IOSUD – University of Polytechnics Timişoara

Doctoral School of Engineering Studies

CONTINUOUS IMPROVEMENT OF PRODUCTION PROCESSES IN SMALL AND MEDIUM ENTERPRISES

Doctoral Thesis – Summary

In order to receive the scientific graduation of doctor
at University of Polytechnics Timisoara in the field
of Industrial Engineering

author Mircea Raul Bogdan

Scientific coordinator: Prof.univ.dr.eng.& ec. Dumitru Tucu

month February, **year** 2024

INTRODUCTION

In a globalized environment, essentially characterized by a deep and generalized industrialization, a special attention must be paid to the most important aspects that influence the continuous improvement of quality.
In this work will be studied the continuous improvement methods and techniques and will be presented the main original results obtained. Further will be detailed the importance and necessity of the chosen topic, the research objectives and the structure of the paper.

The importance and the necessity of the chosen topic

Nowadays, in a globalized environment with advanced industrialization in all fields, the continuous improvement of manufacturing processes, respectively the optimization of quality systems, represents a challenge for increasing the sustainability of the economy (national and even global), reducing costs, streamlining available resources, developing stable and sustainable processes, satisfying the consumer, protecting the environment and, implicitly, the humans. The current and perspective economic potential allows the development of such methods that capitalize on solutions for continuous quality improvement, by capitalizing on human resources and increasing their training level.
We start from the general objective of the Doctoral Thesis, which is represented by the optimization of continuous improvement as a fundamental method of quality assurance through the production processes of Small and Medium Enterprises in Romania through the development of industrial applications.
The methods and procedures currently used in terms of quality assurance in SMEs are considered to be the most important solution for quality assurance and improvement, in all forms of industry. The current and perspective economic potential - especially - in Romania allows the development of such methods that capitalize on continuous quality improvement solutions, by capitalizing on human resources and increasing their degree of improvement.

Continuous process improvement in SMEs is of crucial importance for several reasons:

1. Increase efficiency: By identifying and eliminating unnecessary or redundant activities, optimizing workflow and reducing waiting times, continuous process improvement can lead to

increased operational efficiency. This can lead to cost savings, more efficient use of resources and improved quality of provided product or service.

2. Increasing competitiveness: Continuous process improvement can give SMEs a competitive edge in the market. By adopting more efficient practices and technologies, SMEs can offer higher quality products and services, delivered faster and at lower costs than their competitors. This allows them to distinguish themselves and gain the trust of customers, which can lead to increased market share and profitability.
3. Adaptability to change: Continuous process improvement helps SMEs better adapt to changes in the business environment. By constantly evaluating processes and identifying opportunities for improvement, organizations are more responsive to change and can react quickly to new market demands or changes in legislation and regulations.
4. Increased customer satisfaction: Improved processes lead to better customer satisfaction. By eliminating errors and delays, delivering products or services promptly and on time, and ensuring superior quality, SMEs can build long-lasting customer relationships and gain positive referrals.
5. Innovation and growth: Continuous process improvement stimulates innovation and organizational development. By promoting a culture of continuous improvement, SMEs encourage employees to generate new ideas, try new approaches and contribute to the growth of the organization. This can enhance innovation and open up new opportunities for development and expansion.

Overall, continuous process improvement is essential for the success and sustainability of SMEs. This enables them to maximize their efficiency, increase their competitiveness and respond effectively to market demands in a dynamic and ever-changing business environment.

Research objectives

The main objective which will be achieved during the doctoral research internship is:

MO1 Optimization of continuous improvement as a fundamental method of quality assurance in production processes in small and medium-sized enterprises in Romania, by studying the efficiency of some methods of continuous improvement as well as by the applicability of the studied methods according to the particularities of small and medium-sized enterprises

In order to achieve the main objective, it is necessary to achieve the following **secondary objectives**, corresponding to the activities carried out in the present research internship:

SO1 Analysis of the current state for the main particularities of small and medium enterprises in Romania.

SO2 Analysis of the current state for the main continuous improvement methods applicable to manufacturing processes according to ISO 9001 and IATF 16949 standards.

SO3 Experimental analysis of the compatibility of some methods of continuous improvement of manufacturing processes within small and medium-sized enterprises;

SO4 Identifying fast and accurate methods to ensure continuous improvement of manufacturing processes in small and medium-sized enterprises;

SO5 Establishing some essential indicators of the stability of the processes, respectively their efficiency and optimization from the point of view of continuous improvement;

SO6 Determining the influences of the use of human resources and increasing the degree of their training, respectively of the impact of IPC A 610 standard requirements;

SO7 Modeling the main factors that influence the correlations between process parameters and quality assurance through the imposed standards (ISO 9001/ IATF 16949:2016)

The work's structure

The work is structured on 5 chapters. The specific research approach of this thesis starts with the presentation of three enterprises that produce electronic boards. Solutions are identified for their continuous improvement and for the innovation of production lines. Within the production lines, continuous improvement methods, including Gauge R&R and Kaizen, are analyzed and, through their analysis, improved recipes are determined, such as the implementation of the Industry 4.0 solution. New research and production diversification directions are identified.

Chapter 1 presents the current status of SMEs in Romania. It starts with the definition of SMEs, classification criteria, particularities of management, challenges faced by SMEs nowadays.

Chapter 2 details continuous improvement methods and techniques. There are presented two categories of improvement methods: classical methods and modern methods. Both categories of methods use a number of tools that have been thoroughly presented, especially the methods considered to be state-of-the-art.

Chapter 3 presented in detail how to implement the Gage R&R method in three enterprises in the SME category.

Chapter 4 presents the prospects for optimizing continuous improvement processes within SMEs. In this chapter were studied the main opportunities and challenges in the process of optimizing continuous improvement processes.

Chapter 5 is dedicated to general conclusions and personal theoretical, experimental and applied contributions, including the presentation of research perspectives on continuous improvement processes within SMEs.

The studies carried out through the applications of continuous improvement process, open new perspectives on continuous improvement within SMEs.

1 THE CURRENT STATUS OF RESEARCH ON THE SUBJECT OF THE PROPOSED THESIS

Considering the complexity of the topic, the current status of research can be considered from several points of view, as follows:

- from the point of view of the main types of SMEs and their perspectives
- from the point of view of the main methods and techniques used in SMEs

All these points of view will be further detailed, in order to achieve a more realistic picture of the current state of research in the field.

Next, we enter the second part of Chapter 1, namely applying the practical study taking into account the particularities of SMEs from the point of view of continuous improvement.

1.1. Trends and reference data in the classification and perspectives of SMEs

The main criteria for classifying an enterprise in one of the three categories (micro, small or medium) are the number of employees and turnover. Thus, the European Commission defines three categories of small and medium enterprises:

Micro-enterprises: enterprises with less than 10 employees and a turnover or share capital that does not exceed 2 million Eur;

Small enterprises: enterprises with a number of employees between 10 and 49 and a turnover or share capital of a maximum of 10 million Eur;

Medium enterprises: enterprises with a number of employees between 50 and 249 and a turnover or share capital of a maximum of EUR 50 million. (Smeureanu, 2004)

Another factor is that a non-SME cannot hold more than 25% of the share capital (voting rights) of an SME; otherwise, that enterprise is no longer considered an SME. (Europeana, 2019)

In order to classify a company in an industrial or non-industrial branch of activity, the principle of the preponderance of the volume of activity is applied. (Chirescu, 2022)
In order to classify the goods, services and activities from which they originate, there are three characteristics taken into account:
- the nature of the goods produced and the services provided;
- the way of using goods and services;
- the raw material used, the technological processes used, the way of organizing the activity.

According to these characteristics, the processes carried out within the companies are:
- industrial processes;
- non-industrial processes.

Classification according to the sector of activity:
Industry: SMEs in manufacturing, processing, construction, etc.
Trade: SMEs engaged in retail, distribution or wholesaling.
Services: SMEs providing services in various fields such as consulting, IT, tourism, health, education, e-commerce, etc.
According to the classification of activities in the national economy (CAEN), the industry can be of several types: extractive, processing, electricity and thermal energy.
Industrial processes result in industrial production.
Industrial production is the direct and useful result of the industrial activity of economic agents, without taking into account the indirect results, such as reusable materials, scraps of raw materials, waste. Being a result of the economic agents' own activity, the goods purchased from outside the unit and delivered as such, without any processing, are not included, nor are the results from other activities (agricultural, commercial, construction, etc.) carried out as extra-profile. (Europeana, 2019)

The classification according to capital ownership divides SMEs into the following categories:
Private SMEs: owned and controlled by individuals or groups of individuals.
Mixed capital SMEs: owned by individuals and legal entities.
Public SMEs: owned by the state or public entities.

The classification according to geographical location divides SMEs into the following categories:
Local SMEs: active in a narrow geographical area or a specific community.
Regional SMEs: active in a specific region of the country.
International SMEs: active in international markets and operating across borders.

1.2. Trends and reference data in the use of continuous improvement methods and techniques in SMEs

Continuous improvement is a management approach focused on achieving major improvements by applying small incremental improvements. It is used by small and medium-sized enterprises in the manufacturing sector to improve the performance of production processes. This chapter tries to evaluate the performance of the continuous improvement approach in Romanian SMEs. In this sense, the level of importance of the various improvement tools and the important benefits obtained after their implementation were identified. The results indicated that businesses are highly focused on customer relationship, which plays a vital role in improving product quality. Most companies today are faced with the need to respond to the increasingly complex needs, wants and tastes of customers. To compete in this ever-changing environment, these companies must look for new methods that allow them, on the one hand, to remain competitive and flexible, and on the other hand, to respond quickly to new customer demands (Black, 1991). Moreover, in order to remain competitive, and to keep its market share in the global economy, it became necessary to continuously improve production processes (Shingeo, 1988). Intense global competition and diminishing trade barriers have led companies to opt for total value maximization. Competition and ever-increasing customer standards have proven to be a never-ending driver of organizational performance improvement. Thus, companies constantly seek to identify and implement continuous improvements in the products, services, and processes they make (Reid, 2006). Continuous improvement consists of a collection of activities aimed at improving performance by simplifying production processes and reducing losses (Terziovski, 2002). It is a process of incremental innovation focused and sustained through different types of practices (Malik et al., 2007).

Most small and medium-sized enterprises (SMEs) in the manufacturing sector focus on increasing profitability through system simplification, organizational capacity and incremental improvements, using techniques aimed at continuous improvement in terms of performance, costs and quality.

This chapter attempts to achieve two main objectives:

- the level of importance of the different improvement tools used by SMEs in Romania and,
- the important benefits achieved after successfully implementing continuous improvement tools and methods.

Using distribution and correlation analysis, this chapter focuses on SMEs that have implemented the continuous improvement approach over a period of 1-5 years.

