

ISO 9001 Quality System: An Interpretation for the University*

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The paper provides an interpretation of the ISO 9001 model for quality assurance in a university environment. The objective is to prepare a framework for successful documentation and implementation of a quality system based on the ISO 9000 international standards in education. The systems approach to quality assurance and the concept of a university production system furnish the basis for a consistent interpretation of all twenty elements of ISO 9001 (1994). An interpreted quality system can then be established in any department, faculty or university seeking explicit quality assurance, i.e. providing confidence to customers that their requirements for quality are met.

INTRODUCTION

UNDOUBTEDLY, THE WORLD of education is facing rapid changes today and will probably face even greater changes in the future. With the emerging communication technologies, such as the Internet, video-conferencing and satellite-aided communication, distance education is becoming a reality not only in remote Australian deserts, but across the world. Suddenly, a Canadian student can obtain a degree from a reputable Australian or British university, without ever leaving the comfort of his/her home. The exclusive local university markets will soon cease to exist, and schools will have to both think and act globally in order to survive. So, how will universities assure prospective students and their future employers internationally of the quality of education provided?

The manufacturing sector has already encountered a similar situation: fierce international competition, customers requiring world-class quality at a preferably low price, the necessity of keeping pace with leading-edge production and information technologies. Many organizations have found a part of the answer to these problems in the introduction of internationally accepted generic standards for quality assurance from the ISO 9000 series. Hundreds of thousands of companies world-wide have achieved registration and are now able to compete for international contracts. In a previous paper [1], we argued that engineering faculties in particular should follow their manufacturing counterparts in this respect, and develop quality assurance systems based on ISO 9000. This would provide confidence to employers, students and the general public that their requirements for quality education and research are met, and would

make systematic quality efforts visible. This paper will attempt to further discuss a quality assurance strategy in education, and provide a framework for a systematic interpretation and a successful documentation/implementation of the most comprehensive standard in the ISO 9000 series; namely ISO 9001.

The ISO 9001 (1994) standard: Model for Quality Assurance in Design, Development, Production, Installation and Servicing was written by engineers and quality professionals from large industries with a manufacturing organization in mind, and thus requires an interpretation for application in a university environment. The need for a systematic approach in interpreting the standard is evident considering that the sparse literature on the topic shows considerable shortfalls. Existing literature restricts the scope of the quality system to fewer than the full 20 elements [2, 3]. For example, Lewis and Smith consider only twelve elements of ISO 9001 to be directly applicable to education [2], while Willborn and Cheng address seventeen [3]. Although research is an integral part of university processes and a distinguishing characteristic of academic staff, existing interpretations focus on the 'learning opportunity' and courses as a primary product of educational institutions (e.g. [4, 5]). These interpretations would most certainly become more clear and consistent if underlying production and quality system concepts were to be used.

Therefore, the next section of the paper briefly addresses the concept of the university production system, which will be used in the interpretation. Subsequently, ISO 9001 elements are re-ordered to follow the logical flow of a university's products, from the determination of customers requirements and needs, to the evaluation of whether these needs have been satisfied. Each ISO 9001 element is then interpreted and

* Accepted 1 October 1997.

examples of documentation/implementation of selected elements are provided. Finally, guidelines for a successful and cost-effective implementation are given.

SYSTEMS APPROACH

Although the ISO 9001 standard is generic, i.e. it is applicable to manufacturing and service organizations, as well as health care, small business and education, a number of terms and concepts in the standard have manufacturing background. To assist us in the interpretation, the concept of the University Production System is introduced. This concept is addressed in detail in [1], however a brief outline of main terms and concepts is provided here.

The University Production System (UPS) can be defined as a set of interdependent *processes*, such as teaching, learning and researching, and *resources*, including human, material and information, that function harmoniously to achieve specified educational *objectives*. For example, a

university's objectives can be to create, preserve and disseminate knowledge [6]. Universities create three main *products*:

- student knowledge, abilities and competencies
- courses and programs
- research (new knowledge).

A summary of terms found in the ISO 9001 standard and explanations of these terms with respect to these three products are given in Table 1.

ISO 9000 is about quality systems. A quality system is defined as a set of interdependent processes that function harmoniously in an organization, using various resources, to achieve objectives related to quality. An objective related to quality is to meet and surpass *customer needs* and requirements. Another objective can be to create *zero-defect* products (an analysis of zero-defect products in the university environment is presented in [7]). Processes within the quality system transform customer requirements (required output) into the product bearing the ability to satisfy the requirements (actual output). The current version of the ISO 9001 standard, approved in 1994,

Table 1. UPS terms required for the interpretation of ISO 9001

TERM (ISO 9001)	EXPLANATION		
	Student Knowledge	Program/Courses	Research
Product	Student knowledge, abilities & competencies	Programs & courses	New knowledge
Customers	Industry, community, alumni, professional organizations	Students, industry, community, professional organizations	Industry, research sponsors, other universities, community
Supplier Subcontractor	University/Faculty/Department High schools, other universities, community colleges	Professional institutions, other universities	Researchers, industry sponsors, literature sources (journals)
Executive Management	<i>For a faculty:</i> Dean, department heads and program directors; <i>For a department:</i> Head and associate heads		
Design Plan Designer	Undergraduate programs, M. Sc. programs Academic staff (professors and instructors)		Research objectives
Process Plan	Individual student curriculum	Course outline (plan); Program plan	Research project plan
Raw Material	Student knowledge and comprehension of basic arts and sciences before entering the university	Existing material on courses and programs	Existing practical and theoretical knowledge
Value Adding to Material	Value adding to student's knowledge and abilities	Improvement in course design, delivery and maintenance	Value adding to existing knowledge
Manufacturing Process Lead Time	Learning Time from enrollment to graduation	Teaching <i>Programs:</i> 4 or 5 years; <i>Courses:</i> 1 or 2 terms	Researching Time from contract to delivery
Part	Student knowledge accumulated in a course	<i>Program:</i> course; <i>Course:</i> lectures, labs, tutorials	A phase in a research project
Operation/Tool	'Learning opportunity' in labs, lectures	Teaching labs, lectures, tutorials	Work on a phase of a research project
Machine/Technology Operator	'Learning opportunity' Teacher and student	Teacher, teaching assistant	'Research Opportunity' Researcher, research assistant
Part Specification	Course specification in the 'General Calendar'		Specification of deliverables in a research contract
Quality Policy	The overall quality intentions and direction of the faculty (department), as formally expressed by the dean (department head)		
Quality Control Nonconformity	The operational techniques and activities used to fulfill the requirements for quality The nonfulfilment of specified requirements Student failure	Course, program failure	Research project failure

consists of twenty requirements, each representing one element of the quality system. Nevertheless, interrelationships of the twenty elements of ISO 9001 are not clear, and the elements do not seem to follow a logical order. For example, element 4.4 Design control is followed by 4.5 Document and data control, and 4.6 Purchasing, after which comes 4.7 Control of customer-supplied product. Some organizations have tried to document and implement these quality system elements in the order in which they appear in the standard, and encountered a treacherous path. The danger in this approach lies in the increased emphasis on documentation and a loss of the focus on the quality system [8].

