

UNIVERSALITY AND EFFECTIVENESS OF METHODS AND TECHNIQUES OF QUALITY MANAGEMENT ON THE EXAMPLE OF THE AUTOMOTIVE INDUSTRY

METHODS AND TECHNIQUES OF QUALITY MANAGEMENT

The knowledge about methods and techniques of quality management together with their effective use can be definitely regarded as an indication of high organisational culture. Using such methods and techniques in an effective way can be attributed to certain level of maturity, as far as the quality management system in an organisation is concerned. Such maturity, in turn, can be achieved when the top management is aware that the use of such methods and techniques is reasonable and that it is necessary to incorporate such methods and techniques in corrective actions and actions taken as part of the continuous improvement process. It has to be pointed out here, though, that only a limited number of organisations use the tools. Even fewer organisations do it with deliberation as a permanent element of their quality management systems. The customers most frequently require this type of actions to be taken¹ or standard requirements². For this reason, organisations should be encouraged to learn about at least the most frequent methods and techniques of quality management. At the same time, it should be pointed out, that the number of them is very high³. Only knowledge concerning the methods

¹ e.g. Fortel Q (the requirements of VW), Alliance Supplier Guide (ASG) (the requirements of Nissan and Renault).

² e.g. ISO/TS 16949:2009, TL 9000.

³ See: Z. Martyniak, *Nowe metody i koncepcje zarządzania* [New methods and concepts of management], Wydawnictwo Akademii Ekonomicznej w Krakowie, 2002; T. Osada, *Five keys to a Total Quality Management*, Tokyo 1991; N. R. Tague, *The Quality Toolbox*, ASQ Quality Press, Milwaukee, 1995; G. F. Smith, *Quality Problem Solving*, ASQ Quality Press, Milwaukee 1998; C. Carl Pages, *Total Quality Management, A survey of Its Important Aspects*, State University of New York of Buffalo, 1995; E. Kreier, J. Łuczak, *Łatwy i skuteczny sposób uzyskania certyfikatu ISO 9000* [Easy and effective way to obtain ISO 9000 certificate], Forum 1997 – 2006; J. Łuczak, T. Bramorski, *QS-9000 System jakości dostawców na rynek motoryzacyjny* [QS-9000 Quality management system of suppliers for the automotive market], Quality Progress, 1999; S. Shiba, *Le Management par Peerce, Methode HOSHIN*, INSEP Editions, Paris 1995; A. Ham-

and techniques and the purposefulness of their use will allow the organisations to create a policy regarding them in a deliberate way.

One of the main assumptions underlying a quality management system is improving the ability to define nonconformities, as well as to plan and realise corrective and preventive actions. What it means in practice is that the organisation must implement effective mechanisms thanks to which it can react fast to any problems, analyse the causes of the problems and choose and realise the most appropriate actions that are directed at the causes of such problems. What is more, one should not forget about the requirements set in standardised management systems, and especially in Chapter 8 Measurement, analysis and improvement (ISO/TS 16949). This chapter determines the need to take actions related to defining nonconformities, identifying the causes of nonconformities, correcting nonconformities, as well as planning and realising corrective and preventive actions. However, the standard defines only what should be done. It does not state which methods and tools should be used to meet the requirements and realise the targets. One should look for the answer to this question both in literature and in experience in this area. The standards, which are the basis for quality management system in the automotive industry, require not only teamwork, but also the use of very specific tools and techniques of problem solving. A significant number of those methods are even called systems, because they constitute an integral and necessary element of cooperation between organisations in the customer-supplier relations⁴.

Literature of the trade, describes a great variety of methods and techniques of quality management that are used in practice. Quite often the two terms, i.e. "method" and "technique" are used interchangeably. Encyclopaedic sources⁵ usually define a "method" as a conscious and consistently used way of conduct to

ro], W. Mańtura, *Zarządzanie jakością: teoria i praktyka* [Quality management: theory and practice], Wydawnictwo Naukowe PWN, Warszawa 2004; S. Borkowski, *Mierzenie poziomu jakości* [Measuring quality level], Wydawnictwo Wyższej Szkoły Zarządzania i Marketingu w Sosnowcu, 2004; P. S. Pande, R. P. Neuman, R. R. Cavanagh, *Six Sigma: sposób poprawy wyników nie tylko dla takich firm jak GE czy Motorola* [Six Sigma: a way of improving the results not only for companies like GE or Motorola], K.E. Liber, Warszawa 2003; J. Żuchowski, E. Łagowski, *Narzędzia i metody doskonalenia jakości*, Politech.Radomska, Radom 2004; M. Urbaniak, *Zarządzanie jakością, środowiskiem oraz bezpieczeństwem w praktyce gospodarczej*, Difin, Warszawa 2007; E. Skrzypek, M. Hofman, *Zarządzanie procesami w przedsiębiorstwie*, Wolters Kluwer business, Warszawa 2010.

