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Management Challenges and Factors Determining Their Successful Solution

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Abstract:

Purpose and Originality: This research aims to analyse challenges encountered by managers of educational institutions in their work, the solutions to overcome challenges and factors determining success. The article presents the results of the research conducted in Lithuania in 2022, encompassing structured interviews with 8 heads of educational institutions in Šiauliai region. The research has revealed that the challenges faced by the heads of Lithuanian educational institutions are determined by the specificity of the country's education system, the previous management of the educational institution, and the attitude of the very heads of educational institutions.

Method: The research was conducted employing a generic qualitative descriptive exploratory approach (Kahlke, 2014; Merriam, Tisdel, 2016). The research strategy is not based on a specific qualitative methodology; it is simply sought to discover and understand the phenomenon from the perspective of the subjects participating in this research. The respondents were given two questions: 1) What was the biggest management challenge that you managed to solve successfully? 2) How were you solving this challenge?

Results: Based on the research data, management challenges, their solutions and success factors were revealed. The research demonstrated that the solutions for overcoming challenges faced by managers included the manifestation of general and managerial competencies in the managers' activities, while the factors determining success were the managers' personal, professional competencies and value approaches – managers' distributed leadership competence and organisational culture.

Limitations: The research involved only heads of educational institutions (except gymnasiums) in Šiauliai region; therefore, the research results cannot be applied to the entire population. The research results could have been influenced by the subjective perception of investigated persons, their emotional state, daily institutional situations, workload, and other subjective factors.

Keywords: managers' competence, management challenges, factors determining success, leadership.

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1 Introduction

Empirical research has proved the importance of the manager's competencies for the modern organisation and their influence on organisational performance. Competent management is considered the most important dominant for successful school performance. At the same time, scholars (Spillane, Lee, 2014; Bayar, 2016 et al.) note that the work of managers of educational institutions has recently become more complex since they face an increasing number of challenges such as doubling of work functions; negative attitudes of families towards the school; immigrants, re-emigrants; teacher trade unions; the attitudes of teachers towards school principals and the way they treat them; the increase of unwanted behaviours in the classroom / school; change of the previous leadership style to a more democratic one.

Prompt and smooth solution of arising challenges determines the success of the manager and of the entire educational institution and sometimes even the institution's independence or survival. According to Storey (2016), greater complexity of the society and faster pace of change lead to a greater need for leadership in organisations such as distributed leadership (Lahtero et al, 2017; 2019; Dambrauskienė, 2021; Harris, Jones, Ismail, 2022; Or, Berkovich, 2023), innovative leadership (Khalili, 2016; Atkočiūnienė et al., 2019; etc.), or agile leadership (Hayward, 2018; Collins, 2018; Özdemir, 2023; etc.). For more than a decade, Lithuania has also been undergoing changes in its education policy towards the implementation of leadership, which is reflected in the Lithuania's Progress Strategy "Lithuania 2030" (2012), the Law on Education of the Republic of Lithuania (1991, current version of 01/09/2023). Leadership ideas are set out in the Good School Conception (Ministry of Education and Science of the Republic of Lithuania, 2015). In addition, the Ministry of Education, Science and Sport of the Republic of Lithuania plays an important role in spreading leadership ideas in Lithuania by initiating various leadership projects. Therefore, school leaders are inevitably forced to change themselves and their personalities, their attitudes to the changes taking place in the organisation and to create conditions for other members of the organisation to develop their leadership talents. It is important to note that in Lithuania, heads of schools have fixed-term employment contracts of five years.

According to Videikienė, Šimanskienė (2013), Errida, Lotfi (2021), personal qualities and professional competencies of the organisation's manager remain important in overcoming challenges or seeking to successfully implement change in the organisation. According to Graham-Leviss (2016), innovative managers need competencies such as risk management, curiosity, courage, exploiting opportunities, retaining a strategic perspective. In different organisations, in different political and cultural settings, overcoming of challenges and the successful operation of the educational institution are determined by different factors. Therefore, it is relevant to study not only the challenges faced by the managers of educational institutions but also to find out how the

emerging challenges are solved and what their successful overcoming depends on. A problem question is raised as to what factors determine successful overcoming of management challenges. The research object is the factors determining the success of overcoming management challenges. The purpose of the research is to analyse the challenges faced by the managers of educational institutions in their work, to identify the solutions to overcome them and the factors determining success.

The objectives of the research:

- To identify challenges encountered by managers of educational institutions.
- To reveal solutions for overcoming challenges arising to managers of educational institutions.
- To identify factors determining successful overcoming of challenges.

2 Theoretical framework

Analysing the recent challenges encountered by managers of educational institutions, Tintore et al. (2022) observe that the increasing requirements for the education system and the abundance of work turn managers into bureaucrats and hinder concentration on what is most important in their work, i.e., (self-)education and its improvement. Another challenge mentioned by Tintore et al. (2022) it is the relation between autonomy of managers' activities and their accountability. According to these scholars, the more autonomy school managers have, the more accountability is required from them, the more control of schools and managers' activities as well as requirements to meet standards. Dambrauskienė (2021) also distinguished the abundance of external control as a challenge and a factor limiting the implementation of distributed leadership and other changes in Lithuanian educational institutions. In her opinion, abundant external control encourages managers themselves to increase the bureaucratic mechanism inside educational institutions and retain strict hierarchical responsibility.

The third group of challenges, mentioned by Tintore et al. (2022), is related to the lack of respect for school managers, and, thus, to the increasing demands and expectations of families and the society as a whole. Researchers also note a paradox that increased parental and societal expectations do not lead to more active participation of parents in the activities of educational institutions (Dunning and Elliott, 2019; Tobin, 2014). According to Tintore et al. (2022), the fourth group of challenges is related to insufficient assistance from municipal or state level politicians supervising the educational institution.

Researchers note that new heads of educational institutions face even more challenges in their work since they often encounter surprises and shocks in their professional transition to the manager's

position (Weindling, Dimmock, 2006; Wieczorek, Manard, 2018; Liljenberg, Andersson, 2020). According to Dambrauskienė (2021), managers who started managing the educational institution anew often encounter challenges caused by the hierarchical management tradition, which were formed over a long period of time (as long as 30-40 years) under the leadership of previous managers. Organisational culture shaped by such hierarchical management poses challenges: it limits the implementation of distributed leadership and other changes in educational institutions. Challenges while changing hierarchical management to a more democratic one often arises due to the attitudes and behaviours of older employees. Murphy et al. (2009) acknowledge that most older teachers find it difficult to switch to another management system that is unfamiliar and incomprehensible to them. Employees often perceive familiar hierarchical and bureaucratic structures as security and comfort, since in the event of a failure, hierarchical and bureaucratic structures allow those involved in the change process not to take the blame but rather to assign it to other persons or even to the system itself (Murphy et al., 2009). Therefore, employees are not always interested in changes initiated by new managers, which transform the established organisational culture, and managers must take certain actions to reduce employee resistance to change.

As noted by J. Kotter (2012), the more changes, the more leadership is needed in the organisation. The leadership of the head of the educational institution, his / her personal qualities and professional competencies determine not only success in overcoming challenges in the organisation. Barriers to implementing organisational change are also mostly related to the manager's personal and professional competencies. According to Videikienė, Šimanskienė (2013), failure to implement organisational change is caused by: inflexibility of managers themselves; poor management or weak leadership; lack of skills, proactiveness, effort and resources; and hasty, inconsistent introduction of change.

In summary, it can be stated that challenges encountered by the managers of educational institutions in their work depend on the external environment (e.g., education policies of local and national government: the autonomy and independence granted to educational institutions, the abundance of external control and the like) and on internal factors (e.g., personal qualities of the manager of the educational institution, his / her professional competencies, leadership, employee competencies, activeness of the parent community and the like). Faster and more successful implementation of challenges also depends on managers and their professionalism, personal qualities, leadership, change management skills and on the community of the educational institution. The education policy of local and national government can also contribute to successful implementation of challenges falling on managers through creation of a system of support (counselling, mentoring, training, etc.) for managers.

