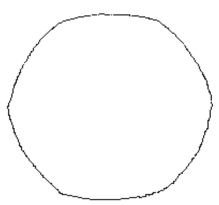


Figure 10.4. Cross-section of type SO1

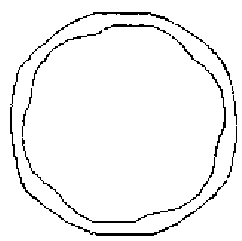


Figure 10.5. Cross-section of type SO2

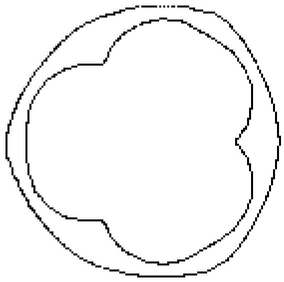


Figure 10.6. Cross-section of type SO2

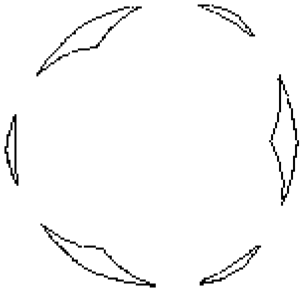


Figure 10.7. Cross-section of type SO3

which is a system of 6 equations with 6 unknowns, from which cross-sections of the workspace with horizontal planes is obtained. In order to plot the workspace border, a computer programme in autoLISP was employed (Moldovan, 2008b). In figures 10.4,...,10.7 I have plotted some horizontal cross-sections through the workspace of the parallel robot.

The vertical section in the robot workspace is represented in figure 10.8, also the intersection with the horizontal cross-section of type SO1,...,SO3 represented in figures 10.4,..,10.7.

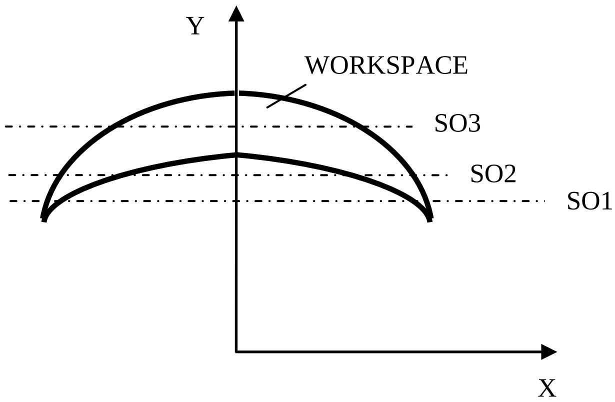


Figure 10.8. Vertical section in the robot workspace

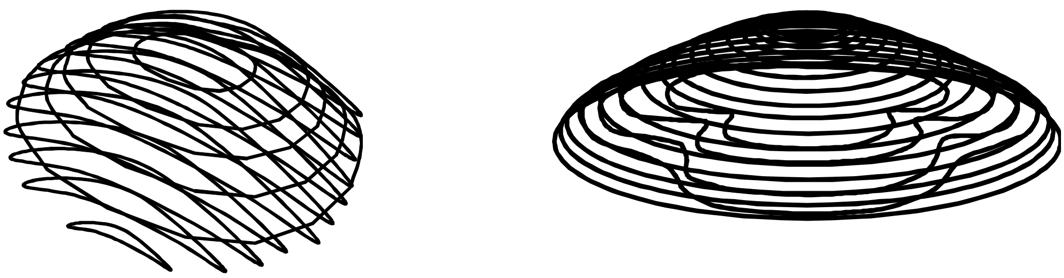


Figure 10.9. 3D views of the workspace

3D views of the workspace are presented in figure 10.9. It was shown that the workspace seems to be like a teapot with six feet (Moldovan, 2008b).

