Quality assurance — its history and meaning

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The objectives of this article are to relate Quality Assurance to the profitability of the organization, to investigate the history and identify the scope of Quality Assurance and to develop a model that illustrates why the management of product quality has certain key result areas. The relationship between product fitness for use and net profit is identified and this indicates that the management of product quality is an important business objective in order to optimize net profit. The historical development of quality assurance leads up to the modern concept which defines the parameters for product fitness for use and identifies those functional areas of the organization that influence product quality. The importance of having to establish key result areas for the management of quality becomes obvious from this exposition. The conclusions are that product quality is tied to net profit and that effective management of quality will in fact optimize net profit. Quality Assurance extends beyond inter-departmental boundaries and involves everyone in the organization. As such the identification of key result areas for the management of quality becomes vitally important.

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Die doelstellings van hierdie artikel is om Kwaliteitsversekering in verband te bring met die winsgewendheid van die organisasie; die geskiedenis van Kwaliteitsversekering na te gaan, die omvang daarvan te identifiseer en 'n model te ontwikkel wat illustreer waarom daar in die bestuur van produkkwaliteit sekere sleutelprestasieareas bestaan. Die verhouding tussen die produk se gebruiksgeskiktheid en netto wins word identifiseer en toon dat die bestuur van produktiwiteit 'n belangrike bedryfsdoelwit is ten einde netto wins te optimaliseer. Die historiese ontwikkeling van kwaliteitsversekering lei tot die moderne konsep wat die parameters vir produkgebruiksgeskiktheid definieer en funksionele areas van die organisasie wat produkkwaliteit beïnvloed, identifiseer. Die belang van vasstelling van sleutelprestasieareas vir die bestuur van kwaliteit word duidelik en die gevolgtrekkings is dat produkkwaliteit gekoppel is aan netto wins en dat effektiewe kwaliteitsbestuur dit sal optimaliseer. Kwaliteitsversekering oorskry interdepartementele grense en betrek almal in die organisasie, dus word die identifikasie van sleutelprestasieareas van die uiterste belang vir kwaliteitsbestuur.

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The entrepreneur and his prime objective

Generally the entrepreneur has as his prime objective, a satisfactory return on his investment. In the industrial environment this is specifically achieved by providing goods and services at a certain price to the user of such goods and services. One of the major aspects that directly affect return on investment is net profit, and therefore the factors that govern net profit will be identified, in order to see what relationship exists between customer satisfaction, and maximization of net profit.

Since net profit before tax depends on income and total costs, the maximization of net profit is dependent on the maximization of sales volume and price, and the minimization of total costs. Price is usually determined by mark-up and variable costs, and whilst sales volume depends on advertising and marketing, in the long run sales volume can only be maintained or increased by the degree to which customers are satisfied with the products. The degree to which customers are satisfied with the products purchased naturally depends on the degree to which these products are fit for customers' use. Hence we can relate net profit to degree of product fitness for use as follows:

Given:
- s = sales volume
- p = price per unit sold
- Fc = fixed costs
- Vc = variable costs
- m = mark-up
- u = degree of product fitness for use.

Then net profit can be formulated as a function of sales volume, price per unit sold, fixed costs and variable costs as follows:

$$\text{Net profit} = F(s.p - Vc - Fc) \quad (1)$$

Since sales volume is a function of degree of product fitness for use, and price a function of mark-up and variable costs, 1 becomes:

$$\text{Net profit} = F[f(u).\ f(m + Vc) - Vc - Fc] \quad (2)$$

Both fixed costs and mark-up are functions of the grade of product fitness for use and variable costs also depend on product fitness for use, since products that are not fit for use result in customer returns, replacements, delays, scrap and rework, which naturally increase variable costs.

