

## A DEVELOPMENTAL QUALITY APPROACH FOR ERGONOMICS

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### **Abstract**

The relationships between the two disciplines quality and ergonomics have been given increasing attention during the last years. The aim of this paper is to elaborate on the opportunities of improving ergonomics applications on the basis of a quality development approach. Participation in quality development concepts such as Continuous Improvement has a good record and potential to contribute to improved ergonomics. TQM is a proponent for process orientation. A process is in fact a series of human work activities. High quality products and efficiency can only be obtained if each employee gets the opportunity to perform and deliver good quality to the next process. Quality production and survival of quality concepts necessitate considerations to the employees in the organisation. The introduction of ISO 9000 seems to give mixed results, both regarding organisational performance and quality of work. The main issue deciding whether the effects of quality concepts on health, safety and working conditions will be positive or not seems to be the way the quality concepts are practised and implemented. A regulatory view restricts personnel involvement and produces few benefits, while a development oriented approach instead contributes to a positive outcome.

Key words: organisation, work, human interactions

### **INTRODUCTION**

The relationships between the two disciplines quality and ergonomics have been given increasing attention during the last years. Several reviews on these relationships have been published lately (2), (12), (16). In addition, compilations of publications in the field have been made in conference proceedings, e. g. (1), (5), (44). A general conclusion from these publications is that both disciplines can benefit from one another by integrating experiences and concepts from the other discipline. The aim of this paper is to elaborate on the opportunities of improving ergonomics applications on the basis of a quality development approach.

The quality movement has evolved rapidly over the last decades. The concept of TQM rapidly spread over the world, and was influential during the 1990's in industry as well as in the public and service sectors. The roots can be traced back to Shewhart in the 1920's, who introduced statistical quality control of production processes. Two other Americans, Deming and Juran, developed the quality philosophy further, where the importance of learning and management for quality was strongly emphasised. They also introduced their thinking in Japan, and had great part in the development of the Japanese quality approach. Quality became strongly integrated in Japanese management and production philosophies, and the Toyota production system is the most well-known example of application excellence (41), (29). Another line of development within the quality movement is standardisation, which has resulted in the ISO 9000 standard (3).

The ergonomics movement is also a relatively young discipline, with its roots from the 1940's. In spite that the two disciplines ergonomics and quality have had mutual influences, they have largely developed separately. Therefore the approaches differ in several respects, in spite of several similar aims. In particular, ergonomics emphasises the interactions between humans, technology, organisation and the environment. The interaction perspective is emphasised e. g. in the definition of ergonomics proposed by the International Ergonomics Association. Well functioning interactions makes the task better adapted to the abilities and limitations of the humans, less strainful and imposes fewer risks for impairments of health and well-being. Also performance of the total system improves, which includes better quality results. With a systems view, ergonomics integrates the humans as a component in a complex system, consisting of humans, technology, organisation and the environment (19).

## RELATIONSHIPS BETWEEN ERGONOMICS AND QUALITY

There are many theoretical reasons for relationships between quality and ergonomics. First, the definitions reveal overlaps. Jurans "Fitness for use" is related to the concept of useability. Bergman and Klefsjö (3) defined quality as "the ability of a product or a service to satisfy the expectations of the customers", where also the workforce of the organisation was regarded as internal customers. When this definition of internal customers is included, this aspect of quality becomes close to the definition of ergonomics. New areas such as participatory ergonomics have developed, which emphasise similarities with the field of quality (42). The quality approach emphasises both management support and employee participation, while ergonomics has focussed the needs of the ergonomics expert and employee participation.

There are a large number of studies showing clear relationships between effects on human (quality) performance and environmental factors such as lighting, noise, vibration, chemicals and climatic conditions (47), (49).

Many studies have identified increased rates of misjudgements due to insufficient lighting, such as light levels, colour rendering, luminance and reflections (22). This has been observed in proof-reading of texts with poor visibility (53), (10). In production industries, increased illumination levels have resulted in up to 40% reductions in rejection rates or wastage (22).

Also, noise may increase the error rate. This may occur due to distraction and lapses of attention or due to masking of essential information. One example from Lovén and Axelsson (39) showed that in the assembly of components with a snap-on function, the snap sound signalled "passed" to the worker. When extraneous noise was introduced, this obscured the snap sound and led to a higher number of quality deficiencies.

