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A quality management model based on the "deep quality concept"

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Abstract

Purpose – According to many authors, differences in firm performances are increasingly attributed to tacit knowledge that cannot easily be transmitted or imitated. On the other hand, current quality management models knowledge typically relates only to people. Situations, in which knowledge that is related to people is not available, sufficient, reliable or lucrative for application, are not considered. This paper aims to investigate how to overcome this gap.

Design/methodology/approach – Based on the adopted classification, types of knowledge typically present in an organisation are identified, and are discussed. Techniques for acquiring and formalising tacit knowledge are explored, and related criteria are defined. Particular attention is shown to knowledge management and artificial intelligence techniques.

Findings – A new approach to quality management called deep quality concept (DQC) is conceptualised, and mechanisms and concepts needed to acquire and integrate formalised knowledge into quality systems are identified. Other concepts that need to be incorporated are also identified. Finally, a new quality management model based on the DQC is developed.

Research limitations/implications – In further research the main points of the presented theoretical framework need to be validated through real examples from practice, and the resulting quality standard, i.e. award criteria, as well as the related handbooks completed and formalised.

Practical implications – Knowledge-related and other relevant concepts need to be incorporated into contemporary quality management systems, as systematically and carefully as conventional quality management concepts. Knowledge of methods and tools suitable for that also needs to be assimilated.

Originality/value – In the paper a novel knowledge-focused approach to quality management is presented. For this reason the paper is of great value for quality management theory and practice.

Keywords Quality management, Quality management techniques, Knowledge management, Artificial intelligence

Paper type Research paper

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Introduction

Knowledge is a complex and variegated good that can be tacit or codified, localised (context-specific) or abstract (generic) (Grimaldi and Torrisi, 2001). At one end of the spectrum, knowledge is assimilated with information and articulated (e.g. a blueprint). It is recordable, storable and transferable at negligible costs (Arrow, 1962). At the other end of the spectrum, knowledge is tacit, embodied in skills, and can be in part transferred through personal, informal contacts and training (Winter, 1987). Unlike information tacit knowledge cannot easily be transmitted or imitated. Even skills and capabilities based on a formal, scientific background (for example mathematics or physics) are in part tacit (Grimaldi and Torrisi, 2001). The same goes for the expert knowledge.

Increasingly, differences in firm performances are attributed to tacit knowledge (Wernerfelt, 1984; Reed and DeFillippi, 1990; Barney, 1991; Peteraf, 1993; Coff, 2002). Tacit knowledge or "know-how" is also referred to as "procedural" knowledge, meaning that individuals know how to perform given tasks or that they have the skills or the ability to solve a given problem (Nelson and Winter, 1982). That means that the process depending on such knowledge, if the knowledge is not formalised, *de facto* depends on individuals that have that knowledge. In the quality context, the question is if such a situation is allowable, and under what conditions. The second question is what are its implications. The uncertainty associated with humans makes these questions even more important.

On the other hand, current quality models typically are not concerned with such questions. Knowledge they relate only to people, and view it as unquestionable. Concepts dealing with knowledge formalisation, such as for example capturing and representing the existing knowledge, thus are not considered. Instead, the focus is still on acquiring skills through training. Important concepts dealing with knowledge availability and reliability are also not considered. Instead, only data and information reliability are considered, and the notion "availability" is mentioned primarily in documentation, information and resource context, where money, time, men, machines, materials, but not knowledge, are typically listed as resources. In other words, situations in which knowledge that is related to people is not available, sufficient, reliable or lucrative to be applied are not considered.

That could be the consequence of the models that are still based mostly on Taylorian philosophy of manufacturing. Taylor (1911) synthesised his own ideas and those of others into a systematic management approach he called "task management", that became a central part of the scientific management movement. The two essential elements of scientific management were the duty of management and workers to cooperate, and substitution of exact scientific knowledge for opinions, rules-of-thumb, or individual knowledge. According to Peklenik (1995), regarding features of manufacturing processes the basic presumptions of the Taylorian philosophy of manufacturing were:

- determinism of operations;
- predictable behaviour of the system; and
- a priori information which is reliable, complete and accurate.

In the current quality management such view still predominates. Consequently, in literature the fact-based management i.e. the factual approach to decision making, are thus still among core quality concepts, listed in the frame of all four most important models (see the next section). Although in that sense there is some progress, dynamic and stochastic side of processes, as well as uncertainty connected to humans, are still not included into considerations.

This paper investigates how to overcome this gap, and it is organised in seven sections. After the introduction, a short overview of current quality management models as well as the analysis of the current trends is given. After that, based on the adopted knowledge classification, types of knowledge typically present in an organisation are identified and their containers are discussed. Then the knowledge formalisation issue is concerned. Techniques for acquiring and formalising tacit i.e. expert knowledge are explored, and related criteria are defined. Based on the research findings, the DQC approach is introduced and the mechanisms and concepts needed to acquire and integrate formalised knowledge into quality systems are identified. Some basic notions of the knowledge management and machine learning, which are partially novel to quality management audience, are also introduced. Finally, the new model of quality management called the DQC model is presented. The steps of its implementation are described and conclusions and recommendations for further work are derived.

The research was motivated by the authors' experience with introducing ISO 9001 standard in two big Croatian shipyards, as well as in several Slovenian factories. One of the shipyards was of repairing type, i.e. with strongly expressed characteristics of dynamic and stochastic systems in which tacit i.e. expert type of knowledge that cannot be formalised with traditional methods plays a particularly important role.

Current quality management models

There are various definitions of quality. However, whichever definition of quality one may choose to adopt, unlike the past times when a single manufacturer was able to cope with quality management and problems related thereto without special systems specifically intended to that (Aravindan *et al.*, 1996), contemporary production systems have become so complex that for the purpose of attaining and maintaining the quality, in accordance with a generally accepted paradigm, organisations are compelled to set up specially designed and developed systems for efficient quality management and support. However, to conceptualise such a system is not a trivial task. With this in view, special models for quality assurance and management have been developed.

Currently, there are several quality management models that an organisation can apply in attempt to maintain and improve quality of its processes, products, services and overall business performances. The most important of them are:

- total quality management model (TQM);
- the Malcolm Baldrige Criteria for Performance Excellence;
- the EFQM Excellence Model; and
- the standard ISO 9001.

Total quality management model is an integrated system of principles, methods, and best practices that provide a framework for organisations to strive for excellence in everything they do. Typically a business or organisation will base the common framework around a process model, like Malcolm Baldrige criteria used in the USA. Other models exist like the Toyota Production System (TPS), Six Sigma or

Phil Crosby's system, etc., and all are applied based on management's interest, experience and direction they wish to go. The TQM core concepts are:

- customer focus;
- leadership;
- continuous improvement;
- strategic quality planning;
- design quality;
- speed and prevention;
- people participation and partnership; and
- fact-based management.

