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DEVISING AN INNOVATIVE METHOD FOR IMPROVING DECISION-MAKING EFFICIENCY AT POLYMERS PROCESSING COMPANIES IN AUTOMOTIVE INDUSTRY

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Enabling the development of technologies for the production of polymer materials directly determines the possibility of achieving the standards of sustainable development in the automotive industry, since polymer composites are used in modern cars as components of almost all assemblies and mechanisms. The expansion of plastics application in the car structure contributes to the reduction of fuel consumption and wear of parts. Technological changes encourage enterprises to constantly improve decision-making methods regarding the introduction of innovative technologies.

This paper reports an innovative method devised for making management decisions at enterprises specializing in the processing of polymers for the automotive industry, which makes it possible to increase production efficiency. Based on the Ishikawa diagram and the PDCA cycle application, management tools and procedures for making production and technological decisions have been developed using the methodology of finding root causes and verifying factors influencing existing production problem. A set of indicators that make it possible to reduce the number of management errors has been substantiated; they increase the reliability of verifying received intermediate results of decisions. The selection of verification indicators was carried out taking into account the specificity of polymer production technologies.

An improved decision-making management procedure is presented, which was embodied in an updated decision-tracking protocol. Unlike its basic version, it contains additional control points: target date of verification, date of verification, and result of verification. An experimental study showed that the application and observance of the full PDCA cycle increases the overall effectiveness of management by 63 %, which in turn has a positive effect on the company's sustainability in a competitive environment

Keywords: decision-making, management methods, organizational innovations, polymer processing

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1. Introduction

The deepening of European integration processes in the economy of Ukraine requires domestic industrial enterprises to comply with the standards of sustainable development. In particular, in the automotive industry, there are a number of requirements for cars and the automotive industry in general. First of all, they are related to the legislative requirements of the European Union (EU) regarding the reduction of motor vehicle emissions into the environment, the reduction of production waste volumes, and the need for their repeated processing [1]. In the world, more than 2 billion tons of petroleum fuel are burned annually in internal combustion engines, which is the main cause of air pollution, since only 15 % of the fuel is used directly for driving a car [2]. In addition, more than 6 million vehicles in the EU expire annually and are disposed of as garbage. If end-of-life vehicles are not properly managed, they can cause environmental problems. The European economy could lose millions of tons of materials as the automotive industry is one of the largest consumers of primary raw materials such as steel, aluminum, copper, and plastic. However, despite the fact that according to Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles, 25 % of the plastic used to make a new car must be recycled, in industry still uses recycled materials quite little [3].

Modern automotive companies widely use polymer composites as component parts of almost all assemblies and mechanisms. Expanding the use of plastics in car construction to replace relatively heavy metal parts is economically and technologically justified. As a result, the own weight of the car is reduced, fuel consumption and wear of parts are reduced, and, accordingly, the possible payload increases [4]. In addition, given the corrosion resistance of plastics, the problem of increasing the durability of parts and assemblies is largely solved, the level of operating noise is reduced, etc. Reducing the weight of the vehicle ensures a reduction in fuel consumption. This, in turn, determines the reduction of emissions of exhaust gases into the atmosphere, which is especially relevant today [5].

Therefore, the modern automotive market requires high competitiveness and adaptation to rapid changes in technologies and materials. Polymer processing is one of the key areas that ensure sustainable development in the automotive industry, because makes it possible to design lighter, more environmentally-friendly and economically profitable parts. The use of innovative approaches to optimize the decision-making process at enterprises engaged in polymer processing contributes to increasing production efficiency, reducing costs, and increasing product quality. Under the conditions of global competition and requirements for environmental responsibility, such methods become an integral part of successful management. The development and implementation of these methods will allow enterprises to respond to market challenges more quickly and efficiently, which will ensure their sustainability and competitiveness.

2. Literature review and problem statement

The problems of developing and implementing new approaches to making production decisions have long been in the field of view of a significant part of scientists and practitioners. Such attention is caused by the need for their constant adaptation to new tasks associated with organizational changes caused by innovative technologies and tasks of sustainable development. The prominent developer of approaches to quality assurance of technological processes, Kaoru Ishikawa, showed in his research that the style and methods of team decision-making could play a leading role in improving production processes [6]. According to his research, not only technologists, designers, and production personnel, but also sales departments, logistics, accountants, and, above all, managers, should participate in making production decisions. As a result, it is possible to have a positive impact not only on the quality of products but also to improve the company's business processes. It has been proven that such an approach in the long term creates the basis for the sustainable development of the country in general by significantly improving the management of economic, social, and environmental processes. Thus, one of the popular methods for improving technological processes, which has been widely researched by various scientists and used by practitioners, is the method of constructing an Ishikawa diagram, or a cause and effect diagram. However, this method does not solve the problem of estimating the intensity and probability of each identified cause, nor does it offer solutions or ways to solve the problem. After constructing the diagram, one needs to use additional methods to determine exactly how to proceed to eliminate errors and problems.

The use of such an approach involves gathering all possible causes that can potentially influence the occurrence of the problem, using brainstorming, followed by ranking by categories. Six standard categories are commonly used: environment, measurement, machine, method, personnel, and management. It should be noted that in practice, if necessary, due to the specificity of the activity, the list of ranking categories may change and include other features. The objective difficulties in this case are that it is important to involve every participant in the production and technological process before identifying the causes and consequences of the existence of a certain problem. It is noted [7] that brainstorming, which has been actively used for more than 50 years, is an effective way of generating cause and effect due to the fact that it combines the advantages of teamwork and individual work, and also has the potential for development in combination with artificial intelligence (AI). However, AI can unify approaches to problem solving, offering more typical or predictable solutions. This can limit the diversification of ideas, especially if AI affects brainstorming participants who begin to adjust to the "correctness" of the solutions proposed by the machine.

To determine the root causes of problems, a number of authors recommend using the "5 Why?" method in practice [8]. But the questions remained unresolved, in which scenarios of the development of events, its use is most expedient or limited. It is worth noting that the result of using the specified method would depend on the level of self-organization of the team, its ability to approach the analysis of the problem in a structured manner. A structured problem management process involves initiating and conducting several rounds of meetings, where the effectiveness may directly depend on the competence of the manager. From the point of view of behavior, there are three stages of conducting effective management meetings: setting the agenda, encouraging the team to solve problems, and forming feedback [9]. However, the use of a structured management process hides a number of dangers. Chief among them are reduced flexibility and increased bureaucratic obstacles, which can delay work and reduce efficiency. Excessive adherence to procedures often results in wasted time.