Whole body vibrations which leads to vibrations of the eye or vibration of the viewed object makes it difficult to see particularly fine objects. One consequence observed is that the error frequency in reading tasks has been shown to increase. Vibrations may in addition cause unwanted movement of the controls in manual control tasks. Vibrations may also interfere with the neuromuscular processes, including finger sensitivity, and thereby cause errors (23).

Low temperatures that cool the hands decrease the sensitivity and precision of hand and finger movements in addition to making hand and finger movements slower. Adverse climatic conditions in combination with cognitive and mental tasks, decrease performance measured as frequency of errors or as accuracy (47), (28). The use of gloves as protection against low temperatures of chemical compounds decreases precision (7), and the tactile feedback,

sometimes necessary in order to judge the quality of the work result, may be lost if gloves are used (39).

The precision of body movements varies depending on the directions of movement and depending on which muscles and joints that are used. Ergonomic design that considers this facilitates greater accuracy of performance. Existing bodily discomfort and pain tend to be aggravated by heavy and strenuous work tasks, which is a situation that is accompanied by avoidance, deteriorating performance and increasing error rates (22), (8), (14). In one study, the quality deficiency rate was shown to be almost 10 times higher for the worst body postures compared to the best postures (2).

The choice of technology in terms of machine and interface design has an important influence on manufacturing time, quality output and ease of manufacturing (25). There are numerous studies in the ergonomics literature which show how ergonomically designed products may improve performance (22), (8), (32). One example from electric connector assembly shows that factors such as visibility, position, layout, sequence, size, shape, weight, colour and surface properties are all important clues for the operator in his or her strive to select and connect the right connectors. Designs not considering this have been identified as potential causes of quality deficiencies, and constitute examples of how insufficient interaction between technology and humans may be the origin of such quality deficiencies (see 19). Another example is the design of computerised equipment from a cognitive perspective, which has decisive influence on performance, quality and loads on the users (26).

Safety and prevention of accidents have long been a high priority in ergonomics. This includes consideration to the error risks built into complex systems including humans. Human error is a major cause of safety problems as well as of quality deficiencies in manufacturing processes and product quality. The process industry is an example of this. Thus, causes of safety issues and quality issues are inherently interwoven, and actions to improve safety will therefore also improve quality (38).

Another important influence on quality is the organisation. Kronlund et al. (35) observed that increased work content appeared to improve product quality. Drury and Prabhu (11) came to the result that job enrichment improved inspection performance, and Eklund (15) obtained data indicating improved assembly quality when self-inspection was included in the assembly tasks compared to using separate quality inspectors. Operators with broader assembly competence were found to perform 33% better quality compared to those with less competence. In addition, the lack of operator feedback was found to be one important reason for poor ability in assessing quality (40). Status differences and tensions between categories of workers in a hierarchical work organisation were also shown to be related to quality deficiencies (14). Furthermore, production philosophy, work organisation and personnel policy, as well as wage form, have been shown to correlate with quality (55), (9), (51). A frequently used argument is that motivation leads to improved product quality and that the best incentives are continuous levels of interest in the work, maintained by challenges and achievements being recognised, involvement through ownership and improved communication (36).

The above examples have shown how ergonomics might be supportive of good quality. Humans may be regarded as a component in a system, interacting with other components. Compared to technical components, humans are particularly sensitive to environmental conditions, negative or positive. Performance is strongly affected by environmental disturbances, as shown above. Also, performance deteriorate markedly as soon as the

physical, social and psychological requirements deviate from the human requirements. We also know from the ergonomics literature that people in general have a desire to perform good quality work and that the ability to perform a good quality job is an important precondition for job satisfaction and motivation (52), (21), (9). However, there are also clear differences between the two disciplines in several respects. This includes the different views on e.g. JIT, SPC, standardisation, discipline, reduction of variability, copying of best practice and reward systems (16). These differences offer interesting opportunities for further research, with a good potential to improve our knowledge.

