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Shop Floor QA Decisions Supported By Computer-Based Expert System
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U.S. companies have been through a series of structural and process designs to remain competitive in the global economy. U.S. companies realized that to remain competitive, they developed and implemented new methods to increase process efficiency and product quality while maintaining profitability. The reason is simple: customers demand high quality products at a completive price. In response to these customer demands, U.S. companies have implemented several key process initiatives: Just In Time (JIT) manufacturing, Efficient Consumer Response (ECR) and Supply Chain Management (SCM). All require the company's Quality Assurance (QA) department to rapidly identify substandard product prior to customer shipment. There is a greater need for QA to quickly analyze shop floor stimuli and reduce reaction times (RT) to process decision-making. This need to reduce QA decision-making RT caused a "revolution" in the design of quality systems.

Since the 1970s, a quality system design has taken on several appearances. U.S. companies have developed and implemented various quality system designs (for the shop floor) in an effort to support the need for rapid data analysis and meet customer quality demands. Total Quality Management (TQM), quality circles, and ISO 9000 are examples of quality system designs implemented on the shop floor. These quality systems tend to empower shop floor operators, which allows for a flatter managerial organization with the point of control within the responsibility of the process operator. The implementation of various quality system designs and employee empowerment requires extensive training of shop floor operators in traditional management skills, such as, financial key performance indicators, quality decision-making, communication and leadership. The success of shop floor quality systems and operator empowerment has been sporadic at best[1]. How operators shift through stimuli directly impacts the reduction of decision-making RT and subsequently how a company maintains globally competitive.

Shop floor operators are confronted with multiple process stimuli, which the operator must disseminate and decide what is the proper course of action. The RT the operator is empowered to act on is (primarily) a choice RT. Choice RT can be defined as one stimulus out of several possible stimuli or as a decision to choose among several possible reactions[2]. Traditionally, QA management provided operators traditional problem solving tools (brainstorming, cause & effect diagrams, Pareto analysis, force field analysis, flow charting, histograms, control charts and process capability studies). However, operators (in general) are reluctant to make decisions in process areas that were traditional managerial responsibilities. A gap exists between the quality system training/empowerment and the decision-making RT (required when confronted with

[1] Sebastianelli, R and Tamimi N (2003) "Understanding Obstacles to TQM Success." *Quality Management Journal* 10/3, 45-56
[2] Kroemer, K, Kroemer, H and Kroemer-Elbert, K, (2001) *Ergonomics – How to Design for Ease and Efficiency* 2nd Prentice Hall 138-139

multiple stimuli). The operator falls into the status-quo gap[3]. The operator allows management to make the decision in response to the stimuli. The operator is criticism adverse, such that, the operator will take no action at all when confronted with a process decision. This lack of decision responsibility extends the time delay for the choice RT. A bridge is needed to facilitate the reduction of operator decision-making RT when faced with multiple shop-floor stimuli. The solution is the development and implementation of an Expert Systems (ES) to help operators quickly make decisions when confronted with multiple shop floor stimuli (thus reduce RT).

Knowledge-based systems and ES can be used in process settings for knowledge management. A knowledge-based ES is an excellent method to bridge the gap between the "managerial knowledge" provided through training materials and quality tools and the contingencies of shop floor stimuli. In its simplest form, knowledge based ES would be a software program located at a quality workstation and running off a networked or stand alone PC. The ES software receives operator input based on a process event (stimuli). Based on the initial input, the ES would request a series of information until a recommended decision is presented to the operator. The ES would help the operator document, and classify process events and to isolate, and dispose substandard product. ES have several key decision-making requirements: they must be well defined, logically structured, primarily cognitive and the knowledge base be defined by recognized experts[4]. The ES knowledge base is developed from written and human sources of knowledge and expertise. For example, review of the typical (80/20 rule) shop floor stimuli (to process stimuli) and the managerial decisions in response to the stimuli would be documented. Logical algorithms would be developed branching into decisions based on the process event. An ES can branch forward or backward based on operator input. Key to a successfully implemented ES is the identification and elimination of Type I and Type II error (type I error is rejecting a solution when it is true, type II error is accepting a solution when it is false). Based upon experience of designing and implementing a knowledge based ES at shop floor QA workstations, ES reduce operator decision-making RT through positive feedback, empowerment enhancement and system learning.