The roots of TQM go back to the teachings of Drucker, Juran, Deming, Ishikawa, Crosby, Feigenbaum and countless other experts that have studied, practiced, and tried to refine the process of organisational management.

The Malcolm Baldrige Criteria for Performance Excellence are applied in the Malcolm Baldrige National Quality Award (MBNQA). MBNQA was created by the National Quality Improvement Act, signed in 1987, to promote excellence in US organisations. The criteria for performance excellence are designed to help organisations enhance their competitiveness through focus on dual, results-oriented goals:

- delivery of ever-improving value to customers, resulting in marketplace success; and
- improvement of overall organisational performance and capabilities.

The Baldrige criteria are a descriptive or diagnostic framework, not a prescriptive model, for excellence. The foundation is a set of core values and concepts that are embodied in seven categories: leadership, strategic planning, customer and market focus, information and analysis, human resource focus, process management, and business results. The core values and concepts are customer-driven quality, leadership, continuous improvement and learning, valuing employees, fast response, design quality and prevention, long-range view of the future, management by fact, partnership development, public responsibility and citizenship, and results focus.

The EFQM Excellence Model was introduced at the beginning of 1992 as the framework for assessing applications for the European Quality Award (EQA). The model is based on nine criteria. Five of these are "Enablers" and four are "Results". The "Enabler" criteria cover what an organisation does. The "Results" criteria cover what an organisation achieves. "Results" are caused by "Enablers" and feedback from "Results" help to improve "Enablers". Within this non-prescriptive approach there are some fundamental concepts that underpin the EFQM model. They are results orientation, customer focus, leadership and constancy of purpose, management by processes and facts, people development and involvement, continuous learning, innovation and improvement, partnership development, and corporate social responsibility. It is the most widely used organisational framework in Europe and has become the basis for the majority of national and regional quality awards.

Standard ISO 9001 is a model for quality assurance in design, development, production, installation and servicing. Different to the old standard (ISO 9001:1994) that was focused on procedures, the new ISO 9001 (ISO 9001:2000) is focused on processes. Its eight key management principles are:

(1) Customer based organisation.

(2) Leadership.

(3) Involvement of people.

(4) Process approach.

(5) System approach to management.

(6) Continual improvement.

(7) Factual approach to decision making.

(8) Mutual beneficial supplier relationship.

In opinion of many authors, the ISO 9001 describes in most cases the minimal set of processes necessary for delivering quality products and services to customers. In other words, it is often viewed as a necessary minimum, i.e. as the lowest common denominator of an effective quality system.

The trends

However, given that these models overlap, and each of them has good and bad sides, initiatives to integrate them are not new. In that the dominating approach is to obtain the ISO certificate first, and then the resulting quality system to use as a platform for a continuous improvement of quality of products and/or services, in accordance with the TQM model (e.g. Ho and Fung, 1994; Rao Tummala and Tang, 1996; Tsiotras and Gotzamani, 1996; Kanji, 1998; Tang and Kam, 1999; Lisiecka, 1999; Najmi and Kehoe, 2000). This approach is explained mainly by the assertion that TQM is considerably wider, far more expensive and demanding in its implementation than are the systems according to ISO 9001 (e.g. Rao Tummala and Tang, 1996).

A different approach has been offered by Sun (1999). He sees a way for integrating the TQM and ISO concepts in the current position of company, and differentiates three such ways: TQM-then-ISO, ISO-then-TQM, and balanced path. Sun, similarly to Hoerte (1994), identifies different implementation patterns in various countries. Hoerte (1994) also has identified size and advancement of the company, as the factor that influences which model will be predominant. In Sun's approach the specific trait is that he views the ISO certification as not necessarily to be applied without exception. In his more recent paper (Sun, 2000) he recommends explicitly that ISO 9000 should be incorporated with the philosophy and methods of TQM. Quite similarly, Zhang (2000) the ISO certification sees only as an element of TQM rather than the basis for it. Keeping in mind that standards series ISO 9000 until now have proved to be over bureaucratised and too narrow, and the expectations with the new series are not fully realised, this approach seems to be more reasonable. On the other hand, TQM model is not structured enough and its implementation often fails.

Consequently, the main disadvantage of described approaches is in their departing from existing quality models as given dimensions. Second, the relationship between ISO 9000 and TQM is often poorly understood. For that reason, for many companies the transition from being an ISO certified company to becoming a total quality company is uncertain (Najmi and Kehoe, 2000). Also, it is not known what will be the situation in the future. Some authors, as, e.g. Terziovski *et al.* (1999), affirm that managers generally lack understanding of the concepts and principles of quality management. So, for instance, they quality still erroneously connect mainly to the area of operations and not to the area of human resources as well, were quality management is practiced the least. They are also frustrated with the slow bottom-line payback from the implementation of quality management practices, which they look on as tools and techniques for problem solving at the shop-floor level rather than as a philosophy.

On the other hand, a generalised model that would integrate concepts of all models, as well as the various strategies adopted by numerous quality management and engineering experts and be focused towards quality enhancement, lack of which has also been mentioned by, e.g. Aravindan *et al.* (1996), is still not reported. According to Lozano (1997) there is also no established form of creating that kind of management or an ideal model to follow. At the same time, there is no organised attempt to spread the interest to other relevant research areas and concepts, such as knowledge management and artificial intelligence, or knowledge formalisation.

So, for instance, although the impetus in development and implementation of the approaches to quality assurance has been expected to bring a significant increase in the smarter use of computer, it has not happened to the extent it was predicted. On the contrary, in some environments, no matter whether they have quality systems established according to one of the described quality models or not, observations in studying the ways for reaching higher productivity levels in western countries reached by Kerr in 1991, unfortunately still stand today. On one hand computers were even at that time capable of having artificial intelligence built into them (capability of storing symbolic knowledge and performing sophisticated symbolic manipulation and reasoning). On the other hand, they were in the frame of various MPR and MIS systems used at the level of information and database technology of the 1970s. The problem is that current quality models allow that computers in qualitative sense at that level are used even nowadays. Moreover, even lack of models regarding the role of information systems in the support of modern quality management practices, found out by Forza (1995), also stands today.

