UNIUNEA EUROPEANĂ

GUVERNUL ROMÂNIEI
MINISTERUL MUNCII, FAMILIEI, PROTECȚIEI SOCIALE ȘI PERSOANELOR VÂRSTNICE
AMPOSDRU

Fondul Social European
POSDRU 2007-2013

Instrumente Structurale
2007-2013

MINISTERUL EDUCAȚIEI NAȚIONALE
OIPOSDRU

Universitatea "Lucian Blaga" din Sibiu

# “LUCIAN BLAGA” UNIVERSITY OF SIBIU

# FACULTY OF ENGINEERING

# DOCTORAL THESIS SUMMARY

# “QUALITY IMPROVEMENT USING POKA YOKE SYSTEMS”

Scientific coordinator:
***Prof.univ.dr.DHC ing.*** **OPREAN Constantin**

***ing.*** **MĂGDOIU Alex**

**SIBIU 2014**

# Contents

# 1 Introduction

In a world which is in a constant motion, where the ability to be one step ahead of the competition is crucial, quality takes a leading role in any organization's strategy. When the constant development promotes globalization by reducing distances and removing borders, and consumers have access to products from all markets and fields, there is an increasing pressure on organizations in different areas to reduce costs and improve products, services and processes so that the quality of the organization's goods or services can be competitive on the global market. All industry leaders understood these issues early and have adapted by integrating quality in all direct or indirect productive activities by adopting and implementing TQM (Total quality management) principles and tools. One of the most important aspects of this concept, namely the avoidance of human error becomes a key point, and this can be achieved using relatively simple techniques that do not require major investments.

This paper aims to conduct a study on the concept of quality and mainly on its improvement. Emphasis will be placed on one of the most popular techniques in this field, namely poka yoke, a method developed by the Japanese engineer Shingo Shigeo in the 60s, as well as new insights into this technique that revolutionized the quality systems around the world, starting from the basic concept created by the founder of this method by presenting the disadvantages of an improper implementation of this method in the automotive industry, but also by broadening the original concept to other areas and processes such as medical field, services or everyday life. Because of the system's diversity, its spreading within the automotive industry and especially with its new applications both in the automotive field but also in other industries or human activities, the poka yoke theme fascinated and became a very interesting subject, which plays the main role in this paper.

**The main objective** of this study is:

- *creating a generic model for poka yoke systems.* Firstly the model must be applicable to any system, regardless of its complexity or area of application. By applying the model to a poka yoke device, an analysis of the effectiveness of the implementation of such a system can be performed, taking into account not only the functionality of its components, but also the disruptive factors that can act on them.

**The secondary objectives** that derive are:

- *developing a quality improvement model throughout the product lifecycle*. By defining the phases of a product's life cycle which are relevant in terms of quality construction and associating to each of them various techniques and tools with big impact from the palette developed over decades by various quality engineers, a model for improving the quality of products and processes can be created which will include both the early stages of goods' life but also the service and recycling phases;

- *studying various poka yoke systems developed along the production flow of an electronic components manufacturer from the automotive industry*. The presentation of these systems will support the main objective of this work and will help obtaining other contributions and highlighting the importance of the poka yoke thematic for the contemporary era in general and the automotive industry in particular.

Through this work, focused on improving quality with poka yoke systems it was attempted on one side to define the quality concept, to present its development from the ancient times to the contemporary era, emphasizing then the most advanced form of this concept respectively the Total Quality Management. On the basis created by this study, the model for the quality improvement for an organization could be shaped, with different methods and techniques throughout the product's life cycle. Because this field is quite broad the study was narrowed to the error avoidance theme, especially on the most popular method of the Zero Quality Control, namely the poka yoke systems. By developing various systems for the automotive industry, new directions of study or modelling needs were identified and afterwards dealt respectively realised in this paper.

This paper is the result of many years of study and research and is due in a good extent to those who supported me directly or indirectly in carrying it out, but also to those who have contributed over time to my professional development. To them I want to thank.

My respect and thanks go firstly to **Prof.univ.dr.DHC ing. Constantin Oprean**, my scientific coordinator, for the very thorough guidance, scientific advice and not least for the high rigor and requirements imposed to this work. I want to thank him for his trust, patience and professionalism which guided me along this scientific research.

Also sincere thanks go to the mentoring committee, respectively Prof.univ.dr.ing. Claudiu Vasile Kifor, Prof.univ.dr.ing. Dănuţ Dumitraşcu and Prof.univ.dr.ing.dr.ec. Mihail Aurel Titu for the objective analyses of the scientific reports achieved during the doctoral studies.

Special thanks go to the staff and management of Continental Automotive Systems Sibiu and Regensburg who gave me the much needed experimental frame for my research and the support in obtaining practical results respectively the realisation of the international assignment in an organization where quality improvement is a constant concern of high importance.

Thanks to the staff of the Technical University of Braunschweig and the University Politehnica of Bucharest - Faculty of Engineering in Foreign Languages, who contributed to my professional development and stimulated my desire to study and research.

Not least I wish to thank the management of the Faculty of Engineering from the “Lucian Blaga” University of Sibiu, teachers, fellow PhD students and administrative staff of the Doctoral Studies Department for the help and support provided throughout the entire period.

A thought of gratitude goes to my family - especially my wife - for the moral support and for the understanding offered in the last years.

# 2 The development of the “quality” concept

Quality takes significance in the XXI century. Thus by “quality” the authors no longer refer to the features of a product, but to all the processes and structures of an organization, developing the original concept till its actual meaning of quality management. How this development was achieved, which are its current forms and how they influence the life cycle of a product and of a company as a whole, these are some of the issues that will be highlighted in order to create a basis for the study of the poka yoke systems.

This chapter is treating the developing of the concept of “quality”, its definition, its evolution in time towards the concept of *Total Quality Management (TQM)* as well as the standards imposed by its appearance. The definition of quality is not a recent concern; attempts in this direction appeared since the beginning of the last century. In order to show the evolution in time of the perception of the term quality and its complexity, we will present the definitions developed by well-known specialists from different decades of the twentieth century as well as the definition found in the dictionary To emphasize the complexity reached by this term in the modern era, the definitions introduced by ISO 9000 will be also presented.

Once defined the term of quality, found also in the title of this work, its evolution will be presented from the ancient times till nowadays. This will show that this concept is not new, it exists in terms of philosophy since antiquity, but the degree of maturity reached today is determined by the technical development beginning with the technological revolution from the nineteenth century in England, continuing with the mass production implemented by Ford, the statistical methods and concepts of quality management developed by the so-called quality gurus and ending with the latest techniques based on or as a reaction to the Toyota Production System as Lean Management and Six Sigma.

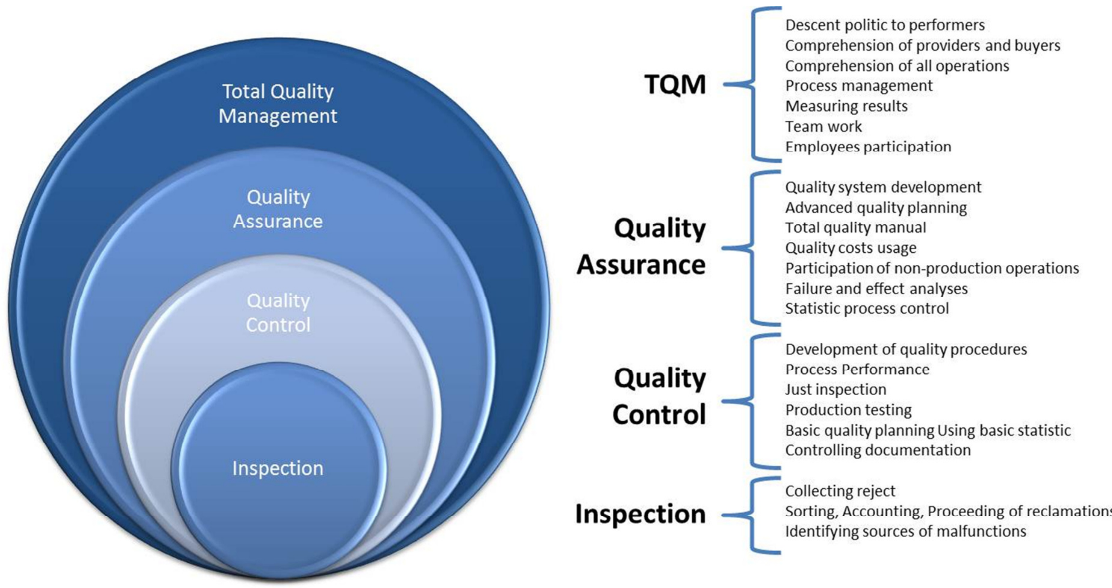


**Figure 1: The evolution of quality [IVAN06]**

The next aspect treated in this first chapter is the classification of the different concepts of quality management under the umbrella of the Total Quality Management, to introduce the quality improvement topics. TQM is the most comprehensive tool for integrating quality at all stages of product manufacturing, in all the activities and departments of the organization. In order to understand this concept, first of all there will be clarified the most important contributions of the twentieth century quality engineers and the innovative tools they have developed and implemented in the organizations where they have worked.