In a university environment, the development of a quality system and concepts of quality assurance will certainly encounter mixed reviews by academics, who are often weary of structured approaches requiring additional documentation. Thus, the focus has to be on the establishment of a meaningful quality system with numerous benefits to each individual professor and staff member, rather than documenting each requirement and having impeccable and seldom-used records made just for a registrar’s visit.

In order to provide the universities with a focus on a quality system, ISO 9001 elements have been re-ordered into two categories: quality loop and supporting elements (Fig. 1) according to [9]. The quality loop is a set of interacting activities and processes that influence the quality of the product through various stages of its life-cycle: from determining customer needs to the evaluation of

whether these needs have been met. The first process in the loop is the determination of customer requirements, and the ability of the organization to meet them. This is the subject of the ISO 9001 requirement 4.3 Contract Review. The product that meets these requirements is then designed (4.4 Design Control), and a quality plan addressing this specific product is prepared (4.2.3). The procurement of necessary resources follows, with sections 4.6, 4.7 and 4.11 of ISO 9001 focusing on these issues. Human resources must be trained to effectively use procured resources (4.18 Training). The product subsequently goes through processing (4.9 Process Control), inspection and testing (requirement 4.10 and 4.12), as well as handling and storage (4.15). Defective products are removed (4.13) and corrective and preventive actions implemented (4.14). Finally, servicing is available, if required (4.19).

The group of seven supporting elements consists first of the requirement 4.1 Management responsibility, which is implied in all other elements of the quality system. Necessary documentation resources are the subject of sections 4.2, 4.5 and 4.16 of the standard. Element 4.8 Product Identification and Traceability, is also implied throughout the product’s life cycle. Finally, 4.17 Quality Audits and 4.20 Statistical Techniques are designed and implemented to improve the quality system.

Armed with this systems approach to ISO 9001, as well as the concept of the University Production System, we will proceed with the interpretation of all twenty elements of the standard for application

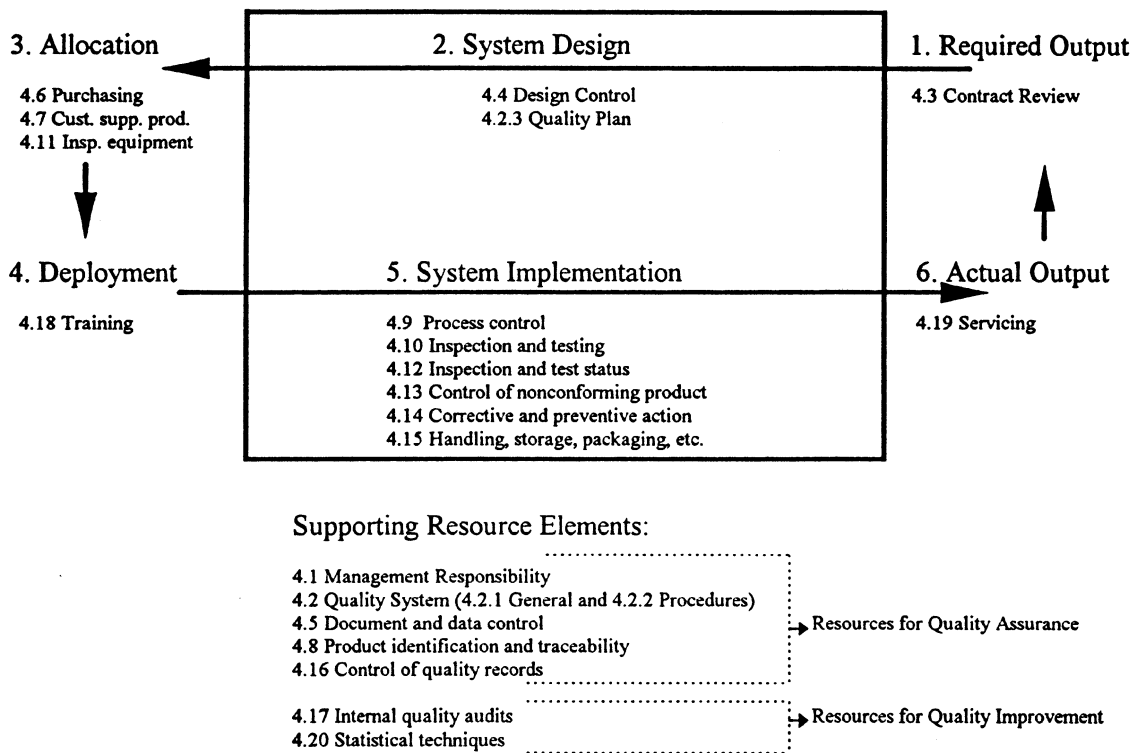


Fig. 1. Graphical model of an ISO 9001 quality system (modified from [9]).

in higher education. In our preceding paper [1], a glossary and interpretation of ISO 9000 terms was included.

ISO 9001 INTERPRETATION

Quality Loop Elements

Contract review. Quality can be defined as the ability of the product to satisfy stated and/or implied customer requirements. Therefore, the first step in the development of a quality system in a university is to adequately identify these requirements. The objective of the contract review element of ISO 9001 is to provide the faculty (department) with a clear understanding of customers' needs and specifications, to evaluate if these needs can be achieved, and to provide the customers with a clear understanding of the manner in which the faculty (department) shall meet them. The following processes are covered:

- Defining and documenting the industry and society requirements with respect to undergraduate and graduate programs offered, by means of alumni and employers surveys, questionnaires, interviews, as well as the analysis of available legislation, governmental guidelines and standards.
- Accreditation of programs by regulating bodies, such as the Canadian Engineering Accreditation Board (CEAB) in Canada or the Accreditation Board for Engineering and Technology (ABET) in the United States.
- Review of contracts with the employers participating in co-operative programs offered by the faculty (department).
- Review of students' understanding of the admission requirements, program content and context, graduation requirements, and their responsibilities and authorities, through interviews and surveys.
- Review of industry and government-sponsored research contracts, such as research projects undertaken with the Natural Sciences and Engineering Research Council (NSERC) in Canada.
- Assessment of the faculty's (department's) ability to meet the requirements.
- Contract changes, such as when a research sponsor changes the requirements.