Types of knowledge typically present in an organisation and its containers

Knowledge differs markedly from information and data. At rock bottom, knowledge is socially constructed in discourse communities (Lang, 2001). It exists within the individual employees, and also in a composite sense within the organisation (Bollinger and Smith, 2001). Besides the classification of knowledge to tacit or codified, localised or generic, given in the introductory part of this paper, there are also other classifications. Lang (2001) thus distinguishes uncodified and uncodifiable knowledge. On the other hand, Cowan *et al.* (2000) distinguish articulated, unarticulated and unarticulable knowledge. Nevertheless, the basic and possibly the most important distinction between the knowledge types was suggested by Polanyi (1966). He made distinction between explicit knowledge, which can be articulated in formal language and transmitted among individuals, and tacit knowledge, personal knowledge embedded in individual experience and involving such intangible factors as personal belief, perspective, and values. Quite similar, Clark and Rollo (2001) distinguish also tacit and explicit knowledge. According to them knowledge flows involve the translation of tacit knowledge into explicit knowledge in a process of codification. Dooley *et al.* (2000) referring to Polanyi distinguish tacit and explicit knowledge as two types of process knowledge. Tacit knowledge is generated from experience. It is subjective in nature and tends to evolve simultaneously with experience. Explicit knowledge is considered more objective in nature and tends to evolve after experience. Hackley (1999) equalises tacit knowledge with unarticulated knowledge. Other authors distinguish also mainly between tacit and explicit knowledge (e.g. Haldin-Herrgard, 2000; Hannabuss, 2000; Smith, 2001; Herschel *et al.*, 2001; etc.).

On the other hand, Jacob and Ebrahimpur (2001) have shown how local and tacit notions of what is knowledge determine what types of intra-organisational mechanisms for knowledge transfer are preferred in a given company setting. In the remainder of the paper we refer to the knowledge classification according to its importance for quality. The classification is given in Table I.

Hicks *et al.* (2002) have proposed four similar categories (general, generic, specific, and case knowledge). The differences between the two taxonomies are:

- our taxonomy is focused on importance of knowledge related to the quality;
- "general" and "generic" categories have been joined; and
- "case knowledge" has been replaced with "expert knowledge", i.e. "expertise".

These three types of knowledge differ not only in their importance for quality, but also in other features. For example, general and generic knowledge tends to be of low equivocality. Their context dependency is also low. On the other hand, expert knowledge is highly equivocal and context dependent (Dooley *et al.*, 2000). Between these two extremes lies specific knowledge. All these types of knowledge can be either tacit or explicit (i.e. codified, formalised).

In an organisation, all types of knowledge given in Table I are typically present. While on the top management level general and generic as well as specific knowledge is usually sufficient, on management and operational levels specific knowledge prevails. Although, in a low-bottom of an organisation manual skills are often important as well, in this paper we will not be concerned with. On the other hand, expert type of knowledge, i.e. expertise can be equally important for all levels in an organisation. Different from specific knowledge, the need for such type of knowledge for some processes or sub-processes can be sporadic. In other words, the need for expert knowledge does not have to be always constant. Nevertheless, whenever the need for expertise occurs, it is mainly urgent and the quality of it is decisive for the output quality of the related processes. For this reasons, it is important that expertise i.e. expert knowledge is easy accessible and reliable. Consequently, it is important that it is as formalised as possible.

Table I.
Knowledge classification according to its importance for quality

Knowledge type	Importance for quality
General and generic knowledge	Low to medium
Specific knowledge	Medium to high
Expert knowledge/expertise	Decisive

The knowledge containers

Whatever the knowledge type, to exist and be usable knowledge must be perceived or discovered, and then it must be stored. Typically, knowledge perception and/or discovery are connected to humans. According to such a view, after being perceived (or discovered), knowledge is stored in the human brain. Part of that knowledge, humans then formalise, mainly in the form of appropriate texts, formulas, diagrams, drawings, etc. Only knowledge that is well structured and understood can be formalised in such a manner. In other words, according to this approach, the human brain is considered as the only knowledge processor, and the human brain and paper as the only media on which knowledge can be stored.

Typical knowledge containers according to this traditional approach are presented in Table II. Given that expert knowledge in many cases is difficult to structure, a significant part of such knowledge within this approach rests necessarily unformalised.

On the other hand, in the last few decades, computer scientists have developed possibilities for knowledge to be derived, discovered and stored by machines. Particular attention, in this context, was put on expert i.e. tacit type of knowledge. To this aim scientists have developed various methods and techniques, as well as tools. To focus their interest more clearly they have also developed various sub-specialisations. The part of computer science especially concerned with such questions is artificial intelligence. Knowledge synthesis and representation are thus the issues of top interest in artificial intelligence. Consequently, computers became very important knowledge processors. They have also opened an almost unlimited space for knowledge capturing and formalising using electronic facilities. Based on these possibilities the traditional knowledge "containers", i.e. the human brain and paper, are supplemented with the new ones. The corresponding overview is given in Table III. In the opinion of the authors, the quality standards i.e. awards' criteria need to take into account these possibilities.

Of course, as in the case of traditional containers, the realisation of the new ones also needs an effort, a planned action to be achieved. To this aim the next sections analyse the problem and conceptualise the possible solutions.

Knowledge type	Knowledge containers
General and generic knowledge	Human brain, books, and the like
Specific knowledge	Human brain, handbooks, manuals, dictionaries, standards, and the like
Expert knowledge/expertise	Human brain, scientific monographs, treatises, studies, and the like

Table II.
Typical knowledge containers according to traditional approach

Knowledge type	Knowledge containers
General and generic knowledge	Human brain, books, and the like databases, knowledge bases
Specific knowledge	Human brain, handbooks, manuals, dictionaries, standards, and the like databases, knowledge bases
Expert knowledge/expertise	Human brain, scientific monographs, treatises, studies, and the like databases, knowledge bases

Table III.
Knowledge containers according to the new possibilities

The knowledge formalisation

Quality of any product and/or service depends significantly on knowledge. To be considered as reliable, knowledge concerning the organisation processes has to be identified, and then it has to be formalised as much as possible. It also has to be stored in a way that it is easily accessible. While formalisation of some knowledge is trivial, for example it can be relatively easily expressed and formalised in the form of written documents, i.e. texts, formulas and/or drawings, etc., and stored in books, hand-books, manuals and the like, to formalise and store tacit side of any knowledge special mechanisms are required.

In the context of domain dependent knowledge, that specially refers for the tacit dimension of expert knowledge. Given that expert knowledge is often decisive for output quality of a product and/or service, and on the other hand experts often lack motivation, skills and time to document their expertise (Karhu, 2002), leads to the conclusion that mechanisms for capturing, representing and storing of such knowledge are necessary to be integral part of quality systems. Conversely, quality systems that have not included mechanisms for continuous integration of formalised knowledge cannot be considered as effective and reliable. The reasons for that are:

- knowledge and experience of an individual could be insufficient for a reliable and complete solution;
- sufficiently competent people are not always available or may be too expensive; and
- there is uncertainty always connected with humans.