⁴ See: J. K. Liker, M. Hoseus, *Kultura Toyoty*, MT Biznes Ltd., Warszawa 2009; J. K. Bandyopadhyay, L.O. Jenicke, *Six Sigma Approach of Quality Assurance in Global Supply Chains: A Study of United States Automakers*, "International Journal of Management" 2007, vol. 24, nr 1; R. Delbridge, H. Barton, *Organizing for continuous improvement. Structures and roles in automotive components plants*, "International Journal of Operations & Production Management" 2002, vol. 22, nr 6; J. K. Liker, D. P. Meier, *Toyota talent*, MT Biznes Ltd., 2008; I. Sila, M. Ebrahimpour, C. Birkholz, *Quality in supply chains: an empirical analysis*, "Supply Chain Management: An International Journal" 2006, vol. 11, nr 6; J. Żuchowski, E. Łagowski, *Narzędzia i metody doskonalenia jakości*, Politechnika Radomska, Radom 2004; M. Imai, *KAIZEN*, Kaizen Institute, MT Biznes, 2007.

⁵ *Encyklopedia Ekonomiczna PWN* [PWN Economic Encyclopedia], 1999, p. 74.

achieve specific aims, i.e. a set of deliberate actions and means. On the other hand, "a technique" is a deliberate and rational way of conduct in a specific area that is based on theory.

Any improvement tools in the organisation must be by all means implemented and used in relation to the particular steps of the Deming Cycle. It is the concept of continuous improvement of all processes in the management system. It is also a philosophy that helps to solve any problems in a systematic way and supports the implementation of accepted solutions⁶. The PDCA cycle (the Deming circle) determines chronologically organised actions that are typical for a control system with feedback⁷ (such actions concern the quality of technological processes and products). The ISO/TS 16949 standards recommend the use of this approach in the process of continuous improvement of the quality management system.

At each step of the Deming Cycle some tools for quality management can be used, as shown in Table 1.

| | |
|-----------------|--|
| Step 1 - plan: | Flowchart, Nominal Group Technique (NGT), Pareto Analysis, Brainstorming, Cause-and-effect Diagrams, Process mapping, Hoshin Planning. |
| Step 2 - do: | Design of experiment. Process monitoring, SPC, Control plan. |
| Step 3 - check: | Control sheets, Control charts, Key process characteristics indicators, Control sheets. |
| Step 4 - act: | Process modelling, Force Field Analysis, Impact analysis. |

Source: own study based on N.R. Tague, *The Quality Toolbox*, ASQ Quality Press, Milwaukee, 1995; G. F. Smith, *Quality Problem Solving*, ASQ Quality Press, Milwaukee 1998.

The methods and techniques that are worth presenting can be grouped according to answers to the questions that are formulated at particular stages of the problem solving and improvement process:

- What shall be achieved and what objectives shall be defined?
- What is being realised at present with regard to the defined targets? What is the current status of the process?
- What can be done better? Which areas can be improved?
- What are the existing limitations and reasons for the unsatisfactory state?

⁶ S. Smith, *Techniki pokonywania problemów* [Techniques of dealing with problems], Wydawnictwo Helion, 2004, p. 109.

⁷ A. Hamrol, W. Mańtura, *Zarządzanie jakością. Teoria i praktyka* [Quality management. Theory and practice], Wydawnictwo Naukowe PWN, 2002, p. 93.

- What is the best way of improving the existing situation?
 - What changes should be made to achieve higher efficiency and effectiveness of undertaken actions?
 - What is the efficiency of undertaken actions?
- If the objectives have been realised, in what way can the undertaken actions be consolidated and made a common practice?

When looking for answers to each question formulated in this way, we can make use of various methods and techniques of quality management, which have one thing in common. This common denominator is the necessity of teamwork together with the possibility and need to involve each and every employee, not because of the level of his/her education, but due to his/her professional experience. The principles of these methods are very simple. Because of that, a short training combined with a properly chosen team can almost guarantee that the defined objectives that concern the use of methods and techniques of quality management can be realised with not much effort.

It is also very important to pay attention to the methodologies of problems solving, which in essence refer to particular tools and methods. Above all, the 8D method (developed at Ford Motor Company) is worth remembering. This method is based on a multi-stage approach to a problem, starting from a full diagnosis of

Table 2. Stages of the 8D method

| No. | Phase of the 8D process | Description |
|-----|--|--|
| 1 | Appointing the 8D team | Establishing a small team of employees with knowledge about the problem/ product/ process that has the authority, time and skills to solve the problem and implement corrective and preventive actions, choosing the team leader. |
| 2 | Defining the problem | Defining the internal or external problem - determining what is improper and describing it in a way allowing answering such questions as: What? Where? How? How many? etc. |
| 3 | Implementing and verifying interim actions | Defining and implementing interim actions to protect the internal/external customers from the problem until permanent corrective actions can be implemented. Verifying the effectiveness of these actions. |
| 4 | Defining and verifying root causes | Identifying all causes that could explain why the problem occurred. Identifying and verifying causes by testing each potential cause against the problem description and available data. Defining possible corrective actions to eliminate the root causes. |
| 5 | Choosing Permanent Corrective Actions | Confirming through pre-production programs that the selected corrective actions will resolve the problem for the customer and will not cause undesirable effects. If appropriate, based on risk assessment. |
| 6 | Implementing Permanent Corrective Actions | Establishing an implementation plan for permanent corrective actions and defining a system of on-going control over their effectiveness. Ensuring that all root causes or undesired effects are eliminated, monitoring the long-term effectiveness and implementing alternative actions, if it is necessary. |
| 7 | Preventing recurrence | Modifying the management system in the scope required to prevent recurrence of this and all similar problems in the future. Identifying possibilities for improvement and establishing a process of initiatives for improvement. |
| 8 | Congratulating your team | Recognising the work of the team. |

Source: materials of Ford Motor Company.

its causes and ending with ensuring the efficiency of undertaken actions that are also consolidated in a system. The table below characterises the phases of the 8D method:

Quality teams established to solve particularly significant problems in case of which neither the root causes nor the mitigating measures are known use the 8D method.