Section 2

PLANS FOR THE EVOLUTION AND THE DEVELOPMENT OF THE PROFESSIONAL, SCIENTIFIC AND ACADEMIC CAREER

2.1. Plans for specialized training

Quality management is a very actual study domain because quality is the main competitively factor in nowadays for organizations. As a consequence a lot of study and research is developed in quality management and the domain is very dynamic. Annually are published a lot of master dissertations/PhD thesis in the area, researchers in quality develop new concepts, in a medium period of 5 years standards become obsolescence due to the rapid evolution of economical practices on the market and standard organisations issue new standards. From this perspective I will continue to study the latest achievements in the field of quality management, to update my information in order to be able to teach the latest discovers in the field and also to contribute with high level research for the progress of knowledge in the field.

Applying the principle that a continuous skill improvement is necessary in teaching and in the specialized training, I will continue to take advantage of the educational and training offers provided through the human resource development program in the university/training providers, but also self-study. The main focus will be the training in the field of quality management systems, the area which I want to develop through research.

2.2. Plans for quality professional activity

Another priority that I will consider is to develop my career as quality professional: specialist, auditor/evaluator and manager and to be prepared for the challenges regarding the quality evaluation of the higher education and the implementation of the ARACIS standards in the faculty and university.

In 1998 I have graduated the Quality system manager course according to European Organization for Quality scheme. Than I have improved my professional development in quality management working in close relations with over 200 enterprises for the implementation of quality management systems in various fields of activity. I will continue this activity by involving students/graduates at various levels for mutual benefit and quality professional improvement, according to latest requirements on the market demanded by organizations.

In 2015 I have been accepted as member of the specialized committee for engineering sciences CEPSI 1 from ARACIS and I plan to continue this activity as coordinator of evaluation teams for study programmes, but also to participate in the process of methodologies/standards improvement.

Thus, in order to improve the quality of academic studies and ARACIS activity I consider that there must be a series of strategic and operational measures, in compliance with quality management principles, especially the principle of Deming, the PDCA principle but also the systematic collection of improvement suggestions and ideas from evaluated and evaluators in order to improve and review the methodology, ARACIS standards and performance indicators, taking into account the obsolescence of certain requirements so that they to respond better to current training requirements from the labor market.

It is required the ARACIS standards compatibilization with - Standards and Guidelines for Quality Assurance Agencies from the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), (2015) and developing new national standards which contain indicators that follow the four steps of the PDCA cycle.

As management representative for quality assurance in the "Petru Maior" University of Tirgu-Mures, and coordinator for establishment, documentation, implementation, maintenance and improvement of the system documentation in the period 2004-1015 in accordance with the 3 requirements: ARACIS standards and performance indicators; ISO9001: 2008 standard – Quality management systems. Requirements and Standards and Guidelines for Quality Assurance in the European Higher Education Area, 3rd edition, ENQA 2009, I will continue my work to study the quality management system performance inside the organization, to instruct annually the internal auditors, to update the system documentation and to implement it according to the new methodologies elaborated by ARACIS, Standards and Guidelines for Internal/External Quality Assurance from the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG), (2015), and also the ISO 9001:2015 standard.

2.3. Plans for the teaching and research activity with students

In future I wish that all the teaching activities to be a continuity of the ones performed since 1990 until now, by integrating updated knowledge and new information.

The teaching activities will be supported by the psihopedagogial principles of active communication with the students, integration of innovative tools and models for learning, employment of mobile learning and peer learning, performance support and competition among students, promotion of feedback and transparency in appreciating the efforts invested in knowledge acquiring.

I have founded the "Quality Management Systems" master field of study since 2001 as time education, and then distance/part-time education and I have developed various innovative tools and models for learning. Along the time many graduates were employed and work as quality professionals in various enterprises in the region or even further. Some of them are involved in the committee for evaluation and quality assurance of the program. I will continue this cooperation in order to ground in realty preparing of future graduates.