(2) can therefore be expanded as follows:

$$\text{Net profit} = F[f(u).f\{g(u) + g'(u)\} - g'(u) - h(u)] \quad (3)$$

It is therefore seen that all the factors that govern net profit are also functions of product fitness for use, and yet, whilst the management of 'volumes' (production and sales) and the management of 'costs and money', (financial) are evident in all organizations, the management of 'product fitness for use' is less evident. One of the business objectives of the entrepreneur should therefore also be that of 'product fitness for use'.

The implementation of a business objective for 'product fitness for use', would naturally result in the investment in a separate unit in the organization to undertake the achievement of such an objective. What is important to know is the relationship between this investment and the costs that reduce net profit due to products that are unfit for use.

Juran[1] discusses the economics of product fitness for use and by utilizing his concept of cost of Quality Control versus loss due to defectives, and the relationship between Net Profit and product fitness for use (equation (3)) a relationship between the investment for attaining product fitness for use and the loss in net profit due to unfit products, can be established. This relationship is shown in Fig. 1.

From Fig. 1 it is seen that at 0% degree of product fitness for use the loss in net profit would be infinite, which means an infinite loss because no one would buy products that are totally unfit for use. On the other hand the investment for attaining product fitness for use of 100% is infinitely high, which results in zero loss of net profit. However infinite investment results in zero profit, and because we cannot have infinite sales, such an investment that results in infinite expenses actually causes an infinite loss.

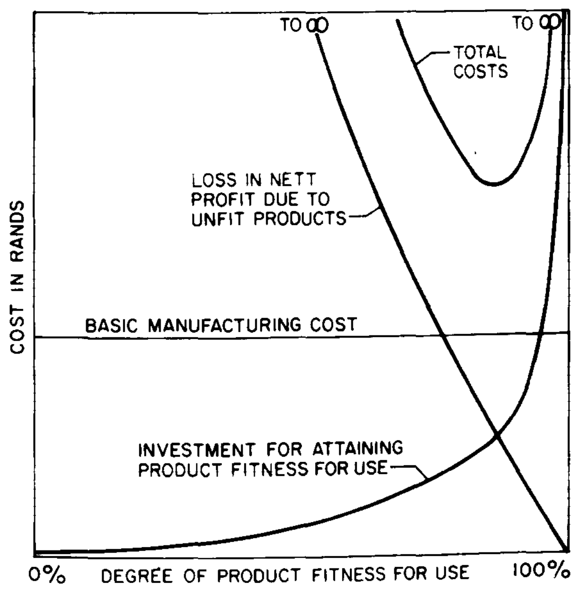

Fig. 1 Degree of product fitness for use

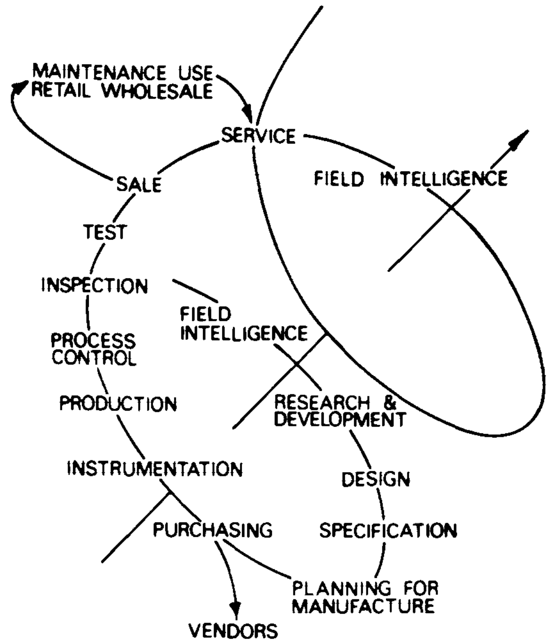

Fig. 2 The spiral of progress in Quality

The optimum loss in net profit and hence the optimum profit is always achieved at a level which is short of perfection in degree of product fitness for use and the total minimum cost is achieved at a very high level of degree of product fitness for use.