In the modern era the quality techniques have gained more importance, especially in America and Europe, where due to the globalization there is a bigger need to improve the quality, an important role is assigned to the concept of quality standardization. A company producing goods or services cannot be competitive without the standardization and auditing of the quality management systems. Further, in order to broaden the concept of quality improvement, there will be presented the ISO 9000 group of standards that provides a unity of the specialized terminology and clarifies the requirements on quality management for different organizations and also a derivative of this standards, the ISO / TS 16949 specific for the automotive industry.

# 3 The quality improvement model throughout the product life cycle

The different methods grouped under the umbrella of Total Quality Management will be presented in this chapter in terms of the four stages of the product life cycle. A model of quality improvement is proposed, for any organization involved in the production of goods, by detailing the various techniques and tools and their association with the life cycle phase where they would bring the maximum added value.

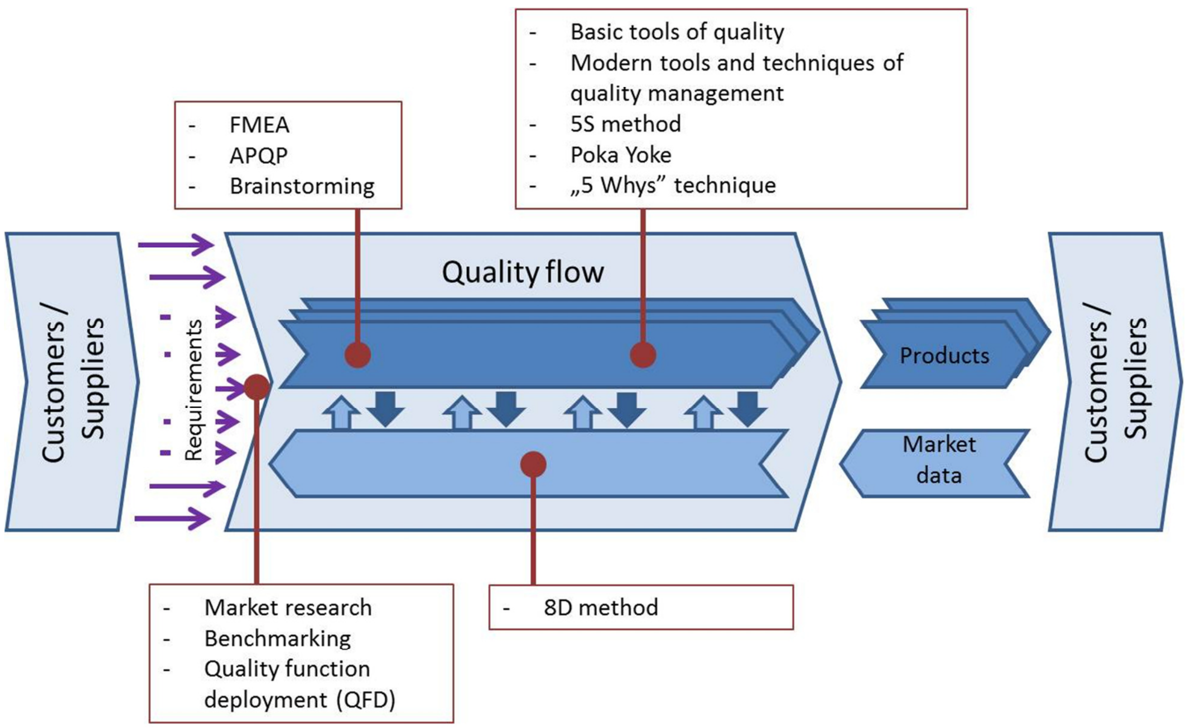


**Figure 2: Using quality tools along the quality chain phases**

For the phase of *requirements' identification* there are clarified initially the tools that will collect the market data on the needs and desires of the customers in terms of quality, such as surveys or market studies. Although they are not necessarily quality management techniques, their importance should not be neglected because they offer the possibility of gathering valuable information on user requirements. Another tool used to collect data, this time from the competition, or market leaders, is the Benchmarking. Thus what the competition is making better in terms of quality processes is analysed, and then adapted to the specific of the own organization. The last technique for this phase is the Quality function deployment (QFD), which can be regarded as a transitional element between this step and the next, because it is a complex tool by which the customer needs are transformed into technical specifications creating correlations between them and, more important, taking into account not only what the user wants but also what he needs.

*The planning and development phase* will present the model proposed by one of the best known quality gurus, Joseph M. Juran, to build quality. The purpose of this model is the removal of discrepancies between what is desired in quality based on customer's wishes and what is possible, feasible and cost-effective in terms of production technology of that good. Therefore known as quality construction phase, it uses techniques such as Brainstorming, a method often used and found in the literature, and other complex tools such as FMEA, allowing a rational analysis of potential failure modes due to the product design or manufacturing and APQP used in planning the quality parameters for the product and process development.

*Realization phase* or the production of the good was the longest and the most important phase in the first half of the twentieth century, when the quality concerns began; that is the reason why the most numerous techniques of quality are referring to this phase. Beginning with the 7 basic tools developed by Ishikawa for quality control and continuing with the 7 management techniques added by JUSE (Japanese Union of Scientists and Engineers) it is shown the evolution of the quality considerations. Other techniques particularly important for this phase will be presented in this work: the 5S method, the Japanese technique that underlies the process of continuous improvement, poka yoke, a tool developed by the Japanese engineer Shingo Shigeo that consists in the introduction of a solution, which is simple, robust and easy to implement to eliminate the defects of a product by preventing or correcting errors as soon as possible and the “5 whys” a very simple method that allows the rapid identification of the source of a nonconformity by repeating the question “why?”.

For a manufacturer the realization phase is not the last issue of concern for quality. The last stage in the life cycle of this perspective is represented by the *using, withdrawal and* *recycling phase*, which even if not directly related to the manufacturer it provides valuable information on the current products and for the future models that the company will bring on the market. Also this phase is closely related to the building of the image of the organization, because during this stage the contact of the customer with the product takes place creating the impressions that will lead to the purchase of other goods.

At the end of this chapter, a series of complex instruments will be presented, which due to their action on several stages during the product life cycle could not be classified as being of major importance for only one of the phases. This includes the 8D method which although used in the realization phase to identify the causes of quality problems after receiving the complaints from customers, has also an important role in the phase of identification of the requirements and in the development phase as it provides crucial information for planning the future products and processes. To this category belong also the Kaizen method and the Six Sigma method, which due to their complexity and their action on all the activities of an organization regardless of the stage of product life, will receive a special status in this work.

This chapter crystallizes the ideas of TQM parents, that the quality that customers expect from a product is not only controlled in the production sections but should be integrated in products and processes in all the phases and continuously improved to face the new challenges of the market. So, a model to improve the quality will be created by using different techniques and tools during the stages of product development from a user's desire to a good that is used and eventually recycled. Using these tools from the early stages of the product life cycle it is recognized the importance of quality building and of mistakes avoiding.

# 4 The error prevention theory

The previous chapters have been designated to present the evolution of quality towards TQM and to open a new perspective on quality improving using a combination of different techniques and tools found in the literature for a certain phase of the product life cycle. The proposed model consists in four important stages in the evolution of a good beginning from a customer desire or need till to its actual use and its eventual

recycling. Some of the concepts and tools introduced are based on the control, the inspection and the quality analysis, but the most interesting perspective brought by the other mentioned techniques is the construction of the quality, the design of the products and processes in order to avoid completely the quality problems. It is much cheaper "to prevent than to cure" as it will be demonstrated in Chapter 5.
These aspects are based on the Zero defects theory, namely the ZQC (Zero Quality Control) concept developed by the Japanese engineer Shingo Shigeo. This chapter will treat the most important aspect of quality management: the errors prevention.

