Holistic Methodological Model for introducing Industrial Quality Management Methods to Manufacturing in Small and Medium Sized Enterprises

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Abstract

In the past, management decisions in small and medium-sized enterprises (SMEs) to introduce new QM-Methods were often based on external influences such as customer demands or regulatory requirements. Furthermore, quality control loops to ensure that the introduced QM-Method is effective were not installed. Hence, no methodology was made available to SMEs to support management with the selection, the introduction and the effectiveness evaluation of industrial QM-Methods. The Holistic Methodological Model for introducing QM-Methods is based on the Deming Circle. It encompasses three modules: a Maturity Level Module to analyze the needs of manufacturing in an SME regarding QM; a Level-oriented Introduction Module to simplify complex QM-Methods so that the inhibitions by the workforce can largely be reduced and an Effectiveness Module to continuously evaluate the economic aspects of the QM-Method. These modules can be applied throughout the lifecycle of industrial QM-Methods.

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1. Introduction

As of 2011, over one million companies have been awarded the ISO 9001 certificate, displaying their successful set-up of a QM-System. While large companies have no problem providing the necessary resources for a fully integrated QM-System, small and medium-sized companies (SMEs) often struggle to provide enough manpower for a QM-System including complex industrial QM-Methods. Especially in industrial manufacturing, where the shop floor workforce is often poorly educated, the introduction of complex QM-Methods often lead to high quality invest, low workforce acceptance and finally little effectiveness of the QM-Method.

In the past, management decisions in SMEs for introducing new QM-Methods were often based on external influences such as customer demands or regulatory requirements. Seldom did management analyze their existing QM-System and identify areas of improvement to then choose the adequate QM-Method.

Furthermore, when finally deciding to introduce a new QM-Method, no quality control loops were installed. As opposed to all other investment areas within industrial manufacturing, the investment into a QM-Method was not monitored and evaluated. At best, the installed quality control mechanisms such as ppm-rate or number of customer complaints were further monitored. However, no connection to the introduction of the QM-Method were made. In addition, when an economic analysis of the company became necessary, the introduced QM-Methods were often disposed of, since no evident benefits could be displayed to management.

Hence, no methodology was made available to manufacturing SMEs to support management with the selection, the introduction and the effectiveness evaluation of industrial QM-Methods.

2. Methodology

The Holistic Methodological Model for introducing QM-Methods is based on the Deming Circle. It encompasses three modules: (1) a Maturity Level Module to analyse the needs of manufacturing in an SME regarding QM; (2) a Level-oriented Introduction Module to simplify complex QMMs so that the inhibitions by the workforce can largely be reduced and (3) an Effectiveness Module to continuously evaluate the economic aspects of the QM-Method.

While the model can be applied to any QM-Method, it always needs to be adapted to meet the content, aims and targets of each QM-Method.

When entering the Holistic Methodological Method, a QM-Method must already be in focus. This is important, because companies will continue to be confronted with external influences such as audit requirements and customer requests when contemplating the introduction of a new QM-Method. Although it would be much more effective to continuously review one’s own QM-System and identify improvement areas, reality shows that most QM-Methods are introduced due to external influences.
The model was realized and tested with a number of SMEs that were given the task of introducing the QA-Matrix. The QA-Matrix is a complex industrial QM-Method. It systematically supports the shop floor workforce during the manufacturing process when reducing product and process failures. It’s set up increases transparency within manufacturing by visualizing production lines, quality gates and customer complaints.

2.1. Maturity Level Module

Before entering the Maturity Level Module, an SME must have one’s sight on a new QM-Method. Before planning the introduction of the new method, the Maturity Level Module supports the company with a complete analysis of the company’s needs in regards to QM.

The Maturity Level Module can be described as the PLAN-Phase within the Deming Cycle. It is based on an adaptable questionnaire, consisting of five parts (Figure 2). These five parts are completed during an audit-type visit by qualified personnel.

The first part entitled company structure examines the size of the SME, the complexity of manufacturing as well as the current shift-model within manufacturing. The larger and more complex manufacturing processes are, the more necessary a QM-Method becomes that supports transparency, such as the QA-Matrix in focus.

The second part evaluates the manufacturing KPIs. Up-to-date quality criteria such as ppm rate, scrap rate, re-work rate and number of internal/external customer complaints is pulled out. The KPIs are compared with internal quality criteria from past months/years as well as industrial standards. While the actual criteria can often be lower than industrial standard, it is important to observe a continuous upward trend over time. If this is not the case, a QM-Method to continuously monitor the progress of internal/external customer complaints – such as the QA-Matrix – can help improve quality criteria.