Our review of theoretical papers [10–12] proved that the optimal result when making decisions regarding the management of technological processes can be obtained by combining different methods. In particular, the Ishikawa diagram and the "5 Why?" method are recommended to improve the results of management decision-making by a combination with the definition of key performance indicators, such as Key Performance Indicators (KPI) and SMART goals (Specific, Measurable, Assignable, Realistic, Time-related). In the course of testing, this approach turned out to be too complicated from the point of view of organizing management processes and time-consuming. Although it is worth noting that it helps establish clear and simple criteria for results, which simplifies the determination of further actions to improve production and technological processes. However, in works [10–12], it is not defined which methods are the most optimal in terms of their combination or simultaneous application. It is noted [10] that it is possible to facilitate the establishment of KPIs by defining SMART criteria, as well as by formulating the right questions using the "5 Why?" method. SMART goals form the basis for subsequent initiatives on the Balanced Scorecard, dashboard methods, portfolio decisions, and other critical organizational processes such as idea management and project and product prioritization. In our study, the described approach was used to devise criteria for evaluating the results of the decisions taken, taking into account the specificity of the production processes in the chemical industry. The application of the above-described approach leaves unresolved the question of how to ensure quality in making production decisions. Because SMART goals emphasize measurability, KPIs can focus on quantitative indicators, such as sales volume, number of completed tasks, etc., without paying enough attention to qualitative aspects of work. This can lead to tasks being formalized without proper emphasis on their quality or long-term benefit. However, the work does not specify how this limitation can be overcome.

An option to overcome the difficulties described above can be supplementing the Ishikawa diagram with the Pareto method to identify factors and determine their priorities. The Pareto chart method helps objectively prioritize the problems that have the greatest impact according to the principle: 20 % of the causes create 80 % of the problems. Often, management attempts to solve problems without a detailed analysis of the underlying problems, resulting in lost economic, social, or environmental benefits. In order to avoid mistakes when making decisions, specialists are recommended [11] to build a Pareto diagram based on the results of brainstorming or after constructing an Ishikawa diagram. However, the question of which algorithm should be used to eliminate the identified errors was left out of consideration. And this means that after the analysis it is necessary to use other tools to develop solutions.

The authors of study [12] showed the improvement of indicators through the implementation of a systematic approach to solving problems. In particular, they recorded a 34 % increase in the quality level and a 9 % reduction in defects. Such results were achieved owing to a systematic approach to solving problems using basic methods for finding root causes: the Ishikawa diagram in combination with Pareto. Applying this approach makes it possible to prioritize efforts (through Pareto analysis). In this way, the company can focus on those causes that will bring the most benefit when they are eliminated. This reduces costs of time and money, allowing it to direct resources to eliminate the most influential factors. This approach is the basis of our research.

It is worth noting that the simultaneous use of several methods when making decisions, although it makes it possible to reduce the number of errors, however, creates an additional barrier in the form of an increase in time spent. Despite the fact that the described methods prove their effectiveness, there are still certain losses in the processes when they are implemented, which may require the use of simpler situational approaches. Issues related to a clear definition of the main criteria that will influence the choice of one or another method and their combination have remained unresolved.

In addition to the selection of relevant techniques, the effectiveness of decision-making also depends heavily on the management style. According to the concept of “8 great losses” [13], the loss of employee potential is one of the significant losses. Managers often make mistakes as a result of focusing on the tasks or processes themselves, and not on the team. That is why it is believed that radical decentralization leads to the formation of effective teams. This makes it possible to increase the responsibility and motivation of teams, however, the issues of ensuring the coordination of the introduction of innovations remain unresolved, which can slow down adaptation to market changes. The decentralization model is based on accountability and reward, transparency of information and processes that arise from the bottom up, not the other way around. In this case, employees are empowered and can be responsible for defining the necessary tasks and ensuring their fulfillment [14], which contributes to their development and, as a result, significantly increases the maturity of the organization. That is why, if leaders want to have responsible teams, they must give them a sufficient level of authority to be able to influence situations independently. However, the authors do not define the essence and limits of these powers, nor do they describe the procedures for making team decisions in different situations. An option for solving this problem may be the development of new production protocols for team decision-making in combination with criteria for verifying the results of these decisions.

It should be noted that solving current issues, especially at the top management level, often contradicts the philosophy of achieving success in the long term. The classic Lean philosophy involves ignoring short-term successes or benefits in favor of long-term achievements [15]. Also overlooked are the problems of developing strategies for companies’ behavior in an unstable environment with frequent changes in customer requests, political or economic conditions, where Lean technology is ineffective. After all, the company’s production system, which is optimized for specific conditions, quickly loses its relevance. Experts emphasize that when making decisions, top managers should focus on solved strategic issues and implement macro-management, combining it with empowering teams to solve situational problems at the places of their occurrence. It is advisable to keep a balance between short-term and long-term perspectives by conducting an analysis of past events (retrospective analysis), considering that anticipatory activity prepares the company for future unpredictable changes [16]. One of the ways to solve the problem of ensuring a balance of decisions can be adaptive management and proper motivation, based on a system of indicators that reflect successes in both directions, as well as constant communication with all interested parties.

In addition to those considered above, there are many other methods for decision-making, such as Multi-Criteria Decision Making (MCDM), which includes the Analytic Hierarchy Process (AHP) tool, Case-Based Reasoning (CBR) – solving new problems by adapting previously successful solutions to similar problems [17]. MCDM methods, particularly AHP, work best when there is a clear criteria structure and enough data to make a decision. However, the consideration of situations of high uncertainty or lack of information, when the results may be unreliable, was left out, because these methods do not take into account dynamic or unpredictable changes. Practitioners also use the Combined Compromise Solution (CoCoSo) method, in which at the final stage after ranking, the aggregated rule of multiplying the ranks or levels of alternatives is used to make a final decision [18] in favor of one or another idea, one or another method. Some tools, such as 6 SIGMA, are standard practices in many companies. However, for a team that wants to grow, it’s not worth limiting oneself to just a standard set of tools. So, for example, in practice, the correlation method can also be used, which has shown its effectiveness in various domains of activity [19]. However, it needs to be clarified what additional methods can be used for analysis in the case when the detected cause-and-effect relationship is non-linear, for example, parabolic or exponential. The objective difficulties associated with the application of the correlation method are that the correlation only shows the presence of a relationship between two variables. At the same time, it does not prove that one variable is the cause of another. They both may depend on a third factor that is not taken into account in the study. The way to overcome this limitation may be to supplement the correlation with other methods and use cause-and-effect analysis.

When investigating decision-making methods, it was found that the issue of choosing criteria or the approach to devising these criteria has not been studied in detail. Therefore, managers should independently determine the criteria for choosing a problem analysis tool among the methods of Ishikawa, 5Why, Pareto, etc. or their combinations, based on their experience, intuition, and awareness. Companies often have problems verifying the results of decisions made, which causes errors in the process of further decisions or their correction in the management of production and technological processes. That is why these problems require further research and the development of algorithms for solving them.