3 Method

The qualitative research was conducted in November of 2022. Research methods included structured interviews with 8 heads of educational institutions in Šiauliai region. The research was conducted by two researchers. Each researcher interviewed 4 informants. Informants were interviewed at their workplaces. The internal validity of the qualitative research was ensured by the direct participation of researchers in the research activity.

The research sample is non-probability, convenience. The subjects were selected based on purposive sampling. Selection criteria: managers with different seniority, working in educational institutions of different types (city, district), subordinate to the municipality (pre-school education institutions, general education schools). The research involved 8 managers. The researchers know research participants, which reduced barriers to communication and enabled to obtain the most diverse information through direct communication with the subjects. The sample size of the study was not predetermined. Data was collected until it became repetitive and their informativeness decreased due to data saturation.

In the first research stage, the research problem, questions, purpose, object, research parameters were considered. In the second stage, purposive sampling of research participants was carried out. In the third stage, verbal requests to the heads of educational institutions for permission to conduct research were made. Managers who agreed to reflect on their experiences were interviewed. In the fourth stage, the research instrument was prepared. In the fifth stage, the analysis of interviews and results was performed.

In the research instrument, the he respondents were given two questions: 1) What was the biggest management challenge that you managed to solve successfully? 2) How were you solving this challenge?

Limitations of the research involved only heads of educational institutions (pre-school educational institutions, primary schools, and pro-gymnasiums) in Šiauliai region; therefore, the research results cannot be applied to the entire population. To reveal the problem under investigation in more detail, it would be appropriate to conduct the research with the heads of gymnasiums too. On the other hand, these results were not intended to represent all educational institutions in Lithuania. The information obtained during the interviews could have been influenced by the subjects' subjective perception, their emotional state, daily institutional situations, workload, and other subjective factors. Although the research sample does not allow making broad generalisations, the obtained findings enable us to see certain trends and opportunities for further research.

For data analysis every informant was assigned a code; for example, S3-1(16), K1-1(1). Code S means that the informant is a manager of a general education school; code K, of a nursery-kindergarten. The first digit shows the number of the informant on the list; the second digit, how many years the head has been managing the current educational institution; and the third digit (n), how many years of managerial experience the informant has in total. The informants managed the current educational institution from 1 to 7 years, the seniority of informants as managers was from 1 to 24 years. Research participants were women.

The responses of all subjects were analysed in parallel, looking for common points and distinguishing differences. The qualitative content analysis was performed, based on the extraction of the most appropriate meaningful units from the text and their coding. The text is analysed consistently, by inductively distinguishing meaningful units, formulating them into sub-categories and then combining into categories (Fig. 1). A category is a statement comprising a group of sub-categories (short statements) that share a common content, the meaning of the text (Bitinas, Rupšienė, Žydžiūnaitė, 2008). The combined categories form the themes that describe the phenomenon under investigation (in the case of this study, the challenges managers face, the decisions managers make to address the challenges, and the results that are achieved when the challenges are resolved). Based on the qualitative content analysis, a discussion was prepared, and research conclusions were drawn.

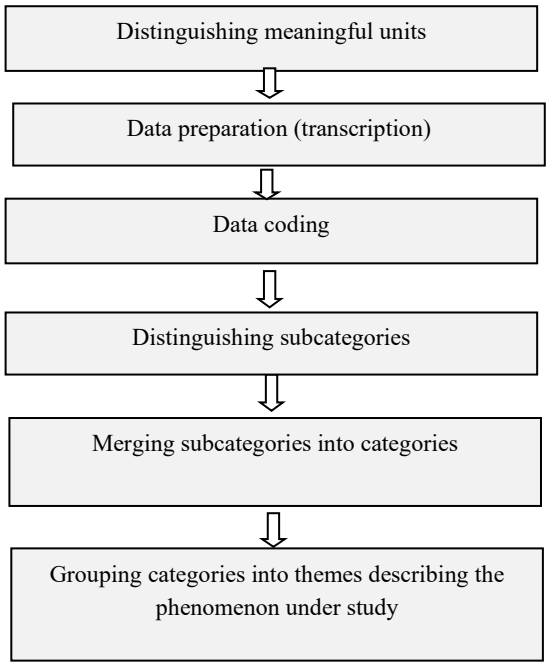

Figure 1. The qualitative content analysis process

The utterances of research participants are presented in quotation marks, indicating the participant code.

The following ethical principles of research were followed while conducting the research: informing the subjects about the purpose, stages, and methods of the research; maintaining confidentiality and anonymity; and the principle of voluntary participation. Research ethics requirements such as the researcher's professional responsibility, which is defined as avoiding fabrication, falsification or misrepresentation of data, results or conclusions; accuracy of presentation of research methodology and procedures; and the researcher's responsibility to the persons participating in the research were followed while conducting the study, performing the data analysis and announcing the research results.

4 Results

The research aimed to analyse what challenges were encountered by the heads of educational institutions in their work, how they were solved and the factors determining successful overcoming of challenges. After conducting the research, 5 challenges encountered by the heads of educational institutions were identified: difficulties arising in the first years of managerial work in a specific institution; poor image of the educational institution; reorganization of institutions; document management and financial management.

The analysis of the research results by every challenge, the decisions made by the heads of educational institutions and their impact on the successful operation of the institution are presented below. Table 1 presents the difficulties arising in the first years of managerial work in a particular institution and the statements illustrating them.

Table 1. Difficulties arising for new managers

Category	Subcategory	Illustrating statements
Difficulties encountered by new managers	Absence of a team	K1-1(1): ***A highly fragmented team***. Before me, another manager worked for about 30 years. S2-1(24): It is specific to the work of us as managers of educational institutions that we come to work at the institution alone, without a team. And ***we have to work with those people that we find at school as a legacy***.
	The organisational culture being changed	S3-1(16): The challenge related to organisational culture is also important. It is necessary ***to understand relationships, what actions were taken earlier, to show that culture changes naturally when new people come*** or to explain what principles we must and can use to build relationships and the like. I would say it is a kind of continuous challenge and at the same time, an opportunity to act differently.

Summarising the data presented in Table 1, it can be stated that the newly appointed managers of educational institutions face twofold difficulties: the newly appointed manager starts working in the institution without a team of his own; thus, has to adapt to the current situation and the team of the institution. At the same time, the new manager takes up the challenge to change the established procedures and organisational culture to pursue the set goals and improve the quality of the institution's activities. To achieve the latter goals, the manager has to make certain decisions (see Table 2).

Table 2. Decisions taken by new managers

Category	Subcategory	Illustrating statements
Decisions to be taken by new managers	Staff turnover	K2-4(7): It happened so that there was a ***significant staff turnover*** in the first year of management. In the beginning, I assumed that I was doing something wrong, that I was not able to maintain the team. <...> Now, I realise that those who were out of the way left, while the remaining ones and the new members of the team have a similar view of the institution's activities. S2-1(24): Over the course of a year, I was gradually ***changing part of employees*** and ***started forming my own team***. I realized that it would not be possible to achieve a breakthrough at school, to achieve better educational results if I don't do this. K1-1(1): ***A person was found who was able to organise STEAM activities***.
	Communication, collaboration with the community	K1-1(1): ***There were a lot of discussions, communication, explaining to parents, consulting the community, the council of the institution***. S2-1-(24): Everything ***is discussed with employees, I listen to their opinion***; therefore, I don't feel resistance to change.
	Creation of a shared vision	K1-1(1): A lot of work had to be done with employees. We were discussing ***what quality was and how we would strive for it***. K2-4(7): When you come to the established team, the biggest challenge is to "unify" thinking, to work in one direction. <...> So, we had to start from the scratch and take small steps: first, ***to find out our strengths and where we could improve***.