As a continuation of my teaching activity at the Department of Industrial Engineering and Management, as a professor, I plan the following:

– to obtain the habillitation in Industrial and Management Engineering;
– to guide students scientific activity for the development of bachelor papers, master dissertations, doctoral thesis;
– to coordinate scientific research groups of students in order to elaborate papers and to participate in national and international scientific events;
– to teach practical and theoretical notions in order to allow the students to acquire skills, knowledge and interdisciplinary abilities;
– to build presentations which can facilitate the understanding of the notions taught in class;
– to employ student centred teaching methods in order to stimulate student learning;
– to diversify the teaching activity by using the educational methods based on discovery and team learning;
– to develop tutoring activities for students in the master program;
– to coordinate students during the study visits in specialized units in order to correctly link the theoretical and practical aspects;
– to publish academic courses up to date according to the new domain discoveries, with a high priority given to Quality Management, Quality Systems Management, Methods for Analysis end Evaluation of Quality, Quality Audit, Conformity Certification, courses which I am currently teaching in the master program;
– to update the course materials according to the new standard ISO 9001:2015;
– to continue cooperation with enterprises in the area like Hirschmann, Matricon, Gedeon Richter, etc. in order to develop activity based training course materials, applied research dissertations, etc.

Constant involvement in European programs Erasmus+ is a direction that I will maintain, at least at current levels, offering further opportunity for my students to study in other European universities.

2.4. Plans for the publishing activity

Regarding the current job position, I will involve in the teams which organize conferences and other scientific manifestations organized by the Faculty of Engineering but also in I will involve in the publication of scientific periodicals.

I will be actively involved in the yearly organization of the Interdisciplinarity in Engineering (Inter-Eng) International Conference as president of the scientific committee. In this way I will continue yearly the tradition of previous editions that were organized in 2012, 2013, 2014, and 2015 in which I was president of the scientific committee. The jubilee 10th edition in 2016 is already launched http://inter-eng.upm.ro/2016/. In organizing the conference I will continue to identify valuable coorganisers like present ones: Romanian Academy for Technical Sciences and Universities from abroad.

With my support the Inter-Eng conference is leading an international professional and scientific forum for engineers and scientists to present research works, contributions and recent developments as well as current practices in engineering, that is falling into a tradition of important scientific events taking place at Faculty of Engineering in the “Petru Maior” University of Tirgu-Mures, Romania.

Also, I will act as guest editor of the Inter-Eng conference proceedings that I will continue to publish in the Elsevier’s Procedia Technology Journal and made available in open access on Elsevier's ScienceDirect for researchers worldwide, continuing in this way the tradition of previous two editions that are also published in Procedia Technology, no. 12/2014 and 19/2015.

I will continue to support indexing of the Procedia Technology next coming issues by Thomson Reuters Conference Proceedings Citation Index-Science (ISI Web of Science).

I will continue to act as editor in chief of the Scientific Bulletin of “Petru Maior” University of Tirgu-Mures (http://scientificbulletin.upm.ro/) coordinating the reviewing in order to ensure the final standard of the accepted submissions. In the previous period of four years I have edited the journal compelled recognition, becoming worldwide renowned. I will continue to increase the standard of the publication and to maintain the actual indexing in 11 databases, but also to submit it for indexing in other prestigious databases like Scopus and Thomson-Reuters. I plan to improve the management information system of works.

I will continue to act as publishing director of “Petru Maior” University Press (http://upm.ro/editura/colegiul.html) and to increase the editorial standard also by developing recommendations for editing.

I will continue the membership in editorial board of national and international journals like the Review of Management and Economic Engineering, Quality Issues and Insights in the 21st Century, etc.

In these publications my PhD students will have the opportunity to publish some results of their research.

As member of the Committee on Publication Ethics (COPE) I will continue to promote the integrity in research publications, for the personal scientific results but also for the publications I manage.

2.5. Plans for the research activity

The research activity will be held in parallel and integrated in the teaching and administrative activity with the objective to include results in the updated courses for students.

I will develop new research themes in the engineering and management domain, according to the institutional profile of research and operational program in “Petru Maior” University of Tirgu Mures and having in view the ARCIS requirements as regards:

- Research programming: establishment of research objectives, research projects applications, expected results from research, allocating resources and prevision ways of achieving valorisation;

- Research achievement: assuring financial resources from research grants, logistics in research laboratories and human resources by doctoral students, doctoral school, creation of a climate and a culture focused on academic research, publications, certification achievement of quality standards for the research, verification of published works with antiplagiarism software;

- Valorisation of research: the results of the researches will be discussed in conferences and published in scientific publications indexed in prestigious data bases and in ISI, didactic publications including research results, patents for relevant results, development of new products, etc.

