# Visual Control Methods—The Basis of Quality Control

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**Abstract** The current information processing speed is very high. To effectively manage a company, information should be speedily processed to make timely decisions at all hierarchy levels, from managers to executors. Information visualization in these conditions significantly speeds up these processes and reduces risks. The quality management system of a modern company includes elements and methodology of various performance improvement concepts, such as risk management, total quality management, lean manufacturing, six sigma, and the theory of constraints. The emphasis in process organization is placed on visual methods. Despite the fact that visualization as a method is considered within the concept of lean manufacturing, there are methods for representing information in a visual form defined in other concepts. The paper discusses the use of the methodology for information visualization in terms of different quality management system concepts. A comparative analysis of modern concepts for improving performance, an overview of the methodology designed to display information in the quality management system in a visual form is made, and successful examples of using various methods of information visualization for quality management in companies are given.

## 1 Introduction

To improve performance and competitiveness, companies implement various performance improvement concepts. These concepts include Lean Manufacturing, Six Sigma, Knowledge Management, Risk Management, Strategic Management,

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Goldratt's Theory of Constraints, and Iwao Kobayashi's 20 Keys to Business Improvement Program. The most common are: quality management system based on ISO 9000 standards, lean manufacturing system and six sigma system. With regard to the development of quality management approaches, the quality management system based on ISO 9000 standards includes elements of strategic management, knowledge management and risk management. Modern concepts of performance improvement are described below according to the following criteria: definition; time of origin; key concepts; basic principles; the cyclic process used; scope of use in quality management; methods used.

## 2 Modern Concepts of Performance Improvement

### *2.1 QMS Based on ISO 9001: 2015 [1]*

Definition: a concept for continuous improvement of activities and increasing the company competitiveness.

Formation: development of the first ISO 9000 standards in 1987.

Key concepts: quality—compliance of inherent characteristics with requirements; process—activity that transforms inputs into outputs; system—a combination of interrelated and interacting processes.

Basic principles:

- Customer focus.
- Leadership.
- Interaction of workers.
- Process approach.
- Improvement.
- Evidence-based decision making.
- Relationship management.

Cyclic process used: Plan-Do-Check-Act (PDCA) cycle, also known as the Deming Cycle, Shewhart cycle, Deming Wheel or Plan-Do-Study-Act.

Scope of use in quality management: achieving the objectives of the company in the field of quality by managing a system of interrelated processes.

Methods used:

- Quality control tools (histogram, Pareto chart, control chart, scatter chart, stratification, checklist, Ishikawa chart) [2].

- Quality management tools (affinity diagram, relationship diagram, tree diagram, matrix diagram, network diagram (Gantt diagram), process decision program chart (PDPC), prioritization matrix).
- Quality analysis tools (functional cost analysis, analysis of the causes and consequences of failures (FMEA analysis).
- Quality design tools (quality function deployment (QFD), theory of inventive problem solving).

## 2.2 *Lean Manufacturing (LM)*

Definition: a management concept based on elimination of all types of waste.

Formation: developed by Toyota in 1950, the concept founder is Taiichi Ohno.

Key concepts: muda (mura, muri)—losses, everything that does not add value to the product; value stream; the principle of pull production.

Basic principles:

- Strategic focus.
- Focus on creating value for the consumer.
- Organization of the value stream for the consumer.
- Continuous improvement.
- Pulling.
- Reduction of losses.
- Visualization and transparency.
- Priority security.
- Building a corporate culture based on respect for a person.
- Built-in quality.
- Fact-based decision making.
- Establishing long-term relationships with suppliers.
- Compliance with standards [3].

Cyclic process used: consists of five sequential steps:

- Determine the value of a specific product.
- Determine the value stream for this product.
- Provide a continuous flow of product value stream.
- Allow the user to pull the product.
- Strive for excellence.

Scope of use in quality management: Increasing the efficiency of activities by reducing losses in all processes.