The expert knowledge formalisation

There are several approaches to acquire and formalise expert i.e. tacit knowledge. With this issue mainly two different research disciplines are concerned. The first one is already mentioned artificial intelligence. The second one is knowledge management. For example, within knowledge management, which according to Newman (1991) is defined as collection of processes that govern the creation, dissemination, and utilisation of knowledge, a method for sharing expertise called expertise cycle where knowledge stewards build personally trusted relationships with experts has been demonstrated by Karhu (2002). Knowledge stewards interview the experts, construct the knowledge and document it, making it available for knowledge seekers. Hannabuss (2000) has examined the role of narrative (in the form of storytelling) in eliciting tacit knowledge (including tacit meta-knowledge) in the sensemaking of organisations. Augier and Vendelo (1999) have demonstrated an approach to management of tacit knowledge focused on how it can be organised in networks. Herschel *et al.* (2001) has examined knowledge exchange protocols as a vehicle for improving the tacit to explicit knowledge conversion process. In an experiment testing the use of knowledge exchange protocols they have demonstrated that while structure may significantly improve the tacit to explicit knowledge conversion process, it also may matter how structure is employed in this process. Some other authors in their research discuss or use artificial intelligence techniques. Thus for example Liebowitz (2001) discusses the link between knowledge management and artificial intelligence. The review of knowledge management approaches and applications from 1995 to 2002 can be found in Liao (2003). His conclusion is that the development of knowledge management technologies tends towards expertise orientation, and knowledge management technologies towards problem domain orientation. That means that already present overlap between knowledge management and artificial intelligence will be increased in the future.

On the other hand, within artificial intelligence which primary goal according to Bratko (1990) is to build computer systems to solve problems that are hard for typical computer systems to solve but easy for people, acquiring and formalising expert knowledge is approached more formally. While in knowledge management the focus is mainly on how to make experts consent to co-operation, and how to ensure mechanisms to share their knowledge, in artificial intelligence the focus is on formal methods and tools for knowledge elicitation and representation, such as for example machine learning techniques, decision and regression trees. Consequently, it is difficult to isolate particular examples of the characteristic approach. Nevertheless, two main approaches can be differentiated:

(1) knowledge acquisition by interviewing experts (typical for building knowledge bases for the first generation of expert systems); and

(2) knowledge acquisition using machine learning algorithms.

The criteria for knowledge formalisation

Depending on organisation characteristics (type, size, complexity, top-management competency and integrity, environment, etc.), knowledge is more or less formalised. Concerning codification of technological knowledge Balconi (2002) stated that whereas an overall tendency to codification of technological knowledge is very clear, the intensity of actual use of codified know-how varies across firms. Small firms might find codification unprofitable and prefer to rely on the tacit knowledge of their employers. According to her, the man-embodied (personal, tacit) competences relying on experience and a codified knowledge base have won the day, while purely tacit knowledge has become marginal, even if it has not been totally eliminated.

However, codification i.e. formalisation of all knowledge within an organisation is not possible to achieve. For this reason, within quality standards i.e. awards, criteria for knowledge formalisation need to be clearly stated. The criteria have to be based on the factors defining the "weightiness" of the particular knowledge, and the cost-benefit analysis. The factors defining the weightiness of the knowledge are:

- the importance of the particular knowledge for organisation (i.e. for its processes);
- the spread of it within the organisation;
- the spread of it on the labour market;
- the time needed to be acquired (i.e. the knowledge type and complexity); and
- the dynamism of changes.

On the other hand, the factors concerning the cost-benefit analysis are:

- the estimated weightiness of the knowledge;
- the possibilities of its formalisation;
- the costs of the formalisation; and
- the costs and risks of having that knowledge unformalised.

All this reveals two important things. First, that for each process the knowledge, including expertise and skills, the process is depending on must be clearly stated. And second, that to be able to estimate the weightiness of a particular knowledge, the data about that knowledge within organisation and labour market must be available. The instrument for that could be obligation for any organisation aspiring after quality certification i.e. award to record and maintain such data on a regular basis. In other words, for each individual, from top management to shop floor workers, must be known what knowledge she/he has at the moment. Quality standard i.e. awards have to encourage that such data are recorded into computer databases. Compared with data on knowledge formalisation, it could be then estimated if any process is endangered, and to what extent. In this context assessments on reached knowledge levels are also important.

The DQC approach

Based on the previous considerations and findings, the new approach to quality management is conceptualised. The approach is called the deep quality concept (DQC). The reasons for that are: introducing the specific mechanisms the approach aims at formalising the domain knowledge, particularly tacit expert knowledge (that is often referred to as "deep knowledge" given that it is mainly based on experience); and it also aims at incorporating other concepts from areas usually skipped out from traditional approaches. In other words the approach emphasises the need for deep analysis of all dimensions of quality and relevant concepts, techniques and tools of various research areas, and aims at integrating them into quality systems.

The mechanisms

The most important mechanisms needed for acquiring and integrating tacit domain knowledge into quality systems according to the DQC approach are described below:

Obligation to record all relevant data. Under some circumstances, knowledge acquisition can be accomplished by analysing a database. A database is a collection of data that is organised so that its contents can easily be accessed, managed, and updated. This approach may be appropriate in situations where a database exists. In the case of deep expert knowledge, database could consist of known solutions to past cases and values of relevant parameters (attributes) that caused such solutions.

The notion "database" is usually connected to computers. However, relevant data can be recorded even on paper. Depending on quality and quantity of such records, it can be time-consuming and hard process to enter these data in the computer database. Nevertheless, the valuable data is preserved and can be used for different purposes. In such data a significant amount of tacit knowledge can be also contained. Obligation to record all relevant data is thus the first and the simplest mechanism towards formalisation of tacit knowledge within an organisation. Quality standards, i.e. quality awards criteria, have to require clearly such obligation. In the same time this request can be understood as the lowest level concerning mechanisms for tacit knowledge formalisation that an organisation can achieve. Consequently, the first level request in the context could be expressed as:

R1. All relevant data need to be recorded.

That also includes data concerning all kind of experts' estimates and assessments, as well as all measured values. What other data are relevant depends on the domain experts and other specialists' judgements, i.e. on system analysis and standard's i.e. award's regulations. Opinions of experts should also be recorded when concerning important decisions. It means that "data" need not to be always a string of characters or the like, but even entire files, drawings, documents, etc.

Insisting on systematism. To have all relevant data recorded is a great thing. On the other hand, to be really valuable, the data have to be recorded systematically. Systematically means continuously in time; and in organised manner. Organised here means that data are to be recorded in specially designed tables or forms with precisely defined fields. For that reason the request of the first level is refined as:

R2. All relevant data need to be systematically recorded.

