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QC^2 Loop Editor: The Methodology and the Tool for Closing Quality Loops of Manufacturing Enterprises (http://qc2.sztaki.hu/)

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Abstract: To meet the challenge of producing innovative and technologically demanding products economically, companies need the ability of quick and flexible reaction to internal and external disturbances. As a result the companies' objective shifts from maximization of quality to a "controlled quality" aiming for the stabilization of the operative and strategic value creation process. So the main problem of manufacturing enterprises is to dampen the oscillation of product, process and system quality caused by impacting disturbances and ineffective activities and measures due to fuzzy or uncertain information.
The paper describes the new approach for the evaluation of the quality of entrepreneurial control mechanisms within production systems. The prepared and freely downloadable (QC)^2 Loop Editor software (look at: http://qc2.sztaki.hu/) is also introduced that supports with a step by step guideline the evaluation of quality problems, the finding of effective solutions and the formulation of the expected quality measures. As result, it forces companies to close and quantify problematic quality control loops.

Keywords: Quality Control Loop, Closed Loop Quality Control, Control Theory, http://qc2.sztaki.hu/

1 Introduction

To survive in today's volatile market, companies need to improve the robustness of their processes vis-à-vis internal and external disturbances [1]. 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.

International standard EN ISO 9000:2005 defines quality as the 'degree to which a set of inherent characteristics fulfills requirements' [2]. 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. 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.

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 [3].
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 [4].

2 Modell for Quantifiable Closed Quality Control, (QC)²

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’ [5].
The reference model delivers a cross-functional flowchart which specifies all relevant process steps of a quality control loop (activities, decisions and information flows) whereby three swim lanes represent the sensor, controller and the actuator (Fig. 1) [6].
The reference model provides the basis for the (QC)² Loop Manager software with its integrated quality control loop assessment tool.

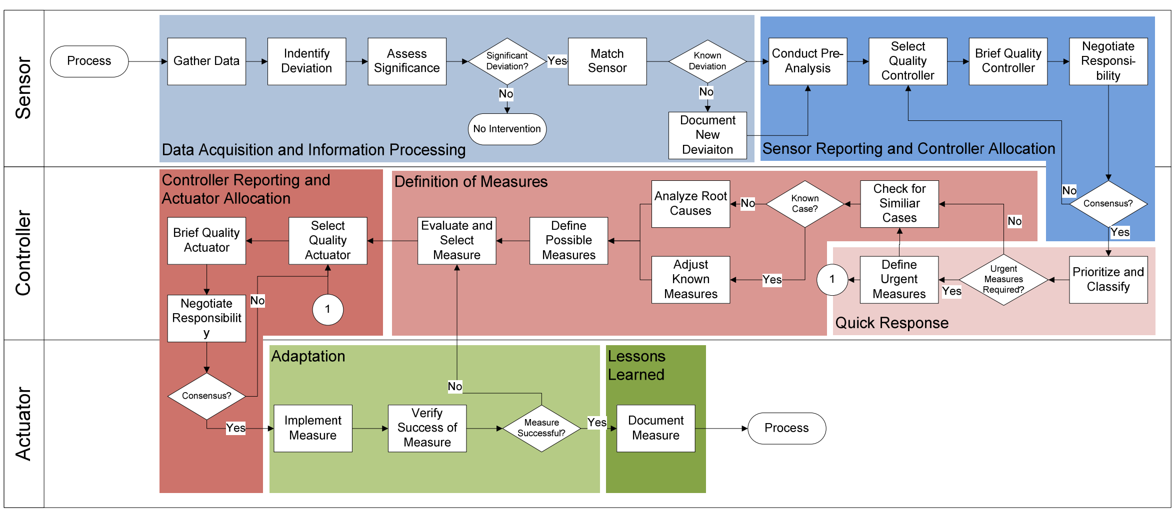

Fig. 1. The (QC)² reference model.

3 The (QC)² Loop Manager – the “one day tool”

The (QC)² Loop Manager (Fig. 2.) is a “one day tool”. This expression represents that, after downloading it in the morning from the http://qc2.sztaki.hu/ website, the user is able to become comfortable and certain in its usage during the first morning hours. The afternoon hours are sufficient in order to completely go through the whole quality loop considered. As a result, at the end of a working day, the analyzed critical quality control loop will already be defined and evaluated together with the related assignments, measures and actions which are allocated to specified positions and individuals. It ensures that the analysed process is transferred from the original, critical level into a quantifiable, closed quality control loop in one day. Experiences mirrored that the most time consuming activities are not related to the understanding and usage of the software but usually arise during the problem related definition of the appropriate sensor, controller and actuator elements. However, this definition process is expressly supported by the application.