During each of the abovementioned phases, different quality management methods can be used. For example, at the fifth phase (Choosing Permanent Corrective Actions) the following methods are used: FMEA, cause-and-effect (Ishikawa) diagram, verification plans, DVPSOR reports.

THE CAUSE-AND-EFFECT ISHIKAWA DIAGRAM

The cause-and-effect Ishikawa Diagram was used for the first time at Sumitomo Electric. It has become a very commonly used tool when it comes to quality management. This method consists in presenting the analysis of interconnections between the causes of a particular problem⁸. It is perfect for teamwork combined with other tools and techniques of quality management e.g. brainstorming. It is sometimes called a hierarchizing tool whose main is to help with finding the causes of the occurring problem. The Ishikawa Diagram is also called the herringbone diagram or the fishbone diagram because of its shape.

The basic features of the abovementioned diagram are the following:

- Orderly presentation of information,
- Accuracy of analysis,
- Creating a hierarchy of actions,
- Diligence,
- Focus on containing and eliminating the causes of a problem.

THE 5M MODEL

The general outline of the herringbone diagram is presented on the picture below. The "Fish head" symbolises a problem, the inner branches meeting a horizontal straight line, called the "spine" represent groups of causes of the problem. The main task of a quality team is to define the problems and arrange them in the right hierarchy. For less experienced teams, the analysis using the 5Ms model is recommended. It suggests five groups of causes, i.e. Manpower, Method, Machinery, Material, and Management.

- Manpower - qualifications, habits, work satisfaction, level of seniority, frame of mind, etc.
- Method - procedures, instructions, scope of duties, specifications, standards, law, rules, know-how, technology, etc.

⁸ See inter alia G. F. Smith, *Quality Problem Solving*, ASQ Quality Press, 1998, p. 110 - 112.

- Machine - licence, durability, modernity, productivity, precision, safety, work conditions, etc.
- Material - input materials, semi-finished products, elements, substitutes, etc.
- Management - organisational structure, work organisation, shift work, work conditions, etc.

For an experienced working group, a herringbone diagram can be very helpful when it comes to defining the groups of causes of a specific problem. Taking these groups into account is a guarantee that most of the root causes will be placed on the diagram. However, in many cases it may be necessary to modify the abovementioned groups of causes, omit some of them or even create new ones.

BUILDING A DIAGRAM

When building the Ishikawa Diagram the following stages of actions can be distinguished⁹:

- Identifying the problem.
- Initiating work on the diagram.
- Defining the main groups of causes.
- Making the diagram more specific.
- Analysing the diagram.

The starting point is defining the problem that we want to solve. This may be the effect of brainstorming; Pareto analysis or simply the problem that generates the biggest costs is to be dealt with.

A very effective way of using the herringbone diagram is putting it on public display e.g. in the corridor of an office building. It can be done either before or after the causes have been put on the diagram. Each person passing by is able to add his/her suggestion to the diagram¹⁰. In this way, not only many good ideas can be obtained, but also every employee and person visiting the organisation has a chance to participate in the process. A completed diagram proves that the employees are involved in the business of their own organisation. Also a completed diagram can be put on public display. In this case, any remark shall be noted down and taken into consideration in future analyses.

Using other methods e.g. ABCD, or Pareto analysis one can grade the significance of causes and draw up a corrective action plan. When specific causes have been eliminated, they shall be crossed out from the diagram and the time of their termination shall be also marked on the diagram. It is also good to mark the causes, which are dealt with at present. In this way, all people involved in a specific action can identify themselves with undertakings aimed at improving quality.

PARETO CHART

The Pareto Chart is a tool that helps to hierarchize the factors influencing a particular problem. It is a graphic image representing both the relative and absolute distribution of types of failures, problems or their causes¹¹. Very often, employees face a significant number of problems, which they would like to solve at once, and overestimate their skills and abilities. When a decision is made to solve a particular problem, it very often becomes evident that there are many causes of this problem, some of which are very significant and others are rather insignificant.

The diagram as a statistical tool was popularised by Joseph M. Juran who dealt with the analysis of uneven distribution of quality losses. During his research he came across the results of work of an Italian economist and sociologist Vilfred Pareto, who studied the distribution of capital resources in Europe at the beginning of the 19th century. He proved that wealth could only be attributed to a few, and that poverty was a highly frequent phenomenon. Based on his research, Pareto formulated the "80/20" rule stating that the occurrence of most events may be observed on a small fragment of reality. His research showed that about 20% of the society possesses 80% of the total wealth. The Pareto Chart is a type of chart containing both bars (with individual values represented in descending order) and a line graph representing the cumulative total. When using this method in quality management one should focus on carrying out corrective actions for this 20% of most significant causes of nonconformities.