The data presented in Table 2 show that the decisions made by new managers include human resources (staff turnover, communication and collaboration with the community) and the creation of a common vision, striving for quality of the institution's activities. Decisions made by the heads of educational institutions have a direct impact on the quality of the institution's performance. Informants named the results achieved after overcoming challenges (see Table 3).

Table 3. Results achieved in the first year of managerial work

Category	Subcategory	Illustrating statements
Results related to the quality of the institution's activities	Changing organisational culture	S3-1(16): It is an ongoing process. ***Culture doesn't change very quickly, it takes several years rather than some months***. S2-1(24): Maybe it's still too early to rejoice, but ***the work is done much faster and smoother***. I believe and trust those people who are around now.
	Created vision	K1-1(1): ***We created a vision of the institution's quality***. We found out what was missing, and that's how STEAM appeared.
Results related to the quality of the manager's activities	Increased trust in the manager	K1-1(1): After 6 months I felt that ***people were starting to trust***. People try hard, work hard, everyone is equally important to me. Equality appeared.

The results achieved by the informants who have overcome the challenges of the first year of work should be related to the improvement of quality of the institution's activities and a more positive attitude of employees towards change and the new manager (trust in the manager increased). In summary, it can be stated that the challenge "New manager, old team", arising for new managers, named by the informants, is surmountable.

The second challenge faced by the heads of educational institutions is the poor image of the educational institution. Table 4 presents the reasons identified by the informants, which in their opinion, lead to the poor image of the institution.

Table 4. Reasons determining the poor image of the institution in the community

Category	Subcategory	Illustrating statements
Reasons determining the poor image of the institution	Diversity of education is not ensured	S1-7(7): When I started working at school, the first thing was that our school was shrinking, shrinking, shrinking and there was that limit where already ... <...> ***The biggest challenge was to offer something that the school did not offer and that would be attractive to the local community or the like***.
	Quality of education is not guaranteed	K1-1(1): The image of this institution in the city was not good <...> It was necessary to do a lot of work with employees. ***We were discussing what the quality of education was and how we would strive for it***.

Summarizing the data presented in Table 4, it can be stated that one of the challenges for new managers of educational institutions is the improvement of the image of the educational institution, which is directly related to the institution's tasks, namely, assurance of quality and diversity of education. In order to improve the image of the educational institution, managers make various decisions (see Table 5).

Table 5. Decisions made by managers regarding improvement of the institution's image

Category	Subcategory	Illustrating statements
Working with people	Improving the quality of education	S1-7(7): In addition to preschool education development, improvement of technical resources (such as a minibus), improvement of the aesthetic school environment, we focused on the aim of improving ***the quality of education***. K1-1(1): We were discussing what quality was and how we would seek it. ***We created a vision of the quality of the institution.***
	Searches for the institution's uniqueness	S1-7(7): ***Pre-school, pre-primary education, full-day education*** seemed attractive. <...> The year until the next September 1st was a sufficient period of time. It was easy to communicate with both the district municipality and the district education department, to reconcile certain fields, voicing certain goals. K1-1(1): We found out what was missing, ***this is how STEAM appeared***. A person was found who was able to organise STEAM activities.
	Learning within the institution	S1-7(7): We were that team where ***we learned from each other a lot*** and sought to support each other. ***We watched each other's lessons***. What can we learn [from each other]. Great respect of basic education teachers for primary education [teachers] appeared. Something has changed in our perception, in getting to know each other. We saw how many and what kinds of creative things [the teachers] applied.
Decisions related to financial resources	Striving to enrich the institution's material resources	S1-7(7): The next step was ***looking for opportunities***. Because we were a district school, a suburban school, the question was ***how to get a minibus, because that also gives a lot of opportunities, a lot of advantages***. For pupils, for families. Especially education in other spaces, other settings and the like.

The solutions named by informants in order to improve the institution's image include activities that should be related to the institution's community activities and depend on the manager's work with people (the focus on improving the quality of education, creation of the institution's vision, learning with and from others) and management of financial resources (improvement of the institution's material resources). It is noticeable that the above-mentioned decisions are not taken by managers alone, i.e., they are supported by both the institution's community and the founder (municipality or ministry). Research participants named the results achieved due to the improving image of the institution (see Table 6).

Table 6. The results determined by the improving image of institutions

Category	Subcategory	Illustrating statements
Results of the improved image of the institution	Increasing number of pupils	S1-7(7): ***And one year, one group appeared. The following year, another group appeared.*** K1-1(1): In summary, ***the kindergarten is full of children***.
	Richer material resources	S1-7(7): It was also a big advantage here when 2 years later or after 3 years, we managed ***to get a school bus*** from the ministry (because of the expansion of pre-school education).

The data in Table 6 shows that research participants named the results achieved due to the improved image of the institution, which directly correlate with the problems previously expressed by the managers, i.e., a decrease in the number of children is replaced by an increase in the number of pupils, and the striving for improvement of the institution's material resources is replaced by a richer material base. Ensuring the optimal number of pupils leads to more funding, and more funding, in turn, leads to the opportunities of enriching the educational settings.

The lack of managers and the striving to reduce administration costs lead to the fact that a share of Lithuanian municipalities takes decisions to optimise the network of educational institutions by merging part of institutions. In addition to the advantages mentioned by municipal administrations, research participants facing the challenges of reorganizing institutions name the problems they have to encounter when merging institutions (see Table 7).

Table 7. Problems encountered by managers of reorganized institutions

Category	Subcategory	Illustrating statements
Problems of managing people	Getting to know the employees	K5-3(14): The biggest challenge was upon reorganisation of institutions. ***The challenge was to get to know people, to let them get to know me***.
	Different organisational culture	K4-1(7): The problem is that ***teams are very different, the mentality is different***. I currently work in two kindergartens; I do not compare them with each other because there are ***completely different traditions and culture of communication*** in them.

Summarizing the data presented in Table 7, it can be stated that the main problems faced by managers of reorganised institutions are related to human resources management, when in order to achieve the common goals of the organisation, managers and the community must get to know each other, find an acceptable communication style, and build new culture while maintaining existing traditions.

While the first three challenges distinguished by informants (difficulties faced by new managers, improvement of the image of the educational institution and solving problems arising upon the

reorganization of institutions) are associated with human resources management, the other two areas of the manager's work, namely document management and financial management, are no less important for informants.

Tables 8 and 9 present the problems arising to research participants, related to document management and the decisions made by the managers in solving them.

Table 8. Problems arising to managers, related to document management

Category	Subcategory	Illustrating statements
Lack of internal documents and / or failure to follow them	Mandatory documents are not prepared	K1-1(1): ***Some orders, other documents are missing.*** S2-1(24): ***Procedure descriptions, protocols, event plans and the like are missing.*** K4-1(7): The institution has a trade union and ***a bilateral agreement has not yet been signed and registered***.
	Prepared plans are not implemented	M2-1(24): ***The annual activity plan, the strategic plan were written, but no one even tried to implement them***.

Table 9. Decisions made by managers in solving problems related to document management

Category	Subcategory	Illustrating statements
Solutions to document management problems	The manager's personal input	S2-1(24): As to the chaos in the documents, I manage it in a simple way: ***I sit and write, I do what has not been done.***
	General agreements with employees	K4-1(7): ***We agreed that the agreement should be rewritten,*** somehow, I managed to persuade those people.

Summarizing the data presented in Tables 8 and 9, it can be stated that problems related to document management emerged in the utterances of part of subjects. The said type of problems were encountered by managers working in specific educational institutions for the first year. Looking for solutions related to document management, subjects took personal initiative to prepare those documents regulating internal procedures, which had not been prepared before they started managing the institution. Solving problems related to poorly prepared or prepared but unimplemented documents, subjects looked for common solutions with the employees of institutions.

