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Design and assessment of quality control loops for stable business processes

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ABSTRACT

Due to their open and dynamic character, business processes in lack of adequate feedback mechanisms tend to become unstable in case of unanticipated disturbances or target adjustments. In order to face this challenge and to ensure entrepreneurial quality the implementation of quality control loops is proposed, whose design is derived from cybernetics. The paper discusses requirements for the characteristics of quality control loops and presents a new approach for their assessment implemented in software. The developed tool also serves as a knowledge exchange platform since it provides an opportunity for exchanging standardized control loop elements.

1. Introduction

In light of intense international competition companies must excel in order to prevail. At the same time, they are obliged to decrease production and labor costs while increasing both product quality and productivity. An aggravating factor is the dynamic, crisis-shaken environment in which companies are operating today. Hence they are currently dealing with barely predictable and constantly changing conditions from the planning level down to the shop floor [1,2].

To survive in today's volatile market companies need to improve the robustness of their processes vis-à-vis internal and external disturbances [3,4]. Uncontrolled business processes in lack of adequate feedback mechanisms tend to instability in case of unanticipated disturbances or target adjustments. Furthermore, the dynamic behavior of business processes is scarcely known to companies and it often varies over time, due to personal and organizational changes. The depicted problems are well-known in cybernetics. In order to cope with disturbances in technical systems, closed control loops are implemented. However, control technology proves that wrong or less precisely designed control loops tend to amplify a system's oscillation caused by disturbances and may even result in its collapse. Control theory differentiates between feed-forward and feedback control. Only the second one allows for an adequate compensation of disturbance and sufficient robustness within the controlled system. To cope with the above-mentioned challenges the implementation of closed quality control loops is proposed for business processes [5–7].

As examples such as the Deming-cycle (plan-do-check-act), Six Sigma's DMAIC-cycle (define–measure–analyze–improve–control) and ISO 9001 show, feedback mechanisms are well-known in the field of quality management. Nonetheless, the structured design of quality control loops in companies is still a problem. The above-mentioned circumstances require a new cybernetic approach for the design and assessment of reactive processes in quality management [8–10].

2. Cybernetic approaches

The theory of cybernetics originates from the theoretical – that is, logical, conceptual and mathematical – analysis of self-regulation, autonomy, hierarchy of organizations and functioning in organisms [11]. First Wiener published findings from the application of cybernetics in order to depict complex relations within systems [12]. Early cybernetics, however, did not differentiate between technical (machines) and socio-technical systems (organizations). This, as one of the main points of criticism, led to a new thinking considering the human being as an inherent part of a control system [13]. Subsequently, cybernetic thinking was applied in various branches of science. Today's vast variety of definitions and conceptions for cybernetics reflects this broad application; see [12,14–18]. Kaufmann differentiates between three main branches of cybernetics which have evolved since 1965 – the scientific and technological branch, the humanistic and physiological branch as well as the branch of economic and social sciences – with quality management being a sub-branch of the latter [19]. According to Glaserfeld, cybernetics is 'metadisciplinary, which is different from interdisciplinary, in that it distils and clarifies notions and conceptual patterns that open new pathways of understanding in a great many areas of experience' [11]. Hence, cybernetics provides a language for describing and understanding the dynamic behavior of complex systems. Based on this understanding, cybernetics can be used as a foundation to develop solutions to both technical and organizational challenges.

3. Towards controlled entrepreneurial quality

International standard EN ISO 9000:2005 defines quality as the 'degree to which a set of inherent characteristics fulfills

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requirements' [20]. This basic definition of quality is based upon the degree of the overlap between market requirements and product features. Aside from customer needs, legislative and normative requirements must be taken into account as well. The normative definition of quality expressly includes these in the term 'requirements'. However, this understanding of quality, which is basically a reduction to an alignment of actual and nominal conditions, is insufficient for entrepreneurial practice. In today's dynamic environment, this one-dimensional understanding proves to be insufficient to prevail against competitors [21,22]. Even companies which offer products of high quality are, nevertheless, driven out of the market. Of great importance in this context are the associated costs [23]. Excessive expenditures render sustainable entrepreneurial success unachievable.

3.1. Entrepreneurial quality management

In order to rise to this challenge, the classical understanding of quality has to be extended by an additional dimension. Following an entrepreneurial understanding, a company's performance is comprised of two main components: the sum of all actions determining a company's orientation and direction on the one hand and all available skills and organizational structures of the company, on the other. Consequently, high entrepreneurial quality can only be achieved when customer requirements are squared with corporate skills and corporate orientation. This implicitly leads to a new understanding of quality as the immediate and waste-free fulfilment of market requirements while taking strategic objectives, entrepreneurial conditions and available resources into account. Entrepreneurial practice, thus, necessitates the application of an organizational framework, which allows for an appropriate active influence on company performance.

