# IMPACT OF TOTAL QUALITY MANAGEMENT PRACTICES ON SUSTAINABILITY OF MANUFACTURING COMPANIES

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***Abstract. This article discusses the importance of quality management in manufacturing enterprises. The impact of the ISO 9001 Quality Management System on the sustainability of manufacturing enterprises is also presented. The research studied statistical methods of quality control and their details.***

***The study concluded the following:***

***a) the importance of statistical methods and experimental design methods for the analysis of numerical data;***

***b) the importance of the operational application of simple graphical, statistical methods for quantitative research instead of using more complex calculation methods after the experiment is completed;***

***c) to obtain all the benefits of using statistical methods, it is important that personnel involved in product research participate in the statistical analysis. This contributes to the early detection and elimination of any cause of possible deviations.***

***Keywords: manufacturing plant, quality management, quality control, ISO 9001 Quality Management System, statistical methods of quality control, Pareto diagram.***

## Introduction

Today, businesses strive not only to meet customer requirements, but also to offer higher quality products and services. On the other hand, they need to reduce their costs in order to compete. The ability of small and large enterprises to achieve quality and cost-effectiveness depends on their ability to develop a comprehensive approach to quality improvement.

The ISO 9001 quality management system is the most popular quality management system standard in the world, certifying more than one million organizations in 180 countries around the world.

The ISO 9001 Quality Management System is a globally accepted quality management system designed to increase customer demand by meeting customer requirements, needs, and regulatory requirements. It covers the state of the quality management system in many ways, from the organizational structure of the organization to the level of customer satisfaction, from the analysis of collected data to effective process management, from internal audit to product design, from purchase to sales. The ISO 9001 standard is basically a control mechanism. The purpose of this standard is to reduce, eliminate, and prevent errors and omissions. The standard is directly related to the quality of the management system, not to the quality of the products and services. The key assumption is that if an effective Quality Management System is created and implemented, quality products and services will be produced to meet customer needs.

The ISO 9001 standard is not difficult and includes general requirements. It can be applied to any sector, large or small. Represents a strong management system when properly understood and applied.

The ISO 9001 standard left it entirely to organizations to create a Quality Management System. What needs to be done is not to create a "standard" Quality Management System, but to create a Quality Management System that meets the standard requirements.

ISO 9001 Quality Management System is a systematic and process-based management system aimed at regulating the activities of various enterprises in each sector. This system creates constant quality and satisfaction to meet the needs and expectations of customers, while also regulating the processes of enterprises.

Thanks to the ISO 9001 Quality Management System, businesses have more control over their activities, everyone working in the organization has clear and secure information about what they are doing, and is able to solve problems quickly and efficiently.

The ISO 9001 Quality Management System can be installed and the ISO 9001 certification can be installed by all enterprises in any sector that wants to increase and improve work efficiency and effectiveness (1, Anh Chi Phan&Yoshiki Matsui).

Certification with ISO-9001 is the main document confirming the quality of the production process in modern enterprises.Statistical methods are also widely used in the ISO 9001 Quality Management System. In some cases, improper and incomplete implementation of quality control has a negative impact on the sustainability of manufacturing enterprises as a result of incorrect selection of statistical research methods.

The purpose of the study, along with the need for ISO-9001 certification, is to study the statistical methods of quality control, the study of errors in them, to propose statistical methods that can be used in the production process.

**Research methodology**

During the study, the method of scientific abstraction was used in the study of the theoretical foundations of quality management and control in manufacturing enterprises. Also, studies based on comparative analysis were conducted in order to study in detail the statistical methods of quality control.

**Level of study of the topic**

Along with the quality of products and services, the quality of the production process is also an important factor in the competitiveness of enterprises of different forms of ownership. Globalization in the activities of industrial enterprises in developed countries is one of the important processes and factors in making sound management decisions on the quality management of the production process.

Improving the quality management system of an industrial enterprise is based on a mechanism to adapt its processes to Total Quality Management (TQM) in order to improve the quality of engineering products by involving every member of the enterprise team.

Foreign experts K. Isikawa (2, Ishikawa), T. Saati (3,4 Saati), S. Siro (5, Siro), A. Feigenbaum, J. Harrington, V. Guerriero (6, Guerriero) and others laid the foundations of the concept for the development of the methodology of quality management systems in terms of the formation of quality theory and generalization of quality management problems. TQM and ISO 9000 series quality standards, as well as CIS scientists: Y.P. Adler (7, Adler), G.G. Azgaldov (8, Azgaldov) , V.G. Versan (9, Versan) was researched.