This method is used in practice when you want to eliminate:

- Events with the highest frequency of occurrence,
- Causes of problems generating the highest costs.
- The course of actions when performing the analysis with the abovementioned aims is the following:
 - The list of causes is defined,
 - The categories influencing the phenomena in question are determined,
 - The timeframe for the analysis is defined,
 - The data is collected,
 - The table is created and the axes are scaled,
 - The bar graph is created (in the descending order),
 - The cumulative total is calculated and the line graph is created,
 - The graph is analysed.

In case of analysis of complex groups of factors, carrying out a repeated analysis is advisable for subgroups of these factors. It means that the groups of factors selected during the analysis are divided into components and analysed for a second time. In this way the most significant factors that influence the number of nonconformities are detected or the costs, which are generated by such nonconformities, are determined.

¹¹ J. J. Dahgaard, K. Kristesen, G. K. Kanji, *Podstawy zarządzania jakością* [The principles of quality management], PWN, Warszawa 2000, p. 91.

⁹ Inter alia C. Carl Pages, *Total Quality Management, A survey of Its Important Aspects*, State University of New York of Buffalo, 1995, p. 97 - 100.

¹⁰ N. R. Tague, *The Quality Toolbox*, ASQ Quality Press, 1995, p. 132

The following example explains the course of actions that shall be taken when performing a Pareto Analysis.

The Pareto Method is often used interchangeably with the Suzuki Method, which is also called the ABC analysis. The main difference between them is the form in which they present the data. The Pareto Analysis is used more frequently due to the fact that its form is easier to comprehend.

The same approach can be used in numerous cases in different industries and when solving various problems.

The Pareto Chart helps us to analyse how to improve quality with limited resources. In addition to that, it identifies the problems that should be solved at first.

FMEA (FAILURE MODE AND EFFECTS ANALYSIS)

As business experience shows, 75% of causes of all failures can be attributed to the design stage of the product. Their detectability at this stage, though, is low as evidenced by the fact that 80% of failures are detected during production, control and when the product reaches the final user. This situation results in very large losses and, above all, in increase in the costs related to correcting, repairing, wasting time, losing customers, etc.

Despite the fact that engineers in the U.S. and Japan had used analyses of the FMEA type before, the first formal application of FMEA took place in the United States in the 1960s, in the space industry.

Frequently, this method is used in industrial sectors producing high-risk products (aviation, army) in electronics, machine industry, and especially in the automotive industry. An example here might be the ISO/TS 16949 standard winning increasing popularity, in case of which the application of FMEA is one of the mandatory requirements to be met by companies interested in obtaining a certificate.

FMEA as a disciplined technique for identifying failures that also helps to eliminate them. It should at least be considered, and if possible used by all organisations seeking to prevent failures and declaring a policy of continuous improvement.

FMEA consists of actions that aim at:

- Identifying and assessing potential failures that may occur in the product or process and the impacts of their occurrence,
- Identifying actions that could eliminate or at least reduce the chances of potential failures,
- Documenting the processes.

When deciding to conduct the FMEA, its purpose and the scope of what is to be covered by it should be specified.

One of the key success factors in the implementation of FMEA is choosing the right time for the analysis. This means the analysis should be done "before the event" and not after it. To achieve the most benefit, the FMEA must be made before the failures are "incorporated" in the product or process in an unconscious way.

Spending more time in the beginning to perform the FMEA in a comprehensive way (at the design stage of the product or process), when any changes in the

designed product or process can be made easily and inexpensively, reduces the problems associated with introducing modifications in the future. FMEA can reduce or even eliminate the need to implement corrective changes that at a later stage. Such corrective changes at a later stage can lead to even bigger complications and higher costs.

This does not mean, though, that we should not use FMEA, for example, to identify corrective actions for existing products or processes.

Types of FMEA

Two types of FMEA are distinguished most often¹²:

- Project FMEA,
- Process FMEA.

Project FMEA

Project FMEA allows one to "do things right the first time." Conducting project FMEA at a very early stage of the product design, allows the organisation in advance to:

- determine the risk of damages and incidents that may occur in the product (also considering other solutions),
- determine which points of the product constitute its sensitive location, specify the ways and measures which are necessary for their removal,
- collect all necessary information which helps in the planning of accurate and efficient tests and development programs and allows, for example, to eliminate unnecessary tests,
- create a list of potential failures ranked according to their impact on the customer, thus establishing a priority of each action.

Project FMEA can be used, for example:

- To introduce new products,
- When there is a particular risk of danger and no failures are allowed,
- When designing new components, changed components and components that have been transferred to new applications or to another environment.

Process FMEA

Process FMEA allows the organisation to understand the problems and disruptions that are encountered during the implementation of the processes planned by it.

Process FMEA is used at a very early stage of the planning process, allowing the organisation with appropriate time in advance to:

- Decide whether a process is suitable or not,
- Identify weaknesses and potential problems and process variables on which control shall be focused in order to reduce the incidence or to detect potential failures,

¹² See AIAG's FMEA 4th Edition, 2008.

- Take appropriate actions to prevent the occurrence of weak spots in the process,
- Create a list of potential threats ordered by their impact on the customer, thus establishing a priority of each action.