At the beginning there will be a short presentation of the creator of this theory, the Japanese author Shingo Shigeo, further there will be clarified the steps that helped to create the "poka yoke" method – the basis of the errors avoiding theory. The poka yoke method has as starting point the idea that the influence of the operator in an automated production process was not sufficiently analysed. The operator cannot be treated as a machine, because his state of mind is significantly influencing his effectiveness and his power of concentration, leaving the possibility of an error occurrence any time such as: forgetting some steps of the process, the wrong installing of components or even their omission, misunderstanding or misinterpretation of the processes and many others more. The using of poka yoke systems is proposed in order to avoid such errors in the manufacturing process. [BINN96]

Further the construction of the basis of this study is continued with the presentation of the method that involves a set of ideas and techniques for achieving the ideal of zero defects, as it was designed and published in "Zero Quality Control" work by its creator and developed later by many other authors.

The Japanese engineer managed through this instrument to bring quality closer to practice, compared to the other techniques based on data collecting and statistics. By using this technique it became more evident that the identification of the causes of the errors was too late after their appearance, although it was quite effective in removing them. If poka yoke systems development may lead to errors avoiding, Shingo still wondered if there was a method to obtain the much desired rate of zero defects, using the inspection. Thus arrived at the concept of *source inspection*, not in the meaning known before, which referred to quality checkout along the material flow from supplier to customer, but based on the idea that the defects are the result of some actions and specific conditions and their identification in real time could prevent completely the appearance of the errors.

So, poka yoke was at that time a method to prevent the reappearance of an error only after it was identified, creating a specific system that prevent recurrence. The new concept of *source inspection* was intended to analyse the possible causes of the errors and to prevent their occurrence with poka yoke devices. These ideas have emerged as the ZQC systems. The concept has been widely treated by Shingo throughout his career, being the subject of one of the most important publications in terms of study of quality "Zero Quality Control - Source Inspection and the Poka-Yoke System" [SHIN86]

The poka yoke techniques, as shown before, are the basis of the *ZQC* concept and had the greatest impact on the appearance of this innovative method to achieve the ideal of zero defects in Japanese companies and not only – over time the two terms merging in the technical literature. These techniques will be presented detailed with examples from the automotive industry, respecting the initial thinking of these error prevention methods, as well as with other examples expanding the original concept to other industries and human activities.

# 5 Original considerations on poka yoke systems

Based on the study on quality evolution from ancient times to the MCT concept and the prevention theory, and taking into account the experience of developing poka yoke systems for the automotive industry some shortcomings in the treatment of this very important quality tool for error avoidance were noticed. These will be addressed further through some original contributions that will be made in order to complete this study on the topic of poka yoke systems.

## 5.1 Model of the poka yoke systems

In order to easily understand the process by which poka yoke systems help in the error prevention, it is important to describe the way in which they are working through an easy to follow sequence of functions. This chapter is devoted to the development of such a generic model that can characterize all poka yoke systems regardless of complexity, type or field of usage. Even if the modelling will be made at a concept level, for each particular case it could be applied and detailed in order to identify any opportunities for improvement and avoid disruptive factors that can influence the correct functioning of the detection and prevention of errors.

Thus the proposed poka yoke model consists of five basic elements:

- “Reading” - before any poka yoke system can correct any error, it must identify the state or action that is intended to be verified. In the proposed model this component was defined as the “reading” function;

- “Algorithm” – represents the main component of the system, the one that decides if an error that affects the final result was identified;

- “Informing” – the component through which the poka yoke device transmits the test result to the user or the system in which it is included;

- “Blocking” - the component that removes the possibility of continuing the operation in case that a non-compliance is detected;

- “Disruptive factors” – they define all the elements that occur on the system and can affect its proper functioning.

Figure 3 illustrates a poka yoke system which consists of the four components mentioned above and the disruptive factors that are influencing them.

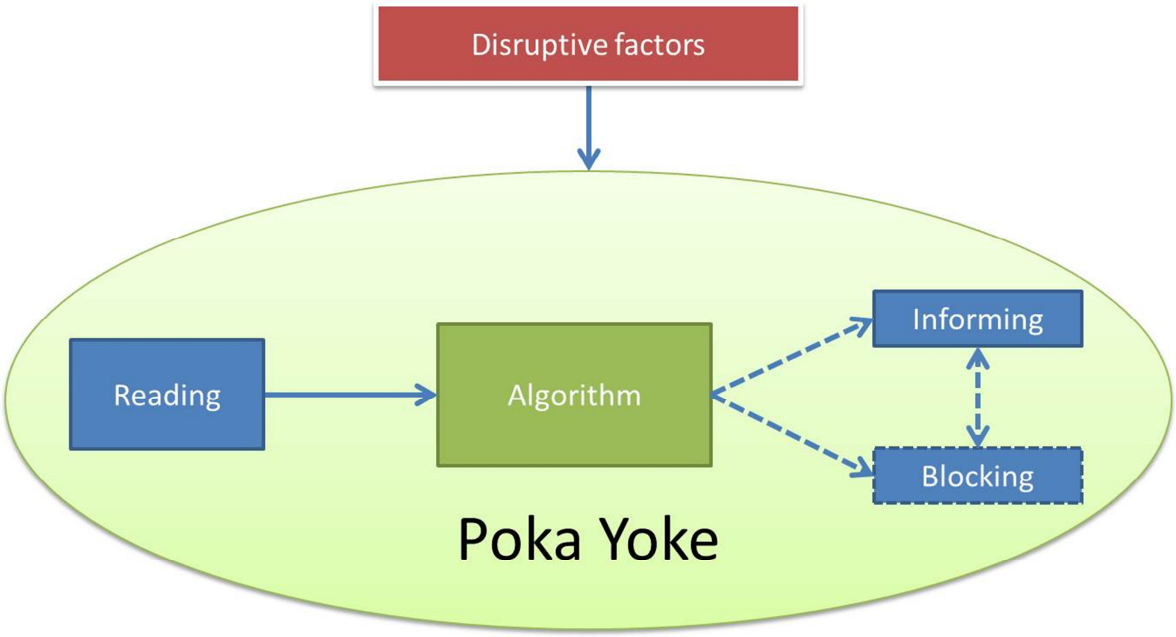


**Figure 3: Generic model of a poka yoke system**

After applying the proposed model to various poka yoke systems, the lack of the blocking component was observed at many of them. Therefore by making an analogy with the safety control systems installed on cars, which will be presented in chapter 5.4, it is proposed to split poka yoke techniques in: *passive and active* ones. *Passive poka yoke systems* are the ones with only an information component through which the operator is acknowledged about the detection of non-compliant situations, but no automatic blocking of the possibility to continue takes place. *Active systems* increase the efficiency of the poka yoke concept by blocking the error propagation in cases of operator negligence. The "informing" component takes place most often in parallel with the blocking or in other cases it is a result of the blocking itself.

Starting from the components of a poka yoke system which were earlier described, a mathematical model to determine the quality of such a system will be proposed.

The notations used for this model are:

| | |
|---|---|
| *Na* | Number of active poka yoke systems in the production flow which have an impact on the final result |
| *Np* | Number of passive poka yoke systems in the production flow which have an impact on the final result |

| | |
|---|---|
| $P_a$ | The probability that the "algorithm" component will work properly in the absence of disruptive factors |
| $P_b$ | The probability that the "blocking" component will work properly in the absence of disruptive factors |
| $P_c$ | The probability that the "reading" component will work properly in the absence of disruptive factors |
| *PD* | Escape probability for a defect from the manufacturing line |
| $P_{da}$ | Probability that the active poka yoke system detects an error |
| $P_{dp}$ | Probability that the passive poka yoke system detects an error |
| $P_e$ | Probability of producing a defect without a poka yoke system |
| $P_i$ | The probability that the "informing" component will work properly in the absence of disruptive factors |
| $P_{ii}$ | The probability of ignoring the error message of the informing function |
| $P_{pa}$ | Probability of disruptive factors appearance with influence on the algorithm function |
| $P_{pb}$ | Probability of disruptive factors appearance with influence on the blocking function |
| $P_{pc}$ | Probability of disruptive factors appearance with influence on the reading function |
| $P_{pi}$ | Probability of disruptive factors appearance with influence on the informing function |

Due to the differences in the use of the two types of poka yoke systems previously introduced also the mathematical model shall be differentiated for:

- Active poka yoke systems:

$$P_{da} = P_c \times (1 - P_{pc}) \times P_a \times (1 - P_{pa}) \times P_b \times (1 - P_{pb})$$

- Passive poka yoke systems:

$$P_{dp} = P_c \times (1 - P_{pc}) \times P_a \times (1 - P_{pa}) \times P_i \times (1 - P_{pi}) \times (1 - P_{ii})$$

The two formulas are based on the multiplication rule for independent events which states that the probability of simultaneously existence of more independent events is equal to the product of the probabilities of these events.