3. The aim and objectives of the study

The purpose of our research is to devise an innovative method for increasing the efficiency of decision-making at enterprises processing polymers for automobile construction based on the search for root causes and verification of factors affecting the existing production problem. The implementation of the developed management tools and procedures will provide an opportunity to increase the quality level of production and technological solutions and ensure the sustainable development of the enterprise in the long term.

To achieve the goal, the following main tasks were solved:

– to determine indicators for verifying the effectiveness of management decision-making;

– to substantiate a comprehensive approach to making effective production and technological decisions at a polymer processing enterprise;

– to systematically analyze the results of practical verification of the proposed method, aimed at increasing the efficiency of decision-making in the production of polymer processing for the automotive industry.

4. The study materials and methods

The object of our study is the process of making management decisions at enterprises specializing in the processing of polymers for the automotive industry.

The main hypothesis of the study assumes the possibility of increasing the efficiency of production and technological solutions at the polymer enterprise through the use of new tools and procedures of teamwork to find the root causes and verify the factors influencing existing production problem.

A set of theoretical methods, including analysis, synthesis, systematization, statistical analysis, and graphical modeling, was used to solve the research problems. With the help of these methods, the key factors affecting the decision-making process at polymer processing enterprises were identified. This helped us understand which aspects needed innovative changes and where efficiency improvements could be achieved. Systematization made it possible to see how various factors (production processes, management, innovative technologies, teams of specialists) interact and influence each other in the decision-making process. Owing to the use of the specified method, it was possible to devise a comprehensive method for increasing the efficiency of decision-making at the polymer processing enterprise. Graphical methods combined with statistical analysis made it possible to investigate innovative approaches in order to increase the efficiency of decision-making at polymer processing enterprises, to obtain accurate and reliable results, as well as to offer reasonable recommendations for process optimization.

Experimental and observation methods were also used to obtain the results of our research. The latter made it possible to acquire real data on the operation of the enterprise, based on which problem areas were identified and measures were devised to improve the efficiency of decision-making. Based on the experiment that was performed at the company LLC "KOSTAL Ukraine" (Kyiv), it was directly verified how the developed approach affects the effectiveness of the decision-making process. That made it possible to determine the practical advantages or disadvantages of the method and to choose the most effective behavior options for use in real production units.

Obtaining a practical result became possible owing to the use of a special Plan Do Check Act (PDCA) method, the cycle of which is shown in Fig. 1. This method has shown its effectiveness not only in production processes but even in medicine, thereby demonstrating significant improvements, for example, in nursing practice [20].

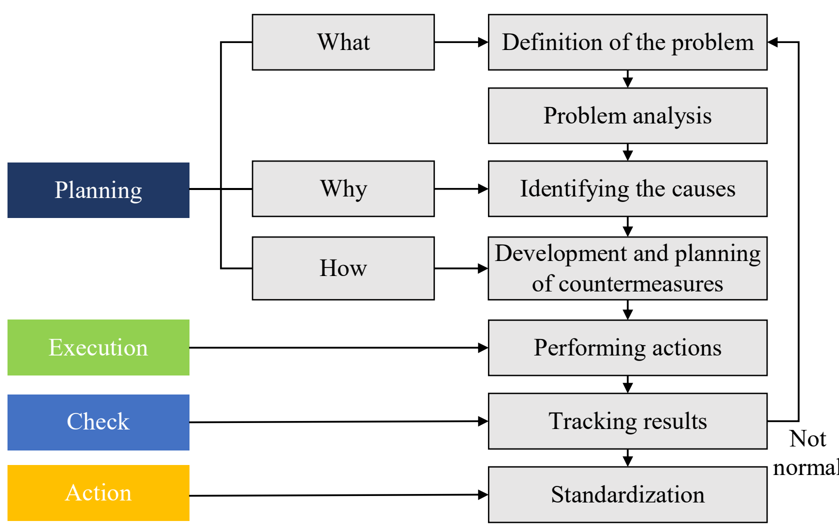

Fig. 1. PDCA process
Source: [21]

PDCA implies the mandatory need to evaluate the impact of a certain action on the result, with the subsequent decision: to disseminate as a best practice or to return to the analysis phase. The problem should remain open and monitored until an optimal solution is found that eliminates the problem completely or minimizes the likelihood of its occurrence again. Thus, the use of this method provides the basis for the creation of new standards in the company, which may contain effective methods of influencing the situation. It is worth noting that standards are only effective when they can be improved or researched. Application of the PDCA method makes it possible not only to improve processes but also refine existing standards.

Despite the fact that PDCA proves its effectiveness and optimality at many enterprises, the process of verification of measures in it is not sufficiently studied or there is only limited data on its application. The process of verifying decisions or management actions involves determining the compliance of the obtained results of these decisions and actions with performance criteria. Verification helps determine the suitability and reliability of implemented solutions, as well as their level of reliability. However, management is prone to mistakes that are associated with practice, when the problem is considered solved only based on the team's report without providing verification data, which would guarantee the preservation of a stable positive result, when the error will not be repeated again. The ideal global level of solved problems that are not repeated reaches the mark of 70 % [21]. As shown in Fig. 2, the remaining 30 % can be divided into those that are financially impractical and those whose root cause cannot be reliably determined.

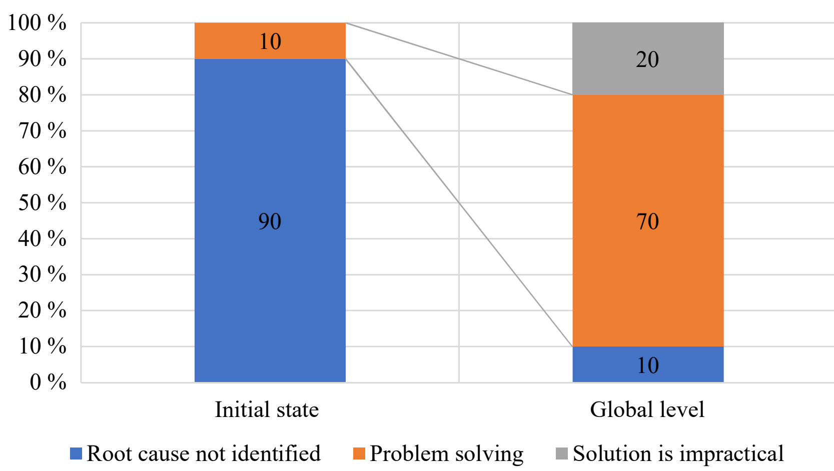

Fig. 2. Comparative diagram of the level of problem solving in organizations

The application of this method made it possible to achieve success in preventing the recurrence of errors or problems. This was primarily facilitated by the addition of this method to the process of verifying the effectiveness of implemented solutions. It is worth noting that the effectiveness of verification has been demonstrated in the fight against the "COVID-19" pandemic, which is confirmed by numerical studies, in particular, the use of analysis based on the "what if" scenario [22].