Process FMEA can be, for example, used:

- Before launching mass production,
- During the planning phase of production to prepare the processes in the most optimal way (including the selection of resources: machines, equipment, instruments),
- When introducing new products or manufacturing processes,
- To improve unstable processes.

FMEA is also used in service, assembly, warehousing and other activities that are not necessarily related to the production processes, e.g. in relation to the organisation to ensure optimal functioning of the departments in the company. The selection, preparation and implementation of FMEA depend on the category of a given problem.

FMEA will bring the expected results only when the analysis is conducted by a properly chosen group of people. They should be specialists in different areas of the company, representing the respective areas of expertise necessary to achieve the objective that is set, when the organisation makes use of the FMEA method. They should also have extensive experience and knowledge concerning mainly:

- results of the control and testing of products or processes;
- the products, technologies and production methods;
- similar products or processes;
- customer needs identified in market research performed;
- data supplied by the service department;
- collecting and analysing data during the implementation of production processes;

as well as,

- all of them should be trained in teamwork and in the methodology and manner of performing FMEA.

The general rule is that the team consists of employees of the company. However, if this is necessary, an expert team from outside the company can join the team. There should be from 4 to 8 people in the team. The head of the team shall be a manager. This should be a person with full knowledge of the subject matter, but it does not have to be a specialist. The main task of the manager is to:

- Choose the members of the team,
- Integrate the team,
- Organise the work in the team,
- Plan and prepare meetings,
- Supervise the meetings,
- Ensure maximum efficiency of the work.

All team members should have smooth and fast access to all information and source materials regarding market research, quality control, statistical analysis, service maintenance and any other areas from which information can be useful and help to achieve the formulated objective.

Stages of FMEA

When the objective and scope of the analysis has been determined, the designated manager and the team responsible for its implementation can begin the FMEA analysis. It should include the following actions:

1. Identifying all components of the product or features of the process in question in sequence of technological processes.
2. Making a list of potential failures.

It is prepared in accordance with the intentions of the team members. It is assumed that the potential failure can occur, but not necessarily. Potential failure that could occur only under specific operating conditions (when it is hot, cold, or dry) and in certain conditions of use should also be taken into consideration. When determining potential failures, the reports of complaints, warranty records, records of inspection and experience related to the production of similar products can be capitalised on.

3. Making a list of possible impacts of these failures¹³.
The impacts of these failures should be determined from the perspective of the customer, taking into account what the customer could have seen or experienced. It has to be remembered here that our customer may be an internal customer, as well as the final user. It should be clearly indicated whether or not the failure could affect safety or lead to nonconformities.

4. Making a list of possible causes of failures.

This is an indication of the weak spots of the product or the process whose consequence is a failure. It has to be kept in mind that the causes of failures shall be described in the most concise and comprehensive way, so that preventive actions can be directed at proper causes.

5. Assigning risk ratings (O, S, D) to possible failures.

The letters signify respectively:

O - probability of occurrence,

S - severity of the risk and significance for the customer,

D - detectability (how difficult it is to detect the risk).

Evaluation of the significance of failures, their causes and impacts is done by point estimation. In most cases the evaluation is done on a scale from 1 to 10, in case of which "1" is the smallest value.

The members of the team evaluate based on the evaluation criteria that are defined for the product or the process.

The evaluation criteria will differ from one another, depending on the nature of the business and the findings of the FMEA team. The entire team should accept the evaluation criteria and rating system, even if they were modified for the analysis of an individual product.

6. Calculating the RPN (risk priority number).

RPN can be easily calculated by multiplying these three abovementioned values, i.e. $RPN = S \times O \times D$. It specifies the level of risk which is related to the occur-

¹³ G. F. Smith, *Quality Problem Solving*, ASQ Quality Press, 1998, p. 187 - 189.

rence of particular failures. In case of a ten-grade scale, the minimum value of RPN is 1 and the maximum value is 1000.

7. Ordering potential failures according to their severity.

When the RPNs are calculated for all possible failures, we should rank them (according to their value). Owing to this it will be possible to see which of the potential failures and which of the potential causes are the most serious ones and to determine the order of preventive or corrective actions that should be taken. Since evaluations made by the team are subjective, it is difficult to determine the level at which we should plan corrective actions, because it seems appropriate to take corrective action in accordance with the value of RPN (from the largest to the smallest).

8. Defining corrective actions.

When the RPNs are ranked according to their value, preventive or corrective actions are determined, which will be taken so as to:

- Eliminate or minimise the probability of a failure,
- Reduce the severity of a particular failure for the customer to a minimum,
- Increase the probability of detecting a given failure.

However, the main focus should be placed on prevention of failure rather than on their detection and subsequent correction.

For each corrective action there should be a designated person who is responsible for implementing this particular action. There should also be specified deadlines for the implementation (e.g. starting date and final date for completion of an action). Actions described in this manner should be reflected in the form of a properly prepared document.

A specially prepared FMEA sheet serves this purpose¹⁴. The form, content and complexity of the document vary and depend on the assumptions that are accepted in the implementation of FMEA.

This type of document can be significantly modified and expanded to include a column indicating for instance:

- employees responsible for implementing corrective actions
- starting and finish dates of these activities
- the O, S, D and RPN indicators calculated after the accepted corrective actions have been implemented

as well as complemented (outside the table) with information regarding:

- the person who compiled, checked and approved it
- the company, production plant or department in which the analysis was carried out
- the scope of the analysis etc.