As an output of contract review activities, program and research design/planning committees should have a clear understanding of the kind of programs/courses/research required, as well as the faculty's (department's) ability to offer such programs and research. A document outlining core requirements can be prepared in the form of a program or research project brief, much like product briefs in manufacturing. An example of a typical contract review process in an engineering department is presented in Fig. 2.

Design control. Following contract review activities, the faculty (department) must demonstrate the ability to translate customers' specifications into appropriate design of programs/courses offered, individual student curricula and research projects. Design control may consist of several stages, such as: identifying the input into the design process, verification of the program/curriculum/research design against design input, as well as validation of the design output against customers' requirements. Design input may include suggestions for new programs from CEAB/ABET or industry, analysis of customer needs and market position of the faculty (department), and feasibility studies for new programs or research. Design output should include the statement of factual content and format of programs, skills and competencies to be developed in students or research projects, as well as an illustration of how the course/program/research project content is relevant to its aims and objectives. The responsibilities and authorities and the vertical and lateral interrelationships between the personnel which are involved in the design process should be defined and documented. Also, the faculty (department) must identify, document, review and approve design changes and modifications. The following processes should be included:

- Design planning, review, verification and validation of new undergraduate and graduate programs and courses.
- Design control of the individual student curricula, including the statement of minimum paths to graduation, elective and compulsory courses, responsibility and authority of students, and defining the student's input into the design process.
- Contractual research with industry and government agencies.
- Identification, documentation, review and approval of program design changes, including the addition of new courses and deletion of existing courses and programs.

An example of a program design control flow-chart is presented in Figs. 3a and b.

Quality planning. Quality planning covers the identification, classification and weighing of product quality characteristics (see [1]), establishing the objectives, requirements and constraints for quality, as well as the preparation of quality plans. Quality plans are documents setting out the specific quality practices, resources and sequence of activities relevant to a particular product, project or contract. This means that each course, program and a contracted research project should have a separate quality plan, standing alone or as a part of the course or research project plan. A typical course quality plan should include:

CONTRACT REVIEW WITH INDUSTRY, SOCIETY AND GOVERNMENT

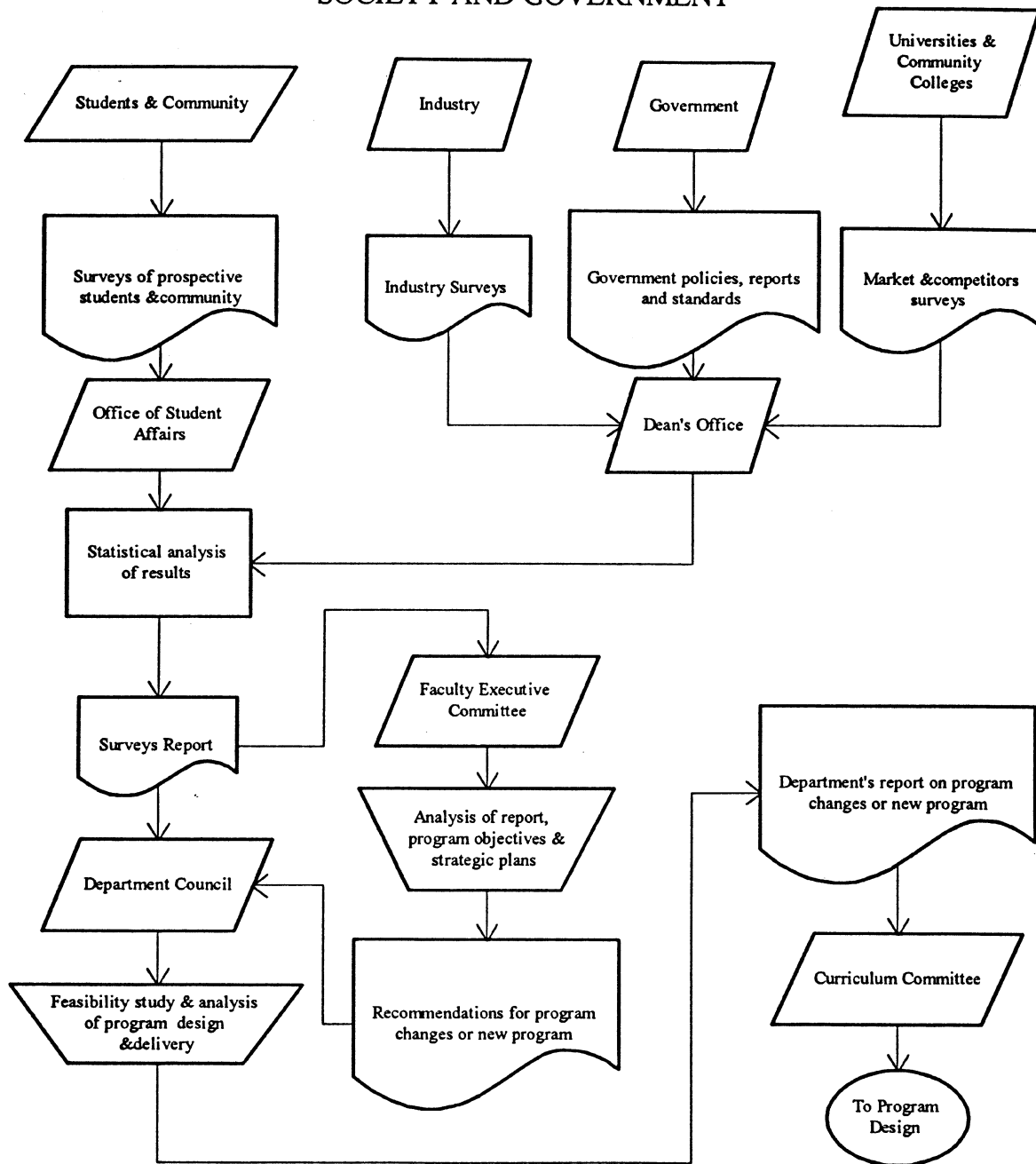


Fig. 2. Example of a contract review process.