This request represents the next possible level in the context of tacit knowledge formalisation within an organisation.

Insisting on the use of computer. Although data can be systematically recorded even in tables or forms drawn on paper, the best place for data to be recorded and stored is without doubt computer database. To this aim, and to avoid later difficulties with data transfer, it is opportune to incorporate computer-oriented thinking, methods, tools and solutions as early as possible. The request of the third level in the context is thus:

R3. All relevant data need to be systematically recorded into computer database(s).

The term "computer" is explicitly mentioned in the request to avoid any possible misunderstanding. Anyhow, insisting on the use of computer has to be *sine qua non* of any serious quality model. Quality standardisation and awards bodies need to include the related requests into their texts and to spread and support computer-oriented thinking among organisations as much as possible.

Expertly designed databases. Computer databases can be of various types and quality. Understood according to the definition given above, the main elements influencing the database quality are:

- data modelling knowledge and domain knowledge built into database design (e.g. in creation of entity-relationship models and related data dictionaries);
- the data standardisation level;
- the chosen database management system (DBMS), such as for example ORACLE, MSSQL, DB4, etc. for physical realisation of the designed data model;
- consistence in filling and the maintenance of the database; and
- quality of data administration.

On the other hand, databases are an integral part of management information systems (MISs). The role of the high quality management information systems should be twofold: they need to be the support to the managers' decision making, and they need to facilitate the knowledge capturing and storing. Consequently, concerning the database design, data modelling knowledge and domain knowledge are equally important. Nevertheless, the nearer the knowledge is to the expert type, the tacit dimension is more expressed and the importance of knowledge on domain compared to classical information knowledge increases considerably. Pieces of data concerning the expert's domain recorded by an expert, or conceived by an expert using tools as simple as Excel, could be equally valuable and useful as the same data recorded in much more sophisticated manner in the information technology sense. Oppositely, database designed using the best data modelling principles, and with the most sophisticated tools cannot result in effective and high quality database if only the shallow knowledge about problem domain is built in. In other words, only cooperation of database specialists and domain experts can ensure that database is really expertly designed. Given that within an organisation there are typically problems from various specialisations, when it is needed the experts of different profiles must be included. In any case, data are connected to processes. It means that to identify relevant data, high quality system analysis and data modelling need to be accomplished.

Concerning the DBMS, the choice must not be related only to available money and quality of the system in a sense of usual information technology parameters, such as database integrity, robustness, security, administration and optimisation capabilities, and so on. The factors that have also to be taken into account are factors concerning the very nature of the problem domain. If domain is rather specific, with a lot of not so well structured processes, and it is dependent significantly on experts' estimates and assessments, choice of an expensive but too rigid system could be inefficient and dangerous. It means that it is not reasonable that systems that do not support relatively simple administration of structure changes, or integrity of the database when data are entered, are chosen is such case, at least in the stage of database development. At the same time much more rigid systems could be used to cover typical business functions for which solutions already exist, or are not difficult to be properly designed. In the choice of the system, the number of users for which a system is recommended could also be a useful guideline.

Finally, whatever DBMS is eventually chosen, to be really useful and reliable the designed database has to be filed and maintained consistently. It means constantly in time, and in a standardised previously predefined way. The fourth level request is thus:

R4. All relevant data need to be systematically recorded into expertly designed and maintained computer database(s).

Standardisation of problem domain concepts. In order to have a database of a high quality, an appropriate data model has to be designed, and user-friendly interfaces for data entering and editing provided. However, it is not enough. To be really useful and usable for further purposes and analyses, data need to be also standardised. It means that different terms, marks and/or abbreviations for the same notion and/or expression are not welcome, or they can be allowed if the data model has the synonyms handling function built into it. Of course, it is understood that all master tables and keys in database models and data dictionaries are recognised correctly. Given that in complex domains, a great part of terms may not be standardised, a good approach is to start with the most important sets of terms and then to proceed with the others.

R5. All relevant data need to be standardised and systematically recorded into expertly designed and maintained computer database(s).

Encouraging the use of machine learning and other sophisticated tools and techniques for knowledge synthesis. Once the mechanisms for data recording ensure their quality are established, or in the ideal case much before, interfaces to machine learning or other special algorithms for knowledge synthesis are opportunely to be examined. To this aim, quality standards i.e. quality award criteria should also take into account such possibilities and encourage them. The sixth level in the context of such requests could thus be formulated as:

R6. All relevant data need to be standardised and systematically recorded into expertly designed and maintained computer database(s) with possible interfaces to machine learning and other algorithms for knowledge synthesis and representation.

In the same way, the use of other sophisticated tools and techniques needs also to be encouraged.

Encouraging the expert and multidisciplinary approach. Quality standards i.e. quality award criteria have to encourage expert and multidisciplinary approach wherever it is reasonable. For example, machine learning or case-based reasoning techniques cannot give usable results without an appropriate representation for the case structure is developed. Appropriate representation, as well as later adaptation rules to expand the database to apply to new situations cannot be developed without close cooperation of domain experts and knowledge engineers. It means that at least specialists of these two different fields are needed to accomplish this task successfully. The related request in the tacit knowledge formalisation context could be thus formulated as:

R7. Besides already established functions like quality managers and quality engineers, in designing, development and maintenance of quality systems the knowledge engineers should also be included.

Encouraging creativity and learning. Creativity has also to be encouraged. In formalisation of tacit knowledge context it means that besides encouraging domain experts to take part actively in database design, they have also to be encouraged to conceptualise and develop their own applications and tools. Sometimes there is no better way to structure and formalise the deep expert knowledge. It is not necessary that such solutions become later the final choice of the organisation, but they always have to be considered and valuated. Given that things always change, the willingness to learn is also important in the context. The relating request thus can be formulated as:

R8. Creativity and willingness to learn have to be encouraged and valuated.

Creativity and willingness to learn, besides competence, experience and responsibility, also has to be an important factor in determining someone's income within the organisation.

Encouraging teamwork and collaboration. Finally, information and knowledge have to be shared. Further, many useful ideas come out from direct interchange of opinions. To this aim, besides friendly climate, and fair and competent management, teamwork and collaboration have also to be encouraged. The relating request thus can be formulated as:

R9. Teamwork and collaboration have to be encouraged.

Other concepts that need to be incorporated
Besides requests dealing with knowledge and its formalisation, and related concepts, in quality management according to DQC approach other relevant concepts and requests should also be included. It is a question of issues relevant for quality and quality management that are usually not included, or are marginalized in traditional approaches. The research areas, from which such concepts should be particularly carefully examined, besides already mentioned knowledge management and artificial intelligence, are contemporary management and organisational sciences, and behavioural science. Particular attention in that has to be put to motivating mechanisms, as well as to educational issues.