Depending on the analysed production flow it is usual to identify more poka yoke systems which in the event of malfunctioning will lead to the delivery of fail parts. The dynamic model proposed for computing the probability of delivery of fail parts is:

$$PD = \prod_{k=1}^{Na} P_{e_k} \times (1 - P_{da_k}) \times \prod_{j=1}^{Np} P_{e_j} \times (1 - P_{dp_j})$$

A reliable poka yoke system should ideally provide an error detection rate of 100%. In order to achieve this performance, each component of the presented model must be analysed to prevent errors either due to an incorrect system development or due to disruptive factors.

For the application of the proposed model a poka yoke system was developed on a production line of electronic components for the automotive industry which could store all working parameters in a database. This created an experimental model operated in series conditions that allowed the identification of the probabilities introduced in the previous presented model.

## *5.2 Modelling the economic efficiency of poka yoke systems*

A dynamic model is proposed, for the analyse of poka yoke systems cost-effectiveness by comparing the total cost of manufacturing as well as in the scenario with no poka yoke but also the version when an error prevention system is installed. After presenting the created model, its use will be exemplified through a case study from the automotive industry.

The developed model aims to analyse a production system over $N$ periods, with a batch size in each period defined as $Li$ where $i$ takes values from 1 to $N$. The total cost of manufacturing further defined as $C_{TF}(N,I_{py},L_i)$ is a combination of raw material, operation, maintenance, fix, logistic, bad quality costs as well as those caused by the investment in a poka yoke system.

The notations used in this model are:

| | |
|---|---|
| $c_{dp}$ | Storage cost for a unit per period |
| $C_F$ | Location fix costs |
| $C_I$ | Maintenance and setup costs |

| | |
|---|---|
| $c_{lp}$ | Maintenance cost per period |
| $C_L$ | Internal logistic cost |
| $C_M$ | Raw material cost |
| $C_{NC}$ | Bad quality cost |
| $c_{ncp}$ | Bad quality cost per unit |
| $C_O$ | Operation cost |
| $C_{PY}$ | Poka yoke cost |
| $F_p$ | Fix cost related to the product per period |
| $I_{py}$ | Investment for the poka yoke system over N periods |
| $L_i$ | Batch size in period *i* |
| $m_p$ | Raw material cost per unit |
| $N$ | Number of analysed periods |
| $o_p$ | Operation cost per unit |
| $P(I_{py})$ | Probability of producing a fail unit in case of a $I_{py}$ investment in the poka yoke system |
| $p_d$ | Probability of producing a fail unit in case of no poka yoke system ($I_{py}$ = 0) |
| $PY$ | Total investment in the poka yoke system |
| $S_i$ | Stock in storage at the end of period *i* |
| $V_i$ | Sales in period *i* |

For an $I_{py}$ investment in the poka yoke system the total manufacturing costs will be defined as:

$$C_{TF}(N, I_{py}, L_i) = C_M + C_O + C_I + C_F + C_L + C_{NC} + C_{PY}$$

with each component being further detailed.

$$C_M = \sum_{i=1}^{N} L_i \times m_p$$

Material costs are the first considered component of the total production costs formula. They sum over *N* periods the product between the number of parts manufactured with the raw material cost per unit.

$$C_O = \sum_{i=1}^{N} L_i \times o_p$$

Operating costs sum the product of the number of manufactured products with the labour cost for a single product over N periods.

Maintenance cost is calculated by adding the maintenance value for the periods in which the line operated. The used formula is:

$$C_I = \sum_{i=1}^{N} I_{(L_i)} \times c_{Ip}$$

where

$$I_{(L_i)} = \begin{cases} 0 & if\ L_i = 0 \\ 1 & if\ L_i > 0 \end{cases}$$

In order to calculate the fix costs in the studied range the number of periods *N* is multiplied with the fix cost relative to the product per period. These costs refer to indirectly productive personnel costs, equipment depreciation and other overheads of the organization.

$$C_F = N \times F_p$$

Internal logistics costs sum over *N* periods the product of the number of stored units in each period with the cost of storage per period and piece. The used formula is:

$$C_L = \sum_{i=1}^{N} S_i \times c_{dp}$$

where

$$S_i = S_{i-1} + L_i - V_i$$

Depending on the studied process, quality costs can have a different impact on the total cost of manufacturing. So if considering a final process that can produce a defect that can no longer be found in the location of production but just by the customer, the cost of non quality is very high. On the one hand there will be claim costs for the defective parts, and on the other it creates a loss of image in front of the client that can have very serious long-term consequences. For processes that can produce defects detectable before the products are delivered, the non quality costs are normally the scrap cost for the affected parts. The following formula can be applied to both described situations the difference being made by the considered non quality cost per product ($c_{ncp}$).

$$C_{NC} = \sum_{i=1}^{N} L_i \times P(I_{py}) \times c_{ncp}$$

where

$$P(I_{py}) = \begin{cases} p_d & if\ I_{py} = 0 \\ 0 & if\ I_{py} = PY \end{cases}$$

The poka yoke cost ($C_{PY}$) is equal to the investment made for the error prevention system.

Based on the equations introduced above, a dynamic model for calculating the total cost of manufacturing can be created, where the objective function is to minimize the costs so it can be afterwards decided if implementing a poka yoke system is efficient or not:

$$C_{TF}(N, I_{py}, L_i) = min \sum_{i=1}^{N} L_i \times m_p + \sum_{i=1}^{N} L_i \times o_p + \sum_{i=1}^{N} I_{(L_i)} \times c_{Ip} + N \times F_p + \sum_{i=1}^{N} (S_{i-1} + L_i - V_i) \times c_{dp} + \sum_{i=1}^{N} L_i \times P(I_{py}) \times c_{ncp} + I_{py}$$

where:

$$I_{py} = 0\ or\ PY$$

$$m_p, o_p, c_{Ip}, F_p, c_{dp}, c_{ncp}\ and\ PY\ \geq 0$$

$$I_{(L_i)} = \begin{cases} 0 & if\ L_i = 0 \\ 1 & if\ L_i > 0 \end{cases}$$

$$S_{i-1} + L_i - V_i \geq 0$$

$$S_0 = 0$$

$$P(I_{py}) = \begin{cases} p_d & if\ I_{py} = 0 \\ 0 & if\ I_{py} = PY \end{cases}$$

The developed model was exemplified and applied to a poka yoke system to verify the economic efficiency brought by its implementation. The example that is treated in this study was developed during the preparation of this thesis and successfully implemented on a production line of a company manufacturing electronic components for the automotive industry. Other aspects apart from the involvement in this project were not considered in the selection of this system as an example, as it was intended to demonstrate the applicability of this model on any kind of device taking into account their diversity.

## *5.3 Removing design flaws of poka yoke systems*

By studying many poka yoke systems, used on the production lines of electronic modules for the automotive industry, several examples of poka yoke systems were identified, that although at first sight were properly implemented contained certain faults:

- Side effects of poka yoke systems
- Human factor stronger than the error prevention system
- Local problem targeted solution is not always sufficient
- Poka-yoke affecting the production capacity

For the problem correction, in most cases the poka yoke system was reviewed through a more comprehensive approach, thus succeeding in eliminating the undesired effects. These issues, namely the various deficiencies found in the poka yoke systems and the way in which they have been removed, will be presented based on several examples [MAGD12].

## *5.4 Broadening the concept of poka yoke*

The XXI century has brought with it an increased interest in the concept of poka yoke and thus its adaptation to certain areas and fields that have no connection to the automotive industry or the Toyota Production System [MAGD13b]. Scientific works that recognize the importance of the concept developed by Shingo Shigeo and the benefits of implementing such systems in constructions [RAMI11] [SANT99] or in software development [ROBI97] [NATA13] were created.

But the most common field found in the new articles regarding the poka yoke topic is medicine. Here, similar to the automotive and aeronautical industry the importance of human errors receives a special attention as they may result in loss of human lives.

Broadening the concept of poka yoke in its application and adaptation to the medicine field was done by various authors starting from the ideas of this method's creator. They named these mechanisms and techniques if not poka yoke -as Shingo Shigeo did- methods for human error avoidance. This chapter will present a further broadening of the initial poka yoke concept to different fields and in other forms, without being seen or recognized by the authors, creators or users as part of the method developed by Shingo Shigeo. Therefore the paper proposes examples of poka yoke systems from fields as:

- Management
- Logistics
- Daily activities
- Services
- Driver assistance systems

# 6 Poka yoke systems in the automotive industry

Chapter 2 stressed the importance of certain periods of the twentieth century in the evolution of quality. While each era has brought innovative concepts, extremely important for the organizations that have implemented them, the TQM era roused the widespread reactions regarding the concern for quality in industry, especially in automotive. In this context the Zero defect theory appeared, as presented in Chapter 4, the concept of quality developing from the quality control, so that the nonconforming goods do not reach the client, to errors prevention, eliminating in this way the waste and the risk that the defects get on the market.