- course requirements from the General Calendar;
- course objectives and specific knowledge/competencies to be developed in students;
- course prerequisites & statement of any incoming inspection of student background knowledge;
- detailed topic layout and schedule of presentation (can be in a checklist form to provide the record of topics covered in class and the topics students would study on their own);
- list of required textbooks, software and laboratory notes;

- instructions for teaching assistants and laboratory technicians;
- detailed inspection plan, including the type of tests (exams) planned, topics covered and weights assigned for each test.

Purchasing. Product design and quality planning is followed by the acquisition of necessary resources, including academic and support staff, information and material resources (hardware, software, equipment and facilities), as well as students. The objective of the purchasing requirement of

NEW PROGRAM DESIGN CONTROL

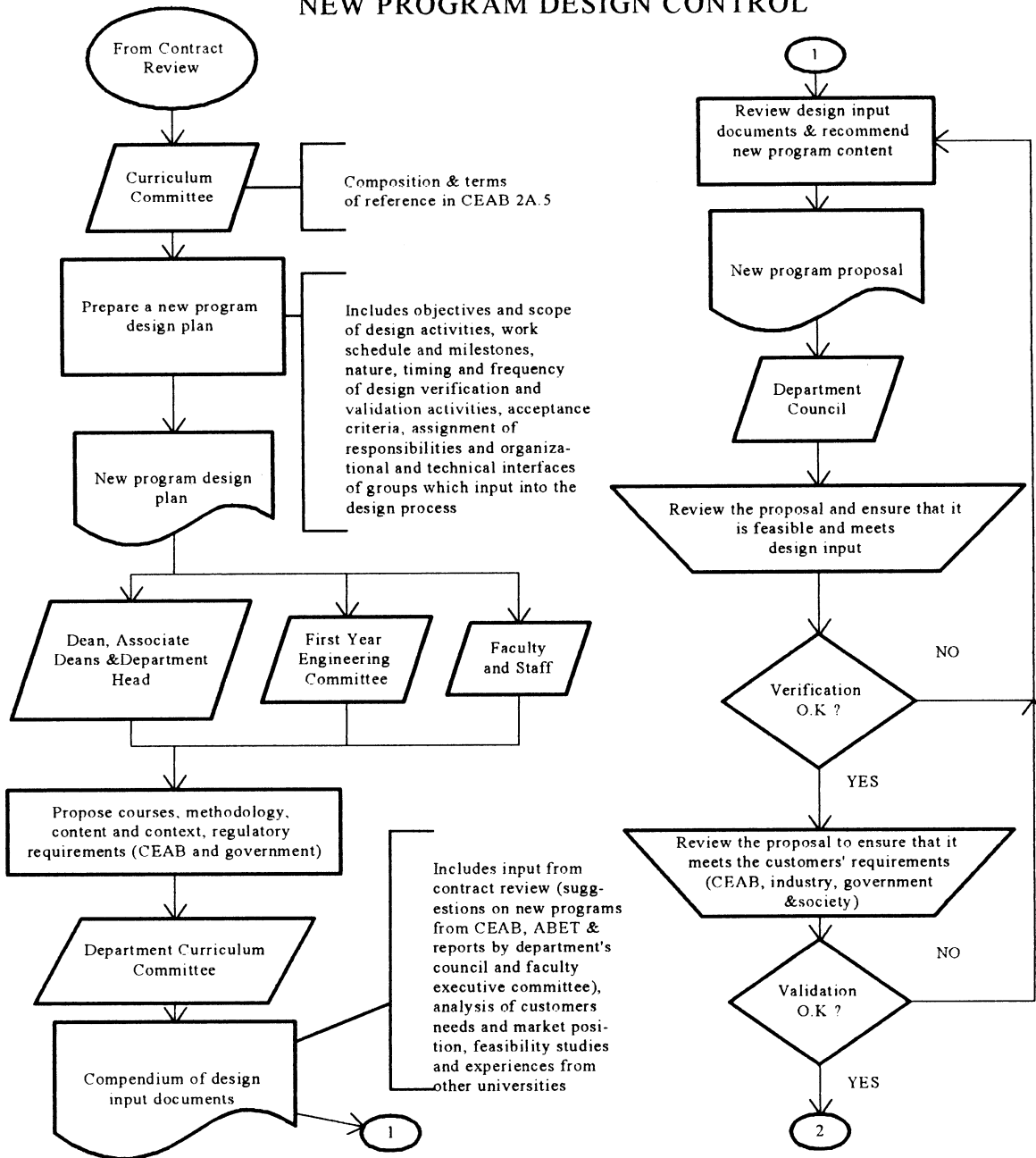


Fig. 3a. Example of design control activities.

ISO 9001 is to ensure that these resources conform to the specified requirements. This is necessary because the university builds the acquired resources into its products. For example, only the students who meet entrance standards should be allowed to enroll. Defective purchased material, such as a faulty overhead projector or inappropriate software loaded on the network, may negatively affect the quality of the teaching, learning or research processes.

The following processes should be covered by adequate procedures and records:

- purchasing of hardware and software required for the proper delivery of programs, courses and research projects;

- subcontracting of resources (facilities management, equipment maintenance, student transport);
- appointment of academic and support staff, including professors, teaching and research assistants/associates, administrative and technical staff (see Fig. 4);
- admission of undergraduate and postgraduate students.

Also, the appropriate verification of a purchased product or an acquired resource must be planned, executed and reviewed. Where specific contracts require the department or faculty/staff members to verify purchased products or acquired resources at subcontractor's premises, this verification should