The DQC model

Finally, based on the so conceived approach, the DQC model is derived. The developed model is shown in Figure 1.

Implementation of the model
In this section the details are described of how the DQC model, presented in Figure 1, is to be implemented. Descriptions refer to the levels of the model.

Level 0. Customers' needs and criteria are the basic information on which any organisation builds its business policy. These needs and criteria are also important for centres of knowledge, quality standardisation and award bodies. That does not mean that for centres of knowledge, quality standardisation and award bodies customers' needs and criteria have the same weightiness as they have for the organisations, but to them these details need to serve as motivating and possibly corrective information.

To handle such information organisations have to:

(1) Collect and record all relevant data, information and documents concerning the customers into the appropriate database.

(2) Define criteria for ranging customers according to their relevance and reliability.

(3) Add these data into database.

(4) Maintain and analyse the database on a regular basis.

Level 1. According to the model the outcomes of this level concerning the domain specific concepts, are anticipated to be the result of centres of knowledge efforts. To this aim centres of knowledge have to:

(1) Identify domain core concepts.

(2) Define domain core concepts.

(3) Identify main sub-concepts of the identified core concepts.

(4) Define these sub-concepts.

(5) Standardise all identified concepts and their sub-concepts having in mind the later use in databases (full names, short names/abbreviations, descriptions, codes for master tables, etc.). Generally, potential computer use should always be taken into account.

(6) Write a glossary of standardised domain concepts.

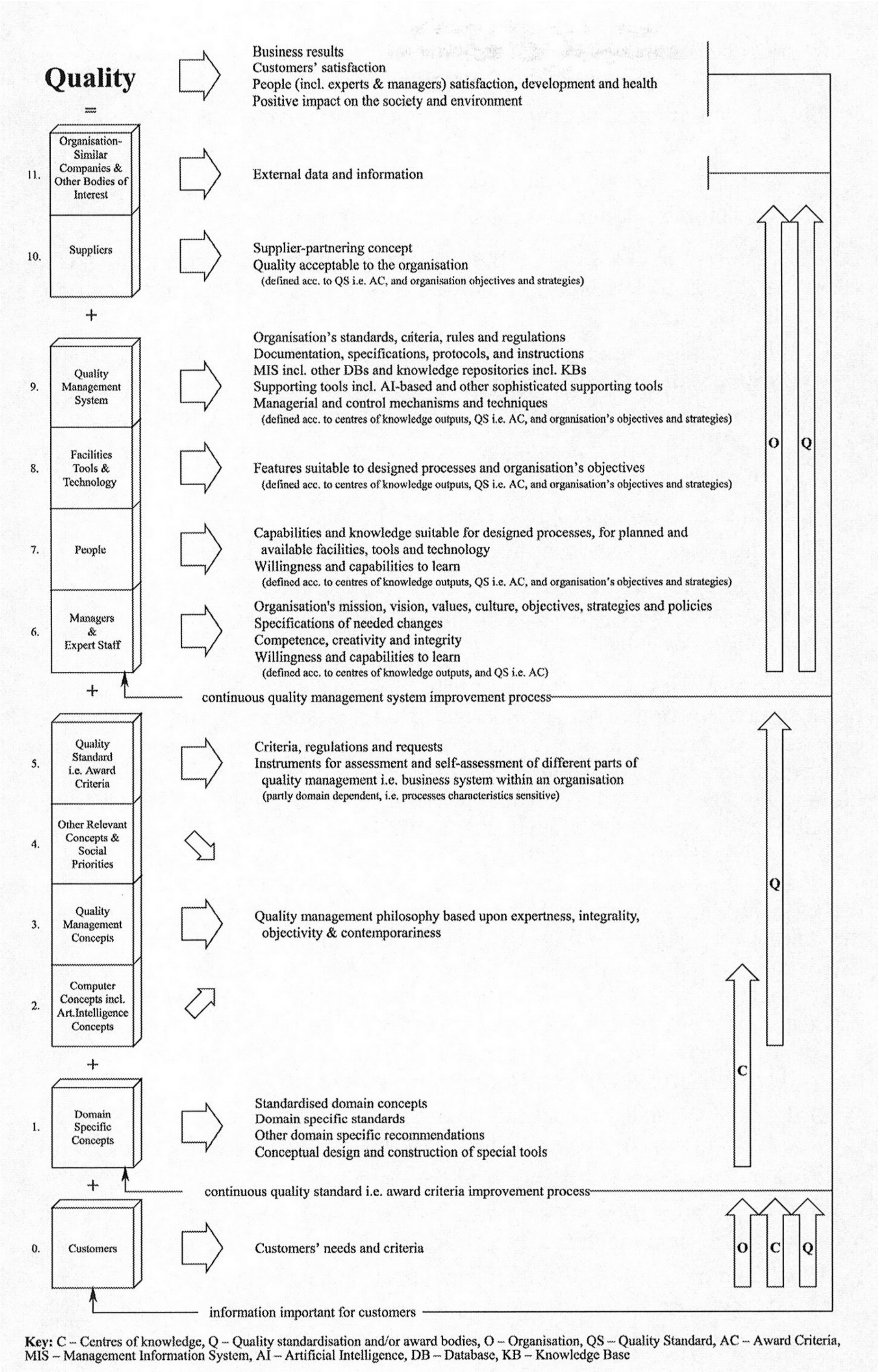

Figure 1.
The DQC model

(7) Write recommendations for implementation of the standardised domain concepts.

(8) Add standardised domain concepts and recommendations to the set of domain specific standards.

(9) Write other domain specific recommendations.

(10) Conceptualise design and construction of special tools.

Level 2. Concerning level 2, i.e. the computer concepts and artificial intelligence concepts, the quality standardisation and award bodies consulting the centres of knowledge have to:

(1) Identify all computer concepts that are interesting for quality management including the related methods and tools.

(2) Define computer concepts that are interesting for quality management.

(3) Identify all artificial intelligence concepts that are interesting for quality management, including the related methods and tools.

(4) Define these artificial intelligence concepts.

(5) Write a glossary of identified computer and artificial intelligence concepts.

(6) Write recommendations for the implementation of these concepts as well as necessary prerequisites. Recommendations should include examples of problems for which a particular concept is assigned.

The second level does not refer to any specific problem domain. As levels 3 and 4, it is also mainly general. Nevertheless, the model anticipates that special appendices are created for each particular domain. Moreover, in the context of quality management, the creation of such appendices for particular domains should be the main role of centres of knowledge. For instance, these appendices should include reviews of concepts and specialised tools available on the market for different special purposes concerning the domain. The same goes for the reviews of available methods and elements for cost-benefit analyses.