The third part of the questionnaire entitled Evaluation of existing QM-Methods evaluates the existing QM-Methods within the SME in order to see which QM-Methods have similar quality targets and quality content as the new QM-Method. In order to evaluate the existing methods, the new QM-Method needs to be analyzed in its thoroughness. All elements of the new method are singled out and each element is connected with a quality target. These quality targets are then integrated into the questionnaire to support the analysis.

For the QA-Matrix, the following quality targets were singled out and then integrated into the questionnaire: “Do QM-Methods exist in the SME that support the …

- visualization of manufacturing steps
- visualization of quality gates
- visualization of internal/external customer complaints
evaluation of effectiveness of quality gates
visualization of measures for failure identification
visualization of measures for failure prevention
effectiveness analysis of measures" 

The thorough analysis of the existing QM-Methods has several advantages. For one, management can better understand the quality targets of the individual methods. On the other hand, it can identify overlapping QM-Methods that have similar quality targets and therefore identify installed multiple resources where they are not needed.

The fourth part of the questionnaire evaluates the knowledge management within the company. It consists of informal interviews of selected shop floor workers, checking to see how well the work force is informed about quality issues. The informal interviews are later summarized by the interviewer, who then completes the questionnaire by evaluating the given answers. Questions can be:

- Is the workforce familiar with all process steps for selected products?
- Is the workforce informed about pending internal/external customer complaints and the measures planned/conducted?
- Is the workforce integrated into the problem-solving process?

The better the workforce is informed regarding quality issues, the less it becomes necessary to introduce the QA-Matrix, a QM-Method geared at improving transparency within manufacturing processes and regarding internal/external complaints. On the other hand, the less information has been distributed among the work force, the more necessary a transparency tool such as the QA-Matrix becomes.

The fifth and final part of the questionnaire permits management to give a subjective estimation as to the effectiveness of the installed QM-System. Aside from a verbal comment, management can choose between three evaluation boxes:

- Good effectiveness
- Effectives needs room for improvement
- Poor effectiveness

It is important that management accompanies the auditor during the entire audit. This way, a better understanding of the QM-system and its quality targets can be achieved. This again generates a more honest subjective estimation, based on the results of part one through four of the questionnaire.

For the QA-Matrix, it becomes evident that the larger and more complex an SME is, the more the SME requires transparency within manufacturing processes (“Does the workforce know why selective measures are important?”), quality gates (“Does the workforce understand what the goal of the individual quality gates are?”) and internal and external customer complaints (“Is the workforce informed about customer complaints? Is the workforce informed about the progress when concluding a customer complaint?”).

When concluding the Maturity Level Module, the SME receives a recommendation regarding the introduction of a new QMM. It offers three generic suggestions:

(A) No demand for a new QM-Method: The analysis shows that the existing QM-Methods already fulfil all quality targets that the new QM-Method has to provide. In this case, an additional QM-Method is not necessary.

(B) Modified demand for new QM-Method: Often, many elements of the new QM-Method already exist with implemented QM-Methods within the QM-System. In this case, it does not make any sense to install a completely new method, since this will result in multiple resource input. In this case, the SME has two possibilities. Either the company can expand its existing QM-Methods to encompass the missing quality targets, or the new QM-Method can be installed and other (inferior) QM-Methods can be de-installed within the SME.

This decision should be made mutually, integrating management and external sources (i.e.
auditor/customer) into the decision making process. The main goal should be to generate the best possible and most efficient solution for the company.

**(C) Introduction of new QM-Method recommended:** In this case, the Maturity Level Module analysed deficits within the QM-System of the company in regards to the identified quality targets. Therefore, the introduction of the new QM-Method is recommended.

While suggestion (A) and (B) lead to an exit of the Holistic Methodological Model, suggestion (C) leads to the introduction of a new QM-Method and within the model to the next module.

### 2.2. Level-oriented Introduction Module

The Level-oriented Introduction Module must be designed individually for each industrial QM-Method, since each method has a different content, different target groups within the workforce and different quality targets. Its main goal is to simplify existing QM-Methods by disassembling the components of the method and gradually introducing them to the workforce, enabling the workforce to slowly become acquainted with the different components before putting them back together. The number of modules and the number of options can therefore differ, depending on the complexity of the QM-Method.