In order to carry out this study, we drew up a questionnaire with a total of 41 questions. Prior to data collection, the survey instrument is pre-tested for content validity. In the first stage, two experienced researchers checked the questionnaire for clarity and appropriateness of the questions; based on the feedback received from these researchers, the instrument was modified to increase the clarity and appropriateness of the items. In the second stage, the survey instrument was sent to two experienced managers from two SMEs; they reviewed the questionnaire for structure, readability, and completeness. The final survey instrument included the feedback received from these managers, which increased its clarity. The questionnaire consisted of 41 different questions, starting from general information (name of the SME, size, field of activity, designated respondent), whether they apply continuous improvement methods and techniques and for how long (years). Responses to the continuous improvement questions consisted of ratings on a scale of importance (1 = not at all important, 2 = less important, 3 = not so important, 4 = very important, 5 = most important) and benefits (1 = not beneficial at all, 2 = least beneficial, 3 = beneficial, 4 = very beneficial, 5 = most beneficial).

1.3. Anchoring research in the current state of knowledge

Tools and technique play a significant role in improving company performance and are highly supported. The result indicated that CI tools and technique are useful in achieving organizations' goals, increasing productivity, improving quality, reducing costs, improving safety, and delivering faster to the customer.

In this paper, various types of methods and techniques that can be used by SMEs to improve production processes are analyzed. The approach based on continuous improvement is the most effective way to achieve the best quality products. In addition, the analysis carried out shows that continuous work with suppliers is most useful in achieving the goals of an organization. By adopting the methods and techniques of continuous improvement, an increase in productivity is obtained. TQM, Kaizen and effective leadership are particularly aimed at improving product quality. TPM and team involvement in improvement activities are very useful in improving both productivity and reducing production costs.

2. APPLIED RESEARCH OF SOME CONTINUOUS IMPROVEMENT TECHNIQUES USED IN SMEs

The objectives of this chapter are:

- presentation of the main methods and techniques used in SMEs
- the presentation of the three experimental companies that were studied
- presentation of the equipment used;
- presentation of the methodology used.

2.1. Methods and techniques for continuous improvement of production processes in Romanian SMEs

In the process of continuous improvement, a series of methods and techniques are applied that ensure a certain dynamic of progress. This dynamic is indispensable for achieving the proposed objectives. (Besterfield and Co., 2012). Continuous improvement methods and techniques are grouped into two broad categories:

- Classic methods
- Modern methods

2.1.1. Classic methods

Developed by Japanese statistician Genichi Taguchi, these methods focus on improving product quality through robust design and minimizing sensitivity to variability. (Amalia, 2023)

These methods can be adapted and combined according to the specific needs of the organization. Implementing a continuous improvement approach can bring significant benefits in terms of quality, efficiency and competitiveness.

This category of methods allows to work on the basis of visible and measurable facts, starting from numerical data and in a curative approach. They also allow to some extent the analysis of the causes. (Augsdorfer, 1995)

Enterprises that operate on the basis of the traditional management model, oriented towards product and profit, ensure their competitiveness by improving technologies, machines, materials, etc., generally through technical, economic, organizational measures, resulting from innovations. The characteristics of this type of improvement are:

- involving a small number of people, well trained professionally, inventive;
- permanent involvement in the process only for employees from the research and development departments, the other departments rarely producing innovations;
- Employees in the lower hierarchical levels have a reduced degree of involvement;
- Applicable innovations that deliver good process results and have cost and market impact

occur over relatively long timescales;

- Producing inventions/innovations requires significant investment;
- The application of innovations causes important leaps of improvement. (Amalia, 2023)

The main classic method used in SMEs are:

- Team work;
- Statistical Process Control (SPC);
- Pareto Diagram;
- Cause-effect diagram (Ishikawa);

2.1.2. Modern methods

During World War II, it was the US arms industry that made extensive use of Shewart's statistical control methods, requiring all suppliers to do the same. The arms industry also requires its suppliers to train their personnel to apply these methods. The power of these methods was universally recognized, and the method of use classified as a "well-kept secret". (Hent, 2017)

After the war, the armaments industry no longer showed considerable interest in these types of methods, although in the 1950s, a large number of American companies continued to use statistical methods of quality control. With the economic development of the 60s and 70s, the vast majority of companies abandoned the use of statistical techniques, the concern moving from quantity to quality.

In Japan, the situation was totally different, due to the fact that the industry was completely destroyed. During the occupation of Japan, the American military had to deal with a great difficulty: the bankruptcy of telephone services. To remedy this problem, the US military is requiring the Japanese telecommunications industry to use modern quality control methods. This represents the beginning of statistical control in Japan, namely in May 1946.

To assist in the recovery of Japanese industry, General Douglas Mac Arthur requested Dr. W.E. Deming and American statisticians to work together with the J.U.S.E. (Japanese Union of Scientists and Engineers) and representatives of industry companies. Dr. Deming will promote the use of statistical control methods to improve quality and productivity in Japanese factories. In 1950, Dr. Deming organizes a seminar for JUSE, whose main themes are:

1. How to use the Plan – Do – Check – Action cycle (known as the “Deming Wheel”) for quality improvement
2. The importance of the notion of statistical dispersion
3. Process management based on control books.

During the 1960s and 1970s, these methods were successfully promoted on a large scale. (Borris, 2006).

The main modern methods of continuous improvement within SMEs are:

- Lean Manufacturing method
  - Kaizen Continuous Improvement

These modern methods use a number of specific techniques, of which we mention:

- 5S / 6S method;
- PDCA.

2.2. Presentation of the three experimental studied companies

For reasons of confidentiality, these companies will be called Company 1, Company 2 and, respectively, Company 3.

2.2.1. Presentation of Company 1

This company is a subsidiary of an international group of Swiss origin, specializing in the provision of electronic manufacturing services and technical solutions for the medical, aeronautical, industrial and defense industries. Company1 is a production and assembly unit of electronic components and modules. Through it, the group offers a wide range of services and solutions in the field of electronics, including:

1. Electronic Assembly: Electronic assembly services, including surface mount (SMT) board assembly

and through-hole mounting. These services cover various types of electronic components and modules.
2. Testing and Quality Control: The company carries out rigorous testing and checks to ensure product quality. This includes functional tests, performance tests, reliability tests and quality control throughout the manufacturing process.
3. Engineering services: These address the development and optimization of electronic products. This includes technical consulting, design, prototyping and other customized customer services.
4. Key Industries: Serves a wide range of industries: medical, aerospace and defense.

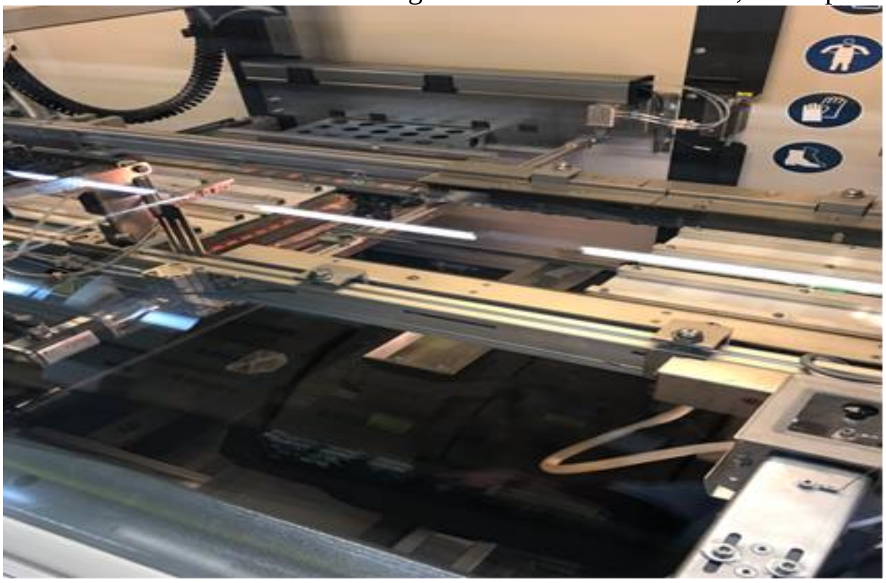


Figure 1: Picture from the production process of the Company 1. Personal archive

SMT is a method of building electronic circuits in which components such as resistors, capacitors and integrated chips are mounted directly on the surface of the printed circuit board (PCB), without being inserted through holes. It is an effective and widely used technique in electronics manufacturing due to its advantages in terms of space and production costs.
The images below show some of the electronic boards assembled by the studied company.

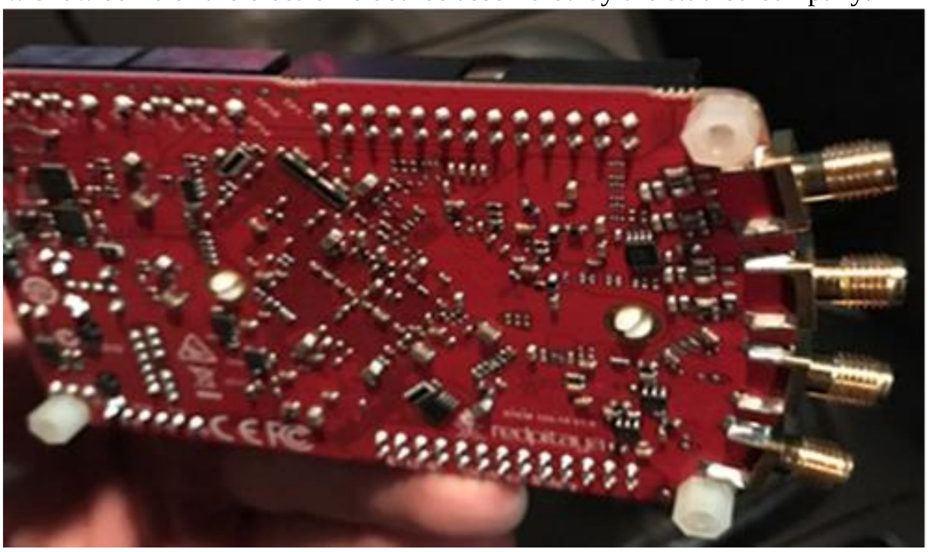


Figure 2: Product from the Company 1's manufacturing range of products. Personal archive

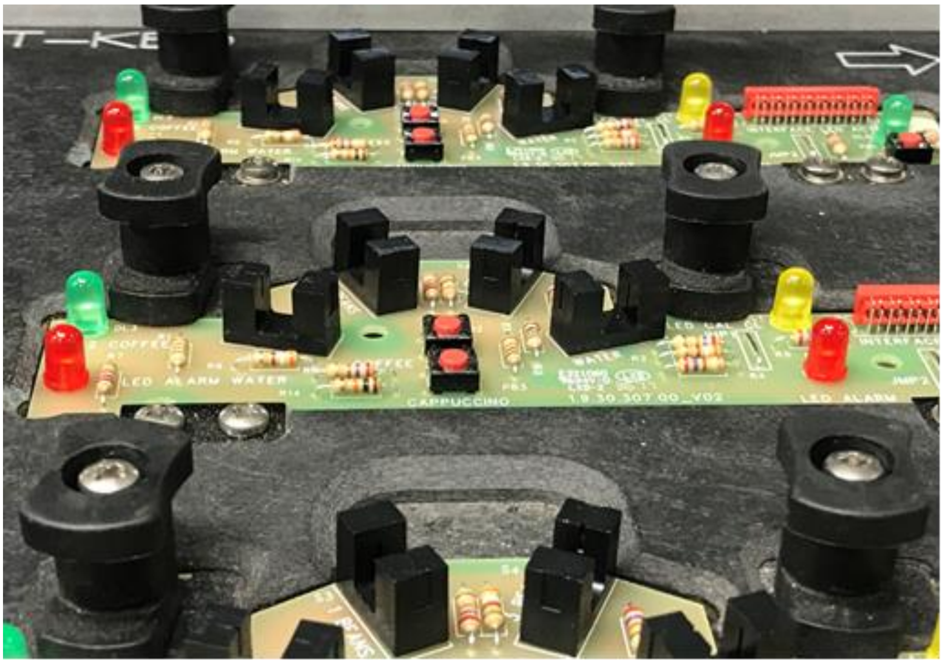


Figure 2: Product from the Company 1’s range of products. Personal archive

In order to place the company in the category of SMEs, the information provided by the accounting balance sheets of the last years was used, from which information was extracted regarding: the number of employees, the turnover, the value of the assets. These data are summarized in the table below.