As the Zero defect theory merged over time with the poka yoke systems, this concept of errors prevention will be treated especially for the automotive industry, because in this area there are significant efforts to improve the quality and to reduce the costs. Before studying poka yoke systems themselves an analysis of the evolution of the automotive industry in terms of quality development will be made, in order to clarify the meaning of poka yoke as a method to prevent errors in this area. Therefore there will be stressed the evolution of the quality concept in the automotive industry in general and not particularly of the poka yoke systems to demonstrate the wide range of quality techniques existing and developed in this field. The fact that the subject of this study is the poka yoke method does not neglect the importance of the other concepts that should not be completely ignored.

It is generally recognized that the automotive industry's history began with the invention of the internal combustion engine in 1876 by Nicolaus August Otto and with the first automobiles built by Karl Benz in 1885 and later by Gottlieb Daimler in 1886 [ BELL13 ] . A particularly important contribution was made by Ford, who was the first to implement the flow production that would revolutionize the concept of manufacturing. Ford's success in the global market has led to the spread of mass production concepts among organizations worldwide. There were, however, negative reactions to this new trend that valued quantity more than the freedom of choice of the consumer. These reactions led to the creation of TPS (Toyota Production System), one of the most comprehensive and popular forms of Quality Management. This concept emerged in the second half of the twentieth century with the contributions of the Japanese specialists and the lectures and techniques developed by the American specialists who have found in the Japanese managers an audience hungry for knowledge and willing to improve.

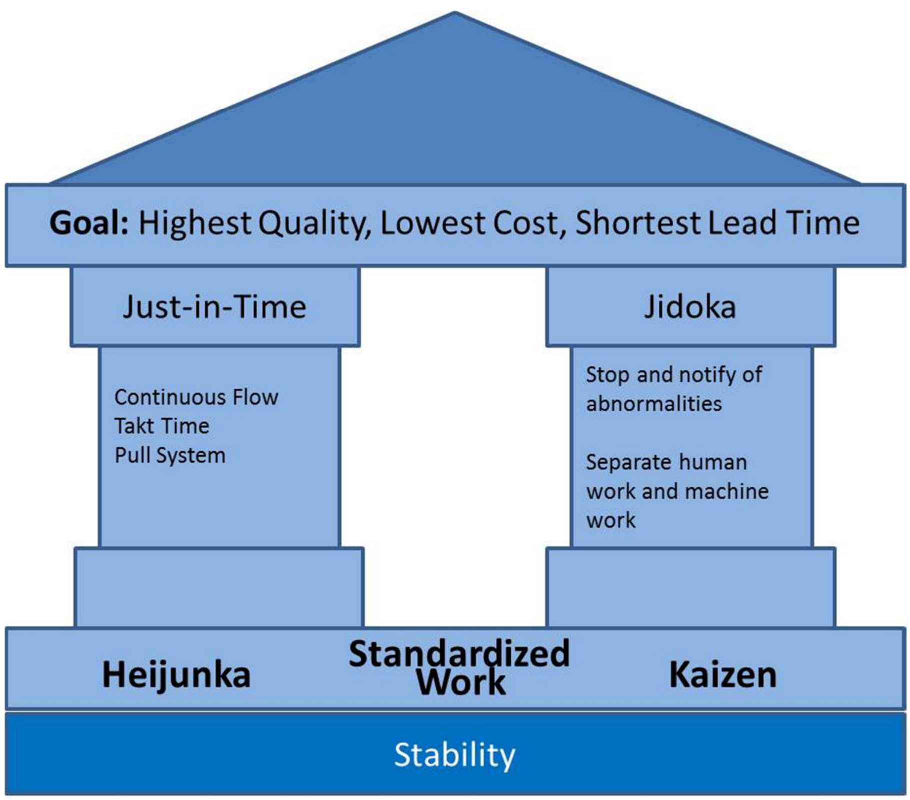


**Figure 4: TPS House [LEI08]**

With this reply given by the Japanese automotive industry in the mid twentieth century the Ford supremacy remained just history, its principles becoming outdated and unsatisfactory for the customers. Therefore the western organizations tried to discover the key of the Japanese success and the result of these tests was outlined in the development of a new management concept called “Lean”.

The term “Lean” has emerged in the 80s-90s, after a 5-year study conducted by the prestigious MIT School with funding from the automotive industry. Womack and Jones analysed the stage of the existing mass production system in America where cost reduction was achieved by reducing the number of variables and processes and the one in Toyota company whose method of cost reduction led to the elimination of waste in all the phases of the production and of the life of the car and to the continuous improvement. A lean plant has two key features: the transfer of the objectives and responsibilities to the line workers that are adding value to the car and the existence of an error detection system that allows quick identification of the root cause. [WOMA90]

The Lean Management is therefore a new way of thinking for the American and European automotive industry, inspired by the approach of the Toyota company's management focused on the inclusion of quality in production, on the waste elimination, on flow production, on continuous improvement and on building of lasting relationships based on respect and trust with business partners. It is an evolving concept whose applications have been extended to other industries.

The western automotive industry even with the implementation of the Lean Management failed to exceed the high quality standards set by Toyota, whose production system in continuous development and improvement, based on the Japanese quality-oriented psychology, still dominates the market. Therefore, the organizations have made efforts to search a system to help them get a much lower rate of defects and thus to shatter the Toyota supremacy. So the Six Sigma concept developed in the early 90s by the Motorola company was brought to attention.

Six Sigma can be defined as a structured process meant to reduce the variation sources of the product as well as of the processes in the whole company, in order to improve quality, to increase the organization's performances and to meet the customer's needs and expectations. [BOZD10]. The method to obtain the 6σ quality is an extension of the Deming's cycle presented in Chapter 2, known by the acronym DMAIC (Define-Measure-Analyse-Improve-Control). Thus each quality problem is treated as an improvement project using different quality methods and techniques for each specific phase. [SCHM10], [KNOW12b], [KIFO06]

Since the subject of this work is the study of the poka yoke concept, after the introduction of the quality improvement concepts in the automotive industry, there will be presented a new perspective on this topic for this industry, which requires a modern classification, different from the one created by Shingo Shigeo and presented in Chapter 4. This one is based on the appearance of the concern of poka yoke designing and involves a new classification of the poka yoke systems making the difference between *process poka yoke* and *product poka yoke*. The illustration of this new classification will be made on the actual example of the electronic control systems production, presenting their rapid development in recent years and the diversity reached today. To conclude the standard production flow for electronic modules is presented, creating an overview of the complexity of these products.

In order to complete the poka yoke concept and to stress on the complexity of a relatively simple technique at first sight, the most important part of this chapter is dedicated to present numerous examples of poka yoke systems implemented in a company producing electronic components for the automotive industry. They were classified according to the process where they were implemented, in the order they occur along the standard production flow - from the freight receiving area, namely the storage of components, continuing along the modules' production lines, testing and repair stations, assembly lines, ending with the packaging process.

The adaptability of the concept to the needs of production processes for ensuring quality at the highest level will be highlighted.

# 7 Conclusions

This study represents the top of the iceberg in terms of the application area of poka yoke systems, presenting only a part of the range of technologies and methods based on the theory founded by Shingo Shigeo, most of the times without being labelled as such. The applications of the poka yoke method are present around us in every area we operate and, even if not perceived, they certainly help us to be more productive and they stop us from making errors that could affect the quality at every level.

As a conclusion of this work there will be presented on one hand the original contributions brought to the poka yoke subject, and on the other hand the future directions of study that could be developed and that the author hopes to be treated in the future to complete a vital concept for the industry in general and for the automotive in particular.

## *7.1 Original contributions*

It has been demonstrated in this work that the theme of quality improving , although it is not entirely new, it will always be a current topic and concern for any organization regardless the type of work they perform or the industry they operate. This study made various contributions to the theoretical and practical treatment of poka yoke systems that have crystallized in developing models, broadening the concept to other areas and to other industries in the same time bringing many examples of applications developed in the automotive industry.

- ***The creation of a quality improvement model*** taking into account all stages of a product life cycle. In order to realize this, the phases' classification in the existing literature on the life cycle of a product was initially analysed. Various authors have studied this concept from different perspectives but none of these was considered to be suitable for this work. Therefore it was developed a model which, even if it took some of the ideas found in various publications, constitutes a new approach to this issue. Thus there were defined four relevant stages for the life of a product in terms of quality improvement: *the requirements identification phase*, *the planning and development*, *the execution phase* and *the utilization, withdrawal and recycling phase*. The identification of these steps made possible the model creation by associating the techniques and tools of quality for each one, to ensure the maximum efficiency in building or improving the quality of products and processes in any organization.

