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The golden integral quality approach: From management of quality to quality of management

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Abstract *Quality is a subject 'in fashion': many top managers are giving this matter greater importance now; many gurus are providing their precepts for making quality; many managers attend several seminars on quality looking for 'cooking books'. Actually, quality is a serious and difficult business; it has to become an integral part of management. Too many companies are well behind the desired level of quality management practices. Managers need to learn and put into practice quality ideas. Therefore, some important principles are: relationship between competitiveness and quality, management and quality, management by if ... then ... else, scientific approach, intellectual honesty, quality integrity, the three quality identities, the rational manager, TQM², FAUSTA VIA, etc.*

Introduction

Quality is a 'very talked' about and 'in fashion' subject today: many top managers are giving this matter great attention, especially because of quality system certification (according to ISO 9001/9002/9003 standards), quality awards (QA) (e.g. the Malcolm Baldridge QA and European QA (EQA)) and quality prizes (e.g. the Deming Prize); many gurus are providing their precepts for making quality; and many managers attend several seminars on quality looking for 'cooking books' they can either apply immediately (with no effort from themselves), or buy packaged programs and off-the-shelf solutions.

Some managers now say "Quality is a factor which interests everybody ... it is no longer true that quality is linked to high cost". Actually, only short-sighted managers have been relating quality to high cost; market surveys and analyses have proved that "profit is positively correlated with quality, whatever is the market share, in the medium time; the advantage to the company, in terms of increased market share, provided by quality is more important when the rate of expansion of the market is low"; moreover, Profit Impact of Marketing Strategies (PIMS) researchers stated that "... changes in relative quality have a far more potent effect on market share than do changes in prices".

Recently, total quality management (TQM) has taken the chair in quality evolution; at

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its first appearance, in 1961, the concept was devised by A. V. Feigenbaum and named total quality control (TQC); after that Feigenbaum spread his ideas all over the world.

From 1950 other scholars, such as W. E. Deming and J. Juran, taught, for more than 40 years, quality ideas without using the adjective 'total'. As a matter of fact, there is absolutely no need for it. In 1988, the presidents of 14 European companies created the European Foundation for Quality Management (EFQM) to stress the importance and value of TQM, to reach 'total customer satisfaction'; the EQA was devised to prize companies "as the ultimate form of benchmarking"!

Many people have provided new ideas on TQM and on quality management during the last 15 years (e.g. Brassard, Bekerjian, Galetto, Gryna, Joiner, Kanji and Asher, Scholtes, to name but a few). In 1994, the standard ISO 8402 reported the 'official' definition of TQM (def. 3.7):

> **Total Quality Management:** A management approach of an organization, centered on quality, based on the participation of all its members and aiming at long term success through customer satisfaction, and benefits to the members of the organization and to society.

In 1984, Galetto developed a model for quality; it was called the integral quality approach (IQA) (it integrated various developments of integral theory of reliability, devised by Galetto in 1973 to overcome the many drawbacks of the Markov processes used for reliability analysis; then, in 1973, the quality system was considered "integration of all company functions for making quality", well in advance of TQM); since then it has been provided to Italian companies and to Italian students. The core of IQA has been prevention (a point that only in 1994--10 years late—was inserted into the ISO 9000 series of standards) and the scientific approach; this last point is very much bigger than in the Juran and Deming philosophies. IQA has been presented in several papers and at several conferences, but it is not known to people writing on TQM.

TQM and TQM Masters have recently entered higher education, but did quality enter? It is important to note that until 1993 the most important 'prophets' of quality did not use the adjective 'total' in relation to quality. Very many people have been writing on TQM, but no one (as far as I know) had the opportunity to read Galetto's idea on quality management.

The purpose of this paper is to show the quality philosophy which is the fundamental issue of the golden integral quality approach (GIQA). Prevention and "future consequences of present decisions" (the 'futurity') have always been characteristics of GIQA, through holism, intellectual honesty and a scientific approach, to provide the customers integrally with the quality they need.

Management is the real management problem

Top managers often think that "all the dis-quality (poor quality) problems are originated by the workers, either in the manufacturing or in other areas". They do not understand the important idea that "more than 90% of times poor quality depends on the managers". The proof of this statement is given by the fact that in many companies the cost of 'dis-quality' is as big as 20--30% of the gross sales: in every firm there is a hidden one producing losses. If managers meditate upon these facts, they have to acknowledge that "low quality can be a very costly luxury for a company" and that "quality has always been a competitive advantage".

Unfortunately, many executives play with words out of reality and they do not know the fundamental principles of quality; they say that "human resources are one of the biggest assets of the company", while in reality they do not permit them to work properly, because

they use the stupid law that "the boss is always right" (see TQM^2 (testify quality of management in management)).

Every day more and more managers are faced with dis-quality problems and they have to make quality decisions on quality of products and of service if they want their companies to be better than their competitors (dis-quality is the opposite of quality). To achieve quality, design is the most important phase. ISO 9001 devoted nine paragraphs to this subject (from 4.4.1 to 4.4.9); several other paragraphs are related to design, such as 'preventive actions', 'training' and 'statistical techniques'.

Quality has always been a competitive advantage. The Japanese recognized that and made the right decision: to learn. They called US gurus to teach them quality ideas and methods, so they broke the dis-quality vicious circle. Actually, quality is a serious and difficulty business; it has to become an integral part of management, because too many companies are well behind the desired level of quality management practices.

As a matter of fact, looking at the decisions of many companies, managers (if they are intellectually honest) have to admit that, in many Western countries, the statements of Ph. Crosby are, unfortunately, absolutely true: there is a general "lack of credible executive action giving people permission to do things right ..."; and "Top managers may or may not realise what has to be done to achieve quality. Worse, they may feel, mistakenly, that they do understand what has to be done. Those types can cause the most harm" (quality is free).

Managers have the responsibility of major decisions in a company and the soundness of their decisions affects the quality of the products and the satisfaction of customers' needs. In order to make sound decisions managers have to be aware of the consequences (which is prevention using management by if ... then ... else (MBITE)) of their decisions; in relation to quality matters, managers have to commit themselves to ensuring that the concepts and disciplines associated with quality will be introduced into the developments programmes of the company.

Often, managers know little about quality; nevertheless they have to make decisions based on few data analysed with 'methods' (devised by experts). Managers do not like to ask themselves whether a method is good or bad, especially when a method provides them with results that are appealing; so-called experts do the same several times.

Recently, Western nations have recognized that education and training are essential, but in some way they are not making quality decisions: they use, blindly, methods imported from Japan, just because they are Japanese methods. In addition ISO 9000 series standards, the new milestone in the West (but not in Japan), never state explicitly that the methods used for quality must be "methods imbedded of quality"; perhaps this is an 'implied need', according to definition 2.1 'Quality' of the standard ISO 8402:1994.