Apart from preventing or eliminating the impacts of failures, using FMEA brings many other benefits. These are:

- Creating teamwork and integrating teams during mutual problem solving,
- Increasing the knowledge and experience of employees,
- Improving product reliability or process efficiency,

¹⁴ see AIAG's FMEA 4th Edition, 2008.

- Increasing customer satisfaction,
- Reducing costs,
- Defining the risk and ensuring appropriate action for its mitigation, which is important and provides exculpatory arguments in case the manufacturer's responsibility for the product.

DESCRIPTION OF RESEARCH METHOD AND DATA COLLECTION TECHNIQUES

In order to explain the research problem the aim of the paper had to be defined at first and then realised. In case of the following paper the aim was narrowed down to identifying the methods and techniques that were used by OE/OES suppliers in the automotive industry, on the one hand, and evaluating how relevant each one of them was for the QMS to be effective, on the other hand.

In consequence, the following tasks had to be performed in order to realise the general aim of the paper:

- Verifying reference literature on quality management in automotive industry, and specifically literature that was directly related to the formulated research problem.
- Collecting documents, standards, procedures that constituted sets of essential methods and techniques and were exclusively determined in customer specific requirements (CSR).
- Identifying requirements which were not formalised and had the nature of know-how used by OEM suppliers.
- Describing key methods and techniques of quality management that were used in the automotive industry.
- Studying the relevance of requirements on a sample of companies which underwent a comprehensive assessment both from the perspective of certifying bodies and customers, as well as which realised their own priorities which were aimed at improving the effectiveness and efficiency of management systems and business efficiency.
- Drawing conclusions in the form of recommendations specifically for supplier companies and potential suppliers for the automotive industry and more generally for all organisations wishing to improve their QMS.

In order to realise the aim of the project the following research hypothesis had to be verified: *the most relevant methods and techniques used by suppliers in the automotive industry for quality management are the Flowchart, the FMEA analysis and the 8D process.*

Two surveys, namely a preparatory survey (S1) and proper survey (S2) were conducted in course of the research. In the proper survey (S2) a questionnaire was used as the research tool. It was given to the general population, which in this case consisted of companies operating in Poland that had certified quality management systems against ISO/TS 16949. Moreover, the direct interest of the author were the methods and techniques used for quality management.

The surveys and analyses that were carried out applied to the automotive industry and above all to the manufacturers of engine-powered vehicles. In practice, these companies were the 1st and 2nd tier OE/OES suppliers.

Experts representing six well-known companies, suppliers for the automotive industry, participated in the preparatory survey. These experts had to meet a number of specific recruitment criteria. First of all, the main aim of the preparatory survey, which was performed by means of the Delphi method, was to determine which methods and techniques of quality management, out of the wide spectrum of methods and techniques, were really of relevance. Then, based on the results of the preparatory survey a research tool (in the form of a questionnaire form) was compiled in order to conduct the proper survey.

So, in other words, the preparatory survey was a prerequisite of the proper survey. The organisations that were examined held ISO/TS 16949 requirements compliance certificates. The fact that they held such certificates also meant that they cooperated within the framework of OE/OES supply contracts.

IDENTIFICATION OF METHODS AND TECHNIQUES OF QUALITY MANAGEMENT

The preparatory survey was carried out in accordance with the rules of the Delphi method and 7 formal sessions had been realised via e-mail, video and teleconferences. The experts analysed the consecutive versions. Initially the versions were related to the specific aims of the survey, defining the category of methods and techniques of quality management, the list of methods and techniques and eventually the questionnaire form.

As a result of the preparatory survey, the list of methods and techniques of quality management was narrowed down to the Flowchart, the cause-and-effect (Ishikawa) diagram, the Pareto diagram, the ABCD (Suzuki), brainstorming, the QFD method, the FMEA analysis, the Histogram, data collection sheets, SPC control sheets, the 8D process, the 5PPJ, the Layout and the Turtle Diagram. However, the respondents could also add some other methods and techniques of quality management that were used in their companies.

In order to verify the hypothesis and research aims, the following questions were put in the questionnaire form:

- Does your organisation use methods and techniques (M&T) of quality management?
- Would you place the following terms and definitions in the category "methods and techniques of quality management"?
- What are the determinant factors of using M&T for quality management?
- Which of the following M&T are used in your company?
- What is the purpose of M&T used in the company?
- What is the relevance (frequency of use and effectiveness) of using M&T in the company (1 – irrelevant, 5 – very relevant)?
- What are the reasons for limited use of M&T in the Company?
- Are reports on the use of M&T created (without using the methods and techniques)?

- How would you assess your knowledge about M&T? ('1' signified very poor knowledge and '5' very good knowledge)?

The questionnaire also included a column to collect basic personal information about the respondents.

EVALUATION OF RELEVANCE OF METHODS AND TECHNIQUES OF QUALITY MANAGEMENT

The S2 survey was performed on a group of companies¹⁵ with principal place of business in Poland¹⁶ that held ISO/TS 16949 compliance certificates. The performed survey was complete and exhaustive in nature. Due to the percentage of returned questionnaires (i.e. 23%) and other statistical parameters it was possible to infer about the whole surveyed population. The questionnaire form provided the author with data that were analysed afterwards. Subsequently on the basis the obtained data, statistical inference was conducted so as to verify the hypothesis that was defined in the paper. Conducting the survey with the use of questionnaire form and according to a scenario can be regarded as a statistical observation, a statistical study and a statistical analysis¹⁷.