Methods used:

- Process mapping.
- Kanban.
- Total productive maintenance.
- 5S system.
- Quick changeover (SMED).
- Kaizen.
- Poka-yoke—a method of avoiding mistakes [4].

### *2.3 Six Sigma*

Definition: A management concept that focuses on improving quality by reducing variation in process parameters and achieving a planned quality level in terms of standard deviations (sigma).

Formation: developed by Motorola Corporation in 1980.

Key concepts: σ (sigma) is root-mean-square deviation; KPIs are key performance indicators of a company that help it achieve strategic and tactical goals.

Basic principles:

- Customer satisfaction.
- Definition of processes, their indicators and methods of process control.
- Teamwork and staff involvement.

Cyclic process used: DMAIC, Define—Measure—Analyze—Improve—Control [5].

Scope of use in quality management: Process control, improvement of process parameters based on the study and analysis of statistical data.

Methods used: Statistical methods of process management, descriptive statistics, methods of testing statistical hypotheses, graphs [6, 7].

All three concepts imply improving the quality of activities and reducing costs. All concepts use a cyclical process to identify a problem, study and fix it. These concepts differ in the field of their application in the company's quality management system and in a specific methodology.

At enterprises, these concepts are typically implemented in the following sequence: QMS ISO 9001, the lean manufacturing methodology starting with the 5S concept, then the 6 Sigma concept related to improvement projects.

The methodology of the three concepts overlaps, for example, all of the listed concepts employ statistical methods of information visualization and process control [8, 9].

All three concepts employ methods of visual information representation, however, the concept of visualization is defined in the concept of lean manufacturing only:

**Table 1** Methods of information visualization in accordance with the stages of the PDCA cycle

| Phase of PDCA cycle | ISO 9001 | Method |
|---|---|---|
| P—plan, developing the system goals and its processes, identifying the resources required to achieve the results in accordance with customer's needs and company's policies, considering risks and opportunities | 6 | Process diagrams<br>Goal matrices<br>Risk register<br>Visual representation of the required quality, work standards<br>QFD |
| D—do, fulfillment of what was planned | 7, 8 | Outlining, color labeling, rational layout, information boards, process maps |
| C—check, monitoring and (where applicable) measuring the processes, products and services with regard to policies, objectives, requirements and planned actions and presenting the results; | 9 | A3 format of the report, descriptive statistics, Shewhart control charts |
| A—act, taking actions to improve performance to the necessary level | 10 | Statistical analysis, value stream maps, spaghetti diagrams |

location of all tools, parts, production stages and information about the production system performance so that they could be clearly visible, and each participant in the production process could instantly assess the system state.

The following methods are used for visualization in the lean manufacturing: labeling; contouring; marking; color coding; information stand.

Visualization tools used in the lean manufacturing are the report in A3 format and andon [10, 11].

However, the integrated quality system exhibits great potential for visual information representation. Text can be converted into tables and color schemes, pictures and numbers can be presented in the form of graphs and diagrams. Visual information increases the speed and quality of decisions and reduces the number of errors.

The stages of the PDCA cycle as the simplest model of the system present in all the concepts have been taken to consider the methods of information visualization that can be used at various stages of the cycle (Table 1).

## 3 Results and Discussion

Let us consider an instrument-making enterprise with a quality management system that has employed a different quality management methodology for 15 years.

Since all stages of the PDCA cycle and the applied methodology cannot be considered within the scope of one paper, we take the analysis stage (Act) as an example.

Analysis of the manufacturing process using statistical methods and lean methodology.