Management need to be made fully aware and convinced that they need to expand their knowledge because experience alone, without theory, teaches nothing about what to do and how to improve quality (as said by Leonardo Buonarroti and Galileo Galilei centuries ago, in different fields from quality). Management must understand that they have a new job: learning how to use quality methods for quality. That is the real challenge of the future.

Actually, if a company is able to produce quality items (products or services) at minimum cost, it can sell them at lower prices than competitors and then it is bound to win the competitiveness fight and increase its market share. This route led the Japanese to their present dominance.

Unfortunately, in the West too many companies are well behind the desired level of quality management practices, and think that 'quality system certification' is the way to quality: their managers commit themselves only formally, while in reality they act as if they are not responsible for the quality of the company, which is the opposite of TQM^2. "Anybody

can make a commitment to quality at the boardroom table" (L. Iacocca). Unfortunately, management commitment to quality is not enough; managers have to understand, learn and apply effectively (see TQM^2) quality ideas.

This paper shows some of the many ideas (and methods) provided (at Turin Polytechnic) for future managers, that is, that logic and the scientific approach are able to provide the right route towards good methods for quality. Quality of methods used for making quality is very important, and managers are asked to break the 'dis-quality vicious circle' and reduce the 'dis-quality' costs. Ideas such as:

- quality tetrahedron
- rational manager tetrahedron
- ten key-areas tetrahedron
- the two-quality fundamentals
- MBITE
- TQM^2
- probability methods
- reliability methods
- competitiveness tetrahedron
- management tetrahedron
- knowledge matrix
- the three quality principles
- integral quality approach
- FAUSTA VIA
- statistical methods
- design of experiments methods

are given to future managers in relation to actual cases of application.

We teach future managers that quality management, according to GIQA, asks managers to commit to mobilizing all levels of management for quality, prevention and continuous improvement. If TQM is "about continuous improvement", as stated in several papers and books, it is apparently clear that the so-called 'total quality' is only a part of GIQA. As a matter of fact, those papers and books relate the improvement to 'problem-solving' and to the use of the plan–do–check–act (PDCA) cycle, called by many people the 'Deming cycle', while W. E. Deming calls it 'the Shewhart cycle': this is very different from problem prevention. Neither the 'project by project improvement' process, based on J. M. Juran ideas, with its 'universal sequence of events' symptom–cause–remedy, is prevention, nor is it the Juran 'Quality trilogy ((quality planning, quality control, quality improvement, the trilogy of quality processes)", as in Juran's book, *Quality Planning and Analysis* (1993)): "The control process detects and takes action on *sporadic* quality problems; the improvement process identifies and takes action on *chronic* quality problems." Tackling the so-called 'quality problems' is not prevention. The Kaizen process of M. Imai is not prevention either. I call dis-quality problems all these 'quality problems' that are due to lack of prevention. Several steps in quality planning (of the quality trilogy) "involve the translation and deployment of customer needs into product features, process features, and process control features. This process is called quality function deployment (QFD)" (J. M. Juran). It is clear that one can plan for product features without planning for prevention: there are thousands of companies acting this way and lacking prevention. ISO standards 9001 and 9002 are not better: see paragraph 4.14, "Corrective and preventive action". It is one of the biggest flaws in the ISO standards.

All this does not mean that quality improvement is not important: improvement is important and saves a lot of money, through the application of the PDCA cycle, using many times the so-called 'seven statistical tools'. But it is very different from problem prevention, which needs quite different methods and gets much better results: problem prevention is always looking for 'customer needs' satisfaction' and therefore looking for new and better ways of providing attractive quality to the benefit of customers. In this respect, it is very important that managers realize that 'customer needs' satisfaction' is quite different from 'customer satisfaction'.

When managers are educated on management, quality, reliability, statistics, design of

experiments and decision-making it becomes clear that 'quality of methods for quality is important' and that some methods are misleading. Unfortunately, Western companies do not understand the essential difference between quality and 'quality system certification'! Moreover, ISO 9000 standards are not a TQM model, and prevention is very different from continuous improvement. "There is no substitute for knowledge" (E. Deming); "There is widespread resistance of knowledge" (E. Deming); "Shortage exists at high levels of knowledge, and this is true in every field" (E. Deming).

The definition of quality in GIQA

In order to find a suitable definition for 'quality' let us consider the following data (Table 1) from a market survey on heavy trucks; 800 customers were asked what they appreciated about quality of the brand they had purchased.

It is apparent that one competitor was rated well below the others; from another source it came out that this one had a 'mean number of failures $M(t)$' three times bigger than the competitors. It is not surprising that the worst company has been losing market share due to dis-quality. Failures are very disappointing for customers: they buy a new product of a different make. This happened in the US, both dis-quality and high costs—and the Japanese conquered the market. President Bush and several executives went to Japan at the end of 1991; European countries decided to limit import of Japanese cars. The absurdity of this attitude is that it is not for the benefit of customers, and therefore it will fail. The customer is the most important driving force of any company. Companies will not be able to survive in the global market if they cannot provide their customers integrally with the quality they have paid for. 'Customer needs satisfaction' must be converted from a slogan to real practice, if companies want to be competitive (TQM^2).

Today, many managers show their commitment to quality; they like the idea of customer satisfaction, but they are not prepared to invest time and money in it; they do not put the theory into practice; they do not speak with the facts, but only with words (the contrary of TQM^2). It is important to stress that 'customer needs satisfaction' is totally different from 'customer satisfaction'.

The previous data and analysis of customers' needs show that a good definition of quality is in order. First, there are other people involved: the user and the society. Let us see some of the latest definitions that can be found in the literature (some of them existed before the dates given here; the date shown refers to the latest document I read):

(1) 'conformance to requirements' (Crosby, 1979);
(2) 'fitness for use' (Juran, 1988);
(3) 'customer satisfaction' (Juran, 1993);

Table 1. *Data on quality appreciation*

Quality characteristic	I(%)	M(%)	S(%)	V(%)
Reliability	15.9	26.8	28.5	28.9
Durability	17.2	22.4	34.3	26.1
Maintainability	23.3	21.1	28.9	26.7
Economy	11.3	21.7	35.8	31.1
Performance	18.1	36.1	26.5	19.3
Service	41.7	17.4	21.5	19.4

(4) 'the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which product or service in use will meet the expectations by the customer" (Feigenbaum, 1983, 1991);
(5) 'totality of characteristics of an entity that bears on its ability to satisfy stated and implied needs' (ISO 8402, 1994);
(6) 'a predictable degree of uniformity and dependability at low cost and suited to the market' (falsely attributed to Deming; I read documents by Deming again and again and I could not find that).