Table 1: Placing Company 1 into SMEs field

YEAR	**TURNOVER (EUR)**	**MEDIUM NO OF EMPLOYEES**	**ASSETS (EUR)**
2019	19.580.000	150	13.112.500
2020	29.180.000	195	14.412.140
2021	32.840.000	200	14.684.900
2022	41.360.000	248	6.043.577
2023	35.700.000	242	5.310.126

2.2.2. Presentation of Company 2

Company 2 operates in the field of production of electronic boards, offering products for the following industrial branches:

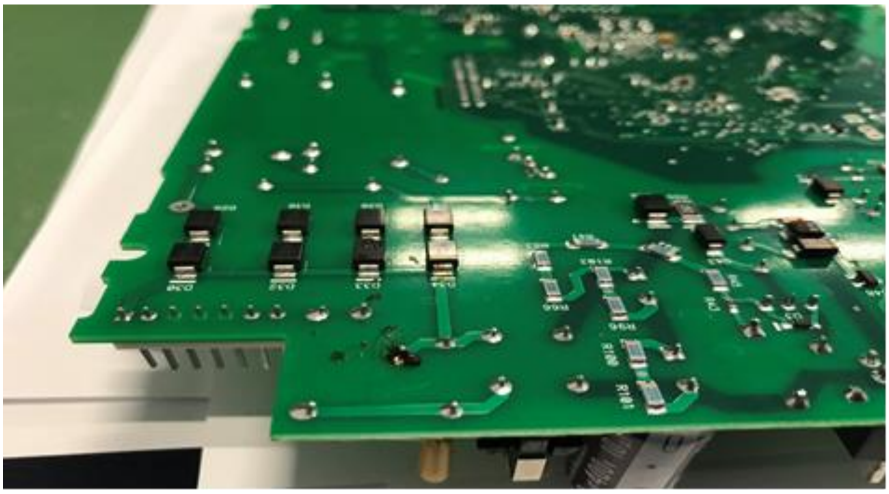
- Industrial products: electronic equipment, electrical equipment, agricultural vehicles;
- Consumer products: household products, hood components;

The company also offers additional services:

- Ultrasonic welding;
- Padding
- Assembly – manual, automated;
- Packing.

The 2500 sq m production area houses 6 ATF-33 machines with high volume wave bonding system, 400mm wide, double wave as standard, compatible with lead free tin and flux spray.
There are a few aspects:
- the self-sensing feature of the spray flow automatically recognizes the position;
- PCB width and length;
- flux is released only in the "Bottom" area of the PCB.

In the figure below we present a product from the manufacturing range of Company 2.



Picture 3: Product from the Company2's range of products

In order to classify the company in the category of SMEs, the information provided by the accounting balance sheets of the last years was used, from which information was extracted regarding: the number of employees, the turnover, the value of the assets. These data are summarized in the table below.

Table 2: Placing Company 2 into SMEs field

YEAR	TURNOVER (EUR)	MEDIUM NO OF EMPLOYEES
2019	1.531.887	52
2020	4.852.452	65
2021	7.452.654	76
2022	9.586.393	98
2023	14.856.846	135

2.2.3. Presentation of Company 3

Company 3 operates in the field of electronic board production, having a SMT and THT electronic board process. Also added as annexes are the finishing phases, electrical test (YCT), functional test, endurance test.

• Industrial products: Electronic boards for coffee machines, televisions, microwave ovens, etc. (according to ISO 9001 quality standard).

In the figure below we present a product from the manufacturing range of Company 3.

Figure 4: Product of Company 3's range of products

In order to classify the company in the category of SMEs, the information provided by the accounting balance sheets of the last years was used, from which information was extracted regarding: the number of employees, the turnover, the value of the assets. These data are summarized in the table below.

Table 3: Placing Company 3 into SMEs field

YEAR	TURNOVER (EUR)	MEDIUM NO OF EMPLOYEES
2019	231.687	5
2020	476.799	8
2021	699.431	16
2022	1.062.393	40
2023	1.271.846	54

2.3. Presentation of the equipment used

In the PCB continuous improvement study, a variety of technologies and tools are used to evaluate and optimize PCB manufacturing processes and performance. In the following we present the equipment used in the present study:

1. **Automated Optical Inspection (AOI)**: This uses imaging technology to inspect the PCBs being produced and detect any defects. AOI can identify routing errors, short circuits, component problems and other failures, helping to improve quality and reduce defects


Figure 5: AOI System. Personal archive

2. **Automated Test System (ATE),** which is used to test assembled PCBs and verify the functionality of components and circuits. Continuity tests, insulation tests, performance tests and other specific tests can be performed with it to ensure the conformity and quality of PCBs.

Figure 6: Automatic PCB testing system. Personal archive

3. **Statistical analysis and quality management software:** The use of statistical analysis tools and quality management software enables the collection and analysis of data relevant to PCB manufacturing processes. This includes statistical process control (SPC), trend and correlation analysis, non-conformance management and performance improvement through data analysis.

4. Tools for measuring PCBs. In the present case, for the study of the Gage R&R method, we used a digital caliper as can be seen in the image below:

Figure 7: Electronic caliper for testing PCB. Personal archive

4. **Universal PCB testing machine 100 kN UTM-E100 INSIZE**

This is specialized equipment used to check and diagnose printed circuit boards (PCBs) and the electronic components mounted on them. It is essential in the manufacturing process of electronic devices to ensure the quality and reliability of the finished products.

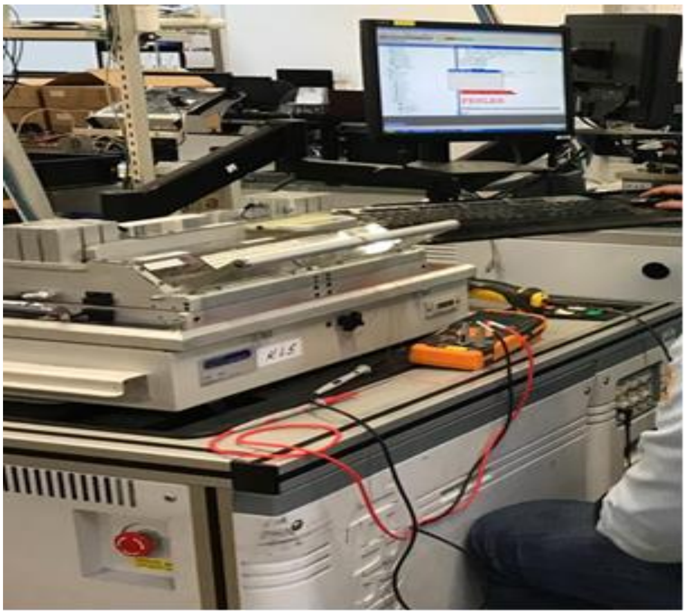


Figure 8: Universal PCB testing machine

2.4. Experimental methodology

In the analysis of continuous improvement methods and techniques within the three studied SMEs, we applied an experimental methodology that involved the following steps:

1. Identification of Improvement Objectives

We set clear and measurable goals. These included reducing defects, improving process efficiency, optimizing resource utilization and reducing production time.

2. Production Flow Mapping

We made a production flow map to identify and understand the workflow of PCBs in the factory. Next, we identified key milestones and potential critical points.

3. Problem detecting:

We noticed that the three companies were experiencing problems with electronic board failures, which were due to improper calibration of the equipment used in production, which led us to choose the Gage R&R improvement method.

4. Application of Continuous Improvement Methods:

As stated previously, for solving defects related problems, we have implemented the Gage R&R improvement method.

Also, within Company 1, being the largest in size, we also implemented the KAIZEN improvement method, through which we promoted a team spirit and a commitment to performance-oriented results. Employees got involved in our project. We took into consideration their feedback, we encouraged innovative ideas, and made sure everyone was aware of the goals and benefits of the improvement process.

5. Monitoring and collecting data

We used monitoring systems to collect real-time data both during and after the implementation of the improvements. This involved the use of sensors, production monitoring software and Enterprise Resource Planning (ERP) systems.

6. Data analysis

We used the collected data to evaluate the impact of the improvements. We analyzed the trends, identified the fluctuations and compared the results obtained.

7. Implementing corrective actions

If we noticed problems, we implemented corrective measures; we have ensured that they are sustainable and that they bring significant improvements.

8. Evaluating continuous performance

In order to evaluate the performance, we used key performance indicators (KPI). The optimization of continuous improvement systems is carried out with the help of performance indicators. Performance indicators - hereinafter called KPI - represent that category of financial and non-financial indicators that companies use to estimate and consolidate success, pursuing long-term objectives, previously established. The proper selection of indicators to be used for measurement is of utmost importance. The organization of processes also implies customer orientation and the necessary flexibility in the current conditions of global competition (Velimirovic, 2010).