The fifth challenge named by respondents, which they had to face in their managerial work, was financial management. Based on the analysis of change in the wording of the article of the Law on Education, which regulates the activities of the heads of educational institutions, "from 2018, the head is responsible for the financial activities of the educational institution, considers and makes decisions related to the use of the educational institution's funds and assets". The head of the educational institution assumes responsibility, which is even more pressing when the institution's management resources are limited (*Švietimo įstaigų vadovai: iššūkiai ir pokyčiai*, 2021 / Heads of

Educational Institutions: Challenges and Changes, 2021). Research participants indicated the factors that lead to the said challenge, namely, financial management (see Table 10).

Table 10. Causes of problems related to financial management

Category	Subcategory	Illustrating statements
Causes of financial management problems	Lack of knowledge and practical experience	S3-1(16): In the first months, at least for me personally, one of the biggest challenges was finances. In my previous professional activities, ***I never analysed estimates, followed financial flows, linked them to the possibilities to buy, not to buy, to go, not to go, whether we can employ a new person or not, etc.*** <...> Today, I can see where I needed to pay attention and ***what I need to pay most attention to, what indicators to monitor, what to analyse when the new financial cycle starts***.
	Additional costs of managerial time	K5-3(14): the idea of centralisation of accounting immediately comes to mind. That moment was very difficult due to various redundant matters; where there used to be one person in charge, now I have seven people above me and ***I have to delve into seven different areas.***

Summarizing the data presented in Table 10, it can be stated that financial management is a complex and time-consuming area of the manager's work, requiring theoretical and practical knowledge. Research participants acknowledged that this challenge could be overcome through both personal qualities and counselling assistance: "Only by constantly giving questions to responsible persons related to this field" (S3-1(16)).

During the research, the informants not only revealed the challenges of managing the educational institution but also identified the factors that led to successful overcoming of challenges (see Table 11).

Table 11. Factors determining successful overcoming of challenges

Category	Subcategory	Illustrating statements
Manager's personal competencies	Proactiveness	K1-1(1): I talked to parents myself, ***I showed initiative***. S2-1(24): To achieve smooth work of the entire organisation, ***I pay much attention to the reorganization or creation of work or activity systems / structures*** <...>
	Empathy, communication skills	K5-3(14): The most important thing in the manager's work is social and communication competencies, i.e., ***your ability to communicate, collaborate, resolve conflicts, and accept the person the way he or she is***. K2-4(7): <...> ***to allow others to make mistakes and to acknowledge your own mistakes***.
Manager's professional competencies	Time management skills	K4-1(7): I remember the first days of working in two kindergartens at a time. I remember the first of September. I had a plan of ***when I was going to go and where I was going to be*** so that I could allocate time for both institutions.
	Information and management competencies	S2-1(24): To achieve smooth work of the whole organisation, ***I pay a lot of attention to redesigning or creation of systems / structures for work or activities***, e.g., the staff information system; the system for recording work that needs to be done; holding meetings (for teachers, administration, etc.).
Manager's value approaches	Striving for constant learning	S3-1(16): What helps in solving problems: conversations, self-analysis, especially ***learning on one's own and constant interest*** in the experiences of colleagues.
	Assuming responsibility	S2-1(24)<...> I do things the simple way: I sit down and write, ***I do what has not been done***.
Organisational culture	A unified approach to work	S1-7(7): <...> the belief of all of us that if we show the result, we will survive. ***We were quite united***. S1-7(7): ***When the administration works in unity, supporting each other***, that is extremely good <...> First, we have a discussion internally and we go out to the teachers in unity. K2-4(7): ***Team members have a similar view of the institution's activities***, we have updated the institution's vision and mission, which is comprehensible to all team members.
	Striving for quality	K1-1(1): We were discussing what quality was, how we would seek it <...> ***We created a vision of quality of the institution***. S1-7(7): <...> Two teachers, in order not to be accused of friendship, fellowship and poor quality, ***made a qualitative step forward by performing activities together***.
	Change as a process	S3-1 (16): To understand relationships, how people acted, to show that when new people come, ***culture changes naturally*** or by explaining what principles we must and can follow to build relationships and the like.

Summarizing the data presented in Table 11, it can be stated that successful overcoming of challenges is determined by the manager's personality and culture of the institution he / she manages. The successful work of the manager is influenced by the manager' personal proactiveness, empathy and the ability to communicate, time management skills, information and management competencies as well as favourable value approaches, i.e., taking responsibility and the wish to learn. However, solely the manifestation of the manager's personal and professional competencies would not be significant if the working environment is not dominated by a unanimous approach of employees and administration to work, acceptance of change, and stiving for quality of education.

5 Discussion

The analysis of the scientific literature allowed us to identify the following challenges encountered by the heads of educational institutions: the increase in work functions, the attitude of parents and teachers and the lack of respect for managers, change in the management style, the relationship between the autonomy of the heads' activities and accountability, insufficient assistance of municipal or state-level politicians supervising the educational institution for the heads of educational institutions. Scholars note that new heads of educational institutions face even more challenges in their work.

Insufficient support from municipal or state level politicians supervising educational institutions, mentioned by scholars (Tintore et al., 2022), is also encountered by newly hired heads of Lithuanian educational institutions. Without sufficient experience and competencies, their team, and assistance from outside they manage staff turnover, organise the community to create a common vision and ensure the quality of the institution's activities. This change carried out by newly recruited managers as well as reorganisation of educational institutions, implemented in the country, determine change in management culture in educational institutions (as well as change in organisational culture) and related challenges, which has been reported in the scientific literature (Spillane, Lee, 2014; Bayar, 2016, etc.). The fact that some of the challenges identified in our research differ from those previously identified by scholars (e.g., the challenges distinguished in the Lithuanian research, related to the institutions' poor image, reorganisation, document management and financial management, etc.), could have been determined by the specificity of the research, since the subjects were interviewed about the challenges that they had managed to successfully solve. Meanwhile, the challenges distinguished by scholars have more negative connotation; their overcoming requires not only managerial or organisational activity but also decisions at the national level. The heads of Lithuanian educational institutions, who participated in the study, did not mention challenges that would be related to the lack of respect for managers or to high demands and expectations of the community, autonomy of managers' activities and their accountability, which were mentioned by other researchers (Dunning, Elliott, 2019; Tobin, 2014;

Tintore et al., 2022). Solutions to the challenges encountered by managers of educational institutions included manifestation of general and managerial competencies in managers' activities General and managerial competencies are distinguished on the basis of The Description of Qualification Requirements for Managers of State and Municipal Educational Institutions (except for higher education institutions) (2011). Current summary version 2022-06-18 https://www.e-tar.lt/portal/lt/legalAct/TAR.EE75CCBEC71F/asr). The group of general competencies: personal effectiveness (solution – personal contribution of the manager), strategic thinking and change management (solution – staff turnover), the ability to learn (solution – learning within the organisation), communication and information skills (solutions – communication, collaboration with the community, joint agreements with employees). The group of competencies in management areas: strategic management of the educational institution (solutions – creating a shared vision, searches for uniqueness of the institution), management of education and learning (solution – improvement of the quality of education), management of the structure, processes, resources of the educational institution (solution – enrichment of the institution's material resources).

6 Conclusion

Challenges identified during the empirical research: difficulties arising in the first years of managerial work in a specific institution (for example, team formation, changes related to change in the organisational culture), poor image of the educational institution, reorganization of institutions, document management, and financial management. In summary, it can be stated that specific challenges faced by the heads of Lithuanian educational institutions are determined by the specificity of the country's education system, previous management of the educational institution, and the attitude of the very heads of educational institutions.