Ishikawa's cause-and-effect diagram (cause-effect-diagram) is a graphical method of analyzing and shaping cause-and-effect relationships, a tool in the form of a fish bone to systematically identify the causes of a problem and then make a graphical presentation. The cause-and-effect diagram was developed in the early 1950s by chemist Kaora Ishikawa and took its name. This method was originally used as part of quality management to analyze quality problems and their causes. Today, it is widely used in other problem areas around the world (2, Ishikawa).

Nevertheless, the existence of a number of studies on the subject under discussion does not preclude the need to further develop its theoretical and methodological position, to generalize practical experience in the specified field.

**Analysis and results**

The ISO 9001 Quality Management System is very simple in concept. In general, the following issues need to be addressed:

- Identify all requirements, including commercial licenses, training manuals, customer requirements, and selected management system standards
- Make sure it meets all the requirements
- Confirm that staff are being trained in accordance with ISO 9001 requirements
- Identify activity-related processes, interactions, inputs, and outcomes
- Maintain records that meet system requirements
- Measure, monitor and report on the performance of the quality management system
- Plan changes in the system and assess the risks and opportunities arising from these changes
- Internal and external audit to analyze the system and correct any discrepancies
- The result of continuous improvement of the quality management system.

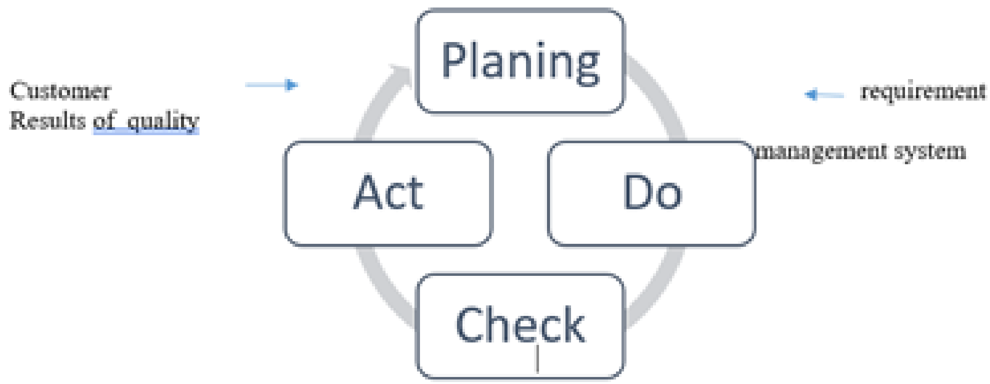



**Figure 1. ISO 9001 Quality Management System***

**Created by the author*

However, along with international standards, statistical methods of quality control also play an important role in the quality management system. In particular, the application of these methods, along with quality control, allows to constantly improve it, to eliminate shortcomings in the process of quality management.

Among the statistical methods of quality control, the most common are the so-called seven quality control tools:

- 1) Pareto Diagram;
- 2) Cause and Effect Diagram;
- 3) Contrat Chait;
- 4) Histogram;
- 5) Scatter Diagram;
- 6) Stratification;
- 7) checklists.

Together, these methods form an effective system of quality control and analysis methods. Seven simple methods can be applied in any sequence, in any combination, in various analytical situations, they can be considered both as a holistic system, and as separate analysis tools. In each case, it is proposed to determine the composition and structure of the working set of methods.

Seven quality control tools are actively used by Japanese firms.

1. The Pareto diagram allows you to visualize the amount of losses depending on various objects; represents a kind of bar chart used to visualize the considered factors in decreasing order of importance.

In 1897, the Italian economist V. Pareto proposed a formula that describes the uneven distribution of goods. The same idea in 1907 was graphically illustrated on a diagram by the American economist M. Lorenz. Both scientists have shown that most often the largest share of income or wealth belongs to a small number of people. Well-known American quality management specialist J. Juran applied this approach in the field of quality control. This made it possible to divide the factors affecting quality into a few essential and numerous non-essential. It turned out that, as a rule, the vast majority of defects and related losses arise due to a relatively small number of reasons. J. Juran called this approach Pareto analysis.