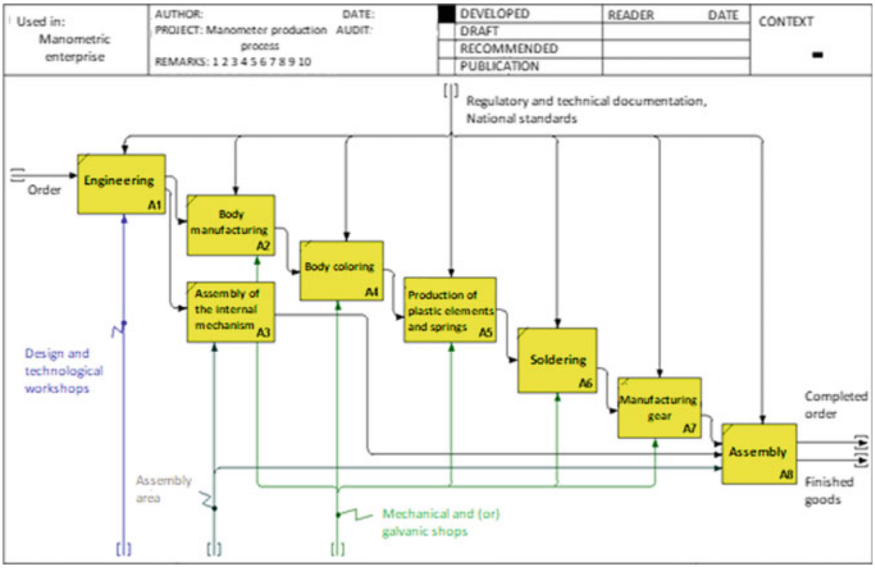


**Fig. 1** Model of manufacturing process of measuring instruments

At the first stage, a diagram of the process was created (Fig. 1). This diagram shows the sequence of the process stages. Similar schemes can be used to analyze the process and train new employees.

Analysis of manufacturing process of measuring instruments.

Shewhart charts, X-MR charts and p-charts were used to study the stability of the manufacturing process in terms of non-compliances over the study period (Fig. 2).

The analysis of claims received from external consumers during the study period was carried out.

A total of 80% of all non-compliances are attributed to poor assembly, defects that occur during transportation, managers' errors, and others (Fig. 3).

An assembly site was chosen for further analysis.

A current state value stream map was developed (Fig. 4).

- value creation time—43% of the total time;
- non-productive time caused by:
- duration of storage of finished mechanisms on the site during the shift (27% of the total non-productive time);
- unused equipment downtime (23%);
- expectations of items due to their lack in stock (8%);
- excessive movement of working personnel (7%).

The production area and workplaces was analyzed using a spaghetti diagram. Workplaces are located irrationally, workers excessively move when switching from one operation to another (Fig. 5).