The effect of positive feedback (to multiple stimuli) on the operator decision-making RT can be explained using three feedback theories: behavioral, control and social cognitive. Behavioral theory views feedback as a reinforcer to process stimuli. Feedback is a reinforcer when it decreases the RT of the operator. The use of positive reinforcement in conjunction with other shop floor tools (such as Shewhart charts or software expert systems) can quicken the decision RT. Control theory views the operator as processing both positive and negative feedback (to multiple stimuli) and adapting to the changing feedback. The operator recognizes the consequences of both positive and negative feedback and adapts accordingly. Both positive and negative feedback can impact

[3] Hammoond, JS and Kenney, RL (1998) "The Hidden Traps in Decision Making." *Harvard Business Review* (September – October) 47-58
[4] Ignizio, JP (1991), *Introduction to Expert Systems*. New York; McGraw-Hill.

(both reduce and increase) decision-making RT. Social cognitive theory explains operator response to stimuli being a combination of an operator's belief in his/her skills and the impact their performance has on the subsequent result. An operator whom believes training and/or tools has prepared him/her to respond to multiple stimuli and understands the objective of the response will react accordingly. Operator confidence and clear objectives can reduce decision-making RT. In general, all feedback theories suggest that proper use of feedback will impact (either positive or negative) decision-making RT. Knowledge based ES provide positive feedback 100% percent of the time. The ES algorithms are designed to provide a clear, recommended decision based upon operator input. The operators learn (through experience) that the ES does not criticize the operator for poor decisions, which affected the current process event. Instead, the ES provides a direction which to solve the process event. As the operator becomes more familiar with the ES logic, he/she reacts quicker to familiar process stimuli. In general, ES turn choice RT into simple RT. Therefore, the RT get quicker.

Operator empowerment is directly linked to positive shop floor feedback. Empowerment has many elements. An empowered operator knows what is expected of him/her (goals ands measurements are consistent). An empowered operator is given the skills and tools to react to process stimuli. An empowered operator is recognized for successful decision-making and contributes effortlessly in traditional managerial roles. Empowerment success is a combination of training/tools and successful process decisions. Empowerment allows the operator to share with management the decision-making power. Feedback theories suggest that when an operator is truly empowered (that is, self reliant and autonomous) to make shop floor decisions, the decision-making RT will be reduced. Empowerment affects an operator's motivation in a positive manner. Empowerment means that at the lowest level of an organization, individuals are making process decisions. Knowledge based ES provide the tool for operator empowerment. An ES allows the operator to an autonomous decision maker. The ES is the tool that directs the operator to a recommended action. What is clear to the operator is that, the ES algorithm consistently recommends similar decisions to similar sets of process stimuli. A properly developed ES algorithm reflects consistent management decisions to similar sets of process stimuli, which is recognized by the operator. Slowly the operator becomes comfortable making managerial decisions supported by an ES. Operator decision-making RT decreases as the operator becomes more comfortable using the ES.

The effect of decreasing operator decision-making RT (due to positive feedback and empowerment can be explained using three feedback theories: stimulus sampling, information processing and adult learning theories. Stimulus Sampling theory developed a statistical explanation for learning. Stimulus Sampling theory suggests that while learning to respond correctly to a certain stimulus is a correct/incorrect process, the overall is gradual and cumulative. Changes is process stimulus patterns will cause variability in the learning process. Therefore, a reduction in operator decision-making

RT will be gradual if the stimulus patterns are constant. The Information Processing theory suggests learning is achieved using TOTE (Test-Operate-Test-Exit) when analyzing process stimuli. In learning, the goal is to test a response to stimuli and perform an operation to test that hypothesis. The test-operate is continued until success or stopped (exit). The TOTE concept of learning theory provides the basis of problem solving and production systems. An operator will test possible actions (to multiple stimuli) until he/she succeeds. If success is not achieved, the operator will abandon attempts in responding to similar patterns of stimuli. Adult Learning theory suggests that there are two variables which impact learning: personal characteristics and situational characteristics. Personal characteristics include an individual's age, work experience and personal experience. Situational characteristics include full time versus part time learning or required versus voluntary learning. Operator learning depends on the operators experience, age and willingness to learn. Operators using knowledge based ES gradually learn what conclusions the ES makes to a recognized pattern of shop floor stimuli. Over time, operators anticipate the ES decision and start to execute the decision before the ES can react. In essence, the operator has become empowered to make managerial decisions at the point of control. Decision-making RT remarkably decreases as the operator gains more confidence in his/her abilities.

In conclusion, US companies have restructured how they go to business in an effort to keep globally competitive. The restructuring has placed pressure on process quality systems to prevent customers from receiving substandard product. New QA systems have placed decision-making at the point of process control where the shop floor operator now disseminates multiple stimuli previously reviewed by management. The Reaction Times (RT) to the choice stimuli was slow since operators were reluctant to make decisions, which involved traditional management issues. To bridge the decision-making gap and reduce RT to choice stimuli, knowledge based Expert Systems (ES) provide operators with positive feedback, empowerment and learning skills.