The Aachen Quality Management Model (Fig. 1) provides such a frame of action for all quality related entrepreneurial tasks and processes, while not being restricted by the traditional definition of quality.

As the model's core element, the Quality Stream, receives market requirements and lifecycle data as input factors and evaluates these. At the same time, the Quality Stream represents the customers' voice and assumes their perspective since the processes contained therein must generate the overlap between customer requirements and company performance. In industrial practice this overlap is generally never complete, due to the existence of influencing factors such as superordinate company principles, company capabilities and economic aspects.

On the one hand, the determination of a company's orientation requires action from the management perspective, which must align the strategic company orientation with the company's abilities. The primary goal is the optimization of operations. It also ensures the coordination of the various business processes so as to take advantage of synergies and preserve resources.

On the other hand, the company perspective focuses on the goals designated by management and the optimization of required processes. This is contingent upon the optimal allocation of internal company resources. Over time this allocation must be evaluated continuously and adapted in accordance with the company's continuous improvement process.

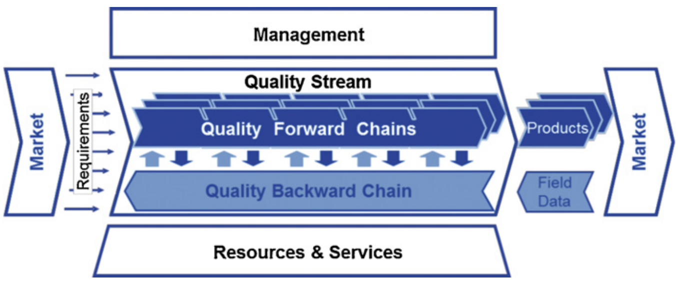

Fig. 1. The Aachen Quality Management Model [6].

3.2. The quality backward chain—a framework for reactive quality management

Within the Quality Stream of the Aachen Quality Management Model, multiple Forward Chains represent all activities for the development and engineering of various product groups and product generations. As opposed to this, the Quality Backward Chain provides a generic feedback structure for the derivation of reactive and corrective measures to improve product and process quality (Fig. 1). In order to connect the Quality Backward Chain to different elements of the Quality Forward Chains as well as to implement closed loop feedback mechanisms, quality control loops are introduced as an approach to the control of entrepreneurial quality.

The global structure of quality control loops is derived from the German standard for control technology DIN 19226 [24]. However, the diversity of business processes and the impossibility to accurately model and predict the behavior of socio-technical systems requires the application of cybernetics in a much broader sense. The consideration of reactive processes in quality management as closed loops allows for the quick identification of weaknesses and potential threats to the stability of individual processes, respectively, the production system as a whole. Following the technical definition of a control loop, a quality control loop can be characterized by its three main elements—the sensor, controller and actuator [25].

The sensor monitors the state of the controlled system and informs the controller about significant deviations from a desired system status. It is distinctive for a quality control loop, that sensors are usually not capable of monitoring the quality of a product or process continuously. Typical quality sensors are reports from employees, failure detections during quality inspection as well as customer complaints or key figure reports.

In case of a detected problem, an appropriate controller is selected, which is responsible for the selection of measures in order to make adjustments to the controlled system. Based on a thorough analysis of the reported problem, corrective actions and, where necessary, containment actions are defined by the quality controller.

Based on selected solutions, a quality actuator is assigned to the problem. Its main task is the implementation of measures within the controlled process and, thus, the closure of the quality control loop itself. Additionally, the actuator is responsible for providing a primary proof of effectiveness by immediately evaluating the success of a measure. A long-term evaluation of measures is – due to the closed loop character – constantly provided by the quality sensor [26].

4. A reference model for quality control loops

The concept of closed loop quality control is suited for all kinds of business processes. For each application the individual tasks of the three control loop elements need to be adapted to the specific situation and should be documented in order to allow for a transparent process. For a practical adaptation of this generic concept, a reference model for quality control loops has been developed within the CORNET project $(QC)^2$—Quantifiable Closed Quality Control.

The main objective of a reference model is 'to streamline the design of enterprise-individual (particular) models by providing a generic solution' [27]. Consequently, reference models are considered as blueprints of best practice, which accelerate the modeling of individual processes by providing a set of potentially relevant processes and structures.

The presented reference model for closed loop quality control is hierarchically structured on three levels (Fig. 2). Within the first and most abstract level of the reference model, main process phases are defined and allocated to the three elements of a quality control loop. The second level of the reference model delivers a cross-functional flowchart which specifies all relevant process