3. EXPERIMENTAL RESEARCH ON CONTINUOUS IMPROVEMENT METHODS IN SMEs

The objectives of this chapter are:

- Implementing Gage R&R method in the three experimental companies
- Implementing Kaizen method in Company 1

Ecuaţion	Component	Component calculation	Calculation of contribution %
1	Gauge R&R total ($CompVar_{total}$)	$= CompVar_{repetability} + CompVar_{reproducyibility}$	11 % Contribution $i = \frac{CompVari}{Variation\ total}$ x 100 i $= \begin{cases} Gauge\ RR\ total, Repetability \\ Reproductibility, Operator \\ Operator\ x\ Operator\ item\ to\ item \end{cases}$
2	Repetability ($CompVar_{repetability}$)	$=CompVar_{repetability}$	
3	Reproductibility ($CompVar_{reproductibility}$)	$= CompVar_{operator} + CompVar_{operator\ item}$	
4	Operator ($CompVar_{operator}$)	$= \frac{CMoperator - CMoperator\ item}{a\ x\ n}$	
5	Operator x Item ($CompVar_{operator\ x\ item}$)	$= \frac{CMoperator\ item - CMrepetability}{n}$	
6	Item to item ($CompVar_{item\ to\ item}$)	$= \frac{CMitem - CMoperator\ item}{b\ x\ n}$	
7	$CompVar_{total} + CompVar_{item\ to\ item}$	$= CompVar_{total} + CompVar_{item\ to\ item}$	

Figure 10. Calculation of contribution %

Generalities regarding the organization of experimental research and the scientific planning of factorial experiments, experimental data processing techniques, elements of operational research, the software used in the thesis to obtain specific results will be reviewed.

3.1.Implemmenting Gage R&R method

3.1.1. Defining and justifying the researches

The measurement system analysis (Gage R&R) is a statistical method used for testing the measurement system. After consulting the specialized literature, an industrial application project was discussed. The statistical evaluation of the project results was also carried out. Quality is an indispensable phenomenon for producers and a way of life for consumers. With this feature, customer satisfaction is the number one priority for organizations. The success of an organization is associated with providing the highest quality products and services in the shortest time at the lowest cost. When this is achieved, customer satisfaction is achieved.

Customer satisfaction also means profitability for companies. Therefore, companies aim to maintain customer satisfaction. If this is achieved, companies can survive in today's fiercely competitive environment. For this, they constantly try to control and improve their processes.

In this regard, a variety of statistical and non-statistical methods are used that identify and eliminate sources of variability in their processes. In order to correctly determine areas for improvement as well as to meet customer requirements, accurate measurement of process variation is one of the most important issues in a manufacturing process. The total variability in a system is due to the variability of the process itself and the variability of the measurement system, as can be seen in the equation below: (Castañeda O, 2021)

A Gauge R&R study should allow estimation of the variability of repeatability (σ repeatability) and reproducibility (σ reproducibility) so that a factorial design approach can be used to estimate component variance. The measurement of operator i in part j of replication k is the Xijk score, and in the factorial design approach, each measurement is represented according to the model below.

Repeatability is the variation in the measurement of a part performed by an operator with the same measuring device and under the same working conditions. Reproducibility is the variation in the mean of measurements made by different operators on the same part with the same measuring device.

3.1.2. Methodology of study

The planning and analysis of the measurement system was carried out in six stages, at all three companies:
- Determination of the piece to be measured
- Determining the parts of the sample, the number of repetitions and the number of evaluators
- Selection of counters (from those using the measuring device)
- Selection of sample parts to measure (depending on Gage R&R study design)
- Determination of the expected sensitivity and variability of the measuring device
- Checking the compliance of the measurement method with the defined procedure. (Gerger, 2021)

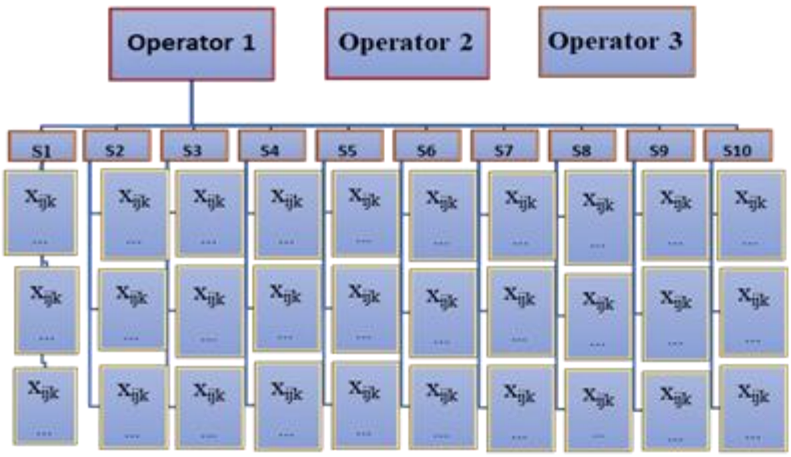


Figure 11 Methodology of study

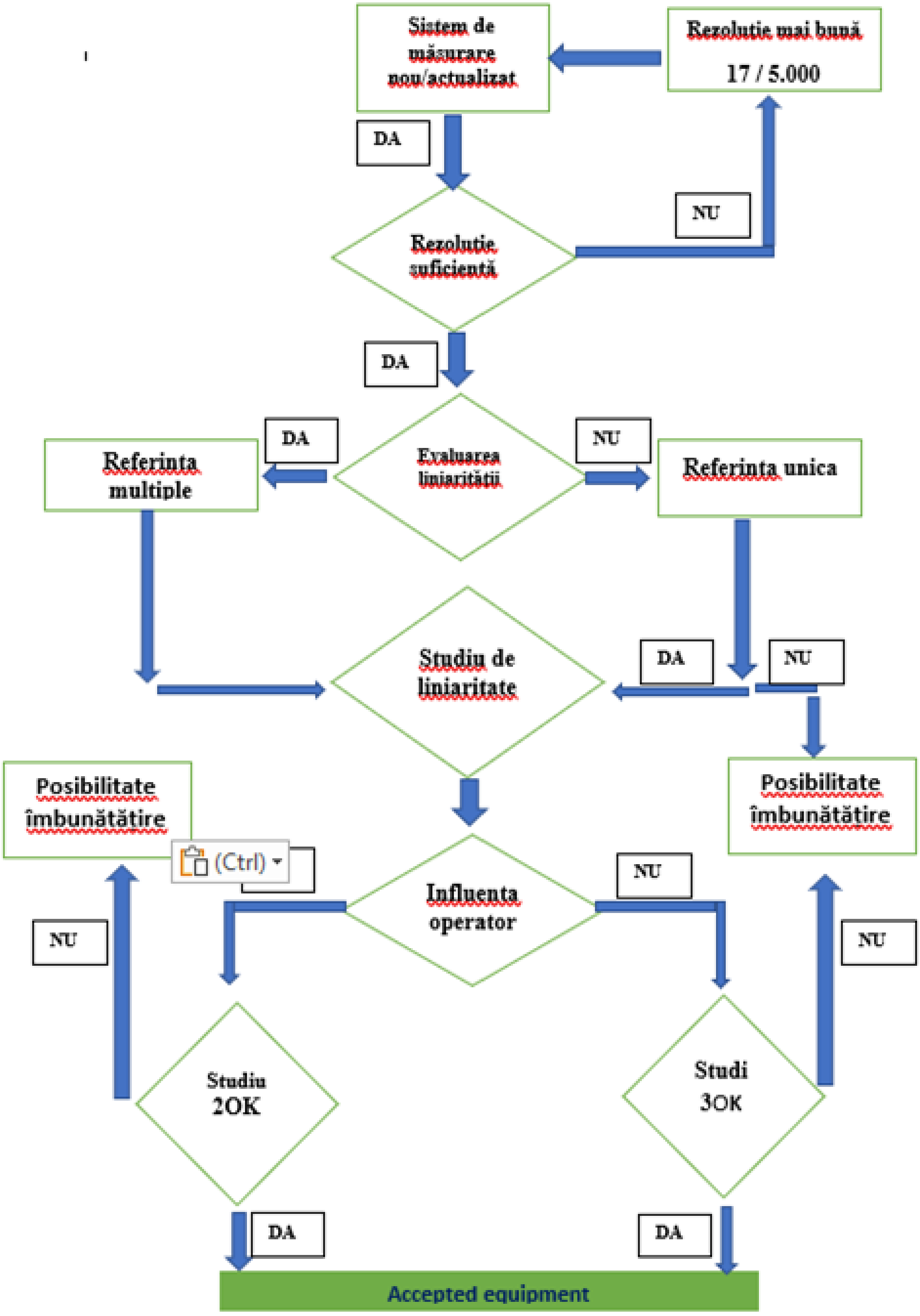


Figure 2: Logical scheme of the applied study

3.1.3. Results obtainded

Based on the established criteria for Gage R&R, we can draw certain conclusions based on the test results:

Gage R&R ≤ 10%: The measurement system is acceptable;

In this case, we can conclude that the measurement system has good repeatability and reproducibility, and its variability is within an acceptable range. The measurements made with this system are reliable and can be considered suitable for process evaluation.

Adjustments or optimizations may be necessary to ensure consistency and reliability of measurements under various conditions of use.

A Gage R&R value greater than 30% indicates significant variability in the measurement system. This suggests that measurements may be unreliable or inconsistent. It is essential to identify and address problems in the measurement system to improve its reliability and accuracy. An important parameter in the notions of statistics is the "number of distinct categories" which tells us important data about the selection criterion of

the samples to be tested in the study. A number greater than 5 tells us that they were chosen accordingly. In our case, this number is 9, so a very good selection of these pieces has been made.
It should be noted that the method that analyzed these results was: VDA-QMC (20/03/16) TYPE2 ANOVA (tolerance).

3.2. Applied research on the Kaizen improvement method

3.2.1. Implemmenting methodology

The process of applying the kaizen method mainly consists of the following steps:
- defining the improvement area,
- analysis and selection of the key problem,
- identifying the cause of the improvement,
- planning remedial measures,
- implementation of the improvement project,
- measuring, analyzing and comparing results,
- Standardization
- Collection of existing data including production line time calculation.
- Balancing the production line by reducing non-value added activities
- Identifying the top 5 defects of the production line through root cause analysis and taking corrective measures to reduce these top 5 defects.
- 5S audit of the existing layout, taking corrective measures. 5S audit after Kaizen implementation.
- Calculation of line efficiency improvement and defect reduction after implementing continuous corrective actions known as Kaizen through 5 days of observation

3.2.1.1. Standardization procedure

The implementation of the standardization operation is necessary because it makes it possible to identify and eliminate variations in the operator's work, as well as to maintain the positive results of the past.

The following actions are required to provide a baseline for future Kaizen activities and to create a standard operation:
1. Performing the analysis of a time loop
2. Document verification for each standard operation
3. Displaying the document
4. Training of all operators

The objective of standardization is to prepare standard operation sheet for all operations and machines. In order to standardize the operating procedure, the existing working method must be taken into account. Processes are then analyzed slowly and unnecessary motion is eliminated to standardize the process method. A standard process method was reviewed by the line supervisor. Then, the ways or methods of processing were documented. If operators follow these methods properly, non-value-added time will be reduced.