In order to provide a practical and managerial definition, in 1985 F. Galetto proposed the following:

> Quality is the set of characteristics of a system that makes it able to satisfy the needs of the customer, of the user and of the society.

It is clear that none of the previous definitions highlight the importance of the needs of the three actors: the customer, the user and the society. They are still not considered in the latest document, the ISO 8402: 1994 (definition 1.9).

Some important characteristics are stated in the quality tetrahedron (Fig. 1) each characteristic has an 'operational definition' that permits one to state goals and verify achievement. The quality tetrahedron shows that management must learn that solving problems is essential but it is not enough: they must prevent future problems and take

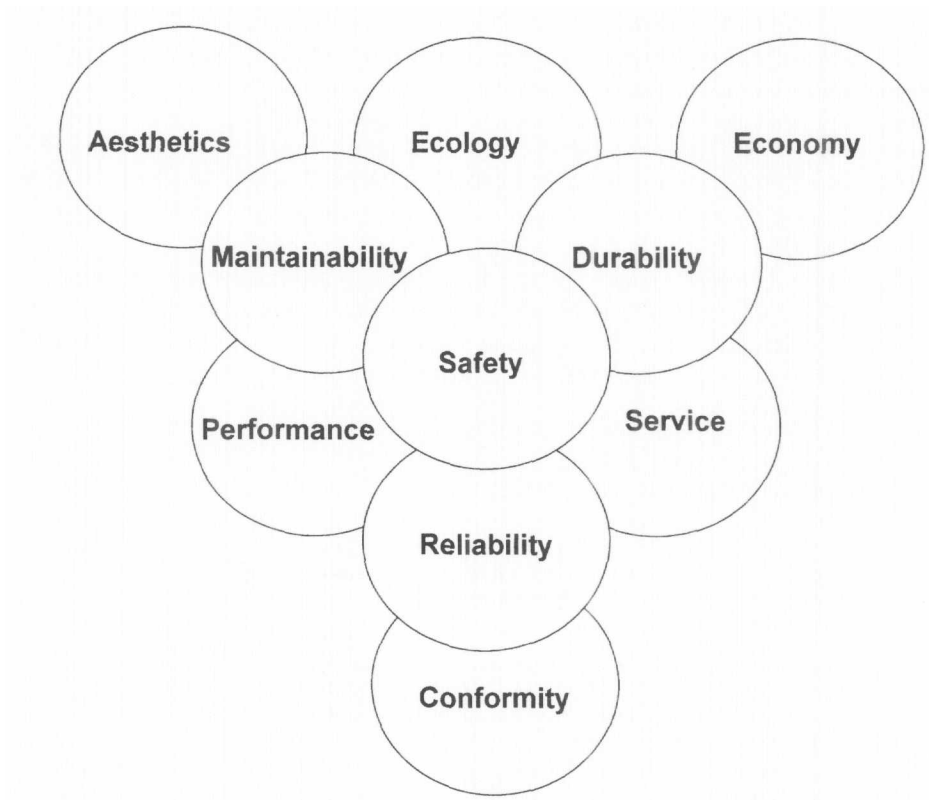

Figure 1. *The quality tetrahedron for the quality definition.*

preventive actions. As said before, PDCA is useless for prevention—it is very useful for improvement. Several of the quality characteristics (in the quality tetrahedron) need prevention. Reliability is one of the most important: very rarely can failures be attributed to blue-collar workers. Failures arise from lack of prevention, and prevention is a fundamental aspect and responsibility of management. The same happens for safety, durability, maintainability, ecology, economy, etc. Let us think of the failures of the Shuttle and of the Russian satellite MIR (April 1997). We are in a new economic age: long-term thinking, prevention, quality built in at the design stage, understanding variation, waste elimination, knowledge and scientific approach are concepts absolutely necessary for management.

Competitiveness and quality

Market surveys show that customers are becoming more and more demanding and conscious of their rights. As a consequence, competition is getting fiercer in order not to lose customers. Unfortunately, many managers do not use intellectual honesty and therefore do not recognize that every customer expects to receive the value he/she has paid for. 'Value for money' is the key point for customers. Companies that want to prosper have to provide better value for money to their customers. They can do that if they understand clearly the 'competitiveness tetrahedron (Fig. 2), with its edges integrally connected to one another. No edge is more important than the others. 'Time to market' is presented as the most important, but it is obvious that time to market and dis-quality can be suicide; let the reader think of the data of the second section: failures spoil the company reputation and customers switch to other brands. Managers at every level have to meditate upon these facts, decide to learn, and to climb the ladder of knowledge:

ignorance → awareness → simple knowledge → know-how → full understanding.

Quality is a competitiveness factor that has to be integrated in all company activities in order to prevent failures; the only way is to give due importance to quality in each phase of

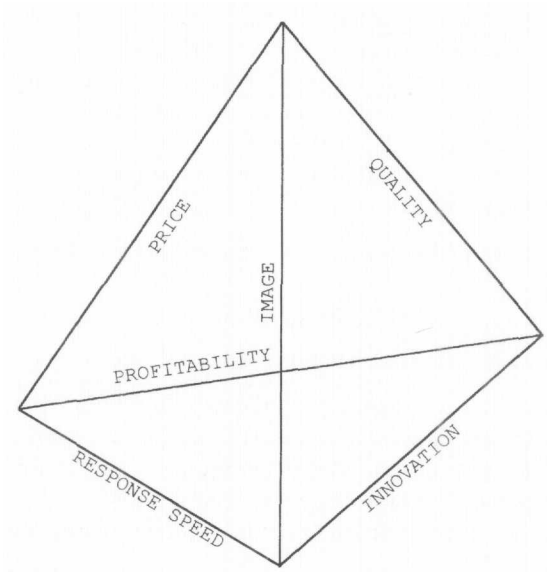

Figure 2. *The competitiveness tetrahedron.*

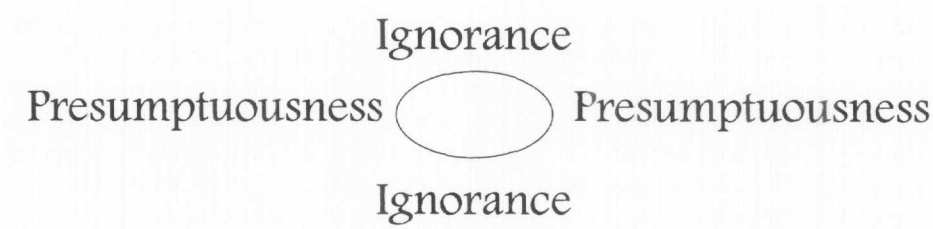

Figure 3. *The dis-quality vicious circle.*

the product development cycle (see Fig. 6 later). This is especially true for higher education! Higher education builds up future managers: we had better make them right the first time.