In terms of quality improving, it was considered that the prevention of design or manufacturing errors, which would lead to quality problems, is of greater importance compared to the inspection or the control. Therefore from the range of techniques presented in the model described in the previous paragraph it was chosen the poka yoke, the best known method to prevent the involuntary human errors. Thereby there were outlined two new models associated this time especially to the poka yoke method.

- ***The modelling of poka yoke systems based on their structure.*** This model involves analysing and identifying the main components that can be associated with any system. On this basis, it was then made a mathematical model by which one can analyse the effectiveness of implementing a poka yoke system, taking into consideration also the disruptive factors that can affect it. It was considered also in the realization of the model the eventual existence of several poka yoke systems implemented on the same production line.

- ***The dynamic model to calculate the total cost of manufacturing.*** This model was developed based on economic considerations in the examples developed for the automotive industry, facilitating the comparison from the costs point of view of two scenarios of production, i.e. one that does not implement any error prevention system and the other in which a poka yoke system is associated to the process. With this model one can analyse the economic efficiency of the introduction of any type of error prevention during the production flow.

- ***The removal of design errors of the poka yoke systems***. A more detailed analysis of the poka yoke systems has led to the identification of some deficiencies of such devices implemented in the production of electronic components for the automotive industry. So, this is an alarm signal over the fact that although this concept was considered robust and 100% safe, with the increasing complexity of the production processes and requirements on prevention devices, the attention to avoid design or implementing errors must be also increased.

- ***Extension of the poka yoke concept.*** This work brings in discussion the broadening of the studied concept. Thus, although the production systems depend on the implementation of poka yoke devices no study would be complete by focusing on just one area. Therefore there were analysed other areas and also the everyday life; other systems were found under the name given by Shingo Shigeo in different areas such as medicine. There are many other examples that are not acknowledged as belonging to this category of systems of prevention. This underlines the spread of this method in activities that its creator has not taken into account as well as the importance of these new applications that sometimes are even saving lives.

A final contribution brought by this work is a practical one:

- ***The illustration of the numerous applications of the poka yoke concept developed over the production flow of a supplier of electronic components in the automotive industry.***

The development of these aspects, namely the awareness of certain deficiencies in the treatment of poka yoke systems brought theoretical and practical additions. However, this study cannot be absolute and considered as a completion of any research on poka yoke systems. Therefore the conclusion of this work will present the possible future directions of study that would bring new perspectives, or would complement those already developed previously.

## 7.2 Future research directions

Chapter 5.1 brought a major contribution to the concept of poka yoke by creating a model for analysing the effectiveness of such a system. By sharing any system in four distinct functions – reading, algorithm, informing and blocking and analysing each of them in terms of disruptive factors, it could be created a mathematical model by which to calculate the efficiency of the entire system, and thus determine the overall effectiveness of developing a poka yoke for that process. The application of this model in an experimental situation has proven the benefits of the classical concept developed by Shigeo Shingo.

The proposed model is a dynamic one and could be in some cases incomplete, especially when taking into account the field in continuous changing where it has been developed. In the automotive industry the pressure to improve quality and to reduce the costs is high, so the efficiency of the poka yoke system is crucial. The further study of the proposed model and its application to several systems in an experimental setting could bring additions that would improve or update that one.

Another issue treated in this work has been the extension of the poka yoke concept to other industries and areas. In this case there were presented systems that are recognized in the literature as poka yoke, applied to other industries, as well as systems to prevent errors in utilization or in other areas. It was stressed a new direction of study that brings new contributions to the broadening of the application area of poka yoke systems. However, this was not exhausted by the study and this field can be expanded further.

Further analysis may lead to an increasing awareness of the importance of the use of poka yoke systems. With the technological development and the increasing complexity of products on the market, preventing misuse of the functions of a good gets a greater importance because it influences the user's perception of the quality. A particularly important area of study which highlights the timeliness of the concept of poka yoke is road safety. Here the applicability of the concept developed by Shingo Shigeo is only at the beginning and the developing of the error preventing systems becomes vital.

The study of poka yoke systems in utilization can be continued not only regarding their applicability but also to broaden their use in other fields and other industries. Thus there have been identified certain systems of errors prevention in the literature that were recognized as belonging to the concept developed by the Japanese specialist in medicine, although there are many other applications in other industries. Therefore, further study of these issues would bring an important contribution to updating initial thinking on these quality techniques.

A final perspective that can be identified as the basis for a future study derives from the many examples presented in this work. Their classification along the production flow, in this case of a manufacturer of electronic components for the automotive industry, offers the suggestion to develop a catalogue of poka yoke systems. Thus the identification and grouping of different examples by production step, and not only , can help the engineers as well as the managers in choosing the best system of errors avoiding in manufacturing, management, logistics and many other processes within a company.

These are just some directions for future studies that can be derived from this work. They emphasized the contributions made by this study, but in the same time they do not close the perspectives on poka yoke systems, actually opening many other aspects that can be analysed in order to update the concept and to stress its importance among the techniques used in improving the quality of products and processes.

# Bibliography


[AHRE06] Ahrens, T.: *Lean production: Successful implementation of organisational change in operations instead of short term cost reduction efforts*, Lean Alliance GmbH, 2006

[AIAG94] AIAG: *Advanced Product Quality Planning and Control Plan (APQP)*, 1994

[AKAO90] Akao, Y.: *Quality Function Deployment: Integrating Customer Requirements into Product Design*, Productivity Press, New York, 1990

[ASQ12] ASQ: http://asq.org/glossary/, accessed on 13.09.2012

[AZTE12] AZTEST: http://www.aztest.com/index.html, accessed on 18.05.2012

[BACI04] Bacivarov, I. C.; Stoichiţoiu, D. G.: Joseph M. Juran – O viaţă închinată calităţii, *Asigurarea Calităţii*, octombrie-decembrie 2004, year X, no. 40, 2004

[BECK10] Becker, J.: *Driver Assistance System*, Patent European no. EP2057053, published 29.09.2010

[BELL13] Bellis, M.: *Automobile History - Famous Automobile Makers*, http://inventors.about.com/od/astartinventors/tp/Famous-Automobile-Makers-.htm, accessed on 10.06.2013

[BINN96] Binner, H. F.: *Umfassende Unternehmensqualität,* Spriger, Berlin Heidelberg, 1996

[BOOK05] Booker, J. D.; Swift, K. G.; Brown, N. J.: Designing for assembly quality: strategies, guidelines and techniques, *Journal of Engineering Design*, vol. 16, No. 3, pg. 279 - 295, 2005

[BOZD10] Bozdogan, K.: Towards an Integration of the Lean Enterprise System, Total Quality Management, Six Sigma and Related Enterprise Process Improvement Methods, in: Blockley, R. – *Encyclopedia of Aerospace Engineering*, vol. 6, John Wiley & Sons, New York, 2010

[BRIE06] Briest, S.; Vollrath, M.: Integrierte Sicherheit und Fahrerassistenzsysteme, *VDI Berichte*, no. 1960, pg. 449-463, 2006

[BRIT99] Britz, G. C.; et. al.: *Improving Performance Through Statistical Thinking*, ASQ Quality Press, Milwaukee, 1999

[CAMP06] Camp, R. C.: *Benchmarking: The Search for Industry Best Practices That Lead to Superior Performance*, Productivity Press, 2006

[CARB00] Carboneau, C.: Reduce Medication Errors By Mistake Proofing, *Quality Progress*, vol. 33, No. 8, pg. 8 - 10, Aug. 2000

[CART12] Carter, M.: *The 8-Disciplines: Problem Solving Methodology*, Amazon Digital Services, 2012

[COHE95] Cohen, L.: *Quality Function Deployment: How to Make QFD Work for You*, Addison Wesley Longman, Reading, 1995

[CROS79] Crosby, P.: *Quality is Free*, McGraw-Hill, New York, 1979

[CUDN02] Cudney, E.: Implementing Effective Mistake Proofing, *IIE Annual Conference Proceedings*, pg. 1 - 4, 2002

[DEMI00] Deming, W. E.: *Out of the crisis*, MIT Press, Massachussetts, 2000

[DENE07] Deneş, C.: *Fiabilitatea şi mentenabilitatea sistemelor*, class support, “Lucian Blaga” University, Sibiu, 2007

[DEX98] Academia Română: *Dicţionarul Explicativ al Limbii Române*, Institutul de Lingvistică “Iorgu Iordan”, Univers Enciclopedic Press, 1998