3.2.1.2. Balancing the time cycle

After implementing the standard procedure, non-value-added activity is reduced.
. Before analyzing the current state, the required time of line 13 was calculated. The required time is the time in which the production is carried out according to the customer's request.

$$\text{Timp necesar} = \frac{\text{timp net de operare}}{\text{cerere client}}$$

Thus, for a request for 6000 electronic boards, to be carried out in a period of 20 days, the time required is: $\text{Timp necesar} = \frac{20 \text{ x } 8 \text{ x } 60}{6000}$ = 1.6 minuts

Taking into account this value, the working times before and after the implementation of the standardization were compared. The results are shown in the table below:

Table 4: Balancing time cycle

Pos.	Operator	Machine	Necessary time	Time before	Time after	Kaizen action
1	Operator1	2NDL	1.6	1.75	1.70	Equipment rearrangement
2	Operator2	SM	1.6	1.80	1.77	Reducing useless moves
3	Operator3	SM	1.6	1.58	1.59	Reducing useless moves
4	Operator4	SM	1.6	1.66	1.64	Rearrangement kept material
5	Operator5	SM	1.6	1.77	1.70	Rearrangement kept material
6	Operator6	2NDL	1.6	1.52	1.51	Periodical cleaning
7	Operator7	SM	1.6	1.95	1.94	Allocating a co-worker
8	Operator8	SM	1.6	1.93	1.85	Reducing useless moves
9	Operator9	SM	1.6	2.05	1.95	Equipment rearrangement
10	Operator10	SM	1.6	1.88	1.84	Periodical cleaning
11	Operator11	SM	1.6	1.54	1.44	Reducing useless moves
12	Operator12	SM	1.6	1.58	0.51	Periodical cleaning
13	Operator13	SM	1.6	1.60	0.55	Reducing useless moves
14	Operator14	2NDL	1.6	1.60	0.60	Equipment rearrangement
15	Operator15	SM	1.6	1.65	0.50	Rearrangement kept material

3.2.1.3. Implemmenting 5S

In order to improve the working environment as well as the score obtained, some corrective measures have been taken, listed below:

1.Removing unnecessary items
2. Review of material storage
3. Carts should not be blocked
4. Easy access to the first aid kit
5. Cleaning the floor
6. Cleaning the car
7. 5S audit

After the implementation of 5S, an evaluation was made, the results of which being presented as follows:

Table 5: 5S evaluation before and after implrmmentation of Kaizen

Pos.	Factor	Description	Score (0-5)	Defective level that needs improvement
1	Useless materials	Unnecessary items are no longer at workplace. There are no items on top of machines, cabinets or equipment	4	1. There are items to redo
2	Safety	Work areas do not present safety hazards. Fire extinguishers and other emergency/first aid equipment are properly stored in the correct color-coded area.	4	1. There is no specific location for first aid equipment
3	Material storage	Boxes and containers are stored and labeled correctly on the cupboard shelves	3	1. Defective boards are stored on a tray 2. 2. Unnecessary materials are present
4	Cleanliness	Machines and equipment are clean, windows and work surface are clean. The floors are cleaned at least once a day	4	1. Unnecessary materials are present, but their quantity has decreased
5	Maintenance of equipment	All cars and equipment are neatly painted. Guards and safety signs are installed correctly. No fluid leaks and frayed electrical cables.	4	1. Equipment is stored away from the work area
6	Control	Completed weekly audits, graphical results supporting improvements	4	1. To fulfill 3S: Sort, Shine, Standardize
Total				
Punctaj 5S				

3.2.1.4. Reducing waste

The main objective of Kaizen is to reduce waste. Thus, by reducing defects, waste is also reduced, improving the quality and efficiency of electronic boards. (Misiurek, Taylor & Francis Group)
They can present different types of defects, the most common of which are:

1. Soldering Defects
2. Improper screen printing
3. Errors in the identification of components
4. Delaminating copper layers
5. Hollow points in a copper layer
6. Alignment and Spacing Issues
7. Issues with Mounting Holes
8. Scratched plate

3.2.2. Results and conclusions

Kaizen assumes that strong, small, incremental changes are routinely applied and sustained over a long period of time, resulting in significant improvements. The comparative results before and after Kaizen implementation are shown in the table below:

Table 6: Results obtained

Poz	Objective	Before Kaizen	After Kaizen	Results
1	Line efficiency (%)	54	61	Increase of 7%
2	5S score	2.64	3.84	Increase of 1.16 unități
3	Standardization	-	Aded-value to some operations	Standardized process

The objective of Kaizen is to increase overall productivity, efficiency, quality. The result of the implementation for five days was very fruitful. After implementation, efficiency improved from 54% to 61%. The 5S improved from 2.67 to 3.83. It can be easily realized that the 5-day implementation of Kaizen led to a 7% improvement in line efficiency.

4. APPLIED RESEARCH ON THE OPTIMIZATION OF CONTINUOUS IMPROVEMENT SYSTEMS

The objective of this chapter is:

- Implemmenting Industry 4.0 in Company 1

4.1. Methodology of implementation

This chapter studies the possibility of optimizing continuous improvement methods within an SME (Company 1, described in previous chapters), through a methodical approach to the Industry 4.0 concept. This concept must be implemented in stages, presented in the following:

• **Stage 1** – Using technology to gather Lean data in one central location using spreadsheets and single-source communication channels. This will initially be carried out as a trial in the Assembly Department. After this stage, we will understand if the new digital solution, communication and recognition process works and improves adherence to Lean practices.

• **Stage 2** – Implementation of the theory and strategy used in stage 1 in the other two assembly departments.

• **Stage 3** – Implementation of the theory from the assembly departments in the two production halls, providing full coverage of the entire company.

• **Stage 4** – Bringing together all Lean data from the assembly and production departments in one central location, enabling the understanding and digitization of the involvement and use of Lean production tools and systems throughout the company.

• **Stage 5** – Implementation of a digital solution that allows data capture without the need for paper listing, in all areas of the company. respectively Connecting directly to the digital solution**.**

4.1.1. New Lean Management process

1. Daily, team leaders on production lines enter information into an embedded spreadsheet on the SharePoint® site. This data is then checked every day by a member of the improvement team. Regular two-way communication is used through the SharePoint® site that ensures effective project implementation.
2. Every month Lean adherence data for SWC/ 5S/ Process Confirmation/ SWC Actions and CCAR Actions will be collected from each area and entered into another embedded spreadsheet by an IPS team member. The results of lean adherence were therefore transparent and visible to all team leaders, process leaders, senior process leader, assembly manager, senior assembly manager, other IPS teams in EMC and the quality manager.
3. Lean onboarding results will then be shared with the SharePoint® site, embedded in an

email for easy access. This email will then be shared not only with the operations team in the boardroom, but also with other operations teams, quality teams and managers in the other departments.
4. The area with the best Lean adherence will be recognized as the Area of the Week and added to a league table, which was also on the SharePoint® site.
5. Once a month, the area with the best Lean adherence for the month, i.e. Area of the Month, will receive a certificate from the Senior Assembly Manager, Assembly Manager, Process Leaders and Quality Manager in recognition of achieving the most good Lean grips for the month.
6. A monthly email will then be sent out showing Lean membership month by month and notifying every one of the Zone of the Month winners

4.2. Results obtained

Regarding the quality management system, the most important indicator is customer PPM which is the ratio of the total number of boards returned from the customer under warranty to the total number of boards delivered and multiplied by one million. Practically, this indicator reflects the quality of the products delivered to the customer and directly and heavily influences the level of customer satisfaction, being a criterion for evaluating the level of quality offered.

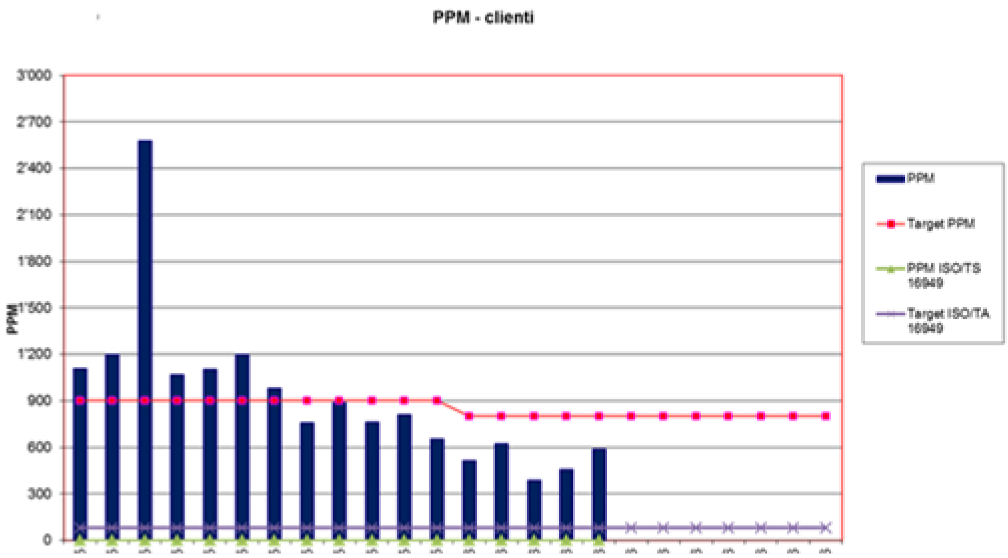


Figure 9: Graph of PPM Customers

The graph shows that there were difficulties in achieving the goal of 900 PPM. In the factory there was a very large variety of products with many technologies and processes. It is often difficult to define a change in the system that brings effective improvements (easy to implement and with low investment and/or maintenance cost) generally valid for all processes or products. The developed recording system allowed the rapid provision of data that allowed the objective evaluation of the effectiveness of the corrective and preventive actions taken following a complaint received from the customer, thus additional improvement measures were taken or other improvement measures were taken following in which it was observed from the records that, internally, following the controls, the frequency of occurrence of the product with that type of defect has significantly decreased or has been permanently eliminated (for example, following the actions taken, no more of this type of defect were registered for a month defects and at the final quality control there were 5 consecutive batches in which the defect traced to the product in question was not identified).

The first sign of improvement in the indicator is observed in first semester, when the objective of having PPM less than 900 was reached, after which the level of PPM remained below this

threshold, and even more, starting from 2013, it went down threshold at 800 and until today there were no cases in which the PPM objective was not met.
Another important indicator is the non-quality costs that are due to the non-conformities that have arisen and that have generated sorting and remediation costs or even rejects.
Thanks to the system used for the validation of the production order where for the identity of a product to be started on the line it is possible to view the records with the defects and mistakes found both after the final quality control and after the intermediate quality control, in addition to the quality warnings alert that allow the tracking of a possible non-conformity that is difficult to detect right at the source of the problem, allowing immediate measures to be taken to remedy the problem or to prevent the occurrence of non-conformities, which means fewer plates to be repaired and therefore, implicitly, lower repair costs.