Working with quality permits one to drive innovation, be on time on the market, reduce prices, build image and have better profitability. But it must be clear that this does not happen overnight, and needs a management metamorphosis. 'Never-ending improvement' is the overwhelming difference between the winners and the losers; the difference is not only in what they do, but also in how and why they do it. "The principle by which we will live and die is that once we do something well, we have to figure out how to do even better" (D. E. Petersen, as President of Ford Motor Company). This statement reminds the managers of their obligations for prevention, which comes before correction (problem-solving and PDCA). Prevention is needed and must be shown by managers (see TQM^2). To be open to this conviction managers have to be educated and trained in quality ideas; they need serious learning, not 1-day 'theatrical seminars' on quality.

The first step towards this serious learning is intellectual honesty. Intellectual honesty is the ability of people who use their thinking skills to deduce logical consequences from their premises (information, methods, theory, facts, etc.). Starting from the seed of any knowledge 'I know that I don't know', intellectually honest people break the dis-quality vicious circle' (Fig. 3) and climb the ladder of knowledge. Doing that removes the idea that 'the ability to think depends on intelligence', which is a wrong idea.

Managers are decision-makers and therefore need the tools for thinking in decision-making in order to be rational managers: to recognize problems, collect information, set priorities accurately, find causes, consider all factors and other people's views, consider alternative courses of actions, consider consequences and sequels to troubleshoot the future, consider risks to any choice, etc.

To make full use of the thinking ability of people there is a basic approach, the if ... then ... else (ITE) approach to decisions:

every time a manager has to make a step in the decision process, he/she must ask him/herself

If	I do this
Then	I shall have consequence
Else	I shall have this other consequence

ITE is an integrated, holistic approach that releases intellectual resources that have been hidden, unused or underused, opening channels of communication among people. This is the fundamental basis for prevention. MBITE is the acronym devised to remind managers of their obligations for prevention and long-term commitment.

There are two fundamental principles to use fully the thinking ability of people:

F1: Reality does exist in spite of human beings' willingness and ability to recognize it.
F2: Variation is in everything and everywhere, all the time.

QUALITY of Quality METHODS is IMPORTANT
the right tools have to be used by managers to decide correctly

A \ B		Good knowledge		Poor knowledge		No knowledge
		Good application	No application	Good application	No application	
Good knowledge	Good application					
	No application					
Poor knowledge	Good application					
	No application					
No knowledge						

Figure 4. *The knowledge matrix.*

When managers become acquainted with these principles and use the ITE approach they arrive naturally at the fact that the scientific approach is the best rational way of making decisions and achieving quality, and therefore of winning the competitiveness battle. By virtue of this they do not mix wrongly improvement (after defect detection) with defect prevention (which is wrongly stated in the ISO 9000 series standards). Too many companies are 'fire-fighting' problems (problem-solving) because they did not prevent them. Unfortunately, they still do not prevent failures—and ISO 9001 does not put this point in the right way (see paragraphs 4.14 and 4.4).

The right tools can be used if managers use correctly the 'knowledge matrix' (Fig. 4), a cell which represents the knowledge situation of two people who have to make a decision based on their knowledge. It is clear that in order to achieve quality, people must move to the left upper corner: both good knowledge and good applications are needed. This point is not understood by people who do not know correctly the methods of design of experiments and, in spite of that, they say the 'Taguchi methods work' (see later).

Very few people dare argue that quality is strongly related to culture (and culture grows with education and interactions with diverse cultural traditions and groups), to management and to their willingness to be good managers, hence the following quality identities:

First quality identity: Quality = culture.
Second quality identity: QP = QM: Quality of products depends strongly on quality of management.
Third quality identity: QM = PQ: Quality of management depends strongly on passion for quality.

From these identities it follows that Western management needs a cultural transformation; management has a new job and drastic changes are required. The first step is to learn, with intellectual honesty, the second is to put it into practice. To get substantial results, in addition to the previous principles and ideas, the following fundamental axiom is necessary:

The MD (or the CEO) considers quality as a strategic issue for the survival and the development of the company. He/she lays down the quality policy; all the employees are well informed, and all the departments must act in accordance with it; no exception is allowed. The MD (or the CEO) him/herself follows the quality policy.

The management tetrahedron and GIQA

In recent years, the quality of Japanese products has been the focus of world attention; due to quality, productivity has grown and prices have fallen, all to the advantage of customers. The Japanese learned to view "Quality as a management goal and the key to competitive position" from Western consultants (Deming and Juran). They put the lessons learned in to practice, overcoming the obstacles that affect Western industries, especially outdated ideas of top management.

In 1951, Japanese Union of Scientists and Engineers (JUSE) established the Deming Prize for Quality Excellence. It was a long time before Western management understood that quality is their responsibility, and productivity and profitability would go up as a result. Now, some US managers think that the Baldrige Award and Quality System Certification will save US companies by making them more competitive. Unfortunately, the Baldrige Award, and Quality System Certification as well, are not well related to quality management principles and to quality theory and methods: "There is no substitute for knowledge" (E. Deming).

European managers are acting in the same way. Those who put their faith in bad procedures will be disappointed: the corporation management, mentioned in the third section, went to visit 'excellent companies' some years ago thinking, at that time, that quality would grow up. But it did not. As a matter of fact, quality needs a cultural transformation of management, not 1 week of travelling seminars: hard work, study, knowledge, sound theories and methods, sound tests and experiments, intellectual honesty and cooperation (horizontal and vertical in space and time) are the pillars of quality. European companies do not need to copy Japanese methods of quality and management (e.g. the Taguchi methods); they need to recover their European culture, with intellectual honesty.

In 1980, N. Sasaki, talking about the Japanese approach to quality, stated "You won't do it anyway ...", and we did not. Before that year, F. Galetto was developing the reliability integral approach, which became the integral quality approach in 1984 (found later as a sound combination of the Deming and Juran philosophies, with a greater emphasis on the scientific approach). The long-term commitment of management in any action and decision (without forgetting the short-term aspect) is the core of the integral approach. Since its origin the integral approach has been wider than the 'company-wide quality control' (at that time referred mainly to quality circles, which used the PDCA cycle): the customers, all the departments of the company and the suppliers were part of the 'company space'.

Any decision in a company has effects and consequences in other departments and on the customer, both in the short term and in the long term (i.e. in the 'company time'). The adjective 'integral' is used since it comprises words as integrated and total, and besides, it conveys the integrity idea that stays regular with time, that is, 'constancy of purpose' (point 1 of the 14 points of W. E. Deming). The integral approach considers any activity of the company in the 'space–time continuum' using MBITE (a scientific approach to decisions).