## **TQM**

The quality movement has to a large extent been formed from a pragmatic point of view, and it has been criticised for lack of a theoretical basis. TQM embraces four assumptions as starting points: improved quality is profitable, people want to do a high quality job, all the parts of the organisation are highly interdependent, and quality is the ultimate responsibility of top management (24). Different authors have somewhat varying views of the basic principles and foundations of TQM, but the following corner stones are generally regarded as the most central: customer focus, process orientation, employee participation and continuous improvements. Different quality traditions can be distinguished, including the Scandinavian (3), (13), the American (48), and the Japanese traditions (41), (29). In the Scandinavian tradition, much emphasis is given to participation and good working conditions of the work force in line with the sociotechnical philosophy. According to the American view on TQM, the ultimate goal is company success and profitability. Thus, this tradition is more result oriented, emphasises cost reduction, and it has also been criticised for being used more as a management tool for rationalisation. Customer satisfaction is rather seen as a means, and working conditions for the employees are regarded as side effects. This view is attractive to managers and owners of companies, and therefore increases the probability of TQM to be implemented and supported (30). The European and Scandinavian view is more based on a stakeholder model, in which the goal is to consider the interests of the customers, owners, and the employees. The reason for a company to exist is its mission to serve the customer. Priority is thus given to creating customer satisfaction, which is a necessary condition for long-term company success (20).

There are a number of stakeholders in a company or an organisation. The most significant are as earlier mentioned employers, employees and customers. Sometimes the local community is mentioned as a fourth stakeholder. Which stakeholders should be given priority? According to the stakeholder model proposed by Eklund (17), the quality philosophy has introduced a more dynamic interaction between the three major stakeholders, compared to the earlier situation with only two, employers versus employees.

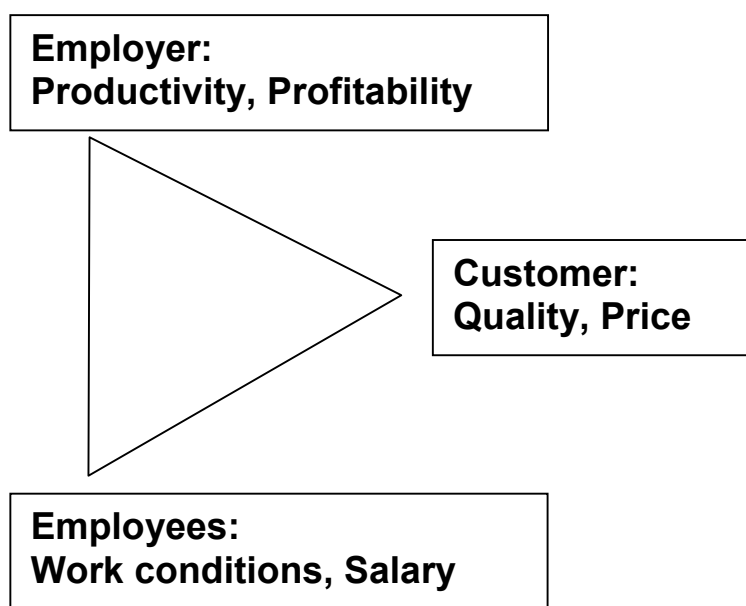


Figure 1. A stakeholder model of the most important stakeholders in an organisation.

In a generalised sense, the employers have a strong interest in profitability and productivity, but of course also other aspect that contribute to company survival. The employees have a strong interest in their work conditions in a broad sense and in salary, rewards and recognition that stem from the job. The customers have a strong interest in the quality of the products in a broad sense, including services and the price. Different philosophies give different priorities to the three stakeholders. Taylorism gives e. g. priority to the employers, the Human Relations School gives priority to the employees, and TQM to the customers. The model allows positioning of different philosophies in the model, and thereby becomes predictive in terms of stakeholder satisfaction. The model also considers contextual changes. When there is unemployment, less consideration is taken to the employees, when there is an economic depression with low customer demand more consideration is taken to the customers. The model also predicts that a system characterised by higher stakeholder satisfaction is more likely to survive than a system with lower stakeholder satisfaction. It also predicts that dissatisfaction from one or two stakeholders tends to create an unstable situation, which threatens the philosophy in the long run, and may therefore risk become a fad.

It can be hypothesised from the model that the American TQM is considering the interests of the employees too little, and therefore unlikely to survive for longer time periods. This situation also increases the probability of quality problems in the production processes. It can also be hypothesised that the Scandinavian model of TQM is more close to a generic philosophy when to a larger extent considering the three stakeholders reasonably well.

