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Quality Value Stream Mapping

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Abstract

Companies in the manufacturing industry today are faced with increasing challenges with respect to cost effectiveness, lead time and quality of the production system. Dealing with these contradictory goals, an important task is the selection of suitable solutions for the integration of inspection processes within the process chain, which are necessary to ensure the required production quality. For this, supportive and easily applicable planning techniques are required to analyze and design the configuration of a respective process chain. Value Stream Mapping (VSM) is a state of the art tool which is very often used for this by professionals. It, however, is not capable of addressing the issue of a suitable integration of testing processes within the process chain. Yet, this provides valuable potential to facilitate the identification of effective testing equipment, testing strategies and quality control loops. Therefore, in this article an innovative approach called Quality Value Stream Mapping (QVSM) is presented. Based on the design elements of VSM, it provides a suitable tool for the visualization, analysis and design of quality assurance measures within process chains in manufacturing. The implementation of the developed approach is exemplarily shown for a complex value chain of a manufacturer in the electronic industry.

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1. Introduction

Nowadays due to changing customer requirements, there is an increase in product variances and fluctuating order volumes. These challenges are accompanied by shorter product life cycles, intensified cost pressure and rising quality requirements [1]. To remain competitive, manufacturing companies are forced to simultaneously optimize their production in terms of cost efficiency, lead time and quality. Especially in the automotive industry growing production volumes and high quality requirements involve difficult challenges in the field of quality assurance. Thus, easily applicable planning techniques are required to analyze and design the configuration of a respective process chain in order to deal with quality issues. In this article the approach of Quality Value Stream Mapping (QVSM) is introduced which combines the method of classical Value Stream Mapping with the field of quality management.

The article is structured as follows. In chapter 2 existing approaches in the field of process and quality oriented analysis and visualization of production systems are stated. Hereafter, the developed method of Quality Value Stream Mapping is elaborated in chapter 3 and an exemplary industrial application demonstrated in chapter 4. Finally, chapter 5 concludes with a summary.

2. State of the Art Methods of Process Analysis and Quality Management

2.1. Business Process Analysis

A business process is a collection of activities taking one or more kinds of input and creating an output that is of value for the customer [2]. There are various approaches in the field of Business Process Management (BPM) dealing with the analysis, design, configuration, enactment and evaluation of processes [3]. The modeling of the process flows can be realized by means of different languages, e.g. petri nets [4] or the Business Process Modeling Notation (BPMN) [5].

The approaches of business process analysis cope with the identification of weaknesses and potentials for improvement [6]. Improvement objectives of these approaches include a reduction of costs, process times and defect rates. Yet, none of the approaches specifically deals with the visualization and analysis of quality defects in production processes.

2.2. Value Stream Mapping

Value Stream Mapping (VSM) is a simple but effective method used for the illustration and redesign of value streams. The method originates from the Toyota Production System [7] and consists of two main phases: value stream analysis, in

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which the current value stream is visualized, and value stream design, in which sources of waste within the production process are uncovered and reduced.

The method targets at a lean, dynamic and customer controlled value stream, with short lead time and reduced inventories [8, 9]. It is widely used in industrial practice. However, within classical Value Stream Mapping quality defects are only addressed in a very rudimentary manner. Inspection processes, their characteristics and the present quality control loops are not considered in the visualization.

2.3. Process Failure Mode and Effects Analysis (FMEA)

Process FMEA is a systematic method to analyze defects of manufacturing and assembly processes. According to the VDA framework [10] the method consists of the five steps structure analysis, function analysis, failure analysis, measure analysis and optimization. Within the structure analysis the considered process chain is systematically structured into individual process elements. In the functional analysis, for each element of the structure analysis, activities are assigned necessary for proper function of the process chain. Within the failure analysis the occurrence of defects within the manufacturing processes is determined. In the measure analysis potential defects are classified by the concept of risk priority numbers (RPN). Depending on the RPN, optimization measures to reduce quality issues can be implemented [11].

Process FMEA is a very effective and widely used tool to identify causes of defects and appropriate prevention measures. Yet, it does not include any visualization of the process chain regarding the occurrence of defects, inspection processes or quality control loops. Neither, quality related costs are taken into account.

2.4. Process Mapping

Process Mapping is an established tool for the visualization of processes. In comparison to process models of Business Process Analysis, Process Mappings contain considerably more details [12, 13]. A Process Mapping is a graphical illustration that shows a sequence of activities using flowchart symbols. A further objective of a Process Mapping is to identify output variables (customer critical features) and input variables (impact on critical features) of each process step. Additionally, controllable factors (e.g. rotational speed) and disturbance variables (e.g. vibrations) are also regarded [12].

Process Mapping is commonly used as a tool within the Six Sigma methodology. In the DMAIC (Define-Measure-Analyze-Improve-Control) circle it is applied as a process visualization method within the Measure phase.

Process Mapping is a very valuable method for the visualization of process flows taking into account the aforementioned key figures. Yet, it does not cope with the quality-related aspects of defect rates, inspection processes, quality control loops or quality related costs.

2.5. Stream of Variations

Stream of Variations (SoV) is a generic math model for the analysis and performance prediction of multistage manufacturing processes in which product geometry and dimensional variation are of critical importance. SoV integrates key processes, product characteristics represented in CAD/CAM models, information on the process layout, the sequence of operations and the production system observability into a unified framework [14, 15].

SoV is an effective measure to improve quality by means of variation reduction. Yet, it is mathematically very complex and does not focus on process visualization. Furthermore, quality related costs are not analyzed in detail.

In sum, the state of the art shows that there are various methods for the visualization and analysis of processes. Yet, none of these approaches is capable of addressing a suitable integration of inspection processes, quality control loops and quality-related costs within a method for the visualization and analysis of multistage manufacturing processes.

3. Method of Quality Value Stream Mapping (QVSM)

The method of quality Value Stream Mapping addresses this issue. QVSM is a procedure model, complementing classical Value Stream Mapping with specific quality related elements to systematically visualize, analyze and improve quality issues within a process chain. In addition to the production processes and flow of materials, present quality defects, quality inspections and quality control loops are considered. Based on this, the status of the quality control along the process chain is evaluated in terms of key indicators with regard to quality and quality-related costs.

Similarly to conventional VSM, in the concept of QVSM the term “value” is defined as the opposite of waste. However, due to the special focus on quality control in QVSM, the reduction of defects as a type of waste and the identification of suitable measures for this are emphasized.

The presented method of QVSM consists of four phases: preparation, quality value stream analysis (QVSA), quality value stream design (QVSD) and implementation. In the following, these phases are elucidated in detail.

3.1. Preparation

Similarly to conventional value stream analysis, QVSM starts with a preparation phase providing a basis for further recording and analysis of the value stream. The preparation phase consists of three steps (Fig. 1).

First, a product or product family to be analyzed is selected to reduce complexity as far as possible. Second, fundamental process knowledge of the process chain to be considered is obtained, e.g. by means of a SIPOC analysis [16]. Third, the quality targets of the analysis are defined, e.g. a reduction of defects or a decrease of the quality-related costs.