It is very odd what happened: the West invented good quality ideas and the Japanese used them; the Japanese invented silly quality methods and the West used them; the West invented silly quality ideas and the Japanese did not use them. Why? Because the Japanese are intelligent, clever and cunning.

The customer is the most important asset of any company, but we must not forget the

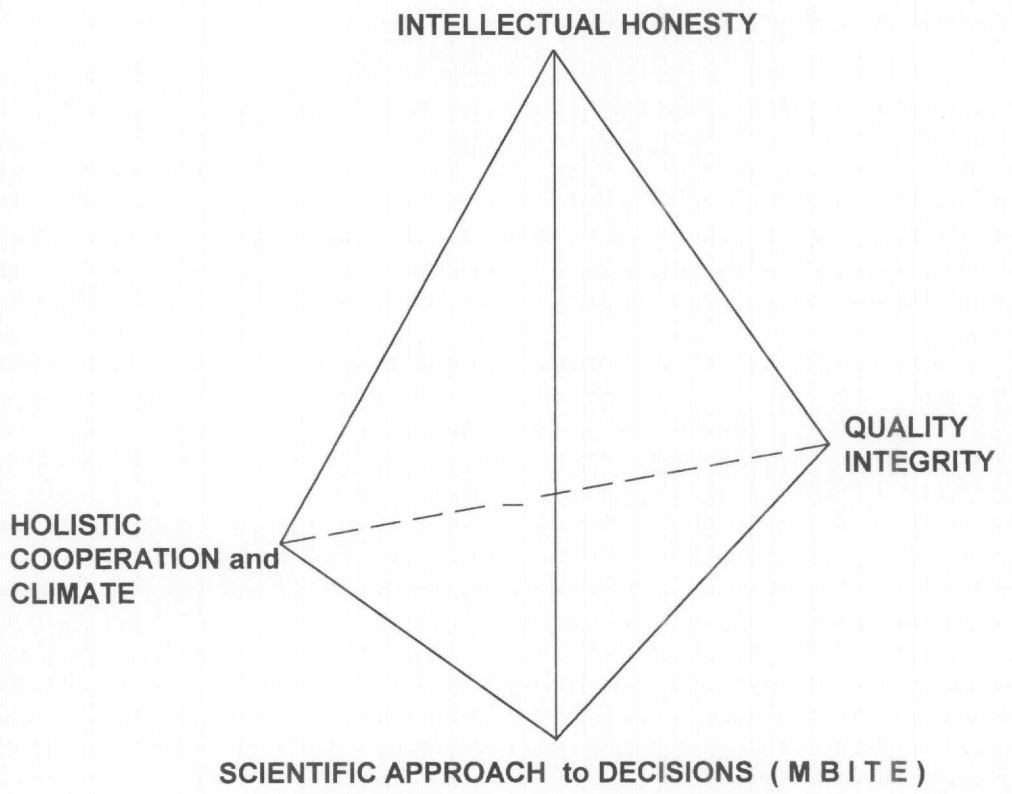

Figure 5. *The management tetrahedron.*

user and the society; quality is satisfaction of customers, users and society needs, therefore quality is an important element of growth for companies and nations. That is why the adjective 'golden' is used for this approach: a long-range view, leadership, education, empowerment, self-improvement, effective communication, evidence of quality, better productivity, less waste, better profitability, holism, pride of work, repeated loyal customers, etc. The customers and users require value for money when they pay for a quality product; the society needs not to be damaged by dis-quality products (e.g. emissions, noise, etc.). This entails that any company has to provide integrally the quality it promises; I call this 'quality integrity'. Only companies that fully act with intellectual honesty and quality integrity will prosper. But we must not forget that cooperation and holism are essential, together with the scientific approach.

All the elements mentioned are linked together in the management tetrahedron (Fig. 5), which reminds managers of their obligations of leadership. One more idea has to be noted. The wealth of a nation depends heavily on its people, management and government, more than on its natural resources. Since the customer is the most important part of the production line, managers have to show through facts that they are really committed and responsive to quality, using their leadership in order to improve all processes, prevent problems and deliver to the customers the quality they need. This management attitude is called, by Galetto, TQM[2].

Only if you provide actual evidence of your willingness of achieving quality can you expect your collaborators to do the same: they learn from your leadership.

Prevention: quality during the development cycle

To get the quality needed, quality has to be designed and verified as early as possible, in order to prevent failures in the field. This is done by detecting weaknesses and correcting them before the product is released to the market-place (this important idea is still not included correctly in ISO 9001: see item 4.14). All this can be a big investment but it has a huge return: reduced warranty costs for the company, reduced cost of use and failure for the customer, the user and the society, more sales, less income tax, i.e. better profitability both for the society and for the producer. If a manufacturer is able to produce quality items at minimum costs, he/she can sell them at lower prices than competitors and gain market share.

There are many quality techniques that are useful during the development phase to gain time and money. Only three are mentioned here, failure mode effect and criticality analysis (FMECA), reliability tests and design of experiments (DOE). FMECA is to be used in order to identify potential failures and take preventive actions. Unfortunately, managers either do not know the technique or they use the silly rule of making decisions based on a priority index, which is the product of three or four indices; in so doing, they do not base their behaviour on a rational approach and they do not make full use of the thinking ability of people (as, on the contrary, is required in the rational manager tetrahedron; see Fig. 8 later). There is no space here to pursue the matter further.

Prototype design and design verifications tests are the 'moment of truth'. At this point every manager can verify not only the reliability of the designed product, but also the reliability of the company: a reliable company that stated valuable quality and reliability goals does not give the go ahead if the goals are not met, until the problems are fixed with an adequate confidence level. Reliability tests cost a lot of money.

The manager's problem is to get the most out of the test data in order to make the 'right' decision, so reducing the company risk, that is to say, given the observations on the life-span of the units tested, he/she is required to decide on the reliability of the parent population that, through the tested sample, produced such data. The only way a manager can 'communicate' with a phenomenon is through 'data' (measurements on a relevant characteristic manifestation of the phenomenon). The manager has to draw 'objective' conclusions about the phenomenon and, since generally the information available in the data is incomplete, he/she has to measure the degree of uncertainty associated with such conclusions (remember principle F2). In reliability tests the phenomenon generates failure times data that exhibit a probabilistic behaviour, which can be described by a mathematical model (the probability density function $f(t)$).

A golden rule has to be understood by managers: tests have to be designed in order to get the information needed to take good decisions. Statistics provides suitable tools for 'DOE' in order to get maximum information at stated costs and risks. Managers, using the ITE approach, have to take into account that some methods can lead to wrong decisions (see references related to the so-called Taguchi methods that are a 'revised and wrong' interpretation of the good methods of DOE).