The management of 'fitness for use'

Juran[1] says that, 'Achievement of fitness for use involves the performance of a number of separate deeds or activities in a logical progression,' and this is illustrated in Fig. 2, which Juran[1] calls the 'Spiral of Progress in Quality'.

The activities needed to achieve 'Fitness for use' are therefore scattered among many people in various departments. Being concerned with multiple functions, the various departments have multiple goals as well. A major problem of modern industry is therefore how to orchestrate the widely scattered activities which collectively are responsible for achieving fitness for use.

The chief executive is actively engaged in co-ordinating these activities into a unified whole so that the departmental objectives would finally coincide with the overall organisational objectives.

The major managerial role of the chief executive is therefore to achieve synergy between the various functions so that fitness for use can in fact be achieved at Optimum costs. One of the major challenges that the chief executive is faced with is the managing of conflicts which arise because of the multiplicity of departmental goals.

In the more advanced economies of the world, the functions of the chief executive have been greatly enhanced by the formation of an activity that assists the company in achieving synergy by unifying all the organizational functions that affect product fitness for use, in such a way that product fitness for use is in fact quantified and achieved at optimum costs. This activity, which according to Juran[1] is performed by the Quality department, must be specialized in the sense that it not only knows how fitness for use can be assured prior to sale, but can also provide and apply the technologies necessary to assure that product fitness for use will be and is being achieved throughout all phases of the Quality Spiral in Fig. 2.

The Quality department, being the sole quardian to assure that fitness for use is defined during marketing, specified during design and development, achieved during production, and sold and serviced during and after sales, must know how each of the other departments function in their own right, in order to achieve synergy for the attainment of fitness for use at maximum profits.

When the product is defective, the Quality department should collate the customer complaint information, ensure that the customer is re-embursed, and is responsible to provide solutions and to see to it that the problem is not only solved, but that it will not re-occur.

Quality assurance and its history

The activity which is concerned primarily with product fitness for use and is managed by the Quality department is Quality Assurance. Quality Assurance is therefore the management of fitness for use and is the function which must provide to all concerned, i.e. management and consumer, the confidence that the products are and will be fit for use and that the necessary systems, and methodologies are available in order to ensure the achievement, maintenance and improvement in product fitness for use.

The modern concept of Quality Assurance has developed from basic inspection and although it does reduce and optimize the historical approach to inspection by providing additional technologies and management over and above inspection; it by no means replaces the inspection systems that are still necessary. This aspect is clearly illustrated by the progress and development of the Quality activity in the United States of America as outlined by Feigenbaum[2]. In this regard Feigenbaum[2] gives an extensive review of the History of the Quality activity with reference to the quality functions and he identifies the various steps through which the Quality activity progressed in the United States of America. He states that the different Quality functions have actually resulted from a half century of evolution and identifies five steps in the evolution, each of which has generally taken a 20 year period from inception to realization.

Feigenbaum[2, p 18] gives the five steps as, Operator Quality Control, Foreman Quality Control, Inspection Quality Control, Statistical Quality Control and Total Quality Control.

Operator Quality Control

The manufacture of goods started with the early craftsmen, whereby the trade of manufacturing was passed from father to son. Each craftsman brought his goods to the market place where exchange of articles took place. The craftsman manufactured, inspected and passed his own products. He was therefore totally responsible for the Quality of his own product. Later when the craftsmen employed apprentices the responsibility for Inspection was incorporated in their jobs.

This system was inherent in the manufacturing job up to the end of the nineteenth century. Under that system one worker, or at least a very small number of workers, was responsible for the manufacture of the entire product and therefore each worker could totally control the Quality of his work.

Even under this system manufacturing organizations were well aware of their Quality responsibilities since free competition occurred between different manufacturers on the world market.