### ISO 9000

Many organisations have invested substantial resources in order to obtain certification according to the ISO 9000 quality standard. There is a debate about the consequences of

this standard. It has been criticised for being too defensive and product-oriented, specifically omitting the areas of human resources and employee attitudes, encouraging a conservative approach without emphasising improvements, and focusing too highly on documentation, especially in small companies (3), (12), (54). Other critics claim that the imposed regulations may create less varied tasks, rule based work, monotony, repetitive work injuries and may counteract learning, creativity and motivation (4). Proponents of the quality discipline regard standardisation as a necessary structure for worker participation and for smooth working operations, in other words to obtain quality, low costs, safe and healthy work conditions. The standard should be seen as an important reference and a basis from which creative improvements are to be made. Standardisation is therefore a necessary basis for learning and creativity (48), (34). However, it is not sufficient to focus on the content of the standards. The process of creating, implementing, maintaining and modifying them also needs much attention.

Studies into the effects of ISO 9000 have pointed to the possibility of accomplishing employee involvement through better communication within the company (57). Another common experience is that people do not change their behaviour to the extent expected (6). Others have come to the conclusion that the influence on physical working conditions is relatively limited, and that positive effects are found in the areas of better order and house-keeping. Further, attitudes towards discussing quality shortcomings become more positive, job descriptions and responsibilities become clearer, work enrichment as a result of the additional tasks within the quality system has been found and a better understanding of external customer demands. The negative effects are increasing bureaucracy with new, apparently meaningless tasks for individual workers, as well as more stress in terms of time pressure and increased responsibility without control and more physically strenuous work. However, the employees in general appreciate reduced role ambiguity and improved structure of their work (31), (27), (54). Karlitun et al (31) confirm that the process of change is an important factor deciding whether the outcome will be positive or not.

Standardisation may be characterised as being performed according to a developmental view or a regulatory view. In short, the developmental view means that management introduced the standards with the major aim to improve the internal processes. The process starts with improving the processes and work activities in a participatory approach, whereafter the employees themselves document the processes for the standard. The standard is regarded as a temporary agreement, until a better way to perform the work has been found and standardised, and it is actively and continuously revised. The regulatory view is in many respects opposite. The major aim is to obtain the certificate for marketing purposes. An expert consultant is hired to write the documentation, which is handed out to the employees just before the consultant leaves the company. This documentation is used to discipline the employees. Changes of the standard are avoided, and it is sometimes overruled by management (18).

Another experience is that the quality objectives in ISO 9000 can lead to a new emphasis on health and safety, due to the inclusion of these factors as a selected objective or as the result of demands on work instructions (50). Many attempts are now being made to integrate ISO 9000 and other standards in the fields of safety, occupational health, environmental control and internal control (38), (54), (45). One reason for this is that the different standards to a certain extent address the same issues. Another reason is that it is easier to handle a single system instead of several.

To conclude, standardisation performed with a developmental view seems to give better

acceptance, more positive effects and survive for longer time, in comparison with standardisation with a regulatory view.

### **CONTINUOUS IMPROVEMENT**

Continuous improvement is one of the most important elements of TQM. It refers to organised activities in order to involve employees to improve production, work processes and products. Improvements are seen as a problem-solving process, and have the explicit purpose of involving the employees. The primary goal may be to achieve improved motivation (the Toyota way), or to achieve better company performance (29). The concept can be regarded on several levels. It may be seen as a strategic tool for improving company performance or customer value, or it may be seen as an operative tool for improving employee motivation and working conditions. It may be seen as a company culture, e. g. stating that "Everything we do today will be possible to make in a better way in the future. As soon as we can identify improvement opportunities, we will implement them. It is important that all people in the company continuously seek new improvement opportunities." Numerous ways of designing systems for continuous improvement or participative problem solving exist. An attempt to classify such applications is shown below.

Table 1. A classification of participative problem solving applications.