The research activity will have the following main directions:

- Quality management / Total quality management;
- Quality management system / ISO 9001;
- Quality audit;
- Methods for analysis and evaluation of quality;
- Conformity certification,

which interfere, but can be exemplified with some research themes:

- Total quality management implementation and its impact on organizational performance (investigations in organizations of various profiles and sizes),
- Impact of total quality management on knowledge management and organizational performance,
- Assessment of current quality management practices in organizations,
- The effects of total quality management practices on performance,
- Cultural analysis of the of quality management implementation in organizations,
- Quality management practices for business services,
- An investigation of total quality management practices in a region/country,
- A study of the significance of organizational culture for the successful implementation and operation of total quality management,
- Total quality management as the basis for organizational transformation,
- The implementation of total quality management in small and medium enterprises,
- Employee involvement in quality management strategies,
- Improvement of quality management system implementation in companies (of various profiles),
- Quality management system in higher education/vocational education and training,
- Implementation and impact of standard ISO 9001,
- The impact of a quality management system on work attitudes,
- Quality frameworks for sustainability assessment,
- A total quality management methodology for universities,
- Quality management systems and performance measurement in a public sector organization,
- Improving service quality (in a specific service industry),
- Enhancing quality management of product supply chains through improved logistics and ensured traceability,
- Service quality indicators for organization support services,

- Performance indicators development,
- Building a performance measurement internal auditing framework for the ISO 9001 quality management system,
- Six sigma management,
- The effectiveness of quality control systems,
- Client-supplier interaction in new product development,
- The effects of conformity certification on organizational performance.

Another secondary direction for research is to study parallel mechanisms as regards development of new parallel structural schemes, study of positional problem, kinematics, dynamic modeling and control.

I will continue the research activity involving in my projects the bachelor/master/doctoral students, which will have the opportunity to elaborate bachelor projects, dissertation papers and doctoral thesis. In this sense I aim to attract students in continuing their studies and following a research career with doctoral studies. I will develop PhD students' abilities and skills necessary for conducting a theoretical and practical research activity and I will lead them in the new research teams structured in the academic community.

For the research activity I will use the logistics form the Faculty of Engineering, but also the one from the companies in the region which I have collaborated. I will develop new collaborations with companies in the framework of various calls and projects of common interest which are available for applied research.

A major objective of the research activity will be the participation in national and international competitions for grants and projects, like Horizon 2020 which can ensure a substantial support for research. Also, the research activity will be continued by participating in possible projects, proposed by companies, which aim to implement the quality management systems, environment, occupational health and safety at work.

In the research activity I will continue collaboration with the partners that already participated in obtaining important results that are already published in prestigious journals with a large international impact.

2.6. Plans for the professional administrative activity

In the next mandate 2016-2020 I will be member in the Department Council, Faculty Council, and Senate of "Petru Maior" University of Tirgu-Mures, where I will fulfill my administrative duties. From this position I will work for a better administration of the university, also by informing the academic community about the ongoing activities and on the decision which are taken in the Senate, Faculty Council and Department Council. In all the administrative activities I will promote the ethical and the active involvement principles.

I will continue to promote the educational offers which are being carried at the Faculty of Engineering and collaboration with the companies will give me the opportunity to help students' employment in the labor.

As management representative for quality, I will have a continuous involvement in the analysis, evaluation, design, and improvement of the study programs of the faculties and university. I will coordinate elaboration of annually academic audit reports and the measures plans for improvement, in this way stating my opinion in the interest of the academic community.

I will act for the promotion of the positive achievements at the university and faculty level with the purpose of increasing prestige of the university and to produce an adequate perception of the teaching and research activities. In this purpose I will collaborate with colleagues from other national or international universities in the research networks I have created during time and I will attend various meetings and activities at both national and international level.

Section 3

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