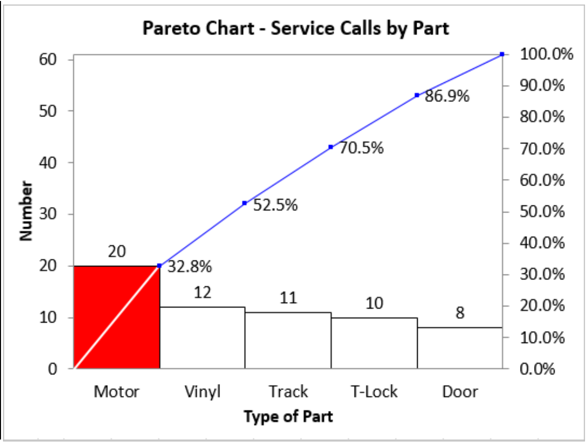
To build the Pareto diagram, the initial data are presented in the form of a table, in the first column of which the analyzed factors are indicated, in the second - absolute data characterizing the number of cases when the analyzed factors were detected in the considered period, in the third - the total number of factors by types, in the fourth - their percentage ratio , in the fifth - cumulative (accumulated) percentage of cases of detection of factors.

The construction of the Pareto diagram begins with the fact that the data of column 1 are plotted on the abscissa axis, and the data of graph 2 on the ordinate axis, arranged in decreasing order of occurrence frequency. "Other factors" are always placed last on the ordinate axis; if the proportion of these factors is relatively large, then it is necessary to decipher them, highlighting the most significant ones. Based on these initial data, a bar chart is constructed, and then, using the data in columns 5 and the additional ordinate, which indicates the cumulative percentage, a Lorentz curve is drawn. It is possible to build a Pareto diagram when the data in column 4 is laid off on the main ordinate; in this case, to plot the Lorentz curve, there is no need to include an additional ordinate in the diagram (10, Pareto).

The Pareto diagram often reveals a pattern called the 80/20 Rule, based on the Pareto principle, according to which most of the consequences are caused by relatively few causes. With regard to the analysis of inconsistencies, this pattern can be formulated as follows: usually 80% of detected inconsistencies are associated with only 20% of all possible causes.

In addition to identifying and ranking factors according to their importance, the Pareto diagram is successfully used to clearly demonstrate the effectiveness of (10, Pareto) certain measures in the field of quality assurance: it is enough to build and compare two Pareto diagrams - before and after the implementation of any measures (Fig.2).

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | | Install | Replace | Adjust | Lube | Total |
| 2 | Door | 2 | 5 | 1 | 0 | 8 |
| 3 | Motor | 2 | 1 | 11 | 6 | 20 |
| 4 | Track | 1 | 0 | 6 | 4 | 11 |
| 5 | Vinyl | 11 | 1 | 0 | 0 | 12 |
| 6 | T-Lock | 9 | 0 | 1 | 0 | 10 |
| 7 | Total | 25 | 7 | 19 | 10 | 61 |



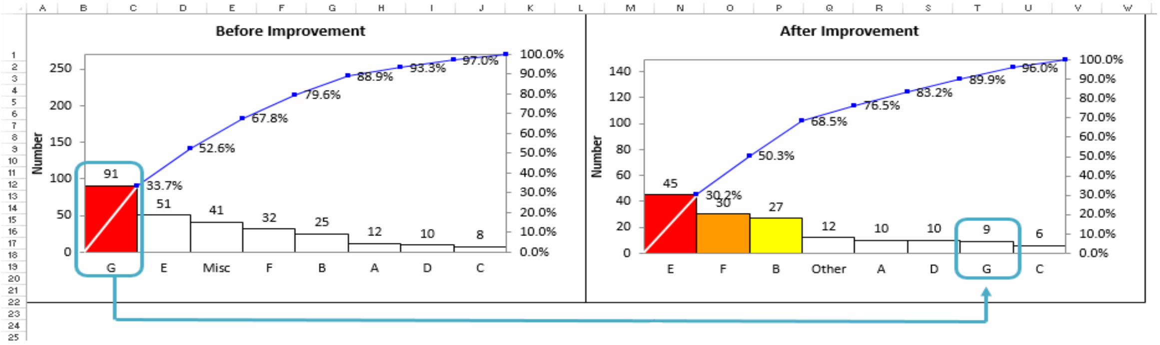



**Figure 2. Pareto - before and after the implementation of any activities (10, Pareto)**

1. Stopping Pareto analysis too soon

A common mistake in a Pareto chart is to stop at a too high level. Two or more levels of Pareto diagrams may be required to narrow the focus to an effective level. How can you say that you stopped too early? At the next step in the process of solving the problem, analyzing the root causes, your fishbone diagram will turn into a whalebone diagram that spans many walls. Reducing the "big bar" to another level, we get a clear idea of where you can improve.