5. Results of devising innovative approaches to the adoption of production and technological decisions at a polymer enterprise

5. 1. Indicators for verifying the effectiveness of production and technological solutions

Modern car companies often introduce innovative, environmentally friendly polymers, materials from secondary raw materials and biodegradable components. Owing to this, they significantly reduce carbon dioxide emissions and the amount of water and soil pollution in the production process. Also, the processing of polymers makes it possible to reduce the amount of new materials needed for the manufacture of parts. The introduction of innovative technologies for the production and processing of polymers reduces the volume of industrial waste and the use of resources, such as oil, necessary for the production of plastic. Owing to the introduction of these innovative technologies, enterprise managers face the task of constantly evaluating the economic efficiency and environmental impact of the use of new materials. Thus, managers should be armed with appropriate management tools to make informed decisions regarding the implementation of innovations related to the replacement of harmful components with safe analogs.

The activity management systems of the company under study are a set of defined processes that standardize and regulate organizational functioning. All processes are divided into three types: main, supporting or service, and management process. The last two are designed to support the functioning of the main processes that create added value. As is known, management and leadership must follow international standards such as ISO 9001, IATF16949. That is why management faces the urgent task of supporting quality management systems, customer orientation, etc. through structured problem solving and decision-making aimed at continuous improvement of production processes.

In this situation, it is not enough to identify the problem and correctly determine its root cause. To achieve the result, it is necessary to devise measures in such a way that a mistake does not happen again. The effectiveness of systemic measures can be demonstrated on the example of improving the state of environment in China where, owing to a structured procedure and existing systematic management plans, it became possible to reduce emissions and improve air quality [23].

It is worth noting that the application of the PDCA method requires the organization of appropriate interaction between the manager and the team. The leadership model significantly affects the behavior of employees [24]. Therefore, an important task in every company that aims at continuous improvement of technological processes is to ensure constructive communication based on reliable data and not containing demotivators. There is also an opinion that a "modest" model of leader behavior [25], appropriate and benevolent humor [26] positively affect team effectiveness by facilitating relationships through full involvement and providing comprehensive support. In addition, operation with reliable statistical data plays an important role in solving technological problems, implementing new projects, and supporting production and technological changes.

For the most part, teams at modern enterprises have the authority to make decisions independently, although there are cases when they lack the authority to influence factors that require strategic changes, financial investment, special experience, resources, or knowledge. In such situations, leaders face new challenges associated with additional responsibility. For decision-making, it is advisable for the team to be able to clearly formulate a problematic issue that cannot be resolved at its level. Subsequently, the top management should help find acceptable ways to solve the problem by providing appropriate feedback to the team leaders based on their report on the actions that had already been implemented but did not bring the desired result.

So, a fairly common problem for decision-makers is the so-called "Escalation", that is, the process of repeating unsuccessful actions that do not give the desired result. It can lead to conflicts, but not between persons or entities, but between processes, instructions, functions, standards, etc. [27]. The process of escalation of problems in the management of organizations is not sufficiently studied or there are limited data on it. That is why leaders need to independently determine the criteria and expectations regarding escalation, taking into account the results of our research.

Based on the observance of the PDCA cycle, research was conducted at the enterprise at three production sites under the same conditions and existing competences in relation to PDCA. Section 1 is a section for the production of plastic products by injection molding. Sections 2 and 3 are assembly sections where the finished product is assembled from plastic parts and printed circuit boards. The level of adherence to the classic PDCA cycle and the effectiveness of problem solving were assessed. The inspection was carried out in accordance with the recommendations of ISO 19011:2011. It is worth noting that recently leading polymer producers have been actively implementing the Industry 4.0 system. This system requires leaders to be prepared to make dramatic changes to fit the company's maturity model, which may have a range of key performance indicators (KPIs). Reasonably effective models are proposed in [28]; however, there is no single concept that could satisfy all enterprises.

During the production of parts for cars, such basic technologies as plastic injection molding, Surface Mount Technology (SMT) electronics manufacturing and installation, and assembly technologies (assembly of mechatronic products from components obtained using the above technologies) are usually used. At the same time, the problem of ensuring quality, preserving the reliability and durability of the car, a successful combination of the necessary operational characteristics and design solutions under the conditions of maintaining production efficiency and reducing the negative impact on the environment often arises.

In the automotive industry, especially in the implementation of plastic injection molding technology and SMT, the Overall Equipment Effectiveness (OEE) indicator is used, which demonstrates the nature of the process flow in the technology-equipment complex. In assembly areas, in addition to productivity and quality, it is especially important to achieve the 5S (Sort, Set in Order, Shine, Standardize, Sustain) target value. This, in turn, in addition to the cleanliness and order of the working area, ensures a high level of quality, safety, and productivity, contributes to the reduction of losses [29].

In our study, a model was proposed for the evaluation of decisions made with ranking by categories "A", "B", "C", which are based on the standard of the association of the German automotive industry VDA 6.3. The description of the ranking is given in Table 1.

In the production experiment, calculations were carried out based on a set of indicators relevant to the technological and production processes at LLC «KOSTAL Ukraine».

The coefficient of effectiveness of implementation (management effectiveness of implementation – ME_i) of the criteria given in Table 2 was determined from the following formula (1):

$$ME_i = \frac{\sum c_a}{\sum A} \cdot 100\,\%, \tag{1}$$

where $\sum C_a$ is the sum of criteria according to the PDCA protocol with the status "implemented"; $\sum A$ is the total number of activities.

Table 1

Ranking of management effectiveness, implemented and verified measures

Ranking	Description	Level of functioning, %
A	Effective management	80–100
B	The process works with delays	60–80
C	Not effective management	<60

The verification effectiveness ME_v (management effectivity of verification) was defined as the ratio of the amount of measures to be verified to the total amount of implemented measures, formula (2):

$$ME_v = \frac{\sum c_{pv}}{\sum R_a} \cdot 100\,\%, \tag{2}$$

where $\sum C_{pv}$ is the sum of implemented measures that are subject to verification; $\sum R_a$ – number of implemented measures according to the PDCA protocol.

The effectiveness of measures was calculated using the following formula :

$$ME_a = \frac{\sum c_v}{\sum R_a} \cdot 100\,\%, \tag{3}$$

where $\sum C_v$ is the number of verified measures; $\sum R_a$ – number of implemented measures according to the *PDCA* protocol.

The Overall Management Effectiveness (*OM*E) was defined as the multiplication of the effectiveness of verification ME_v and the effectiveness of the overall implementation of measures ME_i:

$$OME = ME_v \cdot Me_i, \tag{4}$$

where ME_v was determined from formula (2); ME_i was calculated according to formula (1).