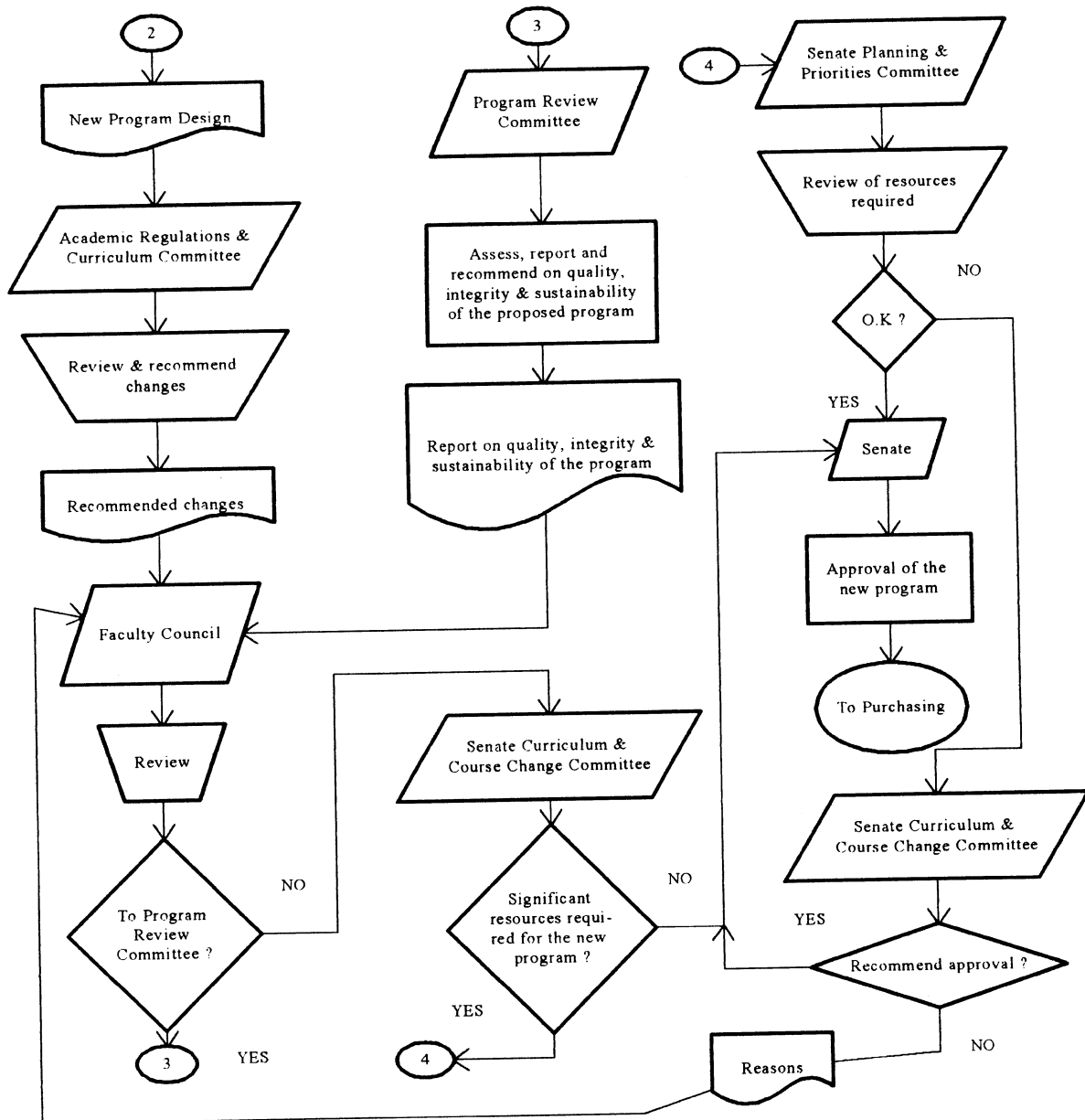


Fig. 3b. Example of design control activities (continued).

be planned, conducted and recorded according to the particular contract. An example of such activities may include screening of high school students through visits, the assessment of community college programs to provide credits to transfer students and so on. In some instances, specific contracts may require the customers to verify purchased products or services at university's premises. This, in general, pertains to research contracts, but may include visits by the representatives of industry and governmental agencies to verify the delivery of programs and research.

Control of inspection, measuring and testing equipment. Another set of resources that has to be allocated before the actual delivery of programs and research includes the inspection/measuring

equipment and methods. This ISO 9001 requirement covers the methods and equipment used for measuring and testing of student knowledge/abilities, methods applied to ensure that programs/courses conform to the specified requirements, as well as the measuring and testing equipment used in research activities. The following processes are included:

- design of tests, quizzes, assignments, project requirements, exams;
- designing, applying, reviewing, validating, changing and improving the marking and grading schemes;
- review of inspection and testing methods for student knowledge, experience and skills;
- control, calibration and maintenance of equipment used for inspection, measuring and

testing at the course level, such as instant scoring machines, standardized and computerized tests;

- control, calibration, maintenance, handling and safeguarding of inspection, measuring and test equipment used in research activities;
- control, maintenance and review of methods used for inspection and measurement of the degree to which an undergraduate or a graduate program meets specified requirements.

Control of customer-supplied product. The objective of this element of the quality system is to demonstrate the capability of the faculty (department) to identify, maintain, store, preserve and properly handle all material provided by students in the course of studies, and all products provided by external organizations with which the department has contracts for research projects. The identification, verification and handling of student-supplied material, such as exams, tests, assignments, reports, theses, software and books are covered. Also, the examination, storage, maintenance, preservation, handling and proper usage of hardware and software provided by research sponsors, industry and governmental institutions and/or agencies should be documented by appropriate procedures and records.

Training. The faculty (department) and individual faculty and staff members must identify the training needs of its faculty and staff, and provide for the adequate training. Also, student counseling needs should be identified and proper counseling services supplied. Thus, the following processes should be addressed by appropriate procedures:

- development and training of faculty, teaching and research assistants, and support staff;
- student curriculum counseling;
- faculty members' maintenance of professional competence;
- research staff development and training, including sabbatical leaves;
- faculty promotion and tenure.

Appropriate records of training activities must be maintained.

Process control. After the allocation and deployment of adequate resources, the delivery of programs and research is soon to follow. In general, the teaching, learning and researching processes are addressed by this requirement. The objective is to ensure proper identification and planning of these processes, and to ensure that they are carried out under controlled conditions. Controlled conditions include:

- documents defining the manner in which the processes are carried out, such as course/research project plans and procedures;
- use of a suitable equipment and a suitable working environment;

- compliance with reference course and research project quality plans;
- monitoring and control of product quality characteristics and suitable process parameters;
- preventive/corrective maintenance of equipment used for teaching, learning and research.

It is important to note that the control of the learning process and its product, namely student knowledge, is also focused by the inspection and testing element of ISO 9001 (see following section). This element covers the student-based control of individual learning, via student presentations, seminars and design projects.

Process control activities may be categorized into four groups:

- process control design
- control of resources
- process control implementation
- process control improvement.

Table 2 illustrates the activities of teaching and research process control, respectively.