In order to appreciate this point, the following ANOVA table is presented, based on a real case developed for piston rings' chromium thickness (Table 2).

Managers and scientists who understand the core of the following ideas will help their nations to reduce the quality gap, and therefore cut the dis-quality costs. Engineering analysis is generally concerned with systematic investigations of phenomena that rule devices and processes (e.g. durability, fatigue, combustion, etc.) in order to understand and gain knowledge for control. A statistical approach is needed to do this; the statistical approach entails:

Table 2. *Analysis of data of a DOE on piston rings' chromium thickness*

	G-method		Taguchi method (S/N 'the larger the better')	
Effect	*df*	*SS*	*df*	*SS*
A + ...	1	9 768.03	1	0.22
B + ...	1	54 522.25	1	5.50
C + ...	1	10 234.69	1	0.85
D + ...	1	363.38	1	0.10
E + ...	1	5 235.13	1	0.67
F + ...	1	6 768.49	1	0.20
G + ...	1	2 475.06	1	0.64
AB + ...	1	8 122.52	1	0.87
BG + ...	1	3 126.67	1	0.49
BC + ...	1	695.64	1	0.02
BF + ...	1	822.97	1	0.08
BD + ...	1	10 306.48	1	0.48
BE + ...	1	13 143.67	1	1.31
DG + ...	1	18 140.72	1	2.34
ACD + ...	1	23 364.40	1	2.51
Residual	560	238 333.65	0	0.0

(1) statistical design of an experiment, which ensures that a maximum amount of information is obtained from the experiment;
(2) correct statistical conduct of it, which ensures that the conclusion will be valid for the phenomenon investigated;
(3) scientific statistical analysis of the data.

The absence of the statistical approach before, during and after the experiment typically results in relatively uninformative output of questionable general validity. Bayesian methods and Taguchi methods do have this fundamental drawback. In order to let managers understand this very important point, a real case is presented (Table 2); it does not fully explore the matter (we can not do so here), but it is very important for managers because it reminds them of their obligation to understand any method before using it. If the method is wrong and they do not know it they waste money and spoil the company's reputation (by dissatisfying customer needs). Doing that, they do not show their TQM^2.

An important method, named DOE, was born in the 1930s thanks to Fischer and Yates; it has been applied to many fields (agriculture, medicine, chemistry, mechanics, electronics). In the 1960s, in Japan, G. Taguchi published books on experimental design and statistical analysis. Many good books have been published by other authors since the 1950s (e.g. Davies, Kempthorne), but no method had as much increasing popularity as the so-called Taguchi method. The merit of that pertains to Ford Motor Co. According to N. E. Ryan, in 1982 Ford introduced the methods to its suppliers. The American Suppliers Institute (ASI) was founded (G. Taguchi was an executive director, Sullivan the chairman) with the support of Ford; D. Clausing, a professor at MIT, edited Tagushi's books. Extremely accurate advertising gave popularity to the Taguchi method, and now people use blindly everything under the name 'Taguchi methods'.

Thousands of people (managers, quality managers, quality consultants, professors) claim that the Taguchi methods are good; the people I met knew little about DOE and reliability theory and methods (including ASI experts). Many examples of the innacuracies of the

'Taguchians' can be shown, using the G-method, where G stands for good, general, guaranteed and golden, based on the Gauss–Markov theorem (that states optimum properties of linear estimators), or Galileo-wise. The G-method is the method of DOE based on the scientific approach, originated by Galileo: it uses the 'normal equations' of analysis of variance and of covariance (Galetto, 1989, 1990, 1993, 1996, 1997). By using the G-method it emerged that the Taguchi methods are a bad version of the good techniques of DOE, as mentioned at the plenary session of the European Organization for Quality Control (EOQC) conference (Galetto, 1989) by J. Juran:

First error:	Taguchi Methods permit one to reduce drastically the number of experiments to be carried out.
Second error:	The 'signal-to-noise ratio' (S/N) is the most suitable way of analysing data (80 S/Ns exist!). It comes from electronics.
Third error:	Interactions are not important; only the factors are.
Fourth error:	Taguchi orthogonal arrays only permit good analysis.

The following real case, developed for piston rings' chromium thickness, shows some of the preceding points. Seven factors were considered worthy of analysis of their influence on the chromium thickness of piston rings in an electrochemical process. Two levels were chosen for each factor. One hundred and twenty-eight different 'treatment combinations' (called 'test states') were needed to investigate fully the factors and their interactions. Only 16 test states were carried out. Any intelligent person understands that one can not know with 16 states the same things he/she could know with 128 states: there is an inevitable loss of information. This entails that some pieces of information, called ALIASES, are inevitably mixed. This case is one of the many that can show the benefits of managerial and scientific conduct of testing activities. The pitfalls of counter-conduct are very costly. There are very many cases of that.

Managers, if they want to be really effective and efficient managers, can and must understand this subject: there is no need for any particular knowledge, only intelligence is needed. That is why the case is presented.

Using mathematics, it is shown that the ALIAS structure is a set of equivalence classes defined by an equivalence relation (reflexive, symmetric and transitive). The reader will appreciate that every factor or interaction is not alone, but entangled in the ALIAS structure. In the example, 'B + ...' is actually formed by eight terms 'confounded' (this is called confounding in the statistical literature). This important fact is hidden in the Taguchi methods (third error). The last example I found is by Park *et al.* (1995); the authors did not consider the ALIAS structure, therefore they found a false optimum.

The analysis of the data collected (the so-called 'facts and figures', in the 'total quality' terminology) shows that current density, B (actually 'B + ...' formed by eight terms 'confounded'), is the most significant factor, according the Faraday law. Interactions DG and ACD (this one was not expected before the test) are more important than any other factor, factor C follows, and the other two interactions, BE and AB, are more important than any of the A, D, E, F and G factors. G is only ninth.

There are many cases where interactions are important, therefore it is quite non-managerial pretending, before any test, to say (Taguchi) "... when there is interaction, it is because insufficient research has been done on the characteristic values", or to say, after a test (Phadke), "... if we observe that for a particular objective function the interactions among the control factors are strong, we should look for the possibility that the objective function may have been selected incorrectly".

Using properly the information provided by the scientific analysis (G-method) of the 16

test states on the piston rings' chromium thickness, we could predict adequately the average thickness and its variance. The optimum setting permitted productivity to be increased by 17%, with huge financial benefits.

Looking at Table 2, it is apparent that the Taguchi method could have misled the experimenters, which could have wasted a lot of money.

This case shows that "facts and figures are useless, if not dangerous, without a sound theory" (F. Galetto). Mathematics, logic and physics can prove that the Taguchi approach is wrong, especially when he writes "... when there is interaction, it is because insufficient research has been done on the characteristic values". Interactions are really very important, according the fundamental principle F1. Managers have to learn logic, DOE and statistical thinking to make good decisions.