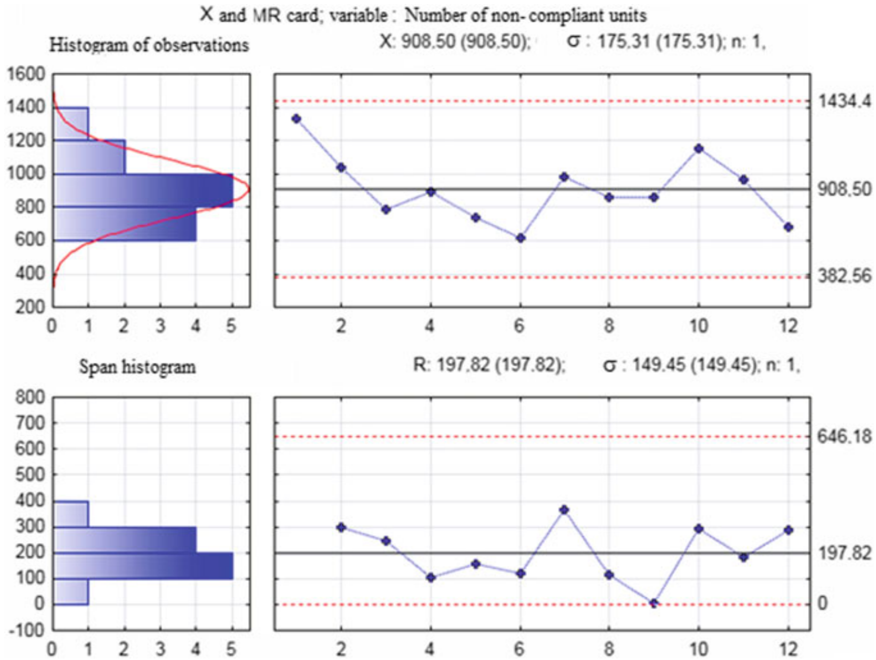


**Fig. 2** X-MR chart by the number of non-compliances over the study period

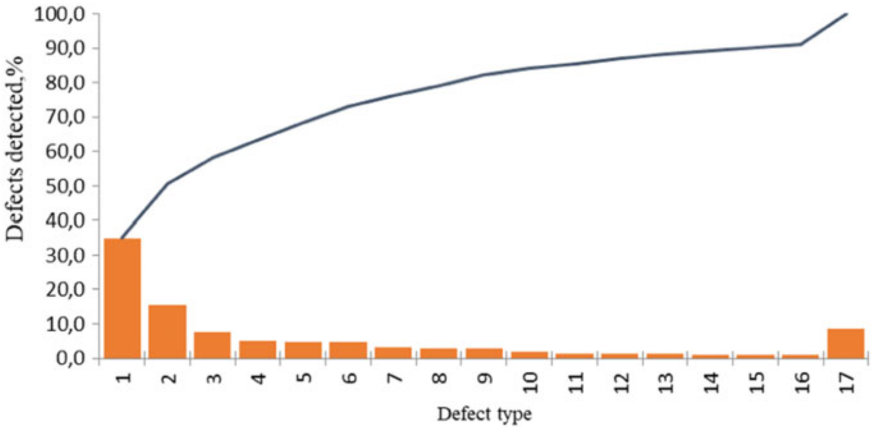


**Fig. 3** Pareto chart by types of defects over the study period: 1—poor assembly; 2—defects caused by transportation; 3—managers; 4—errors; 5—others

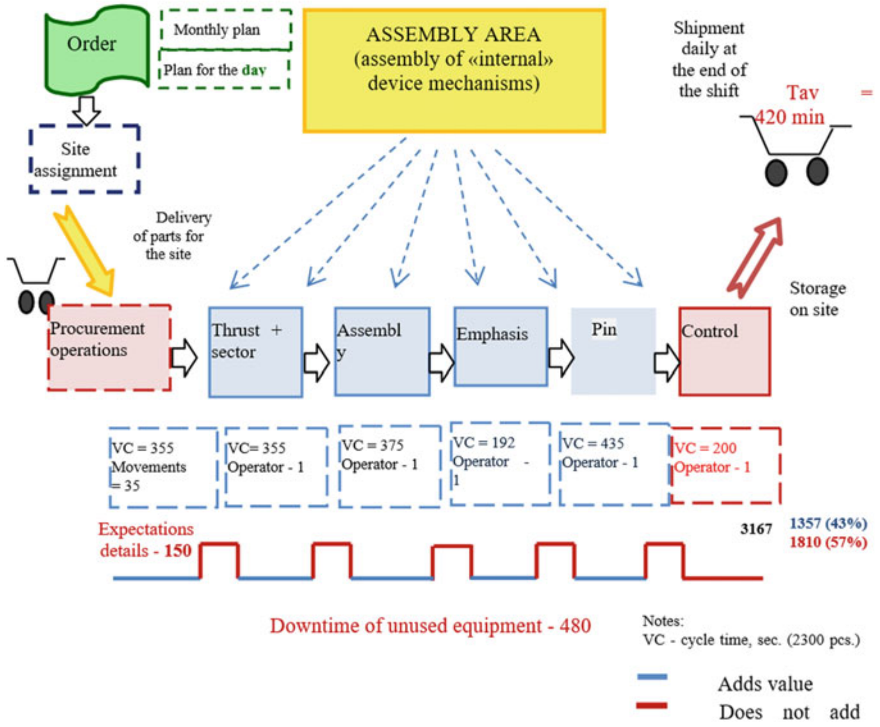


**Fig. 4** Graphic representation of the current state value stream map

About 40% of equipment (and workplaces) are not involved in the production process. An excessive amount of unlabeled stocks, which hinders the search for necessary items. An excessive amount of empty containers that clutters the area.