The formulas above most fully meet the tasks of further evaluation of the results of production and technological decisions at the polymer enterprise. That is why further calculations and verification of results were based on them.

5. 2. Devising a comprehensive approach to the adoption of effective production and technological solutions at a polymer enterprise

The devised comprehensive approach involves the application of relevant methods to find the root causes and verify the factors affecting existing problem. In our production experiment, the Ishikawa diagram and the "5 Whys?" method, which were applied based on the PDCA cycle, were used as such methods. The choice of these methods was determined by the convenience of their application to those situational tasks that were solved at three sites of the company LLC «KOSTAL Ukraine». The approach and process of solving production and technological problems also required a change in the behavior of the leader, and as a result had a positive effect on the motivation of the entire team (Fig. 3).

Our approach involves eight main stages of management actions, which are sequentially cyclic in nature:

Stage I – to determine a production and technological problem that needs to be solved;

Stage II – establishment of a circle of persons who can be involved in the identification, analysis of the causes, and elimination of the consequences of the identified problem;

Stage III – construction of a Pareto diagram and its analysis to establish the priority of the causes of the production and technological problem;

Stage IV – building a team, brainstorming on the problem, and construction of an Ishikawa diagram for root cause analysis;

Stage VI – determining the factors that affect the problem and their verification with further analysis using the "5 Why?" method for each of the identified problems;

Stage VII – development and implementation of measures to eliminate the production and technological problem, comparison of the results with the desired indicators based on the established indicators;

Stage VIII – in the case of obtaining a positive result, standardization of effective methods or measures is carried out. If a negative result is obtained, work on the problem starts again from the first stage.

For a balanced solution to the production problem, the results were subject to analysis and rank determination according to Table 1. It should be noted that each criterion essentially reflects the status of the action aimed at solving the problem. To carry out the evaluation, we determined the criteria given in Table 2. The criteria reflect the statuses of the events initiated by the team leaders at the studied sites.

For the criteria "Implemented", "Verified", as well as for *OME* (Table 2), the efficiency indicator was calculated from formula (1) for each of the four cross-functional teams and the rating was determined according to Table 1.

The rankings given in Table 3 were used to determine management efficiency according to formula (1) for such criteria (Table 2) as: "not verified", "under verification". It should be noted that the criterion "implemented" shows the overall effectiveness of the implementation of measures, the criterion "verified" demonstrates the effectiveness of the measures or actions aimed at solving the problem. However, the criterion "under verification" determines the effectiveness of the verification itself. Data were collected from the implemented protocol of measures (Table 4).

Table 2

Criteria for evaluating the overall effectiveness of management (*OME*)

Criterion*	Criterion description
Implemented	Measures reported by the team as implemented
Verified	The effectiveness of the measures implemented has been confirmed
Not verified	The effectiveness of the implemented measures has not been confirmed
Under verification	Measures implemented and their effectiveness in the research process
In process	Measures not implemented
Total activities	Total number of measures

*Note * – all criteria are evaluated in arbitrary units.*

Table 3

Ranking of the level of effectiveness of unverified measures, in the status of "in process" and those under verification

Ranking	Description	Level of functioning, %
A	Effective management	<20
B	The process works with delays	20–60
C	Not effective management	>60

In Fig. 4, one can see the absence of a category regarding the verification of implemented measures. To carry out the assessment, the method of surveying team leaders regarding verification was used. It is also worth noting that most of the interviewees did not express sufficient motivation to verify measures due to the time spent on them, despite the fact that such a process is one of the indicators of the organization's maturity.

Fig. 5 shows the management's initial approach to solving problems, the process of which was recorded during the experiment.

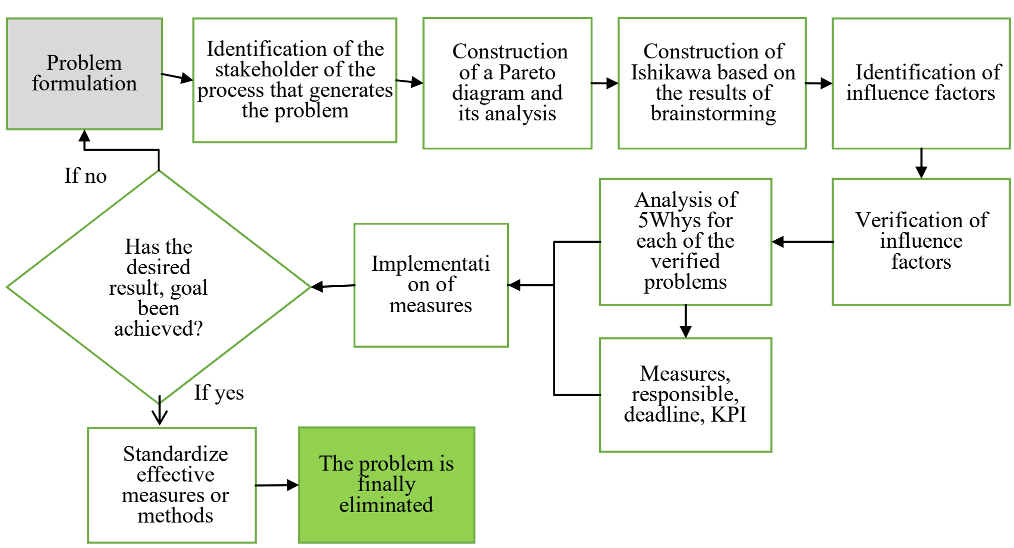

Fig. 3. Devised approach to decision-making regarding the solution of production and technological problems

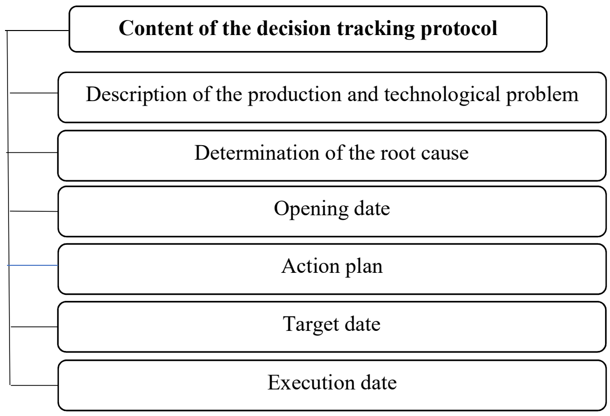

Fig. 4. Standard approach action tracking protocol

Fig. 5 shows that the leaders did not require verification of the implemented measures from the team, which indicates an insufficient level of maturity of the organization and problems with the effectiveness of production and technological solutions. Table 4 gives the summarized results of studies on the effectiveness of management during problem solving in three teams before the implementation of changes.