According to the research data, the distinguished factors determining successful overcoming of management challenges encompassed managers' personal competencies (empathy, proactiveness, communication skills, etc.) and professional competencies (of information, management, time management, etc.) as well as value approaches (striving for continuous learning, assuming responsibility and the like). All these manager's competencies can also be referred to as the manager's distributed leadership competency, because as stated by Dambrauskienė (2021), the manager's distributed leadership competency is a whole, a combination of personal and professional competencies and value approaches that create a culture of trust and ensure the mutual interaction between leaders and followers. Successful overcoming of leadership challenges was facilitated by managers' understanding that "united we stand, divided we fall"; i.e., that an important role is played by culture of the organization being managed, encompassing a unified approach to the work being done, the striving for quality of education and a positive approach to change.

The research results indicate that the key to success of the heads of educational institutions is communication and information skills. This could be linked to theories of organizational behaviour, a relationship-based approach to leadership – the leader-member exchange (LMX) theory or the relational leadership theory.

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Povzetek:
Izzivi upravljanja in dejavniki, ki določajo njihovo uspešno rešitev

Namen in izvirnost: Namen raziskave je analizirati izzive, s katerimi se pri svojem delu srečujejo vodje izobraževalnih ustanov, rešitve za premagovanje izzivov in dejavnike, ki določajo uspeh. V članku so predstavljeni rezultati raziskave, ki je bila izvedena v Litvi leta 2022 in je obsegala strukturirane intervjuje z osmimi vodji izobraževalnih ustanov v regiji Šiauliai. Raziskava je pokazala, da so izzivi, s katerimi se soočajo vodje litovskih izobraževalnih ustanov, odvisni od posebnosti izobraževalnega sistema v državi, prejšnjega vodenja izobraževalne ustanove in odnosa samih vodij izobraževalnih ustanov.
Metoda: Raziskava je bila izvedena z uporabo splošnega kvalitativnega deskriptivnega raziskovalnega pristopa (Kahlke, 2014; Merriam, Tisdel, 2016). Raziskovalna strategija ne temelji na posebni kvalitativni metodologiji, temveč si preprosto prizadeva odkriti in razumeti pojav z vidika subjektov, ki so sodelovali v tej raziskavi. Anketirancem sta bili zastavljeni dve vprašanji: 1) Kateri je bil največji izziv na področju vodenja, ki vam ga je uspelo uspešno rešiti? 2) Na kakšen način ste reševali ta izziv?
Rezultati: Na podlagi podatkov iz raziskave so bili razkriti izzivi upravljanja, njihove rešitve in dejavniki uspeha. Raziskava je pokazala, da so rešitve za premagovanje izzivov, s katerimi se soočajo managerji, vključevale izkazovanje splošnih in managerskih kompetenc v dejavnostih managerjev,

dejavniki uspeha pa so bile osebne, strokovne kompetence in vrednostni pristopi managerjev - porazdeljene kompetence vodenja managerjev in organizacijska kultura.
Omejitve: V raziskavi so sodelovali le vodje izobraževalnih ustanov (razen gimnazij) v regiji Šiauliai, zato rezultatov raziskave ni mogoče uporabiti za celotno populacijo. Na rezultate raziskave bi lahko vplivalo subjektivno dojemanje preiskovancev, njihovo čustveno stanje, vsakodnevne institucionalne razmere, delovna obremenitev in drugi subjektivni dejavniki.

Ključne besede: usposobljenost vodij, izzivi vodenja, dejavniki, ki določajo uspeh, vodenje.

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Monitoring tehnoloških procesov v avtomobilski industriji

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Povzetek:

Raziskovalno vprašanje: Kakšna je povezanost med tehnološkimi kazalniki Cpk in OEE ter finančnim kazalnikom ROI?
Namen: Namen raziskave je bil izboljšati razumevanje in obvladovanje ključnih kazalnikov uspešnosti (Cpk, OEE in ROI) v avtomobilski industriji. Cilj raziskave je razviti orodje za natančno nadzorovanje sistema PTP v avtomobilski industriji, vključno z analizo procesov priprave in montaže ter določitvijo merljivih kazalnikov uspešnosti.
Metoda: Raziskava je temeljila na študiji primera, ki je vključevala analizo podatkov, uporabo sistema za merjenje Cpk ter vodenje dnevnika za sledenje dogodkom. Teoretični okvir se opira na merjenje procesne tehnološke uspešnosti in njeno povezanost s finančnimi rezultati.
Rezultati: V tretji fazi optimizacije so bili zabeleženi znatno izboljšani kazalniki, vključno z višjimi vrednostmi Cpk, OEE in ROI. Ti izboljšani kazalniki so privedli do skladnosti z zahtevami specifikacij končnih izdelkov in hkrati povečali operativno učinkovitost proizvodnje. Avtomatizacija meritev je omogočila hitro zaznavo odstopanja v procesih in prilagajanje meritev v realnem času.
Organizacija: Raziskava predstavlja pomemben prispevek k razumevanju kompleksnih povezav med tehnološkimi kazalniki, finančno uspešnostjo ter OEE v avtomobilski industriji.
Družba: Preliminarni rezultati raziskave že dajejo pomemben prispevek za avtomobilsko industrijo, saj poudarjajo ključno vlogo sistema za merjenje poslovne in tehnološke uspešnosti ter avtomatizacije pri izboljšanju operativne učinkovitosti. S tem lahko podprejo izboljšano obvladovanje procesov ter dodajo vrednost družbeni odgovornosti in varstvu okolja.
Originalnost: Izvirnost raziskave izvira iz poudarka na procesni tehnološki uspešnosti in avtomatizaciji meritev, ki sta ključna za današnjo industrijo.
Omejitve/nadaljnje raziskovanje: Omejitve raziskave se navezujejo na pristop uporabe študije primera ter na časovne in finančne omejitve. Za nadaljnje raziskave se priporoča poglabljanje v korelacije med kazalniki procesne tehnološke uspešnosti in finančnimi rezultati ter razširitev raziskave na druge industrije.
Ključne besede: merjenje, poslovni procesi, tehnološki procesi, kazalniki uspešnosti, Cpk (procesna zmožnost), OEE (skupna učinkovitost opreme), ROI (donosnost naložb), sistem za mo nitoring, avtomobilska industrija.

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1 Uvod

Avtomobilska industrija se sooča z izzivom izboljšanja kakovosti svojih izdelkov ob hkratnem zmanjševanju stroškov proizvodnje. Za obvladovanje tega izziva je ključnega pomena razvoj novih metod za spremljanje in analizo ključnih kazalnikov uspešnosti. V ta namen smo razvili integriran sistem za merjenje poslovnih in tehnoloških procesov (PTP), ki omogoča učinkovito spremljanje in nadzor tehnoloških procesov ter s tem izboljšanje učinkovitosti in kakovosti proizvodnje. Cilj pričujoče raziskave je organizaciji zagotoviti orodje za natančen monitoring PTP, ki vključuje tehnološke procese in omogoča analizo procesov priprave in montaže z njihovimi podprocesi. Pri razvoju sistema PTP smo posebno pozornost definiranju merljivih in preverljivih kazalnikov uspešnosti, ki omogočajo učinkovit nadzor nad tehnološkimi procesi v organizaciji.

V tem prispevku bomo predstavili preliminarne ugotovitve in rezultate raziskave.

2 Teoretična izhodišča

Merjenje uspešnosti in učinkovitosti PTP je ključnega pomena za proizvodne organizacije. Vendar obstajajo pomanjkljivosti pri trenutnih sistemih merjenja, kateri nimajo ustrezno integriranih tehnoloških procesov (Neely, Gregory, & Platts, 1995).