2. Using the Parflato diagram instead of the Pareto diagram

Another common Pareto error is to use the Parflato chart. If the left or two columns in your Pareto chart are not much larger than the other columns in the chart, then you have a "perflato" chart. A flat Pareto chart means that the 80/20 distribution principle does not apply.

Try organizing the data by a different attribute (for example, by subtotal by geography, cost or time of day, and not by type of error) and see if you can get a Pareto chart that helps you better focus your efforts.

3. Do not use before and after charts to demonstrate improvement.

Teams often want to "declare victory" after identifying the root cause and taking countermeasures. The only way to find out if the change really improved the process is to do a Pareto analysis for your data before and after. The pairs below show a reduction in type G error.

2. A causal diagram was proposed in 1953 by K. Ishikawa (the "Ishikawa diagram"). The diagram is a graphical ordering of factors influencing the object of analysis (Fig. 3). The main advantage of the Ishikawa diagram is that it gives a visual representation not only of those factors that affect the studied object, but also of the cause-effect relationships of these factors.

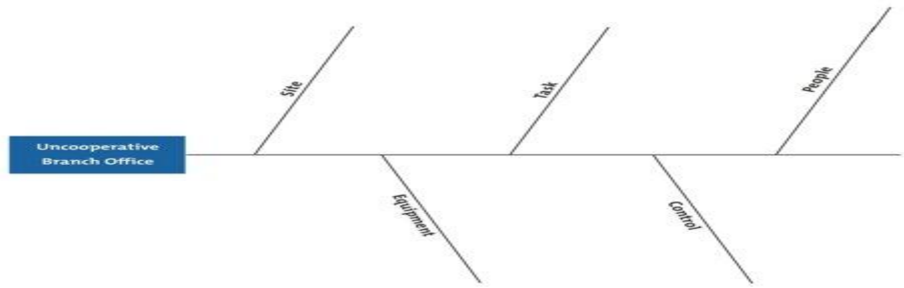



**Figure 3. Ishikawa chart (2, Ishikawa)**

When constructing the Ishikawa diagram, large primary arrows are drawn to the central horizontal arrow depicting the object of analysis, indicating the main factors (groups of factors) that affect the object of analysis. Next, second-order arrows are brought to each primary arrow, to which, in turn, third-order arrows, etc. until all arrows indicating the factors that have a noticeable effect on the object of analysis in a specific situation are plotted on the diagram. Each of the arrows plotted on the diagram, depending on its position, represents either a cause or a consequence: the previous arrow always appears as a cause with respect to the next, and the next as a consequence **(2, Ishikawa)** .

The main task in constructing the diagram is to ensure the correct subordination in the interdependence of factors, as well as its clear design.

When structuring the diagram at the level of the primary arrows of factors in many real-life situations, one can use the Ishikawa-proposed rule of "five M" (materials, machines, methods, measuring, men - materials, machines, methods, measurements, people). This rule consists in the fact that in the general case there are five possible causes of certain results related to causal factors.

A detailed diagram of Ishikawa can serve as the basis for drawing up a plan of interrelated activities that provide a comprehensive solution to the problem posed during the analysis.

3. The control card was proposed in 1924 by W. Shewhart. It is built on a form (form) on which a grid of thin vertical and horizontal lines is applied. Vertically on the map mark the selected statistical characteristic of the observed parameter (11, Shewhart), and horizontally - the time or number of the control sample. So, on the map of arithmetic mean values are pre-applied: horizontal center line corresponding to the value of the center of tolerance (CD) (with this value, the technological operation is considered optimally adjusted); two horizontal lines of limits of technological tolerance established by regulatory documentation (upper - Tv and lower - T); two horizontal lines, which are the boundaries of regulation of the values of the controlled parameter (upper - Rvi lower - Rn).

The regulation boundaries are calculated taking into account the accepted distribution of the values of the monitored parameter and the additional probability of receiving a false warning signal about the disorder of the operation. The confidence interval indicates within which boundaries the true value of the statistical characteristic is expected.