Analysis of the resulting data (Table 4) reveals that the leaders did not properly manage the process of solving problems, because all three groups have the rank "C" of OME. This indicates the ineffectiveness of the management process and weak leadership behavior. To increase the efficiency of team decision-making, a new management decision monitoring protocol was proposed (Fig. 6).

As shown in Fig. 6, the approach to solving problems was changed, namely, requirements for verification with a follow-up plan were added. According to this scheme of work, the team leader is obliged to analyze the impact of the implemented measure on the problem with making further decisions regarding the status of the problem. For the assessment, it was suggested to choose a KPI relevant to the problematic process, followed by monitoring the dynamics of the indicator over a certain period of time (at least 7 calendar days). Then the verification result should be evaluated.

Thus, if a negative verification result is obtained (the set indicator is not achieved or the problem is not solved), the leader undertakes to start the process again, returning to the planning phase of the PDCA cycle. This, in turn, involves re-examining the problem together with the team of the relevant station and implementing corrective actions to achieve a positive verification result. A positive result indicates the preventive nature of the implemented actions and prevents the repeated occurrence of errors.

Devising a method for the integrated approach makes it possible to increase the effectiveness of management decision-making at enterprises processing polymers for automobile construction. The method makes it possible to reduce the number of management errors through the addition of the PDCA cycle with new criteria for verifying decisions based on indicators (1–4). The proposed comprehensive approach to making production decisions can be used at any industrial enterprises, provided it is adjusted according to technological specificity. The results of the implementation of this method and their detailed analysis are given below.

Table 4

Comparative analysis of management effectiveness in solving production and technological problems

Team at site	Criterion	Activity, unit	Management efficiency, %	Rating	Description of indicator
1	Implemented	46	75.4	B	Effectiveness of implementation
	Verified	3	6.5	C	Effectiveness of measures
	Under verification	43	–	C	Effectiveness of verification
	OME	–	*4.9*	C	Management effectiveness
2	Implemented	50	76.9	B	Effectiveness of implementation
	Verified	0	2	C	Effectiveness of measures
	Under verification	49	–	C	Effectiveness of verification
	OME	–	1.5	C	Effectiveness of management
3	Implemented	48	96	A	Effectiveness of implementation
	Verified	2	4.2	C	Effectiveness of measures
	Under verification	46	–	C	Effectiveness of verification
	OME	–	4	C	Effectiveness of management

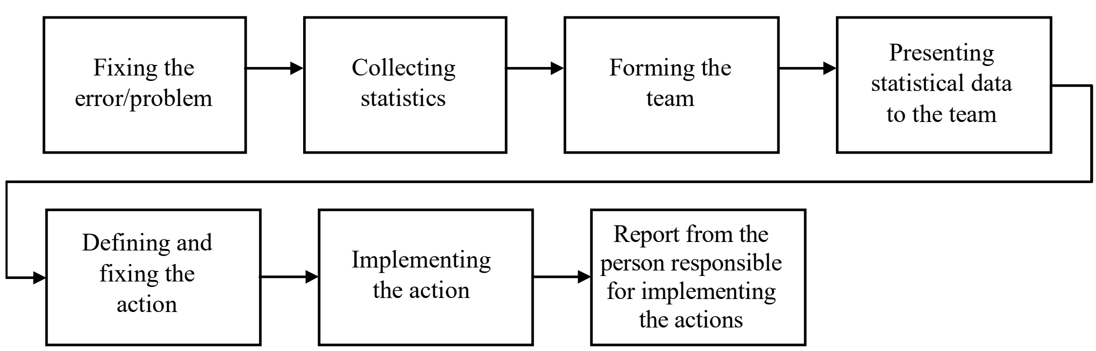

Fig. 5. An initial approach to the problem-solving process

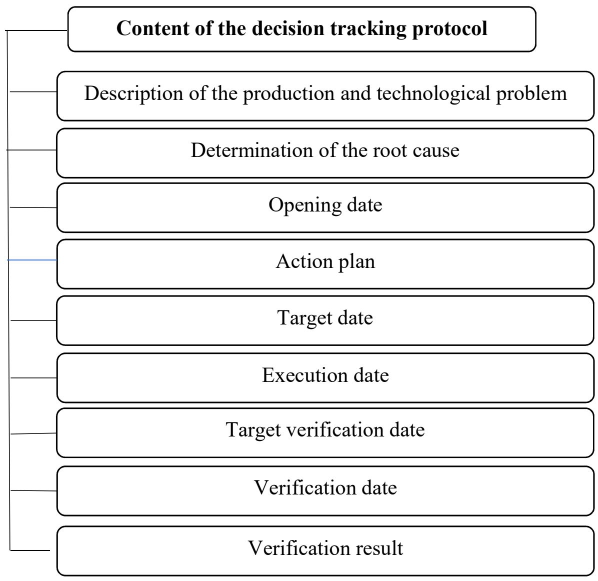

Fig. 6. Decision tracking protocol based on the new approach

5. 3. Analysis of the production experiment regarding the implementation of the devised approach to decision-making at the enterprise

Data collection to evaluate the improved problem-solving process was conducted 6 and 12 months after implementation. The evaluation results (Table 5) demonstrate a significant improvement in the level of effectiveness of management decision-making by an average of 63 %, which indicates the effectiveness of the implemented measures.

According to the devised approach, to solve the problems of packaging plastic parts (Fig. 7), leaders involved members of their teams in analyzing the root causes of technological problems and verifying the results of solutions. Compared to the initial situation, after the implementation of the systematic use of a structured approach to solving problems (Fig. 6), management demonstrated significant changes in the work of teams. This had a positive effect on the main indicators of technological processes.

The use of the Ishikawa diagram (Fig. 7) shows a wider range of causes and effects, which increases the probability of avoiding problems in the future along with the expansion of the powers of precinct teams. The general significant improvement in the level of *OME*, demonstrated by site teams led by their leaders, is illustrated in Fig. 8. It attests to the fact that managers have changed their approaches and style when solving complex tasks. Teams were given more responsibility for the result along with more authority.

Positive changes from the implementation of the devised approach to decision-making are also confirmed by the assessment of dynamics in the key indicator of plastic injection molding technology – Overall Equipment Effectiveness (*OEE*) at site No. 3. Fig. 9 shows the comparative trend of the achieved *OEE* levels by month. A significant improvement in *OEE* was observed throughout 2023 compared to 2022. The trend line shows a steady improvement already starting from February 2022, where there have been changes in the approach to solving problems.