The primary part of the (QC)² Loop Manager applies a capability maturity model for entrepreneurial quality control loops. For each step of the reference model, base practices are appointed. Base practices are essential activities leading to the defined target of a process [7]. For the assessment of a quality control loop, an internal or external assessor collects data on the process by various means e.g., interviews with employees or sifting documents. Based on the findings, the characteristics of the analyzed loop are then compared with the aforementioned predefined base practices. Thereby, the fulfillment of each criterion is rated on a scale from one (not fulfilled) to five (completely fulfilled). The assessment model provides an aggregated evaluation of the process maturity level on different levels of detail (process steps, phases, control loop elements). Additionally, strengths and weaknesses of the process are correlated with different characteristics of the quality control loop, e.g. documentation, process transparency or the ability to monitor process performance. The realization of an assessment easily reveals structural and operative weaknesses within the reactive processes of a company which, otherwise, implicate poor performance of the quality control loop and may result in instable business processes.

Simultaneously, exploration questions aim at collecting detailed information on the adaptation of the generic reference model to company-individual and process-oriented constraints. Based on the acquired information, a description of the sensor, controller and actuator is extracted, which serves as documentation and enables companies to trace back adaptations to their processes.

The concept of the software combines the assessment of a quality control loop with its documentation and step-by-step improvement. The tool can additionally be used to efficiently guide the user through all the steps which are required for defining a new quality control loop. Consequently, the primary procedure is the evaluation of the process. Documentation of the control loop characteristics is incorporated into the different stages of this analysis.

Initially, the controlled system has to be defined.

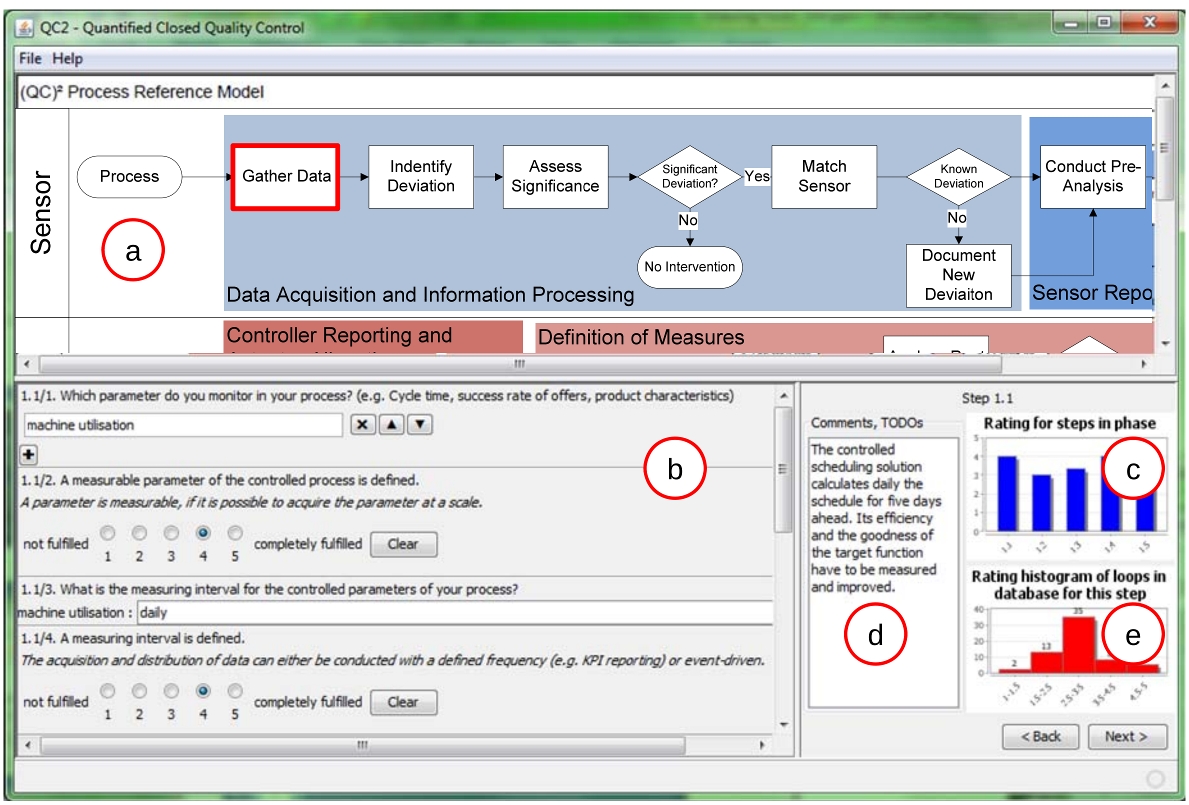

Fig. 2. The (QC)² Loop Manager.