[DOTY96] Doty, L. A.: *Statistical Process Control*, 2nd Edition, Industrial Press, New York, 1996

[EFQM12] EFQM: http://www.efqm.org/en/, accessed on 05.04.2012

[EMOT12] EMOTIO: http://emotio.tim.rwth-aachen.de/, accessed on 21.05.2012

[ESTR08] Estrada, G.; Lloveras, J.; Riba C.: Design for Poka-Yoke Assembly an Approach to Prevent Assembly Issues, *International Desing Conference*, pg. 351 - 358, Dubrovnik, Coaţia, 2008

[EVAN91] Evans, J. R.: *Statistical Process Control for Quality Improvement*, Prentice-Hall, Upper Saddle River, 1991

[FEIG83] Feigenbaum, A. V.: *Total Quality Control*, III Edition, McGraw-Hill, New York, 1983

[GROU07] Grout, J.: *Mistake-Proofing the Design of Health Care Processes*, AHRQ Publication, Rockville, 2007

[GROU97] Grout, J. R.: Mistake-Proofing Production, *Production and Inventory Management Journal*, Third Quarter 1997, 38, 3, ProQuest Central, pg. 33 – 37, 1997

[GUAR12] The Guardian: http://www.guardian.co.uk/business/2012/oct/10/toyota-automotive-industry, accessed on 06.04.2012

[GÜNT05] Günter, H. O.; Tempelmeier, H.: *Produktion und Logistik*, VI Edition, Spriger, Berlin, 2005

[HANC07] Hinckley, C. M.: Combining mistake-proofing and Jidoka to achieve world class quality in clinical chemistry, *Accred. Quality Assurance*, vol. 12, pg. 223 - 230, 2007

[HILL95] Hill, S.; Wilkinson, A.: In search of TQM, *Employee Relations*, vol. 17, no. 3, pg. 8 – 25, 1995

[HOWA13] Howard, B.: *Ford's amazing new tech: Park your car from outside the car*, www.extremetech.com/extreme/168194-fords-amazing-new-tech-park-your-car-from-outside-the-car, accessed on 05.08.2013

[ILIE03] Ilieş, L.: *Managementul Calităţii Totale*, Dacia, Cluj-Napoca, 2003

[IMAI12] Imai, M.: *Gemba Kaizen: A Commonsense Approach to a Continuous Improvement Strategy*, II Edition, McGraw-Hill, New York, 2012

[INJA07] Injac, N: Die Entwicklung des Qualitätsmanagements im 20./21. Jahrhundert, Pfeifer, T.; Schmitt, R: Masing – *Handbuch Qualitätsmanagement*, V Edition, pg. 15 – 34, Carl Hanser, München, 2007

[INMA13] Inman, A. R.: *Poka-Yoke*, http://www.referenceforbusiness.com/management/Or-Pr/Poka-Yoke.html accessed on 14.03.2013

[IONE97] Ionescu, S. C.: *Excelența industrială - Practica și teoria calităţii*, Economică, Bucureşti, 1997

[IONI02] Ioniţă, I.: *Managementul calităţii sistemelor tehnico-economice*, ASE, Bucureşti, 2002

[ISHI90] Ishikawa, K.: *Introduction to Quality Control*, I Edition, 3A Corp, Tokyo, 1990

[ISIX12] I Six Sigma: http://www.isixsigma.com/tools-templates/cause-effect/determine-root-cause-5-whys/, accessed on 22.10.2012

[ISO05] ISO 9000:2005: *Quality Management Systems - Fundamentals and vocabulary,* International Organization for Standardization, 2005

[ISO09] ISO/TS 16949: *Technical Specification - Quality Management Systems,* International Organization for Standardization, 2009

[ISO12] ISO*:* http://www.iso.org/iso/home.html, accessed on 29.10.2012

[ISO97] ISO: *Friendship Among Equals*, ISO Central Secretariat, Geneva, 1997

[IVAN06] Ivanovic, M. D.; Majstorovic, V. D.: Model developed for the assessment of quality management level in manufacturing systems, *The TQM Magazine*, vol. 18, no. 4, pg.410 – 423, 2006

[JOHN03] Johnson, K. G.; Khan, M. K.: A study into the use of the process failure mode and effects analysis (PFMEA) in the automotive industry in the UK, *Journal of Materials Processing Technology*, vol. 139, pg. 348 – 356, 2003

[JURA73] Juran, J.M.; Gryna, F.M.: *Calitatea produselor : tratat practic de planificare, proiectare, realizare şi control*, Editura Tehnică, Bucureşti, 1973

[JURA98] Juran, J. M.: *Juran's Quality Handbook*, V Edition, McGraw-Hill, New York, 1998

[KAMI12] Kamiske, G. F.: *Handbuch QM-Methoden - die richtige Methode auswählen und erfolgreich umsetzen*, Carl Hanser, München, 2012

[KANS12] Kansei: http://www.kansei.eu/, accessed on 11.05.2012

[KETT99] Ketting, M.: Geschichte des Qualitätsmanagements, în: *Masing – Handbuch Qualitätsmanagement*, IV Edition, Carl Hanser, München, pg. 17-30, 1999

[KIFO02] Kifor, C.V.; Oprean, C.: *Ingineria Calităţii*, "Lucian Blaga" University, Sibiu, 2002

[KIFO06] Kifor, C.V.; Oprean, C.: *Ingineria Calităţii. Îmbunătăţirea 6 sigma*, "Lucian Blaga" University, Sibiu, 2006

[KNOW11] Knowles, G.: *Quality Management*, Ventus Publishing, 2011

[KNOW12a] Knowles, G.: *Managing Quality in the 21st Century*, Ventus Publishing, 2012

[KNOW12b] Knowles, G.: *Profit from Six Sigma*, Ventus Publishing, 2012

[LEI08] LEI: *Lean Lexicon*, IV Edition, Lean Enterprise Institute, Goodrich, 2008

[LIKE06] Liker, J. K.; Meier, D.: *The Toyota Way Fieldbook*, McHraw-Hill, New York, 2006

[LOBO10] Lobonţ, L.: *Tehnici şi instrumente pentru îmbunătăţirea calităţii – Lucrări practice*, "Lucian Blaga" University, Sibiu, 2010

[MAGD12] **Magdoiu, A.**; Oprean, C.; Kifor, C. V.: Poka-yoke systems in automotive electronic production; weak points and countermeasures, *Quality – Access to success journal*, supplement to vol. 13, S5, November, 2012

[MAGD13a] **Magdoiu, A.**; Oprean, C.; Nae, L.: Quality along the product life cycle, *Proceedings of the 6th International Conference on Manufacturing Science and Education – MSE 2013*, Sibiu, June, 2013

[MAGD13b] **Magdoiu, A.**; Oprean, C.: Broadening the concept of poka yoke beyond automotive industry, *Proceedings of the 1st International Conference for Doctoral Students – IPC 2013*, Sibiu, November, 2013

[MANA13] The Management Mentor: *Poka-Yoke: A Misunderstood Concept*, http://www.themanagementor.com/enlightenmentorareas/mfg/qm/pokayoke.htm accessed on 01.03.2013

[MAUR04] Maurer, R.: *One Small Step Can Change Your Life: The Kaizen Way*, Editura Workman Publishing Company, 2004

[MCCA06] McCall, J.C.; Trivedi, M.M.: Video-based lane estimation and tracking for driver assistance: survey, system, and evaluation, *IEEE Transactions on Intelligent Transportation Systems*, vol. 7, no. 1, pg. 20-37, 2006

[MCKE04] McKellen, C.: Production Management: Mistake proofing, *Metalworking Production*, pg. 8 - 9, March 2004

[MIHA00] Mihalcea, R.; Androniceanu, A.: *Management: Fundamente. Interferenţe. Studii de caz. Soluţii*, Editura Economică, Bucureşti, 2000

[MOLD03] Moldoveanu, G.; Dobrin, C.: *Managementul calităţii în sectorul public*, ASE, Bucuresti, 2003

[NAE13] Nae, L.; Balan, E.; Constantin, G.; Bendic V.: Forecast the impact of change in a manufacturing environment, *WSEAS International Conference on Industrial and Manufacturing Technologies (INMAT13)*, pg 202 - 205, Athens, Greece, 2013

[NATA13] Nataraj, K.: *How to Use Poka-Yoke (Mistake Proofing) Technique to Improve Software Quality*, http://www.softwaretestinghelp.com/poka-yoke/, accessed on 02.02.2013

[NIKK87] Nikkan Kogyo Shimbun Ltd.: *Poka-Yoke Improving Product Quality by Preventing Defects*, Productivity Inc., Portland, 1987