Foreman Quality Control

In the early 1900's the USA progressed to 'Foreman Quality Control'. During this period the large scale advent of the modern factory concept developed, in which many men performing a similar task were grouped together so that they could be supervised by a foreman who then assumed responsibility for the quality of their work. Initially the Inspection was done by the foreman, but later he appointed separate inspectors to inspect the work of his operators. This initiated the third step known as Inspection Quality Control.

Inspection Quality Control

The manufacturing system became more complex during World War I involving large numbers of workers reporting to each production foreman. As a result, the first fulltime inspectors appeared on the scene initiating the third step, which Feigenbaum[2] calls Inspection Quality Control. This step peaked in the large Inspection Organizations of the 1920's and 1930's separately organized from Production and big enough to be headed by superintendents.

Statistical Quality Control

The mass production requirements of World War II accelerated the fourth step of the Quality activity, which is identified as 'Statistical Quality Control'. This was an extension of the Inspection phase only that large Inspection organizations were more efficient by using statistical tools such as Sampling and Control Charts, since in many instances this eliminated the necessity for 100% Inspection.

Statistical Quality Control was initially pioneered by Dr Walter A Shewhart, of the Bell Telephone Laboratories who published his book; 'Economic Control of Quality of Manufactured Product' in 1931.

During this period Harold Dodge and Harry F Romig, also of the Bell Telephone Laboratories, pioneered the use of Statistics in developing Statistical Sampling plans, the first of which they published in early 1940.

Total Quality Control

The stage was now reached from the 2nd World War onwards where, due to intensified inspection, although more efficient because of Statistical Methods, no time was available to Quality Staff to cope with really big quality problems as business management itself saw them. This led to the stage of 'Total Quality Control' which was largely introduced from 1960 onwards by General Electric in the USA, under the auspices of A V Feigenbaum.

A V Feigenbaum[2, p16-17] describes the Total Quality Control viewpoint as follows: 'The underlying principle of this total quality view, and its basic difference from all other concepts, is that, to provide geniune effectiveness, control must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied'.

The reason for this breadth of scope is that the quality of any product is affected at many stages of the industrial cycle.

- Marketing evaluates the level of quality which customers want and for which they are willing to pay.
- Engineering reduces this marketing evaluation to exact specifications.
- Purchasing chooses, contracts with, and retains vendors for parts and materials.
- Manufacturing Engineering selects the jigs, tools, and processes for production.
- Manufacturing Supervision and shop operators exert a major quality influence during parts making, subassembly, and final assembly.
- Mechanical inspection and functional test check conformance to specifications.
- Shipping influences the calibre of the packaging and transportation.
- Installation helps ensure proper operation by installing the product according to proper instructions and maintaining it through product service.

In other words, the determination of both quality and quality cost actually takes place throughout the entire industrial cycle. This is the reason why real quality control cannot be accomplished by concentrating on inspection, or design, reject trouble shooting, operator education, statistical analysis, or reliability studies individually, important as each of these individual elements may be.

The breadth of the job makes quality control a new and important industrial management function. Just as the theme of the historical inspection activity was 'they (i.e. bad parts) shall not pass', the theme of this new approach is 'make them right the first time'. Emphasis is on defect prevention so that routine inspection will not be needed to as large an extent. The burden of quality proof rests not with inspection but with the makers of the part: machinist, assembly foreman, vendor, as the case may be.

Like traditional inspection, the quality control function in this total quality view is still responsible for assurance of the quality of products shipped, but its broader scope places a major addition on this responsibility. Quality Control becomes responsible for assuring quality at optimum quality costs.

The total quality view sees the prototype quality control man not as an inspector but as an quality control engineer, with an adequate background of the applicable product technology and with training in statistical methods, in inspection techniques, in reliability studies and in other useful tools for improving and controlling product quality.

According to this new philosophy of Quality the typical organization structure that evolved as from 1970 in the USA, was as indicated in Fig. 3. All the Quality functions *viz* Inspection, Test, Quality Engineering, Quality Trouble Shooting, Customer Liason, Customer Service, Vendor Quality Control, Field Trials and Complaint Investigation reported directly to the Quality Manager.