Inspection and testing. Student knowledge, programs/courses and research must be inspected and tested against the requirements set in appropriate procedures and quality plans. Also, records of such activities must be kept. The ISO requirement 4.10 Inspection and Testing applies to the receiving, in-process and final inspection of:

- undergraduate students' knowledge and skills acquired in a particular course;
- student's academic status (program level inspection);
- graduate students, including course-work and thesis-related work;
- research projects against the requirements set out in the research contract and/or project plan.

Specific activities are outlined in Table 3.

Inspection and test status. After performing inspection and testing of its products, the faculty (department) must ensure that the products are properly identified, and that the inspection and test status indicates whether the products are conforming or nonconforming to specified requirements. For example, a class list with grades for specific components of the course indicates a student's inspection and test status in a course. Another example is the student academic status, determined after evaluation by the board of examiners. A student may also be requested to repeat a course, and his/her status indicated on the transcript. Thus, inspection and test status of undergraduate and graduate students at the course and program levels, as well the status of research projects conducted in the faculty (department) must be identified.

Control of nonconforming product. The purpose of inspection is to confirm whether a product

Table 2. Process control activities

TEACHING PROCESS CONTROL	
GROUP	ACTIVITY
PROCESS CONTROL DESIGN	review of course design and quality plans assessing the need and selection for course/program prerequisites identification of critical quality characteristics for the course identification of teaching process parameters to be monitored and controlled planning the methods for monitoring and control of critical quality characteristics and suitable process parameters
CONTROL OF RESOURCES	identification of adequate teaching equipment ensuring proper maintenance of teaching equipment identification of proper teaching and learning environment review of equipment, facilities and services admissibility for the course
PROCESS CONTROL IMPLEMENTATION	incoming inspection of student's prerequisites assessment of student's admissibility to a course assessment of topics and matter taught in course prerequisites course delivery monitoring, measuring and control of critical quality characteristics and teaching process parameters student course evaluation
PROCESS CONTROL IMPROVEMENT	planning, implementing and reviewing preventive and corrective actions assessment and review of critical quality characteristics, suitable process parameters, equipment, environment, facilities and services
RESEARCH PROCESS CONTROL	
GROUP	ACTIVITY
PROCESS CONTROL DESIGN	identification of critical quality characteristics for a research project identification of research process parameters to be monitored and controlled planning of the methods for monitoring and control of critical quality characteristics and suitable research process parameters
CONTROL OF RESOURCES	identification of adequate equipment required for the research project ensuring proper maintenance of research equipment identification of proper research environment review of equipment, facilities and services admissibility for the research project research project quality planning research project delivery
PROCESS CONTROL IMPLEMENTATION	monitoring, measuring and control of critical quality characteristics and research process parameters
PROCESS CONTROL IMPROVEMENT	planning, implementing and reviewing corrective actions assessment and review of critical quality characteristics, suitable process parameters, equipment, environment, facilities and services

conforms or does not conform to specified requirements. Nonconforming products are students who do not meet course or program requirements, courses/programs that failed to achieve stated objectives, as well as research projects that did not meet specified contract requirements. Research activities have such a nature that sometimes a failure to prove a hypothesis is a valuable research result. In this case a 'failure' is not necessarily identical to nonconformance. Only when a contract with industry or a research sponsor exists should this ISO 9001 element be applied in research.

The identification, evaluation, documentation and segregation of nonconforming students, courses/programs or research projects are required. In terms of undergraduate students, control of nonconformances related to term-work and final exams, as well as control of students under academic suspension is required. Control of graduate students who do not meet course or thesis requirements, as well as nonconforming contracted research must be addressed by appropriate procedures and records, as well.

Corrective and preventive action. A logical path after the occurrence of nonconforming products is to look for and eliminate the causes of these nonconformities, if feasible. This is done by planning, designing, implementing and reviewing adequate corrective actions to prevent existing nonconformities from occurring again, and adequate actions to prevent the occurrence of potential nonconformities. Corrective and preventive actions taken at all stages of planning, design and delivery of programs, courses and research in the faculty (department) are included in this element. Existing and potential nonconformances are identified, for instance, by means of internal Quality Audits, statistical techniques, tests or personal observations.

Handling, storage, packaging, preservation and delivery. The material and equipment used in teaching, learning and research should be properly handled, stored and preserved in order to prevent damage or deterioration. Also, a safe and healthy environment should be provided. In case of any

Table 3. Inspection and testing activities

PROCESS	ACTIVITY
RECEIVING INSPECTION AND TESTING AT A COURSE LEVEL	selection of course prerequisites and corequisites assessment of student admissibility to a course keeping records of receiving inspection and testing activities
IN-PROCESS INSPECTION AND TESTING AT A COURSE LEVEL	design and design review of inspection and test plan for the course distribution of the course inspection plan (part of course outline) to students assessment of the scheduling of inspection and tests activities design and review of term tests, quizzes, projects, case studies and other forms of inspection and testing activities to be performed during the term distribution and collection of tests marking and grading handling of marking and grading appeals keeping records of in-process inspection and testing activities
FINAL INSPECTION AND TESTING AT A COURSE LEVEL	design and design review of the final exam conducting the final exam marking and grading of the final exam review of marking and grading handling of appeals and review of final exam results conducting deferred and special exams keeping records of final inspection and testing
RECEIVING INSPECTION OF UNDERGRADUATE STUDENTS	application for admission into the department's undergraduate programs review of the application and eligibility of student to enroll inspection against specified entrance requirements and criteria handling of student appeals keeping records of aforementioned activities
IN-PROCESS INSPECTION OF UNDERGRADUATES	determination and review of the student academic status handling of student appeals keeping inspection records
FINAL INSPECTION RECEIVING INSPECTION OF GRADUATE STUDENTS	Graduation application for admission into the department's undergraduate programs review of the application and eligibility of student to enroll inspection against specified entrance requirements and criteria handling of student appeals keeping records of aforementioned activities
IN-PROCESS INSPECTION OF GRADUATE STUDENTS	advisor's assessment of the student's progress annual review of progress establishment of the M.Sc. thesis examining committee M.Sc. thesis oral examination review of thesis/project by the examining committee establishment of the Ph. D. selection committee review of student's suitability for Ph.D. studies advisor's assessment of Ph. D. student's progress documenting and implementing the program of studies establishment of the Ph. D. advisory committee annual review of the Ph.D. student's progress conducting the Ph.D. Candidacy and Oral Examination
FINAL INSPECTION RESEARCH PROJECT	Graduation Activities specified in the research project plan

damage or deterioration of material, equipment and/or environment occurs, the objective is to ensure detecting and assessing such occurrences, and implementing corrective and preventive actions to eliminate causes of further damage and/or deterioration.