Quality is number one management objective, not only for products and services, but also for quality methods. Since quality must be built into the product during the design stage, the development cycle (Fig. 6), with its 10 key areas, has to be considered immediately by management. It is immediately clear that prevention is totally different from improvement. Moreover, it provides much better return. All points to be remembered are considered in the '10 key areas tetrahedron' (Fig. 7).

Conclusions

Any transformation is always difficult for human beings; they seem to resist new ideas, especially when it is required to use, in a better way, attitudes such as rationality, intellectual honesty, logic, etc. Even when the new ideas are accepted in principle, the following excuse is often raised: "it would be nice if the new ideas could work in practice ...".

Actually, experience shows that good ideas work in practice in any case where people put them into practice with coherence and intellectual honesty (TQM^2). Decisions and actions of managers show whether quality is a real facet of a company—facts count more than words. If first-line managers are allowed to say that "all problems of dis-quality originate from the workers", the MD (or the CEO) does not show that quality is essential. If, moreover, the MD does not want to issue the quality policy, the conclusion is evident: he/she will learn the hard way something very important, competition is going to beat his/her company.

Management need to develop their knowledge: experience alone, without theory, teaches nothing about what to do and how to make quality. Similar ideas in fields different from quality were provided by great scientists such as Leonardo Buonarroti and Galileo Galilei. Management must understand that they have a new job: listening to the customer, users and society and learning and putting into practice the principles for making quality. They have to learn what means and entails designing quality into products and services, procuring quality materials, producing with processes in control, designing experiments to avoid problems, deciding with rational method, managing people, decisions and goals with a long-range view: in short, prevention.

Management must encourage a climate for change and show with facts their dedication to quality (TQM^2), because building in quality brings lower costs and therefore better profits. When managers are educated on quality, reliability, statistics and design of experiments, it becomes clear that 'quality of methods for quality is important' and that some methods are misleading (e.g. the Taguchi methods and Bayes methods).

Using quality methods for managing, preventing problems, improving products, processes and services really means taking care to satisfy customers' needs—and profits really depend on satisfying customers' needs. All that is for managers, the MD (or the CEO) included. MDs must permit their first-line managers the quality manager included, to feel secure to express