The Quality Manager was looked upon as that man responsible to ensure that the company achieved its Quality Mission. The rapid advancement of complex designs and mass production techniques created problems of selling product that was consistently fit for use and hence the earlier techniques of Operator Quality Control, Foreman Quality Control, Inspection Quality Control and Statistical Quality Control now had to be properly co-ordinated, implemented and controlled via a formal Management Control System, such that the combined dimensions of Quantity and Quality could consistently be controlled. This aspect of total Quality Control also had to cater for deviations from Standards to be rapidly identified and corrected, before significant Quality losses were experienced.

Quality Assurance

The Feigenbaum[2] 'Total Quality Control' concept of the 1960's developed into what is commonly known today as Quality Assurance. The modern Quality Assurance concept expanded somewhat on the total Quality Control viewpoint in that modern reliability and Quality Engineering technology was introduced together with more effective management for application and execution of the quality functions. This trend was most significant in the United States of America and particularly Japan. This modern viewpoint of Quality Assurance is most aptly described by Juran[1] as the 'parameters of fitness for use'.

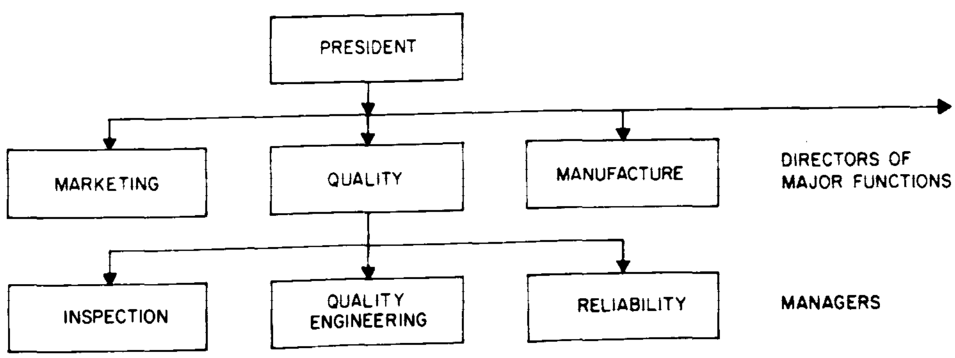

Fig. 3 Typical organization structure in the USA as from 1970

Quality Assurance in terms of the parameters of fitness for use

The degree to which products will satisfy customers' needs will invariably depend on the efficacy of the implementation and management of those parameters which have a direct bearing on the product's fitness for use. Juran[1] calls these parameters: Quality of Design, Quality of Conformance, Availability and Field Service. The Quality Assurance system should result in the effective and economical application of each of the above parameters, because for a product to be fit for customer's use it must:

- Be designed and specified in such a way that if it is made as per the design, it will function according to the customer's use expectations. (*Quality of Design*)
- Be made according to the specifications established. (*Quality of Conformance*)
- Be available and in good working condition when required for use. (*Availability*)
- Be serviced and maintained effectively and expeditiously. (*Field Service*)

Quality of Design

Quality of Design relates to all those activities that are conducted in order to determine what standard or grade of product should be designed and manufactured in order to satisfy the customer's use requirements. For Quality of Design to be effective one must not only ensure that the design is economical, realistic and can be achieved during manufacture, but must also verify that the design will result in a product that is fit for use *before* production commences.

The following three activities should be adequately performed before product is manufactured, and as such represent the Quality of Design phase for all products.

- Identification of what constitutes fitness for use to the user. (*Quality of Market Research*)
- Choice of a concept or service to be responsive to the identified needs of the user. (*Quality of Concept*)
- Translation of the chosen product concept into a detailed set of specifications which, if faithfully executed, will then meet the user's needs. (*Quality of Specification*)

Identification of what constitutes fitness for use to the user

Before any product or service is provided, the entrepeneur must know 'what the user wants'. During this phase of Quality of Design, the entrepeneur must gain adequate knowledge and insight into the required mission accomplishment of the user; i.e. 'what does the user want to accomplish?' Marketing would normally establish the user requirements; however this can not be totally effective if previous product performance data and customer feedback is not utilized as important input criteria for product policy decisions.