For this purpose, the associated business process of the control loop has to be appointed. Processes can be selected from a previously defined, hierarchical process list consisting of the main processes of a typical manufacturing company. This specification will help later on to exchange and benchmark control loop definitions, using the community based collaboration platform.

The graphical representation of the (QC)² reference model and the interactive selection highlight process steps and form an intuitive graphical user interface which guides through the entire assessment, helping the user to close the quality control loop (Fig. 2-a). The software hence leads the user through consecutive lists of questions which are related to individual tasks in the quality control loop. Each list consists of two kinds of information objects (Fig. 2-b). Specific, task-related assessment questions with a rating scale of five form the first question type. The second type determines and stores names, parameters and descriptions of the attributes of the selected quality control loop task. The questions relate to the elements and process steps of the generic reference model and are thus applicable to all kinds of quality control loops. Prompt comments and assignments are also to be documented for supporting the on the field documentation of the explored improvements (Fig. 2-b).

Based on the answers to the rating questions, the maturity level of the whole quality control loop, its elements and process steps is calculated and the software delivers immediate feedback to the expert (Fig. 2-c). Thus, this feature highlights the impact of individual, specific answers upon the aggregate rating of the whole quality control loop, its main elements and process steps.

Having assessed and defined all elements of the quality control loop, the solution supplies an overview evaluation with clear appointments of existing weak points and appropriate guidance (Fig. 3.). Consequently, the user can identify the places where a quality control loop has to be revised and improved.

Fig. 3. Two evaluations of the some quality control problem with around one and a half year difference.

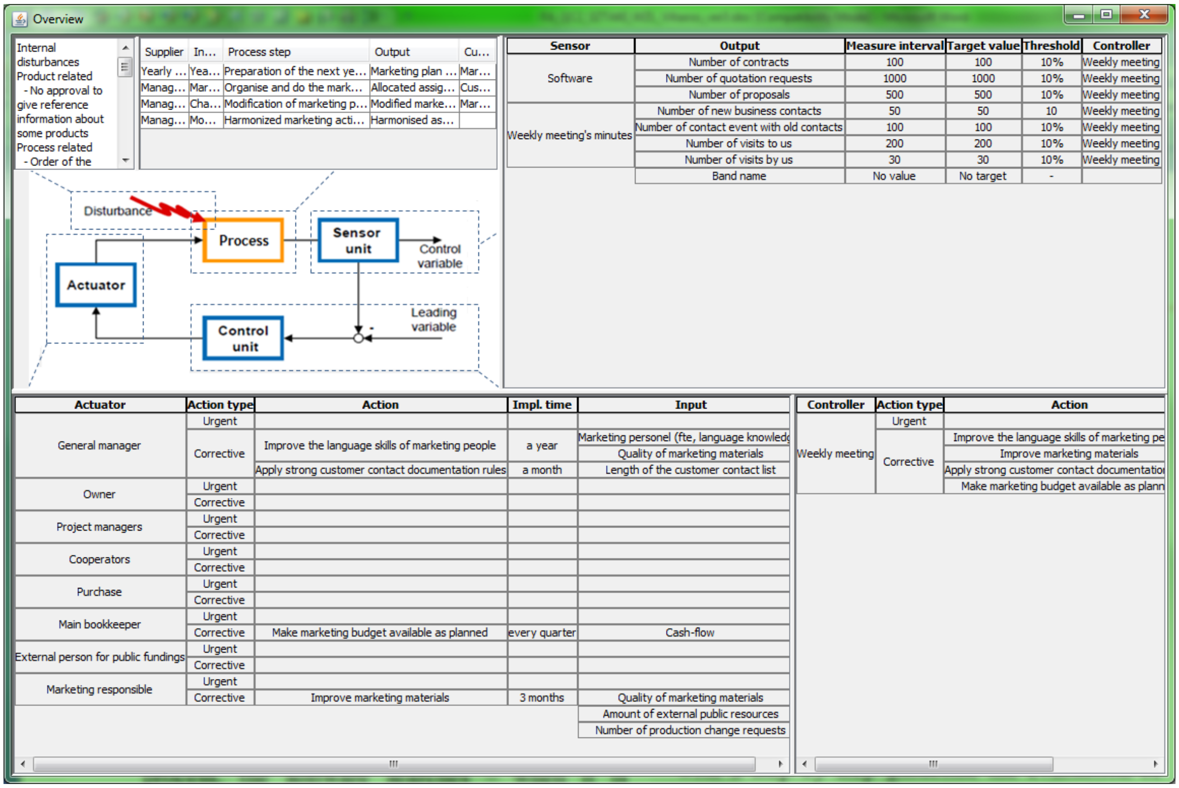

Fig. 4. Content overview of a quantifiable, closed quality control loop in marketing.