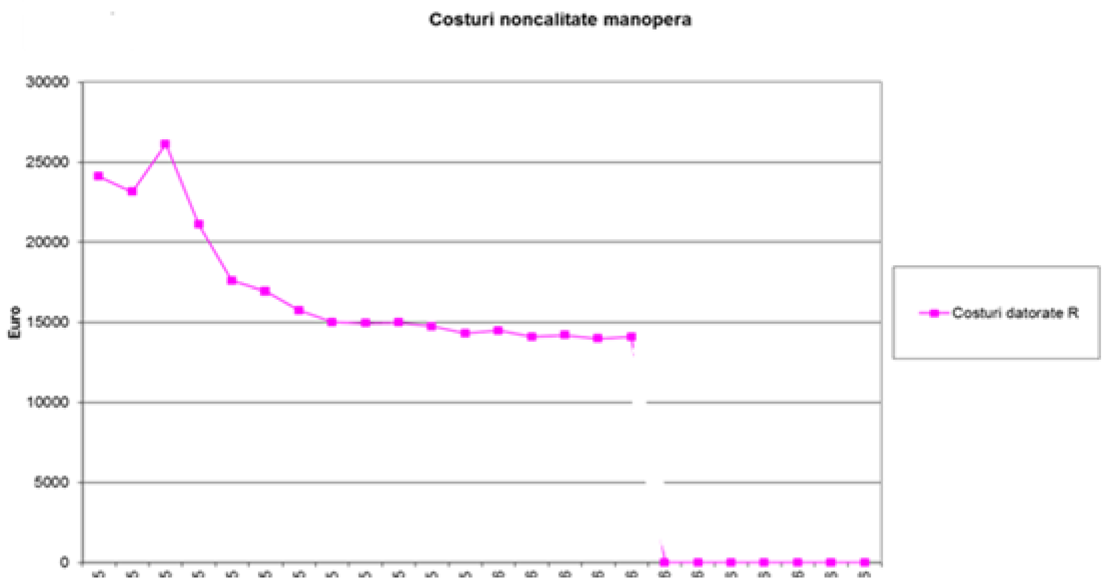


Figure 10: The impact on quality costs

The graph clearly shows a logarithmic and immediate downward trend after the implementation of the system, which from August 2022 brought a reduction in non-quality costs due to repairs from an average of EUR 20,000 to EUR 15,000, which means a gain of EUR 5,000 monthly. This monitoring system was initially estimated to bring a gain of around €1,500-2,000 per month by reducing non-quality costs due to repairs.

Costs were also reduced due to the time lost for plate sorting that reached a statistical control phase after they were produced and a defect was identified. Re-checking lots involves resources allocated to something non-productive which generates non-quality costs by allocating staff resources not paid by the customer and from own funds, machine inactivity and waiting until the products are sorted and the defect is fixed. Time wasted sorting is reflected in overall production efficiency, which decreases with increasing sorting time.

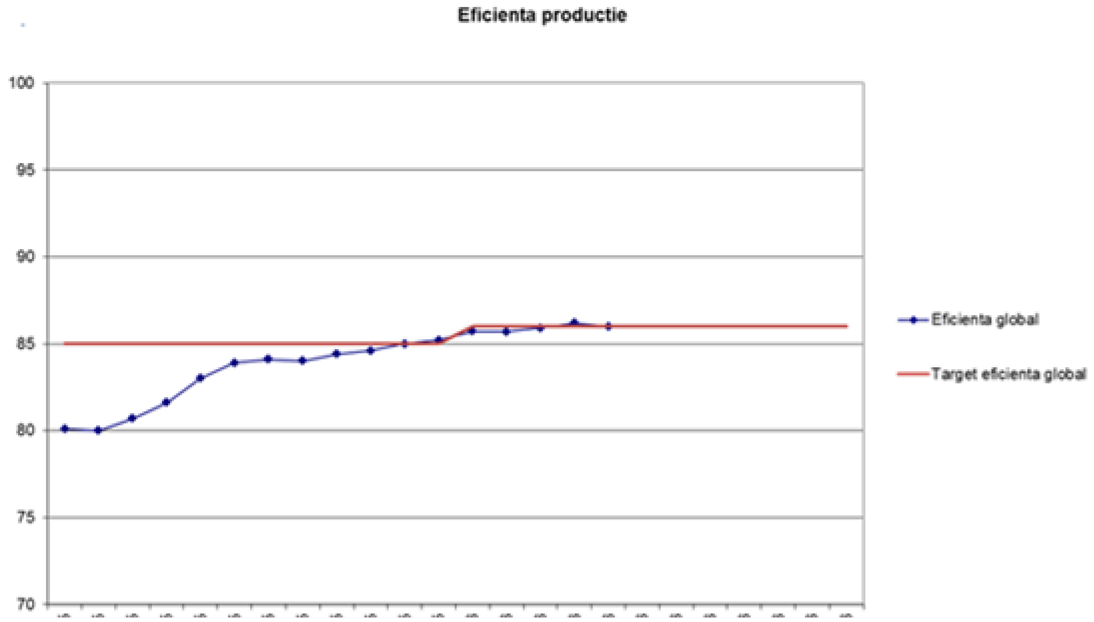


Figure 11: Production efficiency

The results showed that the implementation of the Industry 4.0 methodology, by improving communication and implementing a recognition process, had a positive impact on Lean adherence. There have also been improvements in the confirmation process and the Kaizen method. When comparing the original process to the new process, the number of closed Kaizens increased by 108% and the number of closed Kaizens increased by 182%.

However, this initial increase was not sustained, but there was still an improvement from the original process over the embedded process of 32.5% in the number of Kaizens raised and 76.4% increase in the number of Kaizens closed. Using the SharePoint® site and bringing all information together in one location not only improved accessibility to key systems, tools and data, but also improved communication between the teams involved. There have been a number of improvements in communication. Communication was enhanced through the use of SharePoint site, data communication, use of positive engagement, combination and soft words. It was also enhanced by including team leaders in weekly and monthly communication channels.

Previously there was no recognition process, one of the big improvements was recognizing the areas with the best Lean adherence on a weekly and monthly basis. This creates a competitive environment and increases interest in using systems and tools. One of the major keys to the success of this project is the cross-use of Industry 4.0, improved communication and recognition. Used individually, they would not have had the same impact. Cross-use of systems is therefore important. The future challenge is to sustain the improvements. The production process has improved, but the next stage will consider the quality of the ongoing actions. Are they raised correctly and closed in a timely manner, for example? This could mean that new values need to be added to the weekly communication and included as metrics to achieve the Zone of the Week. Other things to consider are the use of systems and equipment from the other assembly lines and processing lines in the factory. Each line has a different operations team and is at different stages of product maturity. Especially in processing, the organizational structure is different, and the machines and environment are different, so the process will have to be changed to adapt to each department.

5. GENERAL CONCLUSIONS. PERSONAL CONTRIBUTIONS. RESEARCH PERSPECTIVES

a. General conclusions

Starting from the need to implement continuous improvement methods and techniques within SMEs, expressed by three companies active in the field, the present research offered a series of answers related to the implementation of the Gage R&R method and the Kaizen method within SMEs SITES

The contributions brought to knowledge by the thesis will be presented in the following.

b. Theoretical contributions

The main theoretical contributions are:
- critical analysis of the main types of SMEs, in accordance with the methods and techniques for the continuous improvement of their production processes;
- documentary study on the current state of research undertaken in the field of SMEs in Romania
- critical analysis of the main methods and techniques for improving production processes, with an emphasis on the electronic industry, especially the production of PCBs;
- comparative analysis of some representative methods of continuous improvement

the development of an original model for the implementation of the Kaizen Method in an SME from Arad
- development of a model for implementing the Gage R&R method in an SME from Arad
- the development of an original model for the implementation of the Industry 4.0 model in an SME from Arad.

c. Experimental contributions

The work brings a series of experimental contributions, among which the ones with significant impact are presented:

Experimental contributions to process improvement are particularly valuable in various fields and can bring significant benefits to the efficiency, quality and sustainability of these processes. Here are some examples of relevant experimental contributions:

1. Optimizing production processes: By conducting in-depth experiments and analyzes within the production lines, potential weaknesses or inefficiencies were identified and eliminated. This leads to improved workflows, reduced production time and minimized waste.

2. Cost reduction and efficient use of resources: Through experiments, various alternative methods or technologies are evaluated to reduce material and energy consumption in manufacturing processes. It can also identify ways to minimize loss and waste, thus contributing to a more efficient use of resources and cost reduction.

3. Improving the quality of the products: Experiments were used to test different variables and parameters that can affect the quality of the finished products. By better understanding the relationship between production factors and end product characteristics, improved methods and processes can be developed to ensure quality and conformance to specifications.

4. Innovation in product development: Experiments were used to evaluate and validate new ideas and concepts in product development. By testing prototypes and different iterations, improvements can be identified and innovations can be made to meet customer requirements and needs.

5. Reducing the impact on the environment: Through experiments, greener methods and technologies can be identified and implemented in manufacturing processes. This may include

using renewable energy sources, recycling materials or reducing pollutant emissions and waste.

6. Improving occupational safety and health: Experiments were used to assess the risks and hazards associated with certain processes and to develop appropriate protective methods and equipment. This helps to ensure a safe working environment and prevent accidents and occupational health problems.
These are just a few examples of experimental contributions to process improvement. The importance of experimentation and evidence-based approach to process development and improvement is recognized in various industries and fields of activity.

d. Perspectives on further development

Following the experience gained during the doctoral research internship, the following directions for further development were identified:

1. Digitization and automation: The use of digital technologies and process automation are becoming more and more present in continuous improvement. The application of robots, data analysis and artificial intelligence facilitates the collection and analysis of information, the identification of patterns and trends, and the implementation of improvement measures in real time.

2. Use of data analytics and machine learning algorithms: The ability to analyze and understand large amounts of data is becoming increasingly important in continuous improvement. Data analytics applications and machine learning algorithms enable the identification of patterns, relationships, and anomalies, as well as anticipating problems and making more informed decisions about needed improvements.

3. Agile and Lean approach: Agile and Lean methodologies are increasingly used in continuous improvement. These approaches promote team collaboration, communication, and flexibility, accelerating the improvement process and enabling quick and effective adjustments based on customer feedback and requirements.

4. Employee and team involvement: An important trend in continuous improvement is the emphasis on employee and team involvement and active participation in the process of identifying and implementing improvements. Foster organizational cultures that encourage employee input and ideas and provide support and resources to implement individual and team improvements.

5. Integrating sustainability: Continuous improvement focuses more and more on aspects of sustainability and social responsibility. They look for ways to reduce environmental impact, use resources more efficiently and create more sustainable and environmentally friendly products and services.

6. Focus on customer experience: Continuous improvement is increasingly geared towards meeting customer needs and expectations. Methods such as customer experience analysis, feedback and market research are used to identify weaknesses and develop improvements that lead to a more satisfying and valuable customer experience.
The present paper contains both theoretical and experimental and industrially applicable results that can constitute a technology transfer from the academic and industrial research environment to the business environment. These were the basis of 7 scientific works, of which 1 is indexed in Web of Science and 2 are indexed in other international databases.