Working with a control card boils down to the fact that according to the observation of the values of the monitored parameter, it is established whether this parameter is within the control limits, and based on this, a decision is made on whether the technological operation is established or unsettled.

The decision to debug the operation is made when at least one observation, recorded on the map in the form of a point, goes beyond the control limits. However, even before the points go beyond the regulation borders, the control card will make it possible to judge the emerging violations of the technological operation by the following signs:

• several consecutive values of the monitored parameter appear near the regulation boundaries;

• values are distributed on one side of the center line, i.e. the average value is shifted relative to the tuning center (the presence of a systematic deviation is evidenced, for example, by the location of seven values in a row above or below the middle line, as well as the location of 10 out of 11, 12 out of 14, 14 out of 17 and 16 out of 20 values on one side of the middle line );

• the values of the controlled parameter are very scattered;

• there is a tendency for the values of the controlled parameter to approach one of the regulation boundaries.

4. The histogram is a bar graph and is used to visualize the distribution of specific parameter values by the repetition frequency for a certain period of time (week, month, year).

When plotting the parameter's allowable values, it is determined how often this parameter falls into or out of the allowable range.

The histogram is constructed in the following sequence:

• a) a source data table is compiled;

• b) the magnitude of the analyzed parameter is estimated;

• c) the width of the span is determined;
• d) set the reference point of the first interval;
• e) the final number of intervals is selected.

The type of histogram depends on the sample size, the number of intervals, and the origin of the first interval. The larger the sample size and the smaller the width of the interval, the closer the histogram to the continuous curve.

5. The scatter chart (dispersion chart) (Fig. 4) is used to identify the dependence of one variable from another. The diagram does not answer the question of whether one variable serves as the cause of another, but it is able to clarify whether in this case there is a causal relationship in general and what is its strength.

The most common statistical method for identifying such a relationship is a correlation analysis based on an assessment of the correlation coefficient (. The relationship of the studied quantities can be complete, i.e. functional, when the correlation coefficient is equal to unity (+1) if the variables simultaneously increase or decrease, and (-1) if the other decreases with an increase in one variable. An example of a functional relationship is the hardness of the workpiece material: the higher the hardness, the greater the wear.

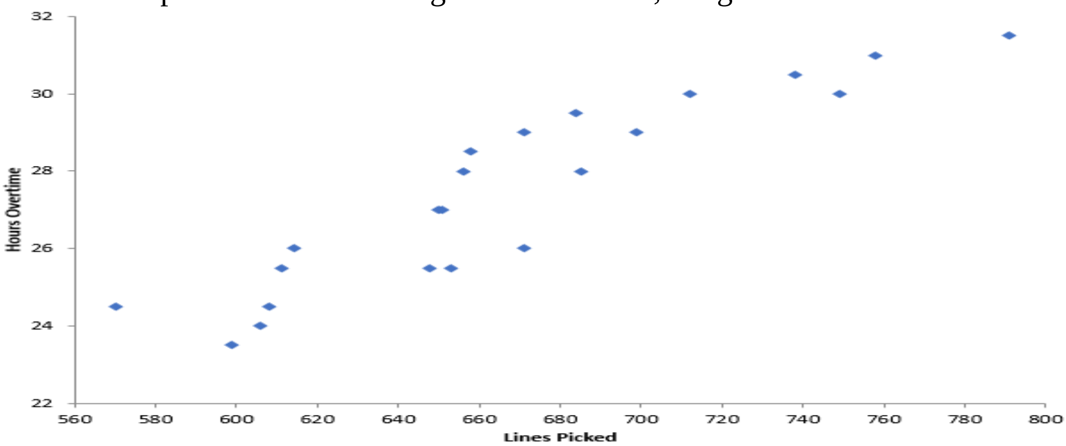



**Figure 4. Scatter chart**

In the case when the relationship is completely absent, the correlation coefficient is zero. An intermediate case is also possible when the dependence of the related quantities is incomplete, since it is distorted by the influence of extraneous additional factors. An illustration of this kind of correlation is the dependence of the labor productivity of workers on their length of service under the influence of such additional factors as education, health, etc. The greater the influence of these additional factors, the less close is the relationship between experience and labor productivity.

Correlation relationships are described by the corresponding equations. In cases where it is required to find out the dependence of one parameter on several others, a regression analysis is used. To determine the influence of individual factors on the studied parameter, analysis of variance is used, in which it is assumed that the significance of each factor in individual conditions is characterized by its contribution to the variance of the experimental result.