Our results testify to the high efficiency of managing the plastic injection molding process, which led to the growth of OEE in 2023 (Fig. 9) by an average of 2.5 % during the year compared to 2022. This correlates with an improved indicator of overall management efficiency OME (coefficient 0.84>0) with the achievement of the target value of 91 %. A positive correlation coefficient confirms the consistency and direct dependence of the improvement of production process management indicators. In particular, at assembly site 1, a significant improvement of the cleanliness and order 5S (Sort, Set in Order, Shine, Standardize, Sustain) indicator was recorded, by an average of 7 %, with the target value of 95 % being reached (Fig. 10). The correlation coefficient was 0.74>0, which is also consistent with the improved level of management effectiveness of the team at site 1.

Verification of the improved approach made it possible to record positive changes in the productivity indicator at site 2 of the company LLC «KOSTAL Ukraine» (Fig. 11).

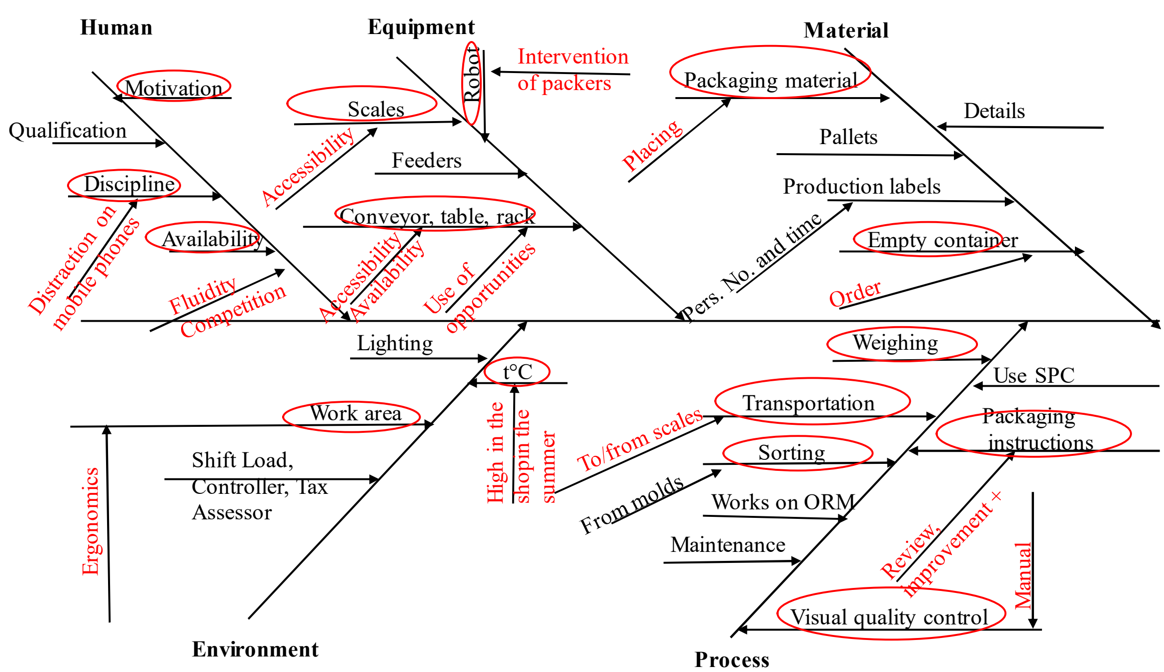

Fig. 7. Application of the Ishikawa diagram to solve the problems of packaging parts of the plastic products production site

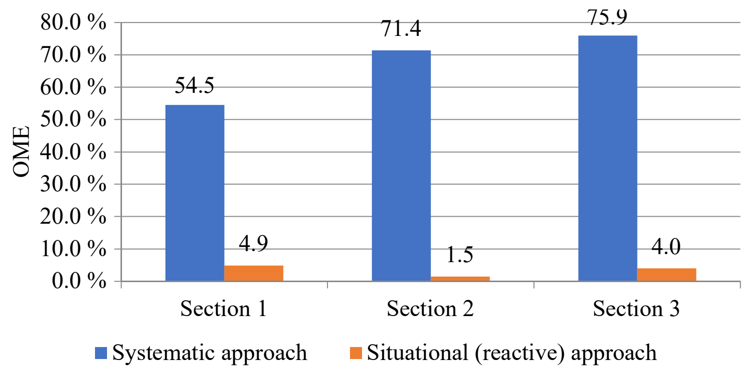

Fig. 8. Comparative diagram of the achieved levels of overall management efficiency in the studied teams of the company LLC «KOSTAL Ukraine»

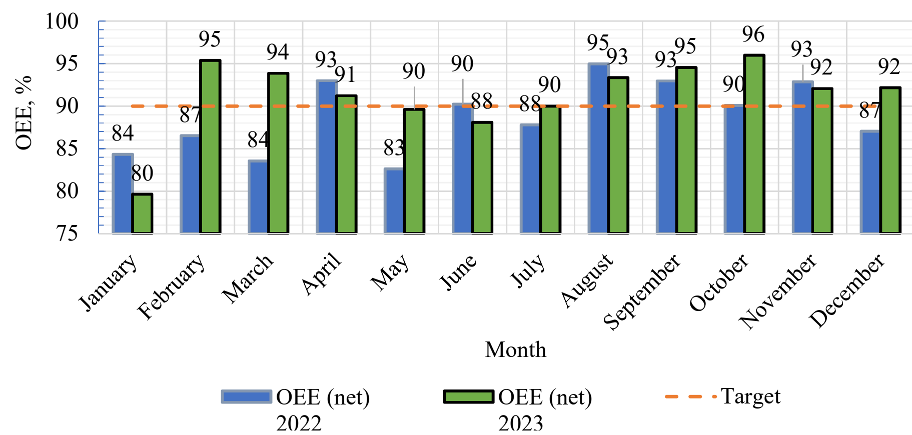

Fig. 9. Dynamics in the achieved indicators of the overall efficiency of equipment by month at site No. 3 of the company LLC «KOSTAL Ukraine»

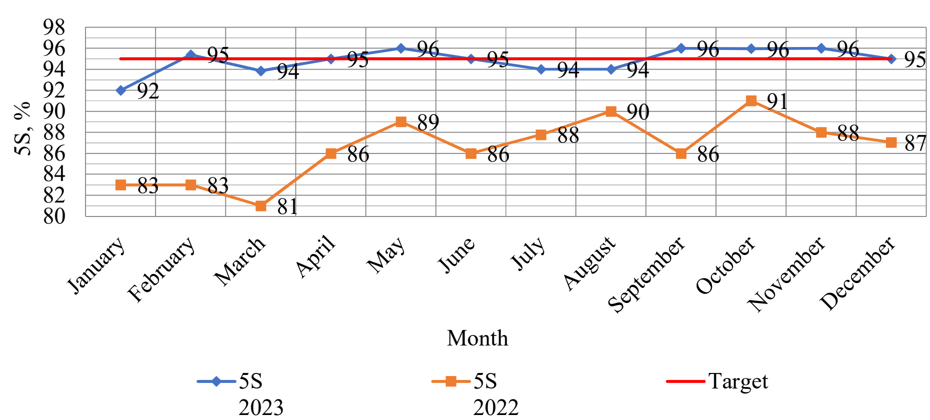

Fig. 10. Achieved 5S indicators by month at site 1 of LLC «KOSTAL Ukraine»