V teoretičnih izhodiščih problema smo se osredotočili na obvladovanje tehnoloških procesov z merjenjem njihove učinkovitosti in uspešnosti. Merjenje učinkovitosti in uspešnosti zagotavlja učinkovit nadzor in omogoča korekcije (Melnyk, Bititci, Platts, Tobias, & Andersen, 2014, str. 175). Dinamično poslovno okolje zahteva, da morajo sistemi za merjenje uspešnosti slediti stalnim spremembam strategij in načinov merjenja. Poleg tradicionalnih metod se pojavljajo tudi nove metode, kot je metoda spremljanja dejavnosti poslovne aktivnosti (Business Activity Monitoring-BAM) (Janiesch, Matzner, & Müller, 2012, str. 626) in metoda storitvenega usmerjanja arhitekture (Service Oriented Architecture-SOA; Malatras, Asgari, Baugé, & Irons, 2008, str. 133). Prav tako se razvijajo nove metode umetne inteligence za spremljanje tehnoloških procesov. Tehnološki proces lahko definiramo kot serijo dejavnosti, ki se izvajajo v določenem vrstnem redu, da se doseže določen cilj. Za učinkovito upravljanje tehnološkega procesa je pomembno uporabljati ustrezne metode in orodja za nadzor in spremljanje procesa ter odkrivanje in odpravljanje napak.

Tabela 1. Pomembni avtorji in njihove raziskovalne teme na področju merjenja uspešnosti tehnoloških in poslovnih procesov

Raziskovalna tema	**Avtor in leto**
Oblikovanje sistema za merjenje uspešnosti: pregled literature in raziskovalni program	Neely, A., Gregory, M., & Platts, K. (1995)
Dejavniki, ki vplivajo na razvoj sistemov za merjenje uspešnosti	Kennerley & Neely (2002)
Temeljni koncept Balanced Scorecard (uravnoteženi kazalniki), ki predstavlja proces strateškega načrtovanja	Kaplan (2010)
Strategije za nadzor procesov in odkrivanje napak	Das, Maiti, & Banerjee (2012)
Dokaz koncepta dogodkovno vodenega upravljanja poslovnih dejavnosti	Janiesch, Matzner, & Müller (2012)
Problem napovedovanja periodičnega delovanja poslovnega procesa v realnem času	Kang, Ki, & Kan (2012)
Upravljanje kakovosti v avtomobilski industriji - Zmožnost merilnih procesov	Verband der Automobilindustrie (VDA) (2011)
Ali sistemi za merjenje procesov (PMS) ustrezajo potrebam upravljanja poslovnih procesov (BPM)	Choong, Kwee Keong (2013)
Okvir za merjenje delovanja vzdrževanja z uporabo analitičnega mrežnega procesa (ANP) za izbiro indikatorjev učinkovitosti vzdrževanja	Horenbeek & Pintelon (2013)
Zanesljivost in statistika procesov	Durivage (2014)
Koraki za izboljšanje delovanja organizacije z upravljanjem poslovnih procesov in dodano vrednostjo	Hyötyläinen (2015)
Sistematičen pristop za diagnozo trenutnega stanja sistemov za upravljanje kakovosti in poslovnih procesov	Garza-Reyes (2017)

Vsi našteti avtorji v Tabeli 1 so prispevali k razvoju teoretičnih in praktičnih pristopov za upravljanje tehnoloških procesov, ki lahko organizacijam pomagajo izboljšati svoje poslovanje in doseči konkurenčno prednost. Ti pristopi vključujejo analizo in diagnozo poslovnih procesov (Horenbeek & Pintelon 2013, str. 34), izbiro ključnih kazalnikov delovanja (Neely, Gregory & Platts, 1995, str. 108), spremljanje in nadzor procesov (Das, Maiti, & Banerjee 2012, str. 721), odkrivanje in odpravljanje napak ter upravljanje sprememb (Hyötyläinen 2015, str. 3; Janiesch, Matzner, & Müller, 2012, str. 627). Avtorji Hyötyläinen, 2015 (str. 163); vom Brocke in Schmiedel (2015, str. 194) se ukvarjajo tudi z vprašanji, kot so relacijski kapital, absorpcijska zmožnost, zanesljivost procesov in upravljanje vzdrževanja. Njihove ugotovitve kažejo na pomembnost merjenja uspešnosti tehnoloških procesov za doseganje konkurenčne prednosti.

Avtorji Durivage (2014, str. 143) ter Horenbeek in Pintelon (2013, str. 36) se ukvarjajo še z različnimi pristopi, kot so modeliranje in simulacija, analitični mrežni proces in uravnoteženi kazalniki, ki se uporabljajo za merjenje in spremljanje delovanja tehnoloških procesov.

Tehnološki procesi, ki jih analiziramo v avtomobilski industriji, vključujejo sestavo in montažo, le ti pa vključujeta vijačenje, lepljenje in končno kontrolo. V procesu vijačenja se uporabljajo različna orodja, kot so vijačni avtomati s katerimi dosegamo ustrezen navor, čas vijačenja in število obratov. Durivage (2014, str. 115) se ukvarja s procesi, ki so primarnega pomena v avtomobilski industriji in predstavlja primer uporabe statističnih metod za ocenjevanje in izboljševanje procesov v industriji.

Proces lepljenja v avtomobilski industriji zahteva natančno merjenje različnih parametrov, kot so temperatura lepila, temperatura komponent in masa lepila, ter čas lepljenja, ki je pomemben za uravnoteženje celotnega tehnološkega procesa z ostalimi operacijami. To predstavlja pomemben korak za uravnoteženje celotnega tehnološkega procesa z ostalimi operacijami v proizvodnji (Agostini, Nosella, & Soranzo, 2017, str. 1151).

Proces končne kontrole je zadnja operacija v tehnološkem procesu, ki ga obravnavamo v raziskavi. Ta proces je ključen za zagotavljanje kakovosti izdelka. Za izvedbo tega procesa se uporabljajo različne metode in orodja za pregled in testiranje izdelka. Ti pristopi vključujejo uporabo analitičnega mrežnega procesa (analytic network process-ANP) za izbiro kazalnikov učinkovitosti in sistemski pristop za diagnozo trenutnega stanja sistemov za upravljanje kakovosti in poslovnih procesov (Garza-Reyes, 2017, str. 22; Horenbeek & Pintelon, 2013, str. 34).

V avtomobilski industriji so montaža, vijačenje, lepljenje in končna kontrola ključni procesi, ki zahtevajo natančno spremljanje parametrov, da bi se zagotovila kakovost in učinkovitost proizvodnje. Avtorji, kot so Durivage (2014, str. 93), Agostini, Nosella, in Soranzo (2017, str. 1147), Garza-Reyes (2017, str. 4), Horenbeek in Pintelon (2013, str. 45) ter še nekateri drugi so predstavili različne pristope in metode, ki vključujejo statistične metode, merjenje parametrov (navor, čas, število obratov, temperatura, masa in čas) in uporabo orodij za pregled in testiranje izdelka.

Iz pregleda literature smo prepoznali priložnost za znanstveni prispevek na področju razvoja integriranega sistema za merjenje poslovnih in tehnoloških procesov (PTP) v avtomobilski industriji, ki bi omogočil boljšo usklajenost tehnoloških procesov, merjenje ključnih kazalnikov uspešnosti ter izboljšanje kakovosti in učinkovitosti proizvodnje. Raziskava temelji na študiji primera.