6. The method of stratification is used to identify the causes of the dispersion of product characteristics. The method consists in the separation of the obtained characteristics depending on various factors: the quality of the starting materials, working methods, etc. In this case, the influence of one or another factor on the characteristics of the product is determined, which allows you to take the necessary measures to eliminate their unacceptable spread.

7. Checklists are used for quality and quantity control. The control sheet is a paper form on which the names of the controlled indicators are given and their values obtained during the control are recorded. The following types of checklists apply:

checklist for recording the distribution of the measured parameter during the manufacturing process;

checklist for registering types of non-conformities;

checklist for evaluating the reproducibility and performance of the process.

**Conclusions and suggestions**

In general, there are many definitions of a quality management system. A common point in all of this is the use of a reproductive, expressive, and constantly evolving system. In accordance with the ISO 9001 Quality Management System standard, better product or service delivery methods are provided with documented information such as procedures, execution instructions, policies and forms. The important point is to provide documentary, clear, and practical instructions that define the expectations, responsibilities, and behaviors of all personnel involved in managing the system to achieve defined quality goals. Here, internal and external audits are important to ensure that the system meets the requirements.

Having examined the basic methods of statistical research, it becomes clear that such a science as statistics provides indispensable assistance in solving state, economic, and sociological issues and in many respects contributes to the development of these sciences and fields of activity. Considering the fact that the influence of statistics extends to the management and economic activities of enterprises and firms, we can conclude that this science is very important for the functioning, growth and success of enterprises. The use of statistical data and statistical monitoring, followed by analysis of the information received, is an integral part of the activities of any enterprise.

Correctly conducted collection, analysis of data and statistical calculations allow providing interested structures and the public with information on the development of the economy, on the direction of its development, showing the efficiency of resource use, taking into account the population’s employment and working capacity, determining the rate of price growth and the impact of trade on the market itself or a single one scope.

An analysis of the data in this example shows:

a) the importance of statistical methods and experimental design methods for the analysis of numerical data;

b) the importance of the operational application of simple graphical, statistical methods for quantitative research instead of using more complex calculation methods after the experiment is completed;

c) to obtain all the benefits of using statistical methods, it is important that personnel involved in product research participate in the statistical analysis. This contributes to the early detection and elimination of any cause of possible deviations.

As a result of the author’s research, the Pareto diagram is one of the most useful statistical methods of quality control. But the pros and cons of using it in the production process need to be taken into account.

The main advantage that the Pareto diagram gives is the ability to focus efforts and resources on eliminating the most significant problems. Like other quality tools, it is easy to apply and understand by the organization’s staff.

The disadvantage of this tool is the ability to mislead on the significance of problems, especially if the cost of the consequences of inconsistencies and defects is not taken into account.

Another method used in the quality control process is Ishikawa's "fish skeleton." This method is one of the most popular methods in the management process. The Ishikawa table is one of the main tools used to measure, evaluate, control and improve the quality of production processes, along with the spreadsheet, stratification, checklist, histogram, Pareto chart and control card "seven quality control tools" included in the list. Based on the above, the clear advantages of the Ishikawa scheme can be identified. They, in turn, are primarily an opportunity to unlock their creative potential, allowing you to find innovative ways to solve a problem. Second, the ability to find the relationship between all the causes and factors that affect the problem and assess its impact on it.

However, the Ishikawa method also has its drawbacks, which must be taken into account in your work as well. The first drawback is that there are no rules for checking the diagram in the opposite direction from the root cause to the result. The logical chain of causes and factors that lead to the root cause is impossible to consider. The second drawback is that the diagram constructed in the final analysis is highly complex, lacking a clear structure that complicates objective analysis and precludes the possibility of drawing the most accurate conclusions.

Therefore, when addressing the causes of problems and finding solutions to them, it is necessary not only to use the Ishikawa diagram, but also to fill it with other tools, including list sheets and maps, as well as other means of checking, analyzing and improving efficiency There are effective methods. movement. All of this applies to the most complex issues and problems, and their solutions need to be considered in a comprehensive way.

If the problem involves an easy way to find a solution to it, then the Ishikawa diagram will suffice because it allows you to clearly understand all the possible causes of this problem, identify the most important of them, find the cause, and then fix or eliminate it will give.

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