The equipment and material include lecture rooms, research laboratories, computer laboratories, overhead projectors, electronic displays, chalk boards, textbooks, software, solution manuals, materials used in tests and experiments, research project reports, and research papers. Provision of a healthy and safe environment includes proper conduct of faculty, staff and students, personal safety and health, as well as parking and traffic regulations, sports services, housing and student life. Adequate procedures and records must be documented and maintained to assure quality.

Servicing. Servicing of programs/courses and research project follows delivery. Under this requirement, students are provided with information on new developments in the field of expertise. Also included are career counseling, provision of the list of engineering graduates to prospective employers and alumni organization's services. In terms of research, servicing activities are performed according to specific contracts.

Supporting elements

Supporting elements of the ISO 9001 quality system address resources necessary for the quality system implementation, as well as resources and processes necessary for the improvement of quality.

Management responsibility. Overall objectives of the quality system are stated in a document called the quality policy. This policy should be

APPOINTMENT OF TEACHING ASSISTANTS

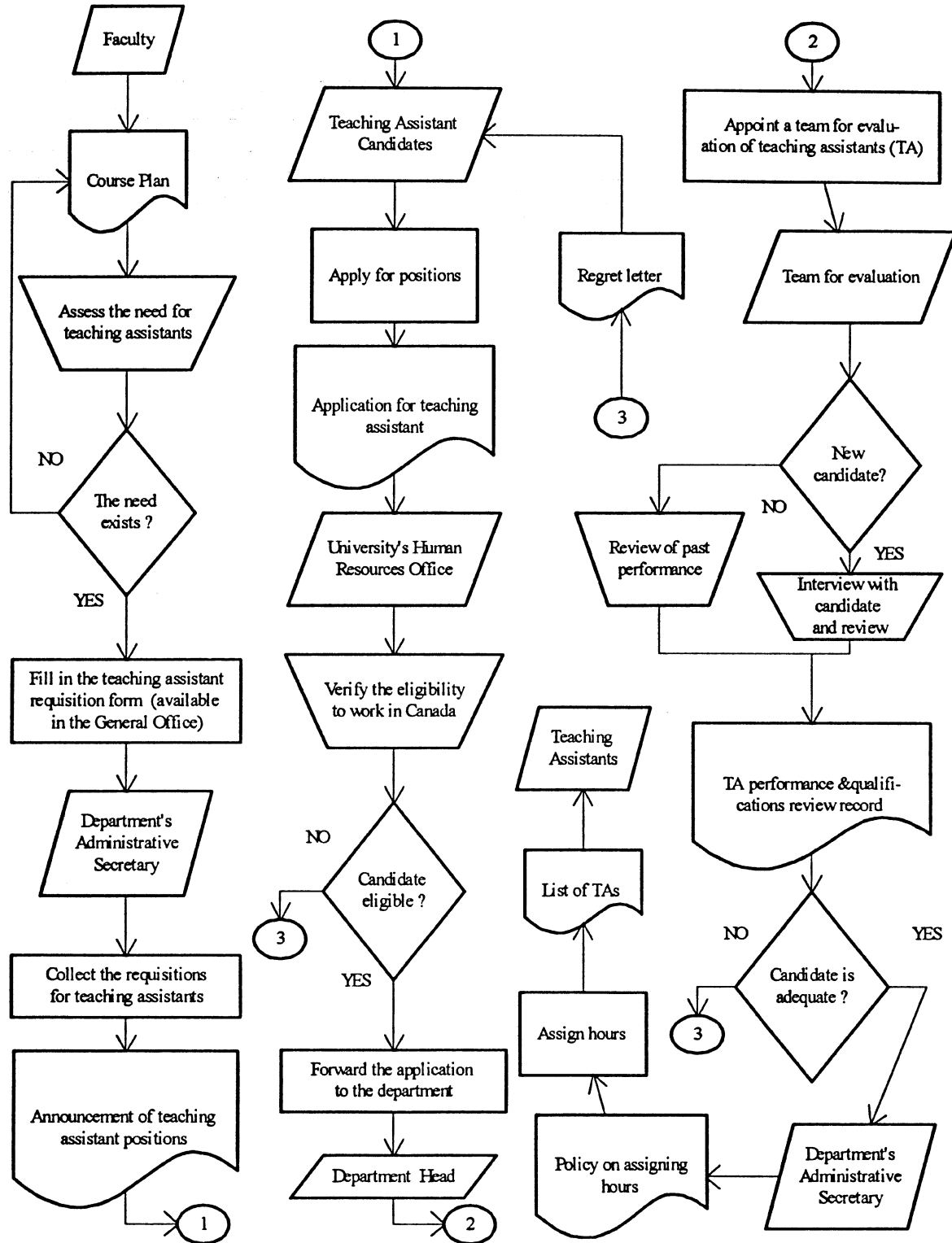


Fig. 4. Example of a purchasing activity.

drafted and signed by the dean (department head). An example follows:

The Faculty of Mechanical Engineering has committed itself to provide the best quality in teaching, learning and research. Meeting the needs of our students, their future employers and the needs of the community in

general is the main objective. A documented and implemented quality assurance system, that complies with the International ISO 9001 Standard, and will be registered, supports this policy. All members of the Faculty understand and follow this policy.

Signature and date

The executive management (defined in Table 1) ensures that the quality policy is understood, implemented and maintained. Apart from clearly emphasizing quality objectives, management responsibility facilitates that the interrelationships and authorities of all persons whose work influences quality of student knowledge, courses and research is defined. This includes responsibility and authority of the faculty/department administration, professors (instructors), teaching/research assistants/associates, technicians and administrative/support staff. Organizational charts or responsibility matrices may serve in this mandate.

The executive management must also identify the need for appropriate resources (instructors, assistants, courses, laboratory equipment, library, audio/video/computer equipment), as well as appoint an ISO 9000 Coordinator. The coordinator should be a faculty member with a thorough understanding of the ISO 9001 quality system and the educational and research processes in the faculty (department). His/her responsibilities include liaison with external parties, such as other faculties and/or universities, university administration, student records office and customers/subcontractors of the faculty (department).

At prescribed intervals, or when required, the executive management conducts management reviews. A management review includes:

- internal Quality Audits;
- overview and analysis of the quality policy and objectives;
- assessment of quality system effectiveness;
- analysis of customers requirements/needs;
- interrelationship between customer requirements and policy and objectives.