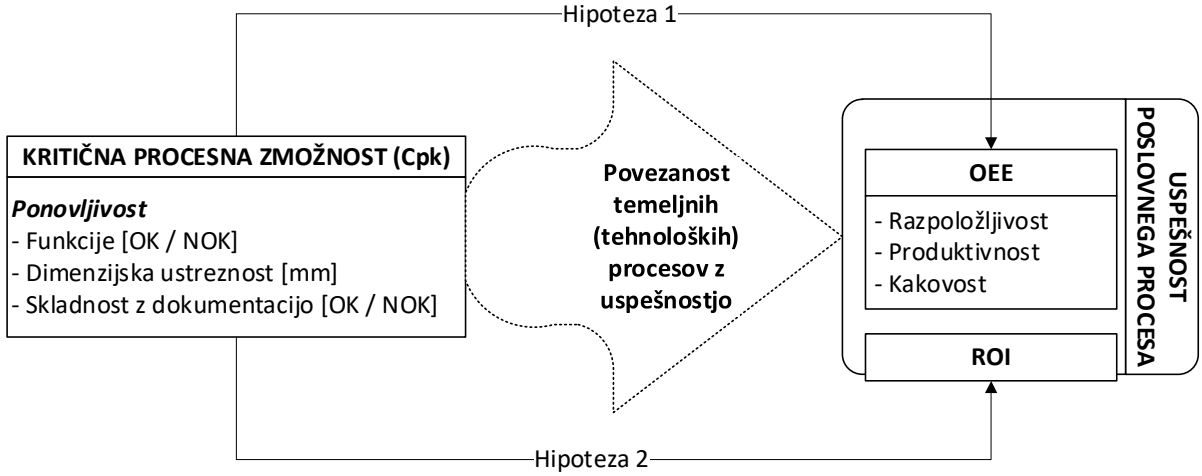
Raziskavo smo izvedli z namenom, da bi razumeli korelacije med tehnološkimi kazalniki kritičnih procesnih zmožnosti (*ang*. Critical Process Capability v nadaljevanju Cpk), splošno učinkovitost opreme (*ang*. Overall Equipment Effectiveness v nadaljevanju OEE) in finančnim kazalnikom dobičkonosnost vloženega kapitala (*ang*. Return on Investment v nadaljevanju ROI) ter pomembnost te korelacije za celovito uspešnost organizacij v tem sektorju.

V okviru konceptualnega modela raziskave (Slika 1) smo postavili Cpk na levo stran, kjer smo preučevali, kako je povezan z uspešnostjo poslovnega procesa, ki vključuje OEE in ROI na desni strani. Ta model smo razvijali med izvajanjem raziskave.

Raziskovalno vprašanje, ki nas je vodilo tekom raziskave se glasi: »Kakšna je povezanost med tehnološkimi kazalniki Cpk in OEE ter finančnim kazalnikom ROI?«, zato smo med izvajanjem preliminarne raziskave preverjali naslednji hipotezi:

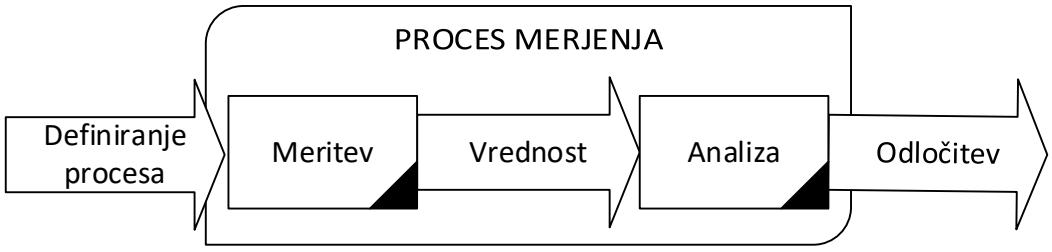
H1: Cpk je statistično značilno povezana z vrednostjo OEE.

H2: ROI je statistično značilno povezana s Cpk.



Slika 1. Konceptualni model raziskave

Merjenje procesov smo izvajali v skladu s procesom merjenja, kot je prikazano na sliki 2. Ta proces vključuje definiranje metode merjenja ter pridobivanje in analizo podatkov o kazalnikih za preverjanje uspešnosti procesa. Na podlagi analize smo sprejeli odločitve o izboljšavah in nadaljnjih ukrepih za doseganje določenih ciljev procesa.



Slika 2. Proces merjenja

Ta raziskava predstavlja pomemben korak v razumevanju kompleksnih povezav med tehnološkimi kazalniki Cpk in OEE ter finančno uspešnostjo v avtomobilski industriji.

3 Metoda

Za namen raziskave smo zbirali podatke o tehnoloških procesih s postopkom merjenja, ki nam je omogočil pridobivanje objektivnih in zanesljivih podatkov za analize. Uporabljali smo različna orodja in metode, ki so segale od preprostih, kot so merila in tehtnice, do kompleksnih naprav, kot je koordinatni merilni stroj in fotometer.

Pri izvajanju meritev smo natančno sledili standardu ISO 22514-7:2012 (ISO 2012), ki določa minimalno število meritev za vsako operacijo. Naš pristop k merjenju je vključeval številne premisleke in natančno načrtovanje (Kaplan, 2010, str. 28).

Za operacije kjer je proces montaže v fazi zagona odstopal od predpisanega tolerančnega območja smo izvedli obsežno analizo montaže, ki je vključevala vsaj 700 meritev. Za merjenje tehnološkega procesa montaže s 15 operacijami smo opravili meritve na vsaj 750 kosih. Za analizo zadnje operacije montaže, kjer smo preverjali funkcijo, dimenzijsko ustreznost in kakovost, smo izvedli 250 meritev. Za merjenje smo uporabili specializirane naprave, kot sta vijačnik in lepilna naprava, ki so omogočile avtomatizirano beleženje ključnih podatkov, vključno z navorom, številom obratov, temperaturo, maso lepila ter časom vijačenja oz. lepljenja. Natančnost meritev smo zagotovili z uporabo kontrolnih orodij, kot so tehtnica, termometer in štoparica. Analogne kazalnike smo merili s preprostim postopkom merjenja cikla, pri čemer smo zabeležili čas, potreben za izvedbo posameznega koraka v procesu. Vsako merjenje smo večkrat ponovili, da bi dobili natančne podatke.

Merjenje procesnih zmožnosti smo izvedli v skladu s standardom ISO 22514-7:2012 (ISO 2012), kar nam je omogočilo oceno Cpk ter učinkovitost in kakovost procesa. Ta zahteven postopek merjenja je trajal eno leto in vključeval več tisoč meritev. V primerih, ko se je po optimizaciji pokazalo, da proces ni bil stabilen, smo meritve in optimizacijo večkrat ponovili.

Vse izvedene meritve so bile ključne za analizo Cpk, ki so v našem primeru zajemale tri ključne kazalnike: funkcijo, dimenzijsko ustreznost in skladnost z dokumentacijo (slika 1). Ta obsežen pristop je zagotovil najvišjo možno kakovost proizvodnega procesa in izdelka.

Za namen raziskave smo izdelali konceptualni model (slika 1), ki je vključeval ožji nabor kazalnikov za analizo. Za izračun uspešnosti poslovnega procesa smo uporabili OEE, ki je sestavljen iz treh kazalnikov: razpoložljivost, produktivnost in kakovost. Poleg tega smo uporabili tudi kazalnik ROI, ki je skupaj z OEE predstavljal uspešnost poslovnega procesa.

V raziskavi smo za statistično analizo uporabili dve različni programski orodji, in sicer Minitab in SPSS. Pri preverjanju hipotez smo se osredotočili na kazalnike Cpk, ki smo jih določili s programsko opremo Minitab. Za potrditev hipotez smo morali doseči vrednost kazalnika Cpk najmanj 1,67, kar izhaja iz metodologije Six Sigma. Ta vrednost je bila ključna za potrditev

hipotez, kot so navedene v virih Pyzdek (2003, str. 475), Aized (2012, str. 251) in Pojasek (2003, str. 4).