Referring to the Spiral of progress in quality (Fig. 2) we see that each new turn of the Spiral leads to Research and Development at a higher level. This is because the experience gained from previous product performance was put into use for newer and better products.

Customer usage feedback data is required in order to establish future fitness for use requirements.

Choice of a concept of product or service to be responsive to the identified needs of the user

One of the most important alternatives for assuring the correct product configuration when a concept of product is chosen is the use of model construction. The model construction activity involves the construction of product models under controlled Laboratory conditions, which are then tried and tested for adequacy of meeting fitness for use requirements. Because of variances between the model and production shop, the utilization of Quality Engineering Technology and Industrial Statistics is of paramount importance as part of the Quality Activity.

Translation of the chosen product concept into a detailed set of specifications which, if faithfully exe-cuted, will then meet the user's needs

The chosen product concept has to be adequately described in terms of specifications and standards, so that manufacturing planning and production can be affected on the basis of meeting defined specifications.

Refering to the spiral in Fig. 2 we can see that, from planning for manufacture right through to Inspection and test; it is necessary to know what the standard or grade of our product should be, if we want to achieve fitness for use. This grade or standard is most effectively described in terms of specifications.

This stage of Quality of Design poses two important activities which have to be correctly done if fitness for use is to be achieved economically:

- Relating the chosen product to a set of specifications.
- Ensuring that the specifications, if followed, will result in product that is fit for use.

In order to ensure that these two activities are correctly performed the Quality Assurance system should provide for the application of numerous technologies, some of which are the following:

- Design Reliability Engineering
- Failure modes and effect analysis
- Design review analysis
- Design analysis.

Quality of Conformance

Quality of conformance relates to the extent to which a product or service meets the specifications. Quality of Conformance is determined by many activities, the most important of which are:

Quality Planning

How well are the Quality systems planned so that nonconformances to specifications are preventable, detectable and repairable. This also applies to the Inspection and test criteria and systems.

Manufacturing processes

To what extent can manufacturing processes meet the specifications and when they do not, how does the entrepeneur know? In this regard the importance of Process

Control and Process Capability should never be underestimated.

Manpower and training

To what extent are Operators trained and motivated to prevent defects and how do they know what the standard is and how to achieve it? Operator skill and motivation will determine the level of *operator controllable* defects.

Provision of processes, tools and controls by management

To what extent does management provide the operating personnel with the necessary training, tools and processes, so that the workmen can in fact produce product according to specification. The effectiveness of management and how well they have provided the Operator with the right tools, processes and instructions will determine the *level of management* controllable defects.

Availability

Availability relates to the extent to which the product provides service when called upon. This is applicable to products that have an extended life and have to function on a repeatative basis. Availability is expressed mathematically by the ratio $\frac{\text{uptime}}{\text{uptime + downtime}}$ or in equivalent terminology by the ratio:

$$\frac{\text{Mean time between failures}}{\text{Mean time between failures + Mean time to repair}}$$

The availability of products depend on the following aspects which are all part of Quality Assurance:

– *Reliability*

This is the probability of a product performing a specified function without failure under given environmental conditions for a specified period of time. The reliability of a product is largely determined by its design and as such bears heavily on the effective application of the Quality of design functions.

Reliability is normally measured as the Mean time between failures or failure rate or probability of performing without failure for time *t*.

– *Maintainability*

Maintainability relates to 'The ease of restoring service following failure' i.e. the ease with which maintenance can be conducted. The two most practical measures of maintainability are: 'Mean time to repair', (MTTR) or 'Probability of restoring service in the time period specified'.