BIBLIOGRAPHY

1. **Xenakis, DM (Xenakis, DM) Dunn, DS (Dunn, DS) Book Group Authors AMER SOC QUAL CONTROL (AMER SOC QUAL CONTROL) AMER SOC QUAL CONTROL (AMER SOC QUAL CONTROL)** Quality improvement via quality costs [Conferință] // ASQC'S 51ST ANNUAL QUALITY CONGRESS PROCE. - [s.l.] : Web of Science .

2. Aalst W Process Miming: A Research Agenda [Periodic]. - [s.l.] : Computers in Industry, 2004.

3. Abdolsah M Jahan, A. How to use Continuous Improvement tools in different life periods of organisations [Periodic]. - Singapore : IEEE International Conference on Management of Innovations and Technology, 2006. - Vol. 2.

4. Abduljaleel M. Outlier Detection in the Analysis of Nested GAGE R&R, Random Effect Model [Periodic] // STATISTICS IN TRANSITION new series. - 2019.

5. Aized T. Total Quality Management and Six Sigma - Smarter Solutions Using Statistical Methods [Periodic]. - [s.l.] : John Wiley and Sons Inc., 2012.

6. Alstrup L. Coaching Continuous Improvement in Small Enterprises [Periodic]. - [s.l.] : Integrated Manufacturing Systems, 2000. - 3 : Vol. 11.

7. Arafat A Problems and Future Trends of Software Process Improvement in Some Sudanese Software Organizations [Periodic] // 2013 INTERNATIONAL CONFERENCE ON COMPUTING, ELECTRICAL AND ELECTRONIC ENGINEERING (ICCEEE) . - 2013.

8. Arezes P. Workplace Ergonomics in Lean Production Environments: A Literature Review [Periodic] // https://www.researchgate.net/publication/265733694. - 2014.

9. Ashmore C. Kaizen and the Art of Motorcycle Manufacturing [Periodic]. - [s.l.] : Manufacturing Engineer, 2001. - 5 : Vol. 80.

10. Augsdorfer P., Harding, R. Changing Competitive Forces in Europe: Continuous Improvement in a Sample of French, German and British Companies [Periodic]. - [s.l.] : European Business Review, 1995. - 4 : Vol. 95.

11. Barrie De Dale G., Plunkett J.J. "Quality Costing", page 138 [Carte]. - [s.l.] : Taylor&Frances Group, 2017.

12. Benbow D. W. , Zarghami A. "Introductionto 8D Problem Solving" [Periodic] // Spiralbound. - 2017.

13. Berger A. Continuous Improvement and Kaizen: Standardization and Organizational Designs [Periodic]. - [s.l.] : Integrated Manufacturing Systems, 1997. - 2 : Vol. 8.

14. Besterfield and Co. D.H "Total Quality Management" [Periodic] // Elsevier. - 2012.

15. Bloom M. Remt de Oudere de Robot [Periodic]. - [s.l.] : Elsevier, 2017.

16. Borris S Total Productive Maintenance. Proven Strategies and Techniques to Keep Equipment Running at Peak Efficiency [Carte]. - [s.l.] : The McGraw-Hill Companies, Inc, 2006.

17. Bourne Mike Bourne Pippa "Handbook of Corporate Management", page 167 [Carte]. - [s.l.] : John Wiley and Sons Ltd, 2011.

18. Bourne Mike Bourne Pippa "Handbook of Corporate Performance Management",page 81 [Carte]. - [s.l.] : Johnh Willey and Sons Ltd, 2011.

19. Brah S, Chong, W Relationship Between Total Production Maintenance and Performance [Periodic]. - [s.l.] : International Journal of Production Research, 2004. - 2383-2401.

20. Bryant J. L Wilburn N. P. "Handbook of Software Quality Assurance Techniques Applicable to the Nuclear Industry" [Lucrare]. - WA 9935 : Pacific Northwest Laboratory, Richland, 2 August 1987.

21. Carp A, "Profitabilitatea ca forma de comunicare a valorii unei unitati care functioneaza in scopul obtinerii de profit", [Periodic] // Romanian Statistical Review – Supplement no 6 / . - 2017.

22. Castañeda O Caraballo I, Bernad MJ, et al. "Design of crossed and nested Gauge R&R studies for the validation of the Heckel and Ryshkewitch-Duckworth mathematical models" [Periodic]. - 2021.

23. Chevalier R. Doutre E. ,Spalanzani A , "Le management de la qualite" [Carte]. - Grenoble : Presses Universitaires de Grenoble, 1996..

24. Chirescu A Analiza Situatiei IMM-urilor din Romania [Articol] // Revista Romana de

Statistica. - 2022.
25. Comertului Registrul Înmatriculări efectuate în perioada 01.01.2023 - 31.05.2023 comparativ cu aceeaşi perioadă a anului trecut [Lucrare]. - Bucuresti : [s.n.], 2023.
26. Dahlgaard Jens J. . Khanji Ghopal K, Kristensen Kai Fundamentals of Total Quality Management [Carte].
27. Danet A. Managementul Proiectelor [Carte]. - Brasov : Disz Tipo, 2001.
28. Dasgupta T., Murthy, S. Looking Beyond Audit-Oriented Evaluation of Gauge Repetability and Reproductibility; A CasecStudy [Periodic]. - [s.l.] : Total Quality Management. DOI:10.1080/0954412010075280, 2001.
29. Desjardins M. "How to execute corporate action plans effectively" [Periodic] // Business in Vancouver. - 2011.
30. Dombrowski U., Mielke, T. Lean Leadership - 15 Rules for Sustainable Lean Implementation [Periodic]. - [s.l.] : Procedia CIRP, 2014.
31. Doraa M., Kumarb, M., Goubergen, D. Operational Performance and Critical Success Factors of Lean Manufacturing in European Food Processing SMEs. Trends in Food Science and Technology [Periodic]. - 2013.
32. Doshi J.A., Desay, D Measurement System Analysis for Continuous Quality Improvement in Automobile SMEs: Multiple Case Study [Periodic]. - [s.l.] : doi:10.1080/14783363.2017.1324289, 2019.
33. Dr. Kent R Quality Management in Plastic Processing [Carte]. - [s.l.] : Elsevier, 2016.
34. Drucker P. Management's New Role [Periodic]. - [s.l.] : Harward Business Review, 1969.
35. Drumond D. Confessions of a Serial Productivity Research [Periodic]. - [s.l.] : International Productivity Monitor, 2011.
36. Eckes G The Six Sigma Revolution - How General Electric and Others Turned Process Into Profit [Periodic]. - New York : John Wiley and Sons Inc., 2001.
37. Emiliani B Better Thinking, Better Results [Periodic]. - Wethersfield : Wetherfield Center for Lean Business Management, 2007.
38. Europeana Comisia Manualul Utilizatorului pentru Definitia IMM-urilor [Periodic] // Oficiul pentru Publicații al Uniunii Europene, Luxemburg. - 2019.
39. Formento H Key Factors for a Continuous Improvement Process [Periodic] // INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P). - 2013.
40. Gergen A, Firuzan, A.R. Taguchi Based Case Study in the Automotive Industry: Nonconformity Decreasing With Use of Six Sigma Methodology [Periodic]. - [s.l.] : Journal of Applied Statistics; doi.org/10.1080/02664763.2020.1837086, 2020.
41. Gerger A Conducting a Gage R&R Study: An Application Example in Automotive Industry [Periodic] // https://www.researchgate.net/publication/349625419. - 2021.
42. Glavan M. Dumitru M., Dumitrana M. Studiu Empiric privind Costurile Referitoare la Calitate in Intreprinderile Prestatoare de Servicii din Romania [Carte]. - [s.l.] : Managementul Calitatii, Vol XI, Nr. 26, Iunie 2009.
43. Gogue JM "Management de la Qualité" [Carte]. - Paris : Ed. Economica, 1997.
44. Gordon R.J. The Rise and Fall of American Growth [Periodic]. - New York : Princetown University Press, 2016.
45. Green A.P., Buckley, A.R. Application of Gauge R&R to the Rigurous Measurement of Quantum Yield in Fluorescent Organic Solid State Systems [Periodic]. - [s.l.] : Review of Scientific Instruments. doi:10.1063/1.473763, 2012. - 83.
46. Hall Dale E. Kondō Yoshio,Kawamoto H. Proceedings of the Simposium on Quality Management [Periodic]. - 1993.
47. Halleel A Gage Repetability and Reproductibility Study [Periodic] // https://www.researchgate.net/publication/328052178. - 2018.
48. Hamada M.S, Borror, C.M. Analyzing Unreplicated Gauge R&R Studies [Periodic]. - [s.l.] : Quality Engineering. d oi:10.1080/08982112.2012.714338, 2012.
49. Harrington H. James Poor-Quality Cost, [Carte]. - [s.l.] : American Society for Quality,

ISBN 978-0-8247-7743-2, OCLC 14965331, 1987.
50. Heleta M. Total Productive Maintenance Models for Business Excellence [Periodic]. - Belgrad : Educta, 1998.
51. Hent R William Andrew Quality Management in Plastic Processing [Carte]. - [s.l.] : Elsevier, 2017.
52. Herman M., Pentek, T, Okto, B. Design Principles for Industry 4.0. Scenarios Proceedings of 49th Hawaii I nternational Conference on System Sciences [Periodic]. - Koloa : HICCS, 2016.
53. Heydorn K Quality Assurance and Statistical Control [Articol] // Microchimica Acta. - January 1991.
54. Hofman C. Development of an Agile Method Kanban for Distributed Part-time Teams and an Introduction Framework [Periodic] // Procedia Manufacturing 23 (2018) 45–50. - 2018.
55. Hoyle David “Quality Management Essentials” [Periodic] // Elsevier . - 2017.
56. Hwang L.T., Horng, T.S. Advanced Stacking and Planar Solution for 5G Mobility [Periodic]. - Singapore : John Wiley and Sons, 2018.
57. Imai M Gemba Kaizen - A Commonsense, Low-cost Approach to Management [Periodic]. - Warsaw : Kaizen Institute, 2008.
58. Imai M. Kaizen - the Key to Japan's Competitive Success [Periodic]. - New York : Random House , 1986.
59. Ionescu C. Ëxcelenta industriala, practica si teoria calitatii [Carte]. - Bucuresti : Ed. Economica, 1997.
60. J Salomé “Ghid de supravietuire in universul professional. Cum sa facem fata situatiilor stresante” [Periodic] // Curtea Veche Publishing, Bucuresti . - 2015. - pg. 39-40.
61. Janes A. https://www.researchgateA_Continuous_Software_Quality_Monitoring_Approach_for_Small_and_Medium_Enterprises [Periodic] // https://www.researchgate.net/publication/316355639. - 2017.
62. Jebreen I., Wellington, R., & MacDonell, S.G. Full citation: Jebreen, I., Wellington, R., & MacDonell, S.G. (2013) Packaged software implementation requirements engineering by small software enterprises, in Proceedings of the 20th Asia-Pacific Software Engineering Conference (APSEC2013 [Periodic]. - 2013. - pg. 50-57.
63. Joglekan A.M. Statistical Methods for Six Sigma in R&D and Manufacturing [Periodic]. - New York : John Wiley and Sons Inc., 2003.
64. Juran J, M, Godfrey, A.,B. Juran's Quality Handbook, Fifth Edition [Carte]. - [s.l.] : Mc Graw-Hill, 1998.
65. Kaushik P, Khanduja, D. Application of Six Sigma DMAIC Methodology in Thermal Power Plants; a Case Study [Periodic]. - [s.l.] : Total Quality Management and Business Excellence, 2009.
66. Kavlani M, A Application of Continuous Improvement Techniques to Improve Organization Performace: A case Study [Periodic] // International Journal of Lean Six Sigma . - 2018.
67. Kim In-Ju The Function of Ergonomics in Lean Manufacturing Design and Control [Periodic] // https://www.researchgate.net/publication/320266018. - 2017.
68. King P. Lean for Process Industries; Dealing with Complexity [Periodic]. - New York : Productivity Press, 2009.
69. Klochov Y Conflicts Between Quality Management Methods [Periodic] // https://www.researchgate.net/publication/323059496. - 2017.
70. Kollenburg T The Future of Continuous Improvement [Periodic] // https://www.researchgate.net/publication/332974315. - 2019.
71. Kostka C., Monch, A. Change Management. 7 Methoden fur dei Gestaltung von Veranderungs Prozessen [Periodic]. - Munchen : Carl Hanser, 2009. - Vol. 4.
72. Kraszewsky R Quality Management - Conceptions, Methods and Tools Used by the World's Business Leaders [Periodic]. - Torue : Scientific Society of Management, 2005.