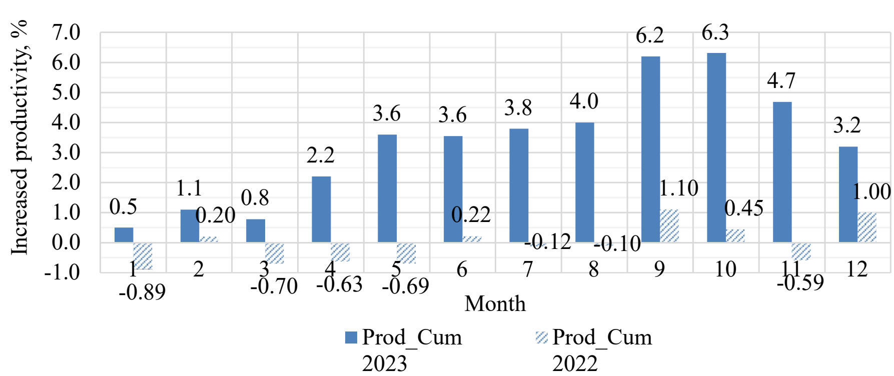

Fig. 11. The dynamics of changes in the level of productivity at site 2 of the company LLC «KOSTAL Ukraine»

Table 5

Comparison of the results of overall management efficiency (*OME*) for three teams of the company LLC «KOSTAL Ukraine»

Team at site	*OME* before, %	*OME* after, %	Ranking before	Ranking after	Improvement, %
1	4.9	54.5	C	B	47
2	1.5	71.4	C	B	70
3	4	75.9	C	B	72

Fig. 11 demonstrates that at assembly site 2, in 2023, an increase in the productivity indicator was established by an average of 3.3 % compared to –0.06 % in 2022. The correlation coefficient is 0.86>0, which shows a direct relationship between a high OME indicator and a constant improvement in productivity.

Thus, the increase in the effectiveness of production and technological decision-making was registered at all investigated sites of the company LLC «KOSTAL Ukraine».

6. Discussion of results of the production experiment on the implementation of the devised methods at the polymer enterprise

The production experiment carried out at the company LLC «KOSTAL Ukraine» proved that the existing problems of continuous improvement in the automobile industry are directly caused by complex technological processes and shortcomings of management procedures used in team decision-making. That is why Lean management based on the PDCA cycle and other decision-making tools prove their suitability and relevance and contribute to productivity growth [30], which is demonstrated in Fig. 11. Our positive results of the experiment were due to changes in the parameters that were included in the decision tracking protocol (Fig. 4, 6), the application of an iterative approach to the verification of the results (Fig. 6) based on efficiency indicators (formulas (1) to (4)), which we have devised.

A special feature of the proposed method and the results in comparison with those reported in [10, 11] is its higher efficiency, which was reflected in the reduction of the number of erroneous solutions. This became possible owing to the application of the iterative search for root causes and the verification of influencing factors on existing production problem based on the indicators system that we have proposed.

Unlike the approach in [12], the proposed method contains additional control points: the target date of verification, the date of verification, and the result of verification, which improves management procedures and contributes to the growth of the quality level of production and technological solutions in polymer production.

The experiment was conducted at one polymer enterprise, but this does not mean that its results cannot be extended to others. However, when using the proposed approach, it is worth considering that in each specific case, it is necessary to take into account the situational conditions that would affect the result. Among them, the most significant are the specificity of the production or technological changes that are implemented, the management style, psychological and professional characteristics of the team that implements production and technological solutions.

The main limitation of our approach is the dependence on the subjective choice of criteria for the verification of a production or technological decision by the heads of structural divisions. This may lead to wrong decisions or excessive time spent when making certain management decisions.

Further research may tackle the development of clear verification algorithms for specific types of management decisions in various types of economic activity. Research related to the development of ways to motivate managers and employees to participate in effective decision-making in teams is also promising.

7. Conclusions

1. To improve the verification of the results of management decision-making at the enterprise, it has been proposed to use the following set of indicators: management effectivity of implementation (ME_i); management effectivity of verification (ME_v); indicator of effectiveness of relevant production and technological measures (ME_a); Overall Management Effectiveness (*OME*) indicator. The specified list of indicators is the most relevant for the tasks of evaluating the results of production and technological solutions, primarily in the production of polymers for automobile engineering. The proposed indicators make it possible to reduce the number of management errors as they increase the reliability of verification of the obtained intermediate results of production and technological solutions.

2. A comprehensive approach to solving problems based on the solution tracking method that we have devised ensures an increase in the efficiency of polymer processing production. Unlike the basic version of the team decision-making procedure, it additionally contains the date and result of the verification. The devised approach consists of a cyclic sequence of stages. Their implementation allows for the following:

1) identification of a production-technological problem;

2) its deep analysis by using the Ishikawa diagram;

3) devising measures to eliminate the problem based on the verification of intermediate results of decisions using the proposed indicators.

The application of such an iterative approach to verifying the results of making production and technological decisions, taking into account the specificity of the technological processes of production from polymer cork, makes it possible to quickly correct erroneous decisions that can be made by managers and teams. The active participation of teams in decision-making contributed to reducing the number of errors in the design of materials that ensure the reliability and durability of the car, reducing its negative impact on the environment.

3. Based on a systematic analysis of the results of practical testing of the proposed approach to making production and technological decisions, an increase in performance indicators was achieved at all three studied sites of LLC "KOSTAL Ukraine". In particular, at assembly site 1, an improvement in cleanliness and order 5S was observed by an average of 7 % with the achievement of the target value of 95 %. Assembly site 2 saw an average productivity improvement of 3.3 % in 2023 compared to –0.06 % in 2022. Positive dynamics in the improvement of overall equipment efficiency (*OEE*), a key indicator of plastic injection molding technology, was also observed at site 3 throughout 2023

compared to 2022. The trendline has shown steady improvement since February 2022, when changes in approach to problem solving were implemented.

An experimental study showed that the application and observance of the full PDCA cycle increases the overall effectiveness of management (*OME*) by 63 %, which in turn has a positive effect on the level of maturity of the organization and on sustainability in a competitive environment. In addition to sustainable development and the relentless growth of the level of maturity of companies, this has a positive impact on the development of ecosystems. The improvement of the social and environmental aspects of the enterprise's activity is facilitated by reducing the volume of defective products and technological waste.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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