For the QA-Matrix, each SME is given three options when introducing the model (Figure 3):

- **Option 1** consists of a one-time complete installation of the new QM-Method, in this case the QA-Matrix. This is a conventional introduction. It includes a high quality invest and a short introduction time. Option 1 is often chosen due to external influences such as a potential new customer order that is connected with the installation of the new QM-Method.
- **Option 2** allows the QM-Method to be disassembled into two parts, giving the workforce more time to understand the set-up of the new method. For the QA-Matrix, the first module introduces a complete matrix to the workforce, which increases manufacturing transparency and a systematic to easily follow-up on internal/external complaints. The second module introduces a complex traffic light system for monitoring the pending and closed complaints. A green traffic light signals a closed customer complaint, a yellow traffic light a pending customer complaint with corrective actions that partially still need to be implemented, and a red traffic light signals a customer complaint with no identified corrective actions implemented.
- **Option 3** is the recommended three-module introduction of the QA-Matrix. Module 1 and 2 simplify the complex set-up of the matrix in Option 2. Module 1 introduces transparency methods for manufacturing and quality gates, module 2 then expands the methodology by monitoring existing internal/external complaints. Module 3 remains the same, introducing the complex traffic light system. Although the
introduction time can increase up to one year, this three module introduction allows the workforce to slowly become familiar and work with the different modules of the QA-Matrix. This again creates an increased acceptance of the method within the workforce.

2.3. Effectiveness Module

The Effectiveness Module consists of two parts: an Effectiveness Analysis and an Economic Control. Both modules play an important part when analyzing the effectiveness of the new QM-Method.

The Effectiveness Analysis evaluates how an SME has integrated the QM-Method into its QM-System. Often, it is not sufficient for management to train the workforce, install the QM-Method and occasionally review documents regarding the QM-Method. Management must understand and evaluate how a QM-Method has been integrated into the QM-System. To ensure a thorough understanding, the following KPIs should be installed and reviewed on a regular basis:

- **Coverage rate**: The number of products and/or manufacturing lines with installed QM-Method should be monitored, comparing them with the number of products and/or manufacturing lines without installed QM-Method. Percentages should be reviewed on a regular basis.

- **Penetration rate**: The number of meetings based on the new QM-Method should be evaluated regularly for each product and/or manufacturing line. This gives management a better understanding regarding products / manufacturing lines with good method integration (many meetings) as opposed to products / manufacturing lines with poor method integration (few meetings). For example, it is interesting to compare the performance of products / production lines with a weekly meeting basis against those with meetings on a 3-month basis.

- **Update frequency**: This KPI is geared towards the actual QA-Matrix print-outs and evaluates the number of updates (new versions and print-outs) the QA-Matrix has in each product / manufacturing line. This KPI shows the actual penetration rate of the QA-Matrix within each product / manufacturing line. The more often the QA-Matrix is updated, the more often it is used a meeting basis.

Only by monitoring the KPIs can management tell if a QM-Method is “alive” within the company. Otherwise, there is an acute danger of having installed a QM-Method that is only updated when management and/or external contacts inquire about it.

The Economic Control is the final module within the method. It calculates the costs for installing the QMM against qualitative and quantitative benefits.

The costs can be divided into the following:

- **Training costs**: Costs for training the workforce in regard to the QM-Method. This includes seminar costs as well as room and board.

- **Design and maintenance costs**: This includes costs for hardware (printouts, information boards) and software (support software) necessary to implement a QM-Method within an SME.

- **Meeting costs for QM-Methods**: Each QM-Method must be implemented in a team. The costs for the team meetings can be calculated by multiplying the hourly wages with the personnel present at the meeting.

The quantitative benefits are easily monitored and are often part of the existing KPIs within a QM-System. It is important that these KPIs show an improvement over time, so that the benefits of the new QM-Method (and other implemented measures) become visible:

- Number of repetitive failures
- Number of failures identified at failure origin
- Scrap rate / re-work rate
- Number of internal / external complaints

The qualitative benefits are most often more difficult to monitor, since they require (anonymous) feedback of the workforce on a regular basis, which is usually very time- and work-consuming.
For the QA-Matrix, the following qualitative KPIs should be monitored on a regular basis and should show an improvement over time:

- Quality awareness of workforce
- Transparency regarding failures
- Transparency regarding processes
- Interdisciplinary teamwork
- Workforce motivation
- Workforce qualification

All elements within the Effectiveness Module must be conducted successively (Figure 4). At first, it analyses the costs of the QM-Method throughout the evaluation period (i.e. one year). After a small time lag necessary to establish the QM-Method within the SME, it reviews the KPIs for qualitative and quantitative benefits at the beginning and at the end of an effect period (between six and twelve months). Finally, at the end of the effect period, it also analyses the three KPIs from the Effectiveness Analysis. While the costs and benefits lead to an economic evaluation of the QM-Method, the Effectiveness Analysis can give first indications if the QM-Method is applied correctly within the SME – and give first suggestions regarding optimization possibilities.

![Figure 4: Chronology within the Effectiveness Module](image)

2.4. Deming Circle

The Holistic Methodological Model is based on the Deming Cycle. This means that the Model should not have a one-time complete run-through, that the results should be documented and that management should then return to “business as usual”. It means that the Model offers several control loops to ensure a continuous evaluation and an ongoing improvement of the QM-Method and the affected processes.

The Maturity Level Module is based on an audit, which should be completed on a regular basis. It analyses the efficiency of existing QM-Methods and identifies areas of improvement. This audit should be completed on a regular basis. Each new analysis again evaluates all aspects of the QM-System, including obvious and not-so-obvious changes in the general framework of the SME as well as in individual products / manufacturing processes. This again might trigger new decisions and actions when deciding on the installation of new industrial QM-Methods.

The Level-oriented Introduction Module simplifies existing QM-Methods by disassembling the components of the method and gradually introduces them to the workforce (Plan). The workforce then is given sufficient time to
become acquainted with the components (Do). If certain components lead to comprehension difficulties and therefore to inadequate acceptance rates within the workforce (Check), management can easily re-train these components (Act). With the easy-to-handle content of the components, it becomes much easier for management to pinpoint the acceptance difficulties and quickly establish training and practice sessions – before a general resentment of the QM-Method has settled within the workforce.

The Effectiveness Module consists of two parts. The effectiveness analysis offers KPIs to ensure that the QM-Method is adequately established within the QM-System (“Are we doing things right?”). The Economic Analysis consists of the bottom line for management: the costs of the QM-Method versus the benefits (“Are we doing things right?”). If these results are not conform with the original economic objectives of the SME, it is often recommendable to review the effectiveness KPIs to ensure if the QM-Method has been integrated into the QM-System correctly.

3. Conclusions

The Holistic Methodological Model offers support mechanisms for management throughout the lifecycle of an industrial QM-Method. After receiving an external request to install a new QM-Method, management can run through the model in order to receive action recommendations throughout the different phases of the QM-Method.

The Holistic Methodological Model is based on the Deming Circle. It encompasses three modules: a Maturity Level Module to analyze the needs of an SME regarding QM; a Level-oriented Introduction Module to simplify complex QM-Methods so that the inhibitions by the workforce can largely be reduced and an Effectiveness Module to continuously evaluate the economic aspects of the QMM. Each Module has an integrated Plan-Do-Check-Act Cycle. Furthermore, a regular run-through of the entire model can support SMEs when evaluating their installed and soon-to-be-installed QM-Methods.

The Maturity Level Module consists of an audit, based on an adaptable questionnaire. The first part is a general company analysis with special focus on quality criteria, the second part analyses the effectiveness of existing QM-Methods. When concluding the Maturity Level Module, the SME receives a recommendation regarding the effectiveness of its QM-System and the potential necessity of a new QM-Method.

The Level-oriented Introduction Module must be designed individually for each industrial QM-Method. Its main goal is to simplify existing QM-Methods by disassembling the components of the method and gradually introducing them to the workforce, enabling the workforce to slowly become acquainted with the different components – and therefore ensuring high workforce acceptance.

Finally, the Effectiveness Module consists of two parts: The Effectiveness Analysis evaluates how a company has integrated the QM-Method into it’s QM-System by defining important KPIs. The Economic Control calculates the input for installing the QM-Method against qualitative and quantitative benefits. Both modules provide important input for management when deciding how and why to further invest in the QM-Method.

The Holistic Methodological Model, consisting of its three modules, provides management support throughout the important phases of a new industrial QM-Method. It offers SMEs a new instrument to monitor and evaluate investments into QM-Methods – and to continuously improve its actions, based on the Deming Cycle.

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