To conduct the survey a questionnaire form was used which by assumption had been distributed exclusively by electronic means (e-mail) and had been appropriately prepared to make use of the Internet questionnaire^{18, 19}.

Realising the aims defined in the paper and verifying the formulated hypothesis was in the first place related to evaluating the relevance of previously specified methods and techniques of quality management.

Nearly all respondents declared that they used methods and techniques of quality management. It was an answer that could be anticipated as the use of methods and techniques of quality management is specified by ISO/TS 16949 and very often in customer specific requirements.

¹⁵ The following synonyms were used in this paper in reference to the surveyed companies: the general population, surveyed population and the statistical population.

¹⁶ Business activity registered in Poland as defined by the Code of Commercial Partnerships and Companies.

¹⁷ W. Ignatczyk, M. Chromińska, *Statystyka. Teoria i zastosowanie* [Statistics. Theory and use], Wydawnictwo Wyższej Szkoły Bankowej, Poznań 2004, p. 24.

¹⁸ See: A. Kaniwska-Sęba, G. Leszczyński, B. Pilarczyk, *Badania marketingowe na rynku business-to-business*, Oficyna Ekonomiczna, Oddział Polskich Wydawnictw Profesjonalnych, Kraków 2006, s. 122; K. Mazurek-Łopacińska, *Badania marketingowe. Teoria i praktyka*, PWN, Warszawa 2005, p. 107; J. Pociecha, *Metody statystyczne w badaniach marketingowych* [Statistical methods in marketing research], PWN, Warsaw 1996, p. 5; R. Mącik, *Wykorzystanie Internetu w badaniach marketingowych* [Using the Internet in marketing research], Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej, Lublin 2005, p. 114-117.

¹⁹ In literature in this field the following terms and expressions are found: questionnaires sent by electronic mail (*kwestionariusze wysłane pocztą elektroniczną*), internet survey (*badanie internetowe*), computer questionnaire (*ankieta komputerowa*) – see also A. Kaniwska-Sęba, G. Leszczyński, B. Pilarczyk, op.cit., p. 122; K. Mazurek-Łopacińska, op.cit., p. 107; J. Pociecha, op.cit., p. 5; R. Mącik, op.cit., p. 114-117.

So the aim, i.e. identifying and selecting methods and techniques used by suppliers in quality management systems, was realised with good results. The respondents indicated which of all of the methods and techniques were used. The following methods and techniques were used by the highest percentage of respondents (more than 60%): the FMEA, the Flowchart, the Pareto diagram, the Layout, brainstorming, histograms, control sheets, the 8D process, the cause-and-effect (Ishikawa) diagram and data collection sheets.

Concurrently, the Turtle Diagram was far less popular, even despite the fact that in literature it was often presented as a tool frequently used in the automotive industry.

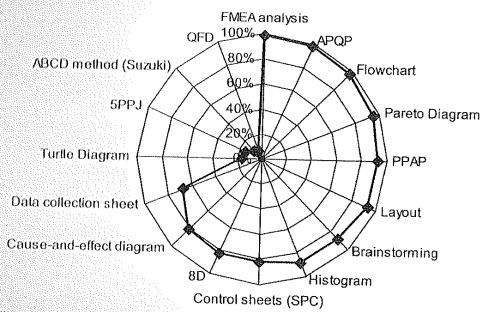


Figure 1. The use of specific methods and techniques of quality management as a percentage. Source: Own study based on the results of the questionnaire survey.

Both the SPPJ and the QFD shall be recognised as highly specific tools. The first one is required only by a limited number of car manufacturers (8D is far more frequent in use). The second one is highly specific due to the fact that only a small share of companies (respondents) realised activities connected to R&D.

Suppliers in the automotive industry use methods and techniques of quality management primarily because of customer requirements (99%) and ISO/TS 16949 (78%). A significant group of the respondents (62%) consider the organisational culture to be of great importance. For them the use of methods and techniques of quality management is obvious and common.

The classic approach to the classification of methods and techniques of quality management is related to using them for activities taken as part of the PDCA circle. The respondents were asked to match the methods and techniques they used with the following actions:

- defining the problem,
- defining the solutions,
- defining the causes,
- control the effectiveness of implemented actions,
- improving the QMS.

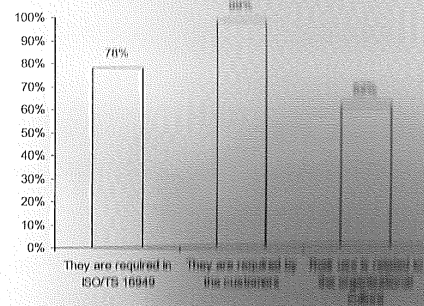


Figure 2. Main reasons for using methods and techniques of quality management. Source: Own study based on the results of the questionnaire survey.