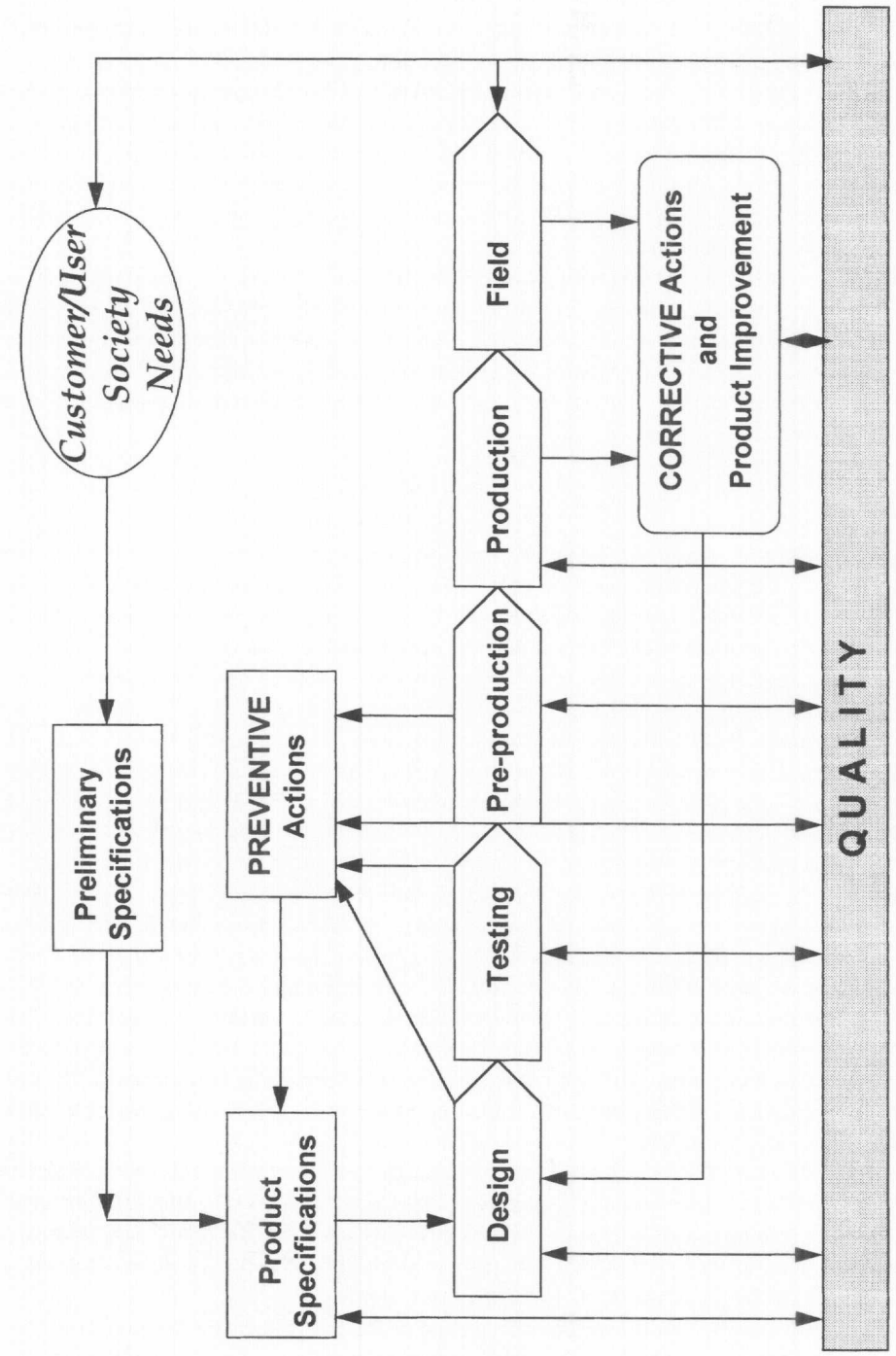

Figure 6. *The development cycle.*

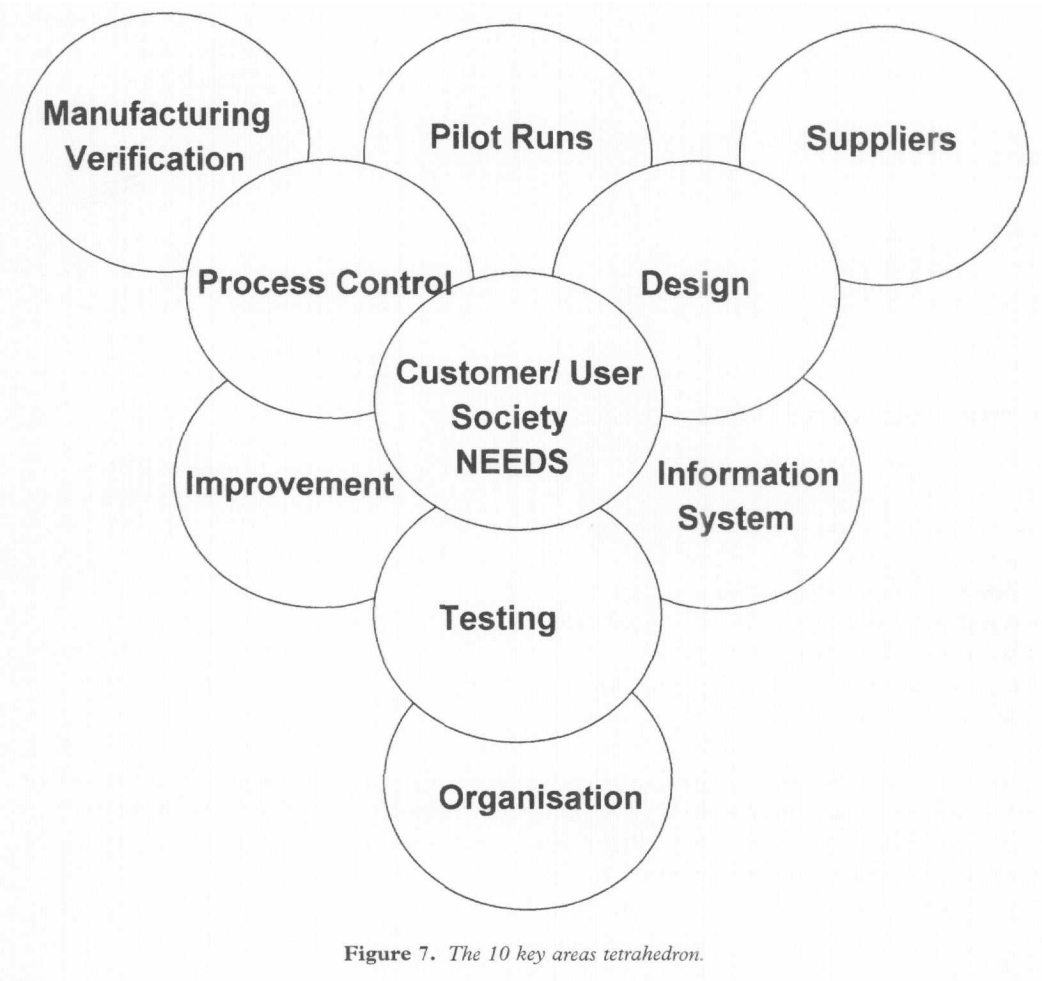

Figure 7. *The 10 key areas tetrahedron.*

their ideas on quality management, with respect to company quality commitment (see the management tetrahedron and the rational manager tetrahedron) (Fig. 8): again, TQM^2.

Unfortunately, the salary and bonuses of managers are based on the rating they get on indicators other than quality, though 'quality matters' are mentioned many times in Management By Objectives (MBO) (the idea hated by W. Deming). Thus, many companies are losing their customers. That is why quality commitment is not enough, and we need quality of managers, because quality is satisfying customers' needs not customers' satisfaction. Again, management need to develop their knowledge because experience alone, without theory, teaches nothing about what to do and how to make quality.

It is apparent how many times companies risk their reputation due to the 'dis-quality vicious circle' of their managers. Since the wealth of nations depends increasingly on the quality of managers, it is rather strange that companies still appreciate managers that have not learnt how to improve themselves continuously through the new theory of management: quality.

We need quality of managers; we need rational managers who analyse decisions, prevention and problems, taking into account the futurity of any action on the customer, user and society needs, using theory and logic. This focus on the customer, user, society needs is condensed in the acronym FAUSTA VIA (the profitable route to quality), which

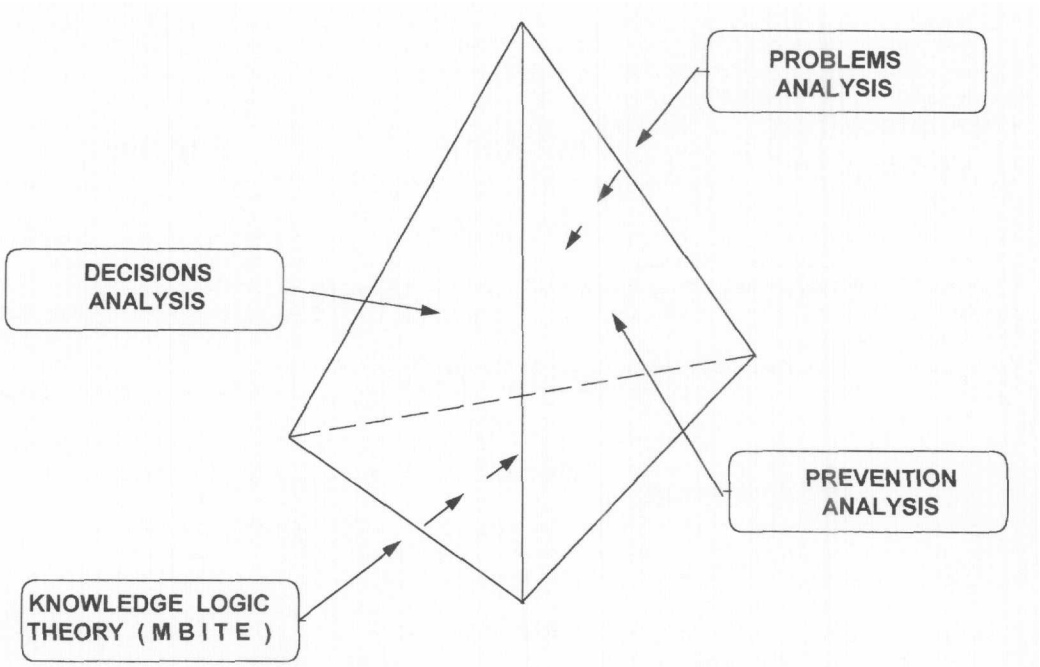

Figure 8. *The rational manager tetrahedron.*

stands for Focus, Assess and Understand Scientifically the needs, scientifically Test ideas and hypotheses, Activate the solutions (preventive or corrective); then Verify their effectiveness and Implement extensively on all other similar cases. Eventually, Assure the satisfaction of the customer, user and society needs.

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