– *Logistical support*

Logistical support is the totality of activities which ensure the supply of the right spare parts of the right quality at the right time.

Field Service

Field Service relates to the extent to which the repair agencies (manufacturer, merchant, service shop) provide competent, promp and honest redress in case of service failures.

Field Service relates to activities which are carried on after sale rather than before sale. It is performed by organizations regarded as service industries rather than manufacturing and it includes extensive contractual and informal contact directly with the user.

Following the sale therefore, the user's ability to secure continuity of service depends largely on some service organization which should:

- Provide clear, unequivocal serviced contracts.
- Establish adequate repair equipment capacity and supplies of spare parts.
- Recruit and train a service force competent to diagnose and remedy failures.
- Provide clear, unequivocal service contracts.
- Conduct its affairs with courtesy and integrity.

The Field Service activities should be a major part of the Quality Assurance system of the producer of the product or service and as such form part of Quality Assurance Management.

Diagramatically Quality Assurance can be related to the parameters of fitness for use as illustrated in Fig. 4.

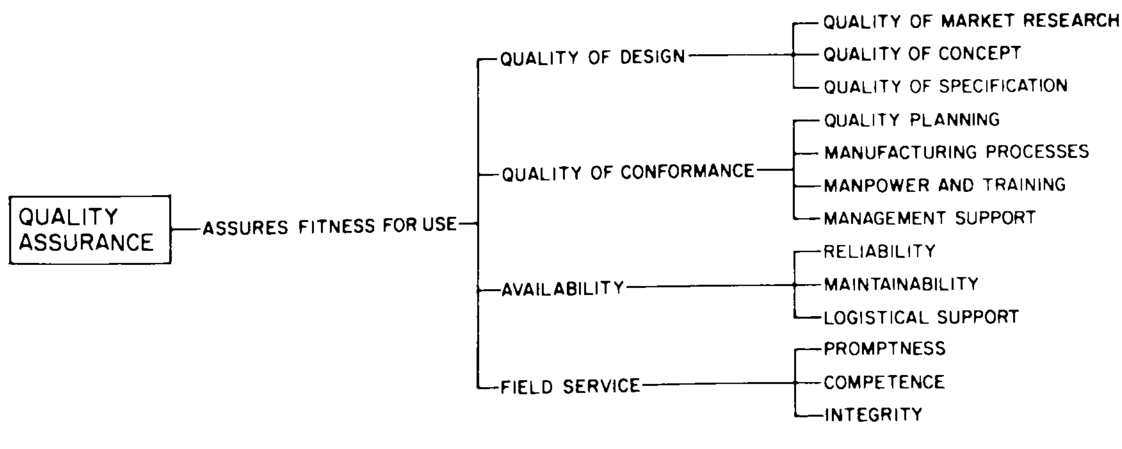

Fig. 4 Parameters of fitness for use

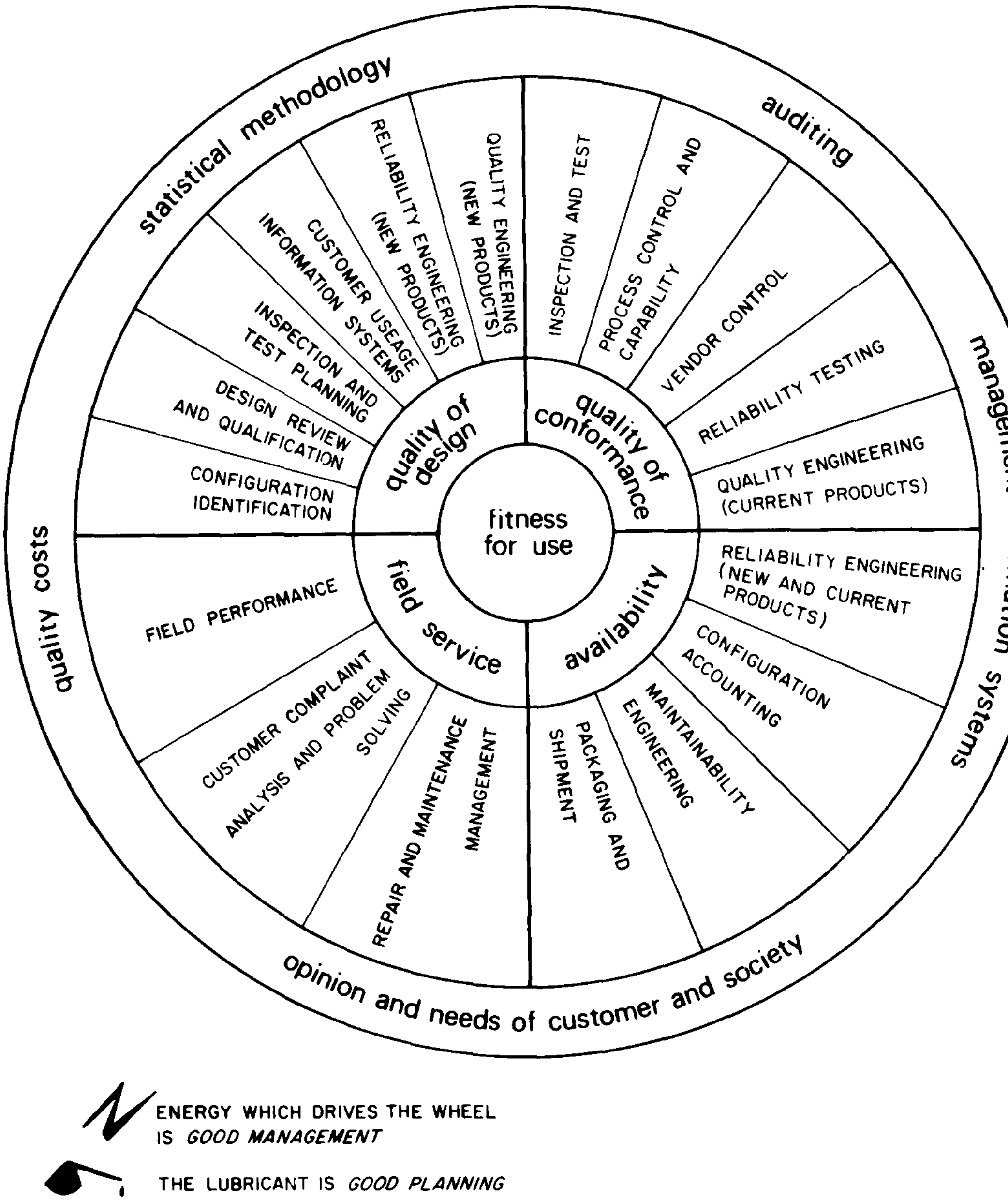

Fig. 5 Quality assurance wheel

Conclusion

The application of Quality Assurance involves the implementation and co-ordination of numerous industrial activities each of which are related to one or more of the parameters of fitness for use. This relationship can be depicted in terms of a Quality Assurance wheel as in Fig. 5.

The activities through which fitness for use is achieved are spread amongst different departments. Co-ordination and effectiveness of the application of the quality technologies. The Quality department therefore needs to be a centralized unit that has sufficient authority and related functions reporting to it so that it can not only perform effective co-ordination for attainment of fitness for use, but can also provide the Quality technologies for the effective functioning of the other departments whenever fitness for use is affected.

The Quality deparment is that major unit of the organization that has to provide answers for the attainment of fitness for use and also provide solutions to fitness for use problems. In this respect the Quality department should supply both the managerial and technological disciplines for the attainment of fitness for use and as such has certain key result areas for which it should be held accountable.

These key result areas are by the very complexity of fitness for use quite different from those for production, Marketing or Finance, and would be well worth while investigating in depth in a future publication.

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