All this information, including the more general, according to the DQC model the parties involved have to find in the hand-books and corresponding appendices describing the concepts of this level and their implementation. In fact, all three levels forming the DQC quality management philosophy, namely levels 2, 3 and 4, are anticipated to be documented in the form of hand-books that are to be added to the quality standard i.e. award criteria. The hand-books could be on paper and/or, preferably, on electronic media.

Level 3. Similar to level 2, concerning level 3, i.e. the quality management concepts, the quality standardisation, i.e. award bodies have to:

(1) Identify all quality management concepts characteristic for the most important quality management models (i.e. for TQM, EFQA, MBNQA and ISO 9001).

(2) Define the precise meaning of all these concepts.

(3) Compare the concepts and choose the best in the sense of contents and terminology, and when necessary refine the contents and/or terminology.

(4) Write a glossary of all so obtained quality management concepts.

(5) Write recommendations for implementation of these concepts and identify the most important ones.

Level 4. In level 4 concerning the other relevant concepts and social priorities the quality standardisation, i.e. award bodies have to:

(1) Identify other research areas interesting for quality management.

(2) Define these areas.

(3) Identify the concepts of all these areas that also need to be included into the quality management philosophy.

(4) Define these concepts.

(5) Add social priorities to the obtained set of concepts.

(6) Write a glossary of identified research areas, concepts and priorities.

(7) Write recommendations for implementation of these concepts.

Concerning the research areas, management and behavioural sciences should also be included. Concerning social priorities, the best law regulations and practices have to be used. When necessary, the centres of knowledge have also to be consulted.

Level 5. While in levels 2, 3 and 4 the final results according to the model are recommendations anticipated to be written in the form of corresponding hand-books, level 5 i.e. quality standard and award criteria have to be more precise. To this aim, instead of the recommendations, the resulting outputs of this level are anticipated to be criteria, regulations and requests concerning each part of the quality management system, or, in an ideal case, each part of the whole business system. Instruments for assessment and/or self-assessment of different parts of quality management i.e. business system, have to be also defined. To this aim the main steps are:

(1) Identify the most important parts of quality management (i.e. business) system. Make a difference between internal and external ones.

(2) Define these parts.

(3) Identify all main dimensions defining the identified parts.

(4) Define these dimensions.

(5) Specify criteria, regulations, and requests that each of these parts has to satisfy concerning each of the identified dimensions. Make difference between general and domain specific criteria. The possibility of gradual achievement of defined requests should be built into the standard i.e. the award criteria. The steps towards excellence should also be defined.

(6) Write the standard i.e. the award criteria.

(7) Design instruments for assessment and self-assessment of all parts of quality management (i.e. business) system.

For instance, the most important internal parts of any quality system (as well as business system) are managers, experts, people, facilities, tools and technology. Concerning people, the most important dimension defining them in the context of quality is their knowledge. On the other hand, according to Table III all knowledge needed for reliable quality could not be and should not be contained only in human brains. Consequently, one of the requests of the standard has to be that all knowledge needed for the particular process is identified, and its containers specified. Concerning other standard requests i.e. criteria, the first one should be the high quality of managers. They have to be competent and honest. The criteria for assessing these dimensions have to be clearly defined. Such criteria belong, for example, to general criteria. Within general criteria particular attention should also be paid to the motivation mechanisms including income-competence relations. The ranges of allowable relations should be clearly defined. The creativity of an individual in that should also be taken into account.

Within a general group of requests the request that all main processes and their sub-processes are identified, and that for each part of them all knowledge is specified and its containers precisely defined, should also be included. It means that the standard has to demand that each organisation is obliged to have the specification of its processes (as it is demanded by the standard ISO 9001), but also specifications of knowledge and precise data on individual knowledge. Organisations also need to have systems of formalisation of the existing knowledge, as well as the list of priorities for further formalisation, and plans for permanent education for all levels and profiles within the organisation. The domain specific requests in that should concern particularities specific for the domain.

In other words, quality standards i.e. award criteria have to look deeply into all parts of organisational and production systems. Instruments for that should also be defined, such as for example expertly designed questionnaires. To this aim, the KBS-based tools should also be included. Generally, it is very important that recommendations of the standard in any segment are oriented towards the use of computer possibilities. One of the requests thus should be that processes are identified and described using the system analysis techniques, and documented in ways accustomed to information systems (e.g. with entity-relation diagrams and corresponding data dictionaries). In other words, instead of emphasis being on quality documentation written and drawn on the paper, the core of any quality management system according to DQC approach should be efficient high quality MIS. To this core then all other tables, data and corresponding applications, tools, etc., specific for any particular job/task/purpose, should be added.

Level 6. Once the quality standard i.e. the award criteria are defined, managers and experts are the front line in their implementation. Managers are also the decisive line. For this reason it is crucial that criteria for assessment of their quality are defined within the standard i.e. award. The criteria have to be defined precisely and clearly based on the state of the art of the relevant sciences, such as for example management and behavioural sciences, and the problem domain. General and declarative statements are not welcome. On the contrary, in this context, lists of symptoms for detecting the good and bad characteristics of managers, as well as general climate within organisation (correct, enthusiastic, resigned, anxious, etc.), could be a useful tool.

Besides competence and integrity, that are the most important criteria determining the managers quality, their openness and relation to experts and other specialists, should be the next important criterion. It is important to find out whether managers respect the knowledge and opinion of experts or not. Without that quality system could be only self-sufficient, lapurlatistic one, without significant influence regarding quality of products or services of the organisation, or its business results. For this reasons mechanisms that will ensure the influence of experts, as well as collaboration and mutual respect, have to be carefully anticipated. Also, it is important to find out the relationship of managers to the subordinate staff: how do they treat them, whether they use and try to increase their knowledge and potentials or not, do they motivate subordinate staff or, on the contrary, they discourage them and hinder their initiatives, are they open to different opinions. The best way to explore such and similar questions could be the system of carefully and expertly designed questionnaires and interviews. The first-hand information principle, i.e. the periodical physical presence of all managers and experts (including the top ones) on all physical points within organisation have to be encouraged. In this context the organisation type (whether it is strictly hierarchical or flexible – based on mutual collaboration and respect) that prevails in an organisation can be also the useful information.

Concerning the experts, the most important is that their knowledge is suitable to the organisation processes. The next important feature is their experience, as well as their personal profile. For both categories, i.e. for managers and for experts, the background is important as well. Their educational history, past results, successes and failures have to be known and recorded. On the other hand, managers and experts have to be informed of the most recent achievements of the relevant fields on a permanent basis. That goes not only for the fields from their specific line but for all relevant fields. The quality standard has to anticipate that as well.