A future state value stream map was created.

Value creation time—65% of the total time. Reduction of non-productive time:

- storage of finished mechanisms on the site during the shift (by 85%);
- unused equipment downtime (by 100%);
- expectations of items due to their absence in stock (by 86%);
- excessive movement of personnel (by 74%).

The identified incompliances were analyzed based on the results of control at the site. 80% of all incompliances were identified using the Pareto chart. Main reasons for appearance of these incompliances:

- negligence of personnel during technological operations;
- delivery of defective items by the supplier.

Based on the analysis, the following recommendations were made for applying the lean manufacturing methodology at the Assembly site:

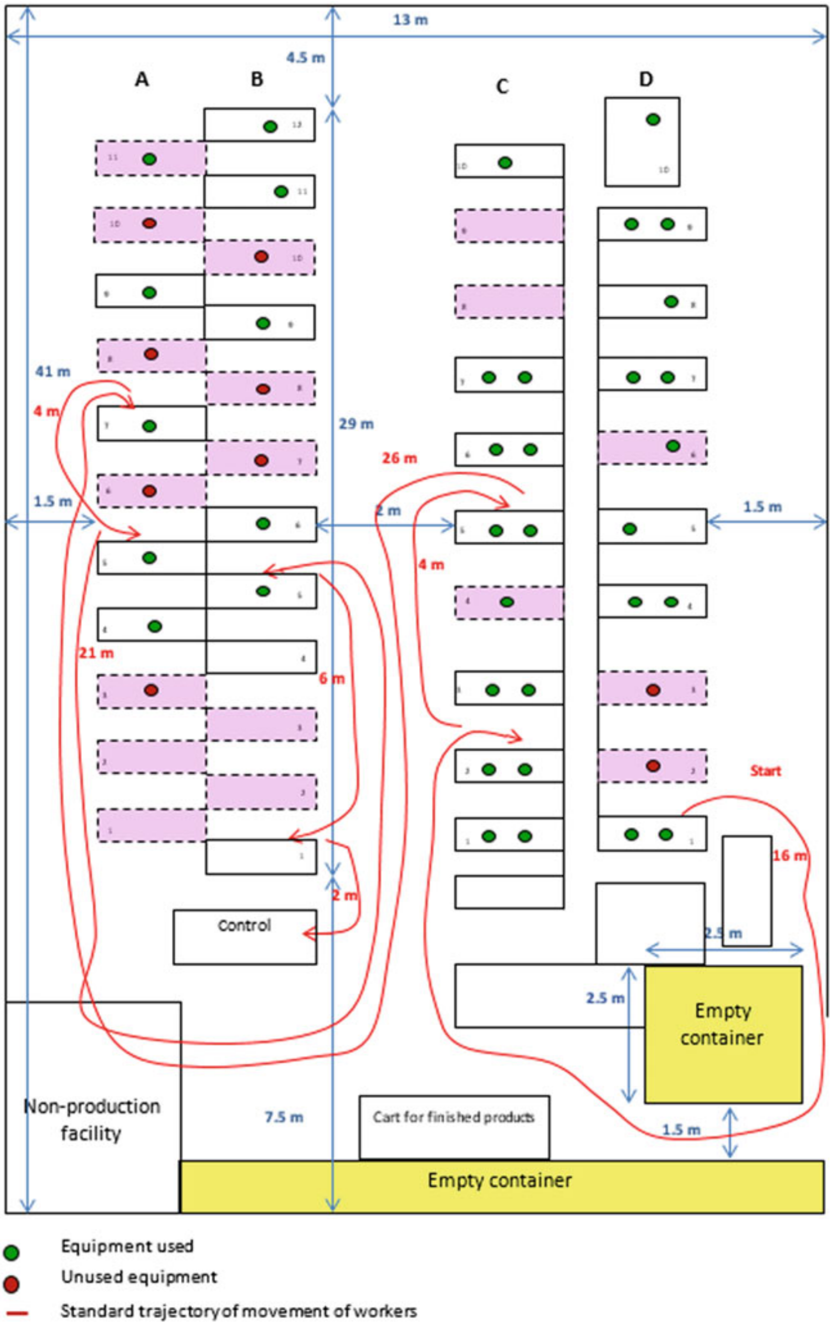


**Fig. 5** Spaghetti diagram

- training of employees on the concept of lean manufacturing is required;
- the assembly site should be reconstructed based on the results of theь spaghetti diagram.

After the reconstruction, the following results were achieved:

- 1.5-fold reduction of the area occupied by production facilities (475 vs. 300 $m^2$);
- workplaces are located along the most frequent operations;
- working tables are placed parallel to each other with a passage between them;
- removal of unnecessary empty containers from the production area (except for the quantity required for 2 shifts, 250–300 pcs).

Using 5S elements and visualization at the assembly site.

Creation of a quarantine zone at the assembly site for unused items, tools and devices:

- use of red date tags by workers to indicate unused items;
- removal of unused items from the production premises.

Division of all items (tools, supplies) into frequently and rarely used. Fixing a specific place for each object.

Determination of the area for placing the cart with finished products, empty containers, and stocks using adhesive tape for marking the floor.

Labeling containers with stocks:

- labels must contain: item name, material, size or thickness.
- Maintaining order:
- cleaning is required at the end of each shift, put all tools in the right places;
- general cleaning at the end of the month.

Establishing a system for assessing (controlling) the order and appointing responsible persons:

- level 1—weekly control performed by the site foreman;
- level 2—control performed by the head of the mechanical assembly site during the round;
- control results (point and percentage system) are placed on stand 5S;
- photographs of ‘in the past/now’ and most active workers are placed on stand 5S.

Standardization of the assembly site:

- creation of a standard for each operation (in A4 format—a brief, understandable version in the form of diagrams);
- creation of a standard for the workplace (appearance and frequency of cleaning).

Creating a Kanban Board (Fig. 6).

Main results obtained after fulfillment of the recommendations:

- improved operational performance of the assembly process;
- reduced amount of defective mechanisms and reworking;
- improved organizational culture;

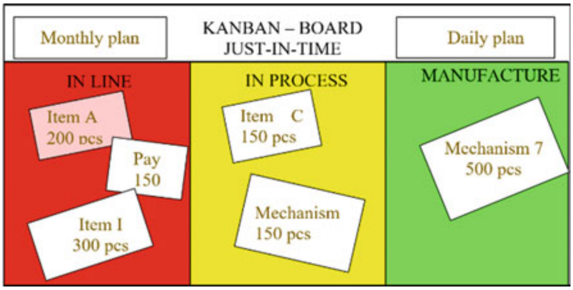


**Fig. 6** Model of Kanban-board

- reduced production areas.

## 4 Conclusion

Information visualization methods are required for a more detailed analysis of the situation. In contrast to textually presented information, graphical methods provide more details about the situation under consideration and help understand the essence of the problem being solved. A generation grown up in the digital age thinks differently, and the graphic series is essential for the decision-making processes.

The paper discusses the use of information visualization methods that include three concepts applicable to the analysis stage of the PDCA cycle.

Despite the fact that methods of visual management are primarily associated with lean manufacturing, a number of improvement concepts are integrated into modern quality management. Each concept provides visual or graphical methods that enable effective management at all stages: planning, implementation, control, and analysis.

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