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Aim/focus

level of participation  
reactive / proactive  
radical steps / incremental steps  
controlled focus / free focus  
structure / process  
strategic management / process management / daily activities  
work routines / workplace / products  
productivity / quality / cost / safety / ergonomics  
knowledge / empirical findings  
result improvements / process improvements  
motivation / relationships / effectiveness / learning

Working methods

top-down / bottom-up  
integrated system / isolated system  
representative participation / direct participation  
voluntary membership / mandatory membership  
individual / group  
mixed skills / uniform skill  
within ordinary work activity / outside work  
permanent / temporary  
structured / unstructured  
participation in proposals / idea development / implementation / evaluation  
decisions: individual-group-supervisor-committee-management  
type of feedback / time to feedback

Rewards

extrinsic rewards / intrinsic rewards  
financial rewards / other rewards  
within ordinary salary / extra rewards  
profit sharing / fixed sum per suggestion  
low budget rewards / non-maximised rewards

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Some systems may be designed to consider only the interests of the employers or the customers. Other systems might also give substantial benefit to the employees, in terms of better working conditions or better motivation. Systematic quality work, e.g. in quality circles, not only improve quality but can also solve working environment problems. Several studies have confirmed that at least one third of the problems addressed in quality circles are related to shortcomings in the working environment and deal with ergonomics improvements (43), (56), (37), (2). Ongoing studies indicate that stakeholder benefit is an important determinant of the probability of success and survival of the systems (46).

## PROCESS ORIENTATION

Many definitions of processes have been proposed. Here, a process is defined as a series of activities, performed or controlled by humans, with the aim to transform an input to a desired output. The quality movement emphasises the importance of focussing on the processes that lead to the end result in terms of customer value and satisfaction. By using a process

view, a different perspective of organisations is obtained, which makes non-logic ways of organising activities visible. If the processes are running well, the result will subsequently be high quality products and efficiency. Employee motivation thus becomes a very important means in order to create good quality at all stages in the production (29). The processes consist of human activities, where the humans are interacting with technology and other humans, within the frame of the organisation and the environment. There might also be automated technological processes without immediate human involvement. However, there have always been human activities preceding this situation, namely in the development, in the control of and in the maintenance of these technological systems. In other words, all production is based on human activities. The quality of the output from all the activities in all stages are decisive for the quality of the end product (33). This could be expressed so that all employees must be given the opportunity to perform good quality, and thus deliver good quality to the next work activity or process.

## CONCLUDING DISCUSSION

Quality and productivity are generally seen as strategic management issues, while in most cases ergonomics is not. This paper shows that ergonomics is an important determinant for quality. Also, it is considered that quality is a better basis for arguing ergonomics considerations than productivity is. Quality can easier be supported by all stakeholders, the opportunity to perform a good quality job is a criterion for good and rewarding work, quality improvements tend to be seen not only in economical terms, and good quality is a strong driving force for productivity and also for ergonomics.

TQM is a development oriented approach, although it is not always applied that way. The same can be said about the sub-concepts of TQM, i. e. continuous improvement, standardisation and process orientation. Experience support that a developmental approach with broad involvement and participation of employees in the organisation has a better potential to drive quality and ergonomics improvements than a regulatory approach.

The two disciplines can mutually benefit from one another. Ergonomics would benefit from developing participative methods for analysis and design, and from strengthening its relationships with strategic management. Quality on the other hand would gain from more emphasis on the design of work for the internal customers, i.e. the employees. In order to obtain better quality processes in an organisation, experience has shown that a focus on work activities is effective, i.e. improvements of the interactions between the humans, the technology, the organisation and the environment. Consequences in terms of accidents, unforeseen events and quality deficiencies often have the same causes, based on deficient interactions between the humans, the technology, the organisation and the environment.

Today, TQM is even considered a fad in several countries. Has the quality philosophy become a fad? It is argued here that as long as the philosophy considers the most important stakeholders reasonably well (i.e. the employers, the employees and the customers), it is a generic philosophy. By definition, the quality approach must give high priority to quality and customer interests. Some traditions use TQM as a rationalisation movement, thereby giving priority to productivity on behalf of working conditions. The Nordic working life tradition has a long history of consideration to the situation of the workforce. Therefore, it is argued, the Nordic approach to quality with its emphasis on participation and humans has a greater probability to survive and not becoming a fad compared to productivity and cost driven versions of TQM.

Participation in quality concepts such as continuous improvement has a good potential to contribute to improved health and safety. Standardisation, for example ISO 9000 may in some cases contribute to health and safety. The main issue deciding whether the effects on health, safety and working conditions will be positive or not seems to be the way the quality concepts are practised and implemented. In this respect, our findings point to that a regulatory view restricts personnel involvement and produces few benefits, while a development oriented approach instead contributes to a positive outcome.

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