Table 3. The purpose of using M&T in the company.

| | Yes | No |
|--|-----|----|
| Defining the problem | 13 | 13 |
| Defining the solutions | 13 | 13 |
| Defining the causes | 16 | 12 |
| Controlling the effectiveness of implemented actions | 20 | 18 |
| Improving the QMS | 67 | 13 |

Source: Own study based on the questionnaire survey.

Almost all suppliers use methods and techniques of quality management as far as improving the quality management system is concerned. They are most useful when it comes to the defining problems (80.88%) and defining their causes (82.35%). The tools which support defining solutions and which are used to control the effectiveness of taken actions are more theoretical in nature.

As it was assessed how frequently the selected methods and techniques of quality management were used it was also possible to evaluate their relevance defined as the resultant of the frequency and effectiveness of their use. The most relevant methods as indicated by the respondents were: the Flowchart, the ABCD method, SPC control sheets as well as multi-stage problem solving methods (e.g. 8D, 5PPJ). However, not only the 8D method was considered to be relevant by the respondents, but also the cause-and-effect (Ishikawa) diagram.

The selected statistical population (suppliers certified for ISO/TS 16949 compliance) guaranteed that the methods and techniques of quality management would be frequently used. As it turned out, the motivating factors to use M&T tools in each individual case different. In most cases they resulted from necessity, i.e. requirements set by the QMS or customers. It can be certainly assumed that consistent and effective use of methods and techniques of quality management (irrespective of the reasons) is a sign of maturity as far as quality management is concerned.

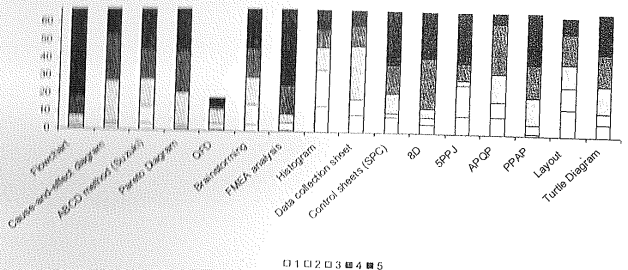


Figure 3. Evaluation of relevance of M&T in companies
Source: Own study based on questionnaire survey.

The respondents (60%) admitted, though, that not seldom the requirement of using appropriate methods and techniques is fictitious, i.e. 8D reports, FMEA reports etc. were compiled not as the effect of teamwork, one of the stages of problem solving activities, but as a formal task which simply had to be completed. This is caused by a number of unequivocal factors, such as:

- the fact that such actions require much time (77.94%),
- insufficient staff (72.06%),
- and the fact that the employees are not sufficiently prepared to use them (72.06%).

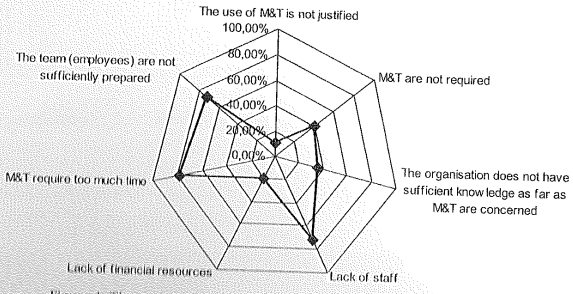


Figure 4. The causes of limited use of M&T in a company as a percentage
Source: Own study based on questionnaire survey.

It must be pointed out that the respondents did not consider using M&T as unjustified or connected with significant financial expenses. It may be assumed that suppliers in the automotive industry are aware that such methods and techniques

can be used effectively. What is more they feel the need to use them and even the lack of requirements related to their use does not contribute to the fact that such M&T are applied less frequently.

The results of self-evaluation concerning the knowledge of respondents (quality managers, quality department managers, people for quality) confirmed that limitations in the use of M&T exist. Generally, respondents evaluated their own knowledge as quite good (46%).

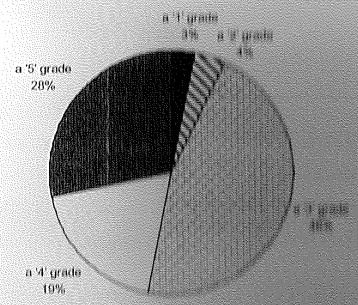


Figure 5. Self-evaluation of respondents concerning their knowledge about M&T (1 - indicated very poor knowledge and 4 - very good knowledge)
Source: Own study based on questionnaire survey.

However, there were no randomly selected people in this group. All of them felt the need to educate and develop in that specific area of expertise.

CONCLUSIONS

The author verified the common theoretical approach regarding the methods and techniques of quality management. The research also showed that companies in the automotive industry used in practice only a limited number of the huge number of tools described in literature. In addition to that, the results of the research helped to determine which methods and techniques were the most effective when it came to their use. This was of key relevance as effective methods can considerably support non-compliance monitoring, or taking corrective and preventive actions.

The results of the conducted survey and the conclusions of the author can show actual and potential OEM suppliers (both 1st and 2nd tier in which area their strategies for development and improvement of quality management systems should go in order to be effective. When the universal character of methods and techniques used in the surveyed population of companies is taken into consideration, it can be assumed that the results of the survey are also universal for all organisations realising the TQM strategy.

The results of the research confirmed that methods which are also the basis for creating key system documents are the most relevant ones, i.e. flowcharts and FMEA, and moreover process monitoring tools (SPC) and problem solving methods - above all 8D.