After the application of appropriate changes or adaptations, the improvement effect can be calculated. This feature makes the control loop quantifiable and enables the continuous improvement of existing quality control loops. The inherent versioning system enables tracking the improvements in time and in the defined content, consequently, it is possible to measure the resulting increase in performance of the enhanced quality control loop. Fig. 3. represents an example of two comprehensive evaluations of the same quality control loop of a small-, and medium sized company where the first evaluation occurred around one and a half year before the second one. The first analysis (Fig. 3. top-left) introduced many changes and new activities for the applying company. The resulted improvements are clearly represented in the second evaluation view (Fig. 3. bottom-right), moreover the comparison of the two figures clearly represents the original fields of weaknesses and the improved control loop, too. The depicted activities enabled the applying company to successfully manage and improve its marketing process. Moreover, this development substantially contributed e.g. to an increase of the company's number of proposals by around 15% (effectivity improvement) and the customer order ratio by even 50% (efficiency improvement). These positive effects significantly improved the company's strategic position and contributed to a nearly doubled company income.

The (QC)² Loop Manager software represents also the quantifiable, closed quality control loop in a comprehensive view, similar to the traditional, technical control loops (Fig. 4.). In this picture, all of the main, basic elements of the introduced loop are shown that can help the applying experts to overview and further improve the prepared solution. Their working mechanism will become stable and controlled due to the new feedback mechanism and result in a stable solution in spite of existing external and internal disturbances having dynamic behavior.

4 The (QC)² Community: http://qc2.sztaki.hu/

Besides the aforementioned aspects of the introduced cybernetic approach to quality management – the reference model and the assessment tool – the developed (QC)² Loop Manager software was extended with further collaboration and information exchange functions. To encourage the cooperation among the quality control loop experts, a central service is available to evaluate loops or loop elements in comparison to the control solution defined by other companies and experts. When defining or assessing a quality control loop of a preselected, standardized process, the software searches – when it is allowed by the user – for other control loop definitions available in the central database. Ratings of centrally available control loop elements for the same process are then highlighted (Fig. 2-e). This service indicates that it is possible to view and download good practice examples from the central database. Information sharing is possible in the opposite way, too. Having defined a complete loop or a loop element, the expert is proposed to upload a good solution as an example to the central database in order to help others with suggestions and possibilities. That way the central service is a continuously growing set of good and best practice quality control loops and elements. This will encourage the emergence of a live community for quality control loop experts in manufacturing companies. Should a company or an expert not intend to participate in this knowledge exchange, the software tool can also be used as a simple stand-alone solution.

4 Conclusion

The paper introduced the new approach for the evaluation of the quality of entrepreneurial control mechanisms within production systems. The prepared and freely downloadable QC2 Loop Editor software is also introduced that supports with a step by step guideline the evaluation of quality problems, the finding of effective solutions and the formulation of the expected quality measures.

The paper has shown that the structured design and analysis of quality control loops, supported by an appropriate software solution, can bring numerous immediate and long-term benefits for companies operating in highly dynamic markets while dealing with various internal and external disturbances to the quality of products and processes.

The $(QC)^2$ Loop Manager is a freely downloadable “one day tool” and the extended information sharing services are available at: http://qc2.sztaki.hu/ [8].

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References:

[1] Jovane, F., Koren, Y., Boër C.R., Present and Future of Flexible Automation: Towards New Paradigms, Manufacturing, *Annals of the CIRP*, 52/2., 2003, pp. 543-560.

[2] *EN ISO 9000:2005*, Quality Management Systems – Fundamentals and Vocabulary, Trilingual Version, 2005, p. 18.

[3] Schmitt, R., Monostori, L., Glöckner, H., Stiller, S., Viharos, Z., Designing Closed Quality Control Loops for Stable Production Systems, *Proceedings of 55th EOQ Congress*, 2011, paper nr.: 11.1.3.

[4] Hon, K.K.B., Performance and Evaluation of Manufacturing Systems, Manufacturing, *Annals of the CIRP*, 54/2., 2005, 139-154.

[5] Rosemann, M.; van der Aalst, W. M. P, A Configurable Reference Modelling Language, *Information Systems*, 32/1., 2007, pp. 1-23.

[6] Schmitt, R., Monostori, L., Glöckner, H., Viharos, Z. J., Design and assessment of quality control loops for stable business processes, *Annals of the CIRP*, http://dx.doi.org/10.1016/j.cirp.2012.03.055, 2012, in print.

[7] *ISO/IEC 15504-1:2004*, Information Technology – Process Assessment – Part 1: Concepts and Vocabulary, 2004, p. 7.

[8] http://qc2.sztaki.hu/: *the website for downloading the free $(QC)^2$ Loop Manager software* and for becoming linked to the information exchange community.