[NISS13] Nissan Motor Corporation: *Predictive Forward Collision Warning*, http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/predictive.html, accessed on 20.08.2013

[NIST12] NIST*:* http://www.nist.gov/baldrige/about/what_we_do.cfm, accessed on 05.04.2012

[OHNO88] Ohno, T.: *Toyota Production System: Beyond Large-Scale*, Productivity Inc., Portland, 1988

[OLAR00] Olaru, M.; Isaic-Maniu, A.; Lefter, V.; Pop, N.A.;Popescu, S.; Dragulanescu, N.; Roncea, L.; Roncea, C.: *Tehnici şi instrumente utilizate în managementul calităţii*, Editura Economică, Bucureşti, 2000

[OPRE05] Oprean, C.; Kifor C. V.; Suciu, O.: *Managementul integrat al calităţii*, "Lucian Blaga" University, Sibiu, 2005

[OPRE06] Oprean, M.; Andreescu, C.; Bataus, M.; Dragne, D.; Toma, M.; Moisescu, R.: Road Traffic Event Detection Using an Informatic System – eRS, *Conferinţa Internaţională ITS-România*, Bucureşti, June 2006

[OPRE07] Oprean, C.; Ţîţu, M.: *Managementul Calităţii*, "Lucian Blaga" University, Sibiu, 2007

[OPRE11] Oprean, C.; Kifor, C. V.; **Magdoiu, A.**: Aplicaţii ale sistemelor Poka – Yoke în producţia de component electronice pentru industria auto, *Revista Calitatea – acces la succes*, vol. 12 / 2011, pg. 27 – 32, 2011

[PANT05] Pantazopoulos, G.; Tsinopoulos, G.: Process Failure Modes and Effects Analysis (PFMEA): A Structured Approach for Quality Improvement in the Metal Forming Industry, *Journal of Failure Analysis and Prevention*, vol. 5(2) April 2005, pg. 5 – 10, 2005

[PHIL12] Philip Crosby Associates: http://www.philipcrosby.com/25years/index.html, accessed on 06.04.2012

[PQAI13] Process Quality Associates Inc.: http://www.pqa.net/ProdServices/sixsigma/sixsigma.html, accessed on 15.09.2013

[PROD97] The Productivity Press Development Team: *Mistake Proofing for Operators: The ZQC System*, Editura Productivity Press, New York, 1997

[QFDI12] QFD Institute: http://www.qfdi.org, accessed on 10.09.2012

[QUAL13] Quality Gurus: http://www.qualitygurus.com/gurus/, accessed on 12.03.2013

[RAMB11] Rambaud, L.: *8D Structured Problem Solving*, II Edition, Phred Solutions, 2011

[RAMI11] Ramin, S.; et. al.: Improving Productivity through Mistake-proofing of Construction Processes, *CSIT International Conference on Intelligent Building and Management,* vol, 5, pg. 280 - 284, Singapore, 2011

[REVE98] ReVelle, J. B.; Moran, J. W.; Cox, C. A.: *The QDF Handbook*, John Wiley &

Sons, New York, 1998

[ROBI97] Robinson, H.: Using Poka-Yoke Techniques for Early Defect Detection, *Sixth International Conference on Software Testing Analysis and Review*, pg. 134 - 145, San Jose, USA 1997

[ROSS96] Ross, P. J.: *Taguchi Techniques for Quality Engineering*, II Edition, McHraw-Hill, New York, 1996

[ROTH01] Rothlauf, J.: *Total Quality Management in Theorie und Praxis*, Oldenbourg Wissenschaftsverlag, 2001

[SAIN11] de Saint Maurice, G.; et. al.: Comprendre la notion de détrompage, *Annales Françaises d'Anesthésie et de Réanimation*, no. 30, pg. 51 - 56, 2011

[SANT99] Dos Santos, A.; Powell, J.: Potential of Poka-Yoke Devices to Reduce Variability in Construction, *Proceedings IGLC-7 26-28 July 1999*, University of California, Berkeley, CA, USA, pg. 51 - 62, 1999

[SAUR12] Saurin, T. A.; Ribeiro, J. L. D.; Vidor, G.: A framework for assessing poka-yoke devices, *Journal of Manufacturing Systems*, no. 31, pg. 358 - 366, 2012

[SCHM10] Schmitt, R.; Pfeifer, T.: *Qualitätsmanagement Strategien-Methoden-Techniken*, IV Edition, Carl Hanser, München, 2010

[SHEW31] Shewhart, W. A.: *The Economic Control of Quality of Manufactured Product*, D. van Nostrand Company, New York, 1931

[SHIN13] Shingo Prize: http://www.shingoprize.org/index.html, accessed on 11.03.2013

[SHIN86] Shingo, S.: *Zero Quality Control: Source Inspection and the Poka-Yoke System*, Productivity Press, Protland, 1986

[SILI12] SiliconFarEast: http://www.siliconfareast.com/8D.htm, accessed on 29.10.2012

[SPEA99] Spear, S.; Bowen, H. K.: Decoding the DNA of the Toyota Production System, *Harvard Business Review*, September-October 1999, pg. 97-106, 1999

[STAN00] Stanciu, C.: *Managementul calităţii - Analiza reflectării calităţii produselor în performanţele economico-financiare ale întreprinderii*, ASE, Bucureşti, 2000

[STAP09] Stapenhurst, T.: *The Benchmarking Book: A how-to guide to best practice for managers and practitioners*, Elsevier, 2009

[STEW01] Stewart, D. M.; Grout, J. R.: The human side of mistake-proofing, *Production and Operations Management*, Winter 2001, 10, 4, ProQuest Central, pg. 440 - 459, 2001

[SUPP13] Supply Chain Services: *Advantages Abound with Barcode Labelers*, http://supplychainservices.com/news/blog/2013/8/15/advantages-abound-with-barcode-labelers/, accessed on 30.02.2013

[SZAD08] Szádeczky-Kardoss, E.; Kiss, B.: Path Planning and Tracking Control for an Automatic Parking Assist System, *European Robotics Symposium*, vol. 44, pg. 175-184, 2008

[TAGU05] Tague, N. R.: *Quality Toolbox*, ASQ Quality Press, Milwaukee, 2005

[TAYL03] Taylor, F. W.: *Shop Management*, American Society of Mechanical Engineers, New York, 1903

[TAYL11] Taylor, F. W.: *The Principles of Scientific Management*, Harper & Brothers, New York, 1911

[TERN97] Terninko, J.: *Step-by-Step QFD: Customer-Driven Product Design*, II Edition, CRC Press, Boca Raton, 1997

[TISB12] Tisbury, J.: *5S – Your 60 Minute Lean Business*, I Edition, lulu.com, 2012

[TOYO12] Toyota Production System: http://www.toyotageorgetown.com/tps.asp, accessed on 22.10.2012

[TOYO13a] Toyota Company*:* http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/, accessed on 22.06.2013

[TOYO13b] Toyota: *Technology that Supports Parking*, www.toyota-global.com/innovation/safety_technology/safety_technology/parking/, accessed on 10.07.2013

[VARD13] Vardeman, S. B.; et. al.: *The Impact of Dr. Shigeo Shingo on Modern Manufacturing Practices*, http://www.public.iastate.edu/~vardeman/IE361/f02mini/bumblauskas.pdf, accessed on 05.02.2013

[VDA11] VDA: *Quality Management in the Automotive Industry*, VDA, Berlin 2011

[VISI13] VisIt: https://wci.llnl.gov/codes/visit/gallery_22.html, accessed on 25.04.2013

[VIŞA11] Vişan, A., Ionescu, N.: *Managementul Calităţii*, Politehnica Bucureşti

University, class support, 2011

[WATS07] Watson, G. H.: *Benchmarking Reloaded with Six Sigma*, John Wiley & Sons, New York, 2007

[WEBB07] Webber, L.; Wallace, M.: *Quality Control for Dummies*, Wiley Publishing Inc., Indianapolis, 2007

[WEDW12] W. Edwards Deming Institut: http://deming.org/, accessed on 06.04.2012

[WILL08]. Williams, S.: Lean Sigma Part VIII, *CircuiTree*, vol. 21, No. 2, pg. 50, Feb. 2008

[WINN09] Winner, H.; Danner, B.; Steinle, J.: Adaptive Cruise Control, în *Winner - Handbuch Fahrerassistenzsysteme - Grundlagen, Komponenten und Systeme für aktive Sicherheit und Komfort*, Springer Verlag, pg. 478-521, 2009

[WOMA90] Womack, J. P.; Jones, T. D.; Roos D.: *The Machine That Changed the World*, Harper Collins, New York, 1990