73. Krowley Elster K. “Working with you is killing me” “Working with you is killing me”, [Periodic] // Ed. Trei, . - 2013. - p. 258.
74. Lean Manufacturing Tools http://www.leanblog.ro/wp/instrumente-lean/instrumente-lean/5s/ [Interactiv] // www.leanblog.ro . - 2012.
75. Liu S, Batson, R.G. A Nested Experimental Design for Gauge Gain in Steel Tube Manufacturing [Periodic]. - [s.l.] : Quality Engineering. doi:10.1081/QEN-1200240160898-2112, 2003.
76. Locher D. Lean Office and Service Simplified [Periodic]. - New York : Productivity Press, 2011.
77. Lopez-Herrejon Roberto E.) [1] [și alții] Evolutionary Computation for Software Product Line Testing: An Overview and Open Challenges [Carte]. - [s.l.] : Web of Science Core Collection, 2016.
78. Lorenz M., Waldner, M., Engel, P. Industry 4.0. The Future of Productivity and Growth in Manufacturing Industries [Periodic]. - [s.l.] : Boston Consulting Group, 2015.
79. M. Bucur Economia Intreprinderii [Carte].
80. Maxwell J. C. Dezvolta leaderul din tine [Carte]. - Bucuresti : Ed. Amalteea, 1990.
81. Mc Kie M.G. Improving Lean Manufacturing Systems and Tools Engagement Through [Conferință] // 30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2021) . - Athens : [s.n.], 2021.
82. Mehedintu G. OPTIMIZAREA PROCESELOR DE LUCRUL PRIN INTERMEDIUL MANAGEMETULUI SCHIMBĂRII [Periodic]. - Bucuresti : https://www.researchgate.net/publication/313651063, 2016.
83. Meriam J.L. Engineering Dynamics [Carte]. - Texas : Library of Congress Cataloging-in-Publication Data, 2015.
84. Michalska J, Szewieczek, D The 5S Methodology as a Tool for Improving [Periodic]. - [s.l.] : Journal of Achievements in Materials and Manufacturing Engineering, 2007.
85. Misiurek Bartosz “Standardized Work with Training Within Industry: Eliminating Human Errors in Production and Service Processes”, page 4 [Carte]. - [s.l.] : 2016, Taylor & Francis Group.
86. Montgomery D.C. Introduction to Statistical Quality Control [Periodic]. - New York : John Wiley and Sons Inc., 2009. - Vol. 6.
87. Mougin Y. Provessus: Les Outils de L'Optimisation de la Performance [Carte]. - Paris : Editions D'Organisations, 2004.
88. Nicolecu C, Petre S.C., Uritu, D, Samek, D, Cristof C “Carta alba a IMM-urilor din Romania; 2021, vol. 19”, [Periodic]. - Bucuresti : Prouniversitaria, 2021.
89. Nicolescu O Verboncu, I. “Management” [Periodic] // Editura Economica, Bucuresti. - 1997. - pg. 361-363.
90. Nicolescu O. Popa I.,Nicolescu C., Stefan S.C., Simion C.P.“” Starea de sanatate a managementului din Romania i n 2019, Ed. A XI-A [Carte]. - Bucuresti : Ed. Prouniversitaria, 2020.
91. Nicolescu O. Verboncu I. Fundamentele Managementului Organizatiri [Carte]. - Bucuresti : Tribuna Economica, 2001.
92. Nistoreanu B. Aspecte Definitorii Privind Sistemele de Management al Calitatii in Intreprinderile Mici si Mijlocii [Periodic] // Revista de Marketing Online – Vol. 4 Nr. 4. - 2013.
93. Odeh R.E. “Parts per Million Values for Estimating Quality Values”, page v [Carte]. - [s.l.] : CRC Press.
94. Pande P.S., Newman, R.P., Cavanagh, R.R. The Six Sigma Way. How GE, Motorola and Other Top Companies a re Honing their Performance [Periodic]. - New York : Mc Graw Hill, 2000.
95. Peruchi R.S., Balestrassi, P.P. A New Multivariate Gage R&R Method for Correlated Characteristics [Periodic]. - [s.l.] : Int. J. Production Economics. doi:10.1016/j.ijpe.2013.02.018, 2013.

96. Pieczonka A, Quality Vademecum [Periodic]. - Cracow : Center of Training and of Quality Systems of Cracow University, 2003.
97. Pop L. Study of Creating a Simplified Model of Quality Management System in a SME from the Central Region of Romania [Conferință] // 9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015. - Targu Mures : [s.n.], 2015.
98. Practices King Timothy in Best https://solutionsreview.com/data-management/the-best-data-quality-tools-and-software/, [Interactiv]. - 22 December 2021.
99. Registrul Comertului Situatia Statistica privind Infiintarea SRL la data de 31.05.2023 [Lucrare]. - Bucuresti : [s.n.], 2023.
100. Robert Kent [Carte].
101. Rya T.P. "Statistical Methods for Quality Improvement", 3rd Edition [Lucrare]. - [s.l.] : Elsevier, August 2022.
102. Saikaew C. Paper Organizers International [Periodic]. - An Implementation of Measurement Systems Analysis for Assessment of Machine and Part Variations in Turning Operations Measurement : [s.n.], 2018.
103. Sathishkumar S. Unconventional Machining Process [Periodic] // https://www.researchgate.net/publication/330968191. - 2019.
104. Shanmuganathan S. Lean Six Sigma [Periodic] // https://www.researchgate.net/publication/255910300. - 2010.
105. Shanmuganathan Sankar Lean Six Sigma [Periodic] // https://www.researchgate.net/publication/255910300. - 2010.
106. Shingo S. Zero Quality Control [Carte]. - [s.l.] : Productivity Inc., 1996.
107. Shirose K. Total Productive Maintenance. New Implementation Program in Fabrication and Assembly Industry [Periodic]. - Tokyo : JIPM Solutions, 2007.
108. Singh J Continuous Improvement Philosophy - Literature Review and Directions [Periodic] // https://www.researchgate.net/publication/271712469. - 2015.
109. Smeureanu I, Onete, B, Anghel L.D. Studiu comparativ si analitic al definirii si pozitionarii IMM-urilor romanesti [Periodic] // https://www.researchgate.net/publication/256461517. - 2004.
110. Smith J. The KPI Book, Insight Training and Devellopment [Periodic]. - Stourbridge : [s.n.], 2001.
111. Sol E. Factories for Europe: Towards Smart and Flexible Factories [Periodic]. - Tilburg : Avans University of Applied Science, 2017.
112. Staff F. Leak Testing Components Offers Cost Savings, Helps to Meet Gage R&R Requirements [Periodic]. - [s.l.] : Fopundry Management and Technology, 2010. - Vol. 10.
113. Summers D. Quality Management [Periodic]. - London : Perason Education, 2005.
114. Suzuki A Practical Kaizen for Productivity Facilitations [Periodic]. - Tokyo : Japan Productivity Center, 1993.
115. Swenson B. How Lean Management Improves Business, Saves Money [Periodic]. - [s.l.] : allbusiness.com, 2004.
116. Taghizadegan S. Essential of Lean Six Sigma [Periodic]. - Oxford : Elsevier Inc., 2006.
117. Tatroe Kevin MacIntyre Peter, Lerdorf Rasmus "Programming PHP: Creating Dynamic Web Pages",Chapter 1 [Carte]. - [s.l.] : O'Reilly Media Inc., 2013.
118. Tavera Sainz J.G. Conducting a Gage R&R [Periodic]. - [s.l.] : Six Sigma Forum Magazine, 2013.
119. Tucu D. Optimizarea Costurilor Calitatii in Sistemele Industriale [Carte]. - Timisoara : Eurostampa, 2016.
120. Valdez L.M. Gauge Repetability and Reproductibility Study on Hemishell with a Brown and Sharpe Coordinate Measuring Mashine [Periodic]. - [s.l.] : Universityof New Mexico, 2011.
121. Vayvay O Quality Improvement Through Ergonomics Methodology: Conceptual Framework and an Application [Periodic] // https://www.researchgate.net/publication/247834808. - 2008.
122. Vladimirovic D Role and Importance of Key Performance Indicators [Periodic] // Serbian Journal of Management. - 2010.

123. Vykydal D. A Study of Quality Assessment in Higher Education [Periodic] // http://www.mdpi.com/journal/sustainability. - 2020.
124. Wawak S. Quality Management. Theory and Practice [Periodic]. - Warsaw : Onepress Published, 2004.
125. Weaver B.P., Hamada, M.S., Vardeman, S.B. A Bayesian Approach to the Analysis of Gauge R&R Data [Periodic]. - [s.l.] : Quality Engineering. doi: 10.1080/08982112.2012.702381. What is action plan? Definition and meanings [Periodic] // WebFinance. - 2016.
126. Womack J., Jones, D., Roos, D. The Machine that Changed the World [Periodic]. - New York : Rawson Associates, Macmillan Publishing Company, 1990.
127. Zhu Li [și alții] Key performance indicators for manufacturing operations management – gap analysis between process industrial needs and ISO 22400 standard [Conferință] // Proceedings of the 8th Swedish Production Symposium (SPS 2018.