Duties and responsibilities of managers and experts concerning the organisations quality system are described within level 9.

Level 7. Besides managers and experts, people are the next important level in any organisation. For this reason their capabilities and knowledge have to be suitable for designed processes and for planned and available facilities, tools and technology. As well as for managers and experts, their willingness and capabilities to learn are also important. For these reasons, within the quality system the motivating mechanism has to be worked out thoroughly, as well as the system of permanent education, training and recognition. Their duties and responsibilities concerning organisations quality system are described within level 9.

Level 8. Features of facilities, tools and technology have to be in accordance with designed processes and objectives, i.e. products and services of the organisation. Their choice has to be based on the high quality cost-benefit analysis. Once chosen, within organisation's quality management system activities concerning facilities and tools are:

- acceptance and installation of facilities and tools in accordance with the manufacturers' instructions and designed processes;
- use of facilities and tools in accordance with the manufacturers' instructions and designed processes;
- permanent and periodical maintenance according to the manufacturers' instructions; and
- renewal and exchange of facilities and tools in accordance with development and changes of processes.

Activities concerning technology are:

- creating the conditions for acceptance and implementation of the new technology and/or renewal of the existing technology; and
- implementation of the new technology or renewal of the existing technology.

For all these activities managers and experts have to be responsible.

Level 9. Finally, as the result of the previous levels the organisation's quality management system has to be formalised. It means that managers and experts with assistance of representatives of the standard i.e. award bodies, and when it is necessary even consultants from centres of knowledge, have to cover all parts and dimensions of the organisation's quality i.e. business system and their management relevant for the quality. The system has to be documented and wherever it is possible supported by computer and appropriate software.

In this process the steps that managers and experts have to perform are:

(1) Analyse processes, organisation and corresponding results in the view of defined objectives. Identify strong and weak points. Specify the needed changes. Define the priorities. Define the new or improved solutions.

(2) Analyse features of the facilities, tools and technology. Identify strong and weak points. Specify the needed changes. Define the priorities.

(3) Analyse available people in the view of their knowledge, profile and number. Identify strong and weak points. Specify the needed changes. Define the priorities.

(4) Analyse MIS and other databases, and knowledge repositories including knowledge bases. Identify strong and weak points. Specify the needed changes. Define the priorities. Define the new or improved solutions.

(5) Realise the specified changes and document it within quality i.e. business management system.

Besides other, the documentation has to include:

- detailed processes specifications;
- detailed facilities, tools and technology specifications, including computer-based tools specifications;
- detailed knowledge specifications (the needed knowledge);
- detailed staff specifications, including managers and expert staff specifications with data on their individual education, knowledge (the available knowledge), personal profile and background; and
- detailed database(s) i.e. MIS specifications (preferably in the form of entity-relationship diagrams and data dictionaries).

Managers and experts have also to:

(1) Define organisation's standards, criteria, rules and regulations.

(2) Define managerial and control mechanisms and techniques necessary to achieve settled objectives and values.

(3) Standardise procedures, methods and tools within the organisation, including computer-based tools.

(4) Define input and output parameters i.e. attributes of each process that need to be supervised and recorded.

(5) Record all relevant data concerning their own activities and tasks into the corresponding databases or forms, or organise their recording.

(6) Organise and support writing of detailed work specifications and instructions.

(7) Define criteria for assessment and choice of suppliers.

At the same time the duty of managers and experts is to manage and support, as well as improve the defined processes, the quality system and the whole organisation. They also have to make decisions and find solutions to problems, give people meaningful tasks, and take care of people, facilities and tools, business results, customers' satisfaction, and the environment. That also includes the care of each individual's working environment.

At the same time, people have to:

- take part in processes and databases design and improvement;
- perform their part of the job in designed processes according to the work specifications and instructions, and/or the given tasks;
- record precisely data relevant for processes in corresponding databases or forms for each working place where it is anticipated;
- think about processes and suggest further improvements and/or new solutions and approaches;
- maintain facilities and tools; and
- keep the working environment in order.

Level 10. Suppliers are an external part of quality system, as they are, conditionally speaking, organisation-similar companies and other bodies of interest. The suppliers' quality has to be acceptable to the organisation. Within a quality system the criteria for measuring their quality have to be precisely defined. The concept that has to be aimed at is the supplier-partnering concept.

Level 11. Organisation-similar companies and other bodies of interest are sources of important external data and information. To achieve good results, organisations have to systematically gather and analyse these information.

Conclusions

Despite the rapid advance of many interesting research areas such as, for example, knowledge management and artificial intelligence, however, there is lack of understanding of the importance of their concepts for quality within quality management society. The role that information technology and computers play in quality management is also not sufficiently understood. On the other hand, however, the developments of production and business systems and technologies reached a state, which needs to be re-examined and reassessed in its fundamentals. It also includes the quality management systems. In this research a model that overlaps present deficiencies is developed. The model explains clearly what are the place and the role of high quality databases and formalised knowledge within quality management systems. Particular attention is put on standardisation of domain concepts and domain tacit knowledge. In other words, the DQC model expands other systems, as for example ISO 9001 and TQM model, in a way that systematically involves knowledge and concepts related to knowledge in the field through which the emphasis is put on the very core of quality. According to this approach knowledge management and formalisation are viewed at as one of the fundamental parts of any quality system, as well as prerequisite for reliability of quality. Therefore the approach represents the important shift in the relation to the current approaches.

The core concepts of the DQC model are:

- standardisation of domain concepts;
- processes specifications;
- knowledge specifications related to processes;
- data on individual educational history, knowledge and background;
- expertly designed databases and MIS;
- systematic recording of relevant data and information;
- knowledge synthesis and representation;
- knowledge bases and repositories;
- involvement of people and teamwork; and
- fair and motivating managerial mechanisms.

The core values are:

- knowledge and expertness;
- creativity and integrity; and
- social awareness.

These concepts and values, as well as other already included in current quality management models, have to lead to the quality whose four dimensions according to the DQC model are:

(1) Business results.

(2) Customer satisfaction.

(3) People satisfaction, development and health.

(4) Positive impact on society and environment.

Although in this research the emphasis was on concepts regarding knowledge, the developed model is general and complete. Consequently, the approach is expected to be promising for all industries and organisations, and help to overcome the existing gap between theories and practice in different, currently not sufficiently connected but logically close areas. In further quality research the main points of this theoretical framework need to be validated through real examples from practical work. Also, the resulting quality standard i.e. award criteria, as well as the mentioned hand-books, need to be completed and formalised.

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