While Quality Audits are performed against the departmental goals and objectives, management reviews are performed by the executive management against the quality policy. A management review may include the review of documentation emerging from the audits. Records of management reviews must be kept and evidence of actions arising from them must be available.

Quality system. This requirement addresses the scope of the quality system, and the required documentation. If the faculty (department) plans not to include certain products in the quality system, such as research, the range of products and services included in the quality system must be stated. A quality system must be documented with an appropriate quality manual, procedures, instructions and records. This allows proper communication, audits and verification activities. The Quality Manual describes the quality system and refers to quality system procedures. Depending on the scope of the quality system and the organizational structure of the institution, a Quality Manual can be drafted on a faculty or departmental basis, or it can address specific products, such as programs or research. For example, an

engineering faculty with three departments can have three separate manuals, one for each department, or one for each product: undergraduate programs, and graduate programs and research. In terms of procedures, the faculty (department) may decide to prepare one procedure for each requirement of the standard. The procedures explain in detail who does what, when and where. Procedures make reference to instructions that define how an activity or part of a process is performed. Examples of instructions may include the teaching assistant's instruction for conducting laboratory experiments, librarian/technician instructions, and so on.

Document and data control. Document control ensures that accurate, up-to-date documents are readily available when and where required. All documents and data pertaining to the quality system must be adequately identified, prepared, reviewed, revised, approved and maintained. Thus, the issuance and approval of quality system documents and data, including the preparation, updating and maintaining the Master List of Quality System Documents, as well as the document and data changes are covered here. The scope of documentation to be controlled includes the Quality Manual, procedures, instructions, records and course and research project plans. The need for and use of each document must be clear and regularly reviewed.

Control of quality records. For the purpose of providing evidence that adequate quality assurance activities are being carried out, the faculty (department) must have a procedure in place for the control of all quality records. This requirement of the standard applies to the identification, collection, indexing, access, filing, storage, maintenance and disposition of quality records. To maintain the scope of these records, a master list of all forms considered to be 'quality records' should be kept.

Product identification and traceability. There is a need to properly identify the product and provide means for the traceability of related quality problems to their causes. Therefore, adequate identification of all courses, research projects, students, faculty and staff, as well as the traceability of nonconformancies in student academic progress, courses/programs and research projects are very important. The following processes are addressed by this ISO 9001 element:

- issuing and safekeeping of student numbers and identification cards;
- issuing and safekeeping of faculty and staff identification cards;
- handling of department and course numbers;
- issuing and distributing registration calendars to students;
- assigning numbers and codes to research projects.

Internal Quality Audit. The objective of this element is to verify that the quality system complies with planned arrangements, such as the ISO 9001 International Standard, and to verify whether these arrangements are implemented effectively and are suitable to achieve quality objectives. Internal quality audits serve to improve the quality system from the perspective of individual faculty and staff members, since they raise official attention to shortcomings and problems within the system. An effective internal quality audit system should be established on the basis of ISO 10011 Guidelines for Quality Audit, with faculty members trained as internal quality auditors.

Statistical techniques. In order to control and improve the quality of education and research, statistical techniques should be used. This ISO 9001 element requires that the need for statistical techniques in learning, teaching and research is established, and that the identified techniques are implemented and controlled. Statistical process control (SPC control charts), the seven quality tools, analysis of variance, hypothesis testing, design of experiments (DOE) may be included. It is advised that the need for the implementation of these techniques is analyzed in each of the fourteen quality loop elements of the quality system, as well as appropriate supporting elements. For example, statistical techniques in contract review may be used for analysis of customer satisfaction through surveys and interviews. Also, the analysis of industry and government needs and specifications can be included. In handling, preservation and delivery, number of nonconformancies in classrooms, equipment malfunctions and downtime, damaged teaching material, availability of software and computers, and many other quality indicators can be tracked and improved using statistical techniques.

IMPLEMENTATION ISSUES

The establishment of an ISO 9001 quality system in a university environment certainly requires a considerable amount of human, financial and information resources. However, this does not imply that universities or departments that are considering implementation have to start from scratch and spend hundreds of thousands of dollars in the endeavor. As suggested in the preceding paper [1], engineering faculties across the world have already encountered quality assurance schemes in the form of accreditation of their undergraduate programs. Examples include the CEAB accreditation in Canada and ABET accreditation in the United States. Using the existing CEAB or ABET documentation, faculties and departments can build a framework for an ISO 9001 quality system. This approach will basically fill in the documentation gaps, rather than require a total and unpredictable change of the processes and workings of an academic system. If the advantages of an ISO 9001 quality system for each individual member of an academic community are set up front, and the executive management is committed to achieving this goal, the ground for a successful implementation of the system will be set. Ultimately, the benefits of having a meaningful quality assurance system will certainly outweigh unavoidable concerns.

CONCLUSION

The ISO 9001 quality system is interpreted for application in a university environment. The concepts of the University Production System and the Quality System provided the necessary framework for the interpretation of all twenty elements of ISO 9001. Examples of processes covered by the requirements of the standard are given, followed by a brief discussion on some of the issues faculty will face during the implementation.

REFERENCES

1. S. Karapetrovic, D. Rajamani and W. Willborn, The University Manufacturing System: ISO 9000 and accreditation issues, *Int. J. Engineering Education* **13**(3), p. 180–189 (1997).
2. R. G. Lewis and D. H. Smith, *Total Quality in Higher Education*, St. Lucie Press, Delray Beach, Florida (1994).
3. W. Willborn and T. C. E. Cheng, *Global Management of Quality Assurance Systems*, McGraw Hill, New York (1994).
4. British Standards Institute, *BS 5750: Guidance Notes for Application to Education and Training*, BSI, Milton Keynes, UK (1994).
5. National Accreditation of Certification Bodies, *Guidelines on the Application of the ISO 9000 Series to Further Education and Training*, NACCB, London, UK (1994).
6. Mission of the University of Manitoba, General Calendar, 1997, University of Manitoba, p. 4.
7. S. Karapetrovic and W. Willborn, Creating zero defect students, *Total Quality Management Magazine*, **9**(4), pp. 287–291 (1997).
8. J. Velury, ISO 9000: Focusing on Quality Systems, *Industrial Management*, **38**(6), p. 11–15 (1996).
9. S. Karapetrovic and W. Willborn, The system's view for clarification of quality vocabulary, *Int. J. Quality and Reliability Management*, **15**(1), pp. 99–120 (1998).

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