Cpk je kazalnik skladnosti procesa s specifikacijami in meri, kako dobro obvladujemo proces glede na zahteve specifikacij izdelka ali storitve. Metodologija Six Sigma si prizadeva za zmanjšanje variabilnosti procesov in zagotavljanje visoke kakovosti izdelkov Pyzdek (2003). Uporaba Cpk v naši analizi nam je omogočila natančno in kredibilno preverjanje naših hipotez.

V besedilu uporabljamo oznake, kot na primer »_L3«, ki so ključne za razumevanje določenih lastnosti v našem analitičnem postopku. Vsaka oznaka sestoji iz črke (npr. L za levo stran in D za desno stran montažne linije) ter številke, ki označuje zaporedno številko optimizacije tehnološkega procesa, na primer »_L3« za levo stran in tretjo optimizacijo.

Za preverjanje H1 smo uporabili regresijsko analizo, pri čemer smo v model vključili kazalnike, ki smo jih izmerili po drugi optimizaciji. Ničtih in prvih kazalnikov nismo testirali, saj se je izkazalo, da Cpk po drugi optimizaciji tehnoloških procesov še vedno ni bil skladen s specifikacijo. Kot neodvisne spremenljivke smo v model vključili vse kazalnike Cpk, med katerimi je bil tudi kazalnik ponovljivosti, ki ga prikazujejo kazalniki funkcij, dimenzijske ustreznosti in skladnosti z dokumentacijo, na drugi strani pa smo kot odvisno spremenljivko uporabili OEE, ki ga predstavljajo kazalniki razpoložljivosti, produktivnosti in kakovosti (glej sliko 1). Enak regresijski model smo uporabili tudi za kazalnike po tretji optimizaciji, saj so bili ti kazalniki skladni s specifikacijo. Zato smo s 100 % gotovostjo izvedli še eno analizo, ki je vključevala kazalnike, ki so ustrezali specifikaciji, to so bili kazalniki po tretji optimizaciji.

Na podlagi H1 smo zapisali enačbo regresijskega modela za napovedovanje vrednosti OEE_L3 na osnovi kazalnikov (Cpk) Funkcije_3L, Dimenzijska ustreznost_3L in Skladnost z dokumentacijo_3L (preglednica 31):

$$\begin{aligned} \text{OEE\_L3} = {} & \text{b}_0 + \text{b1funkcije\_3L} + \text{b2dimenzijska\_ustreznost\_3L} \\ & + \text{b3skladnost\_z\_dokumentacijo\_3L} + \varepsilon \end{aligned} \qquad 3.1$$

Kjer je:

b0 konstanta, b1, b2 in b3 so koeficienti regresijskega modela, ε je napaka modela.

Na podlagi osnovane H2 smo zapisali enačbo regresijskega modela za preverjanje odnosa med ROI_3L in Funkcijami_3L, Dimenzijsko ustreznostjo_3L ter Skladnostjo z dokumentacijo_3L. Enačbo (3.2) smo zapisali:

$$\begin{aligned} ROI_{3L} = {} & b0 + b1 * Funkcije\_3L + b2 * Dimenzijskaustreznost\_3L \\ & + b3 * Skladnostzdokumentacijo\_3L + \varepsilon \end{aligned} \qquad (3.2)$$

Kjer je:

ROI_3L – odvisna spremenljivka, ki predstavlja donosnost naložbe (ROI) po tretji optimizaciji;

Funkcije_3L – neodvisna spremenljivka, ki predstavlja oceno funkcionalnosti izdelka po tretji optimizaciji;

Dimenzijska ustreznost_3L – neodvisna spremenljivka, ki predstavlja oceno dimenzijske ustreznosti izdelka po tretji optimizaciji;

Skladnost z dokumentacijo_3L – neodvisna spremenljivka, ki predstavlja oceno skladnosti izdelka z dokumentacijo po tretji optimizaciji;

regresijski koeficienti b0, b1, b2, b3 – predstavljajo spremembo v odvisni spremenljivki zaradi spremembe neodvisne spremenljivke, pri čemer je b0 konstanta;

ε – napaka modela, ki predstavlja vse druge dejavnike, ki vplivajo na ROI in jih ni mogoče meriti z vključenimi neodvisnimi spremenljivkami.

S H2 smo preverjali, če obstaja povezava med ROI in Cpk. Za preverjanje hipoteze smo uporabili statistično testiranje z regresijsko analizo, ki temelji na analizi podatkov in ugotavljanju verjetnosti, ali so opaženi rezultati naključni ali resnični. Za preverjanje hipoteze 2 smo primerjali ROI med skupinami z različnimi Cpk. Primerjali smo statistične kazalnike in izračunali p-vrednost, ki nam pove, kolikšna je verjetnost, da so razlike med kazalniki naključne. Če je p-vrednost manjša od ravni pomembnosti (0,05), zavrnemo ničto hipotezo in sklepamo, da obstaja statistično pomembna razlika med kazalniki.

Validacija je ključnega pomena, saj nam omogoča dokazovanje zmožnosti procesov za doseganje načrtovanih rezultatov. Kljub temu pa se včasih znajdemo v situacijah, kjer dvomimo v zmožnost ustvarjanja zanesljive ocene, ki bi nas prepričala o vsebinski veljavnosti validacije, kot sta jo opisala Carder in Ragan (2004, str. 129).

Skladno s standardom ISO 9001:2015 (ISO 2015) mora vsaka organizacija validirati svoje procese PTP, kadar se skladnost procesov ne da zagotoviti s poznejšim nadzorom in merjenjem. To vključuje vse procese, pri katerih se pomanjkljivosti razkrijejo šele v fazi uporabe izdelka ali storitve. Po vsakem opravljenem merjenju je potrebno izvesti validacijo meritev. Validacijo oz. preverjanje celovitosti meritev lahko izvedemo na podlagi prejšnjih analiz, meritev, razmisleka o problemu in našega poznavanja okoliščin.

4 Rezultati

Za potrditev hipotez smo uporabili Cpk analizo v programu Minitab. Hkrati smo izvedli regresijsko analizo, kar predstavlja temelj za potrditev znanstvenih predpostavk v našem raziskovalnem delu.

4.1 Analiza kazalnikov z Minitabom

Analiza podatkov prikazuje rezultate merjenja funkcije gradienta DRL (dnevnih luči - Daytime Running Lights) - obvezne opreme avtomobilov. Namen analize, izvedene s programsko opremo Minitab, je bil preveriti funkcionalnost dnevnih luči.

V nadaljevanju so predstavljene funkcije, označene kot Funkcija_2L, Funkcija_2D, Funkcija_3L in Funkcija_3D. Oznaki "2L" in "2D" predstavljata meritve po drugi optimizaciji za levo in desno DRL. Številka "3" pa se nanaša na tretjo optimizacijo. Kazalnik funkcije predstavlja gradient, matematični koncept, ki omogoča razumevanje sprememb funkcije DRL v različnih kontekstih. Gradient predstavlja stopnjo spremembe te funkcije v odvisnosti od različnih dejavnikov.

Analiza podatkov za Funkcijo_L3 in Funkcijo_3D kaže, da so bile ciljne vrednosti za ta kazalnik tudi postavljene na sredino med spodnjo (*ang.* lower specification limit-LSL) in zgornjo (*ang.* upper specification limit-USL) specifikacijo. Povprečna vrednost za Funkcijo_L3 je bila izmerjena na 160,116 z nizko standardno deviacijo znotraj vzorca (1,00621) in splošno standardno deviacijo 1,00109. Povprečna vrednost za Funkcijo_3D je bila izmerjena na 160,194 z zelo nizko standardno deviacijo znotraj vzorca (0,99799) in splošno standardno deviacijo 0,99292. Rezultati analize kažejo, da so bile ciljne vrednosti za Funkcijo_2 dosežene, vendar so bile standardne deviacije pri Funkciji_2D višje kot pri Funkciji_2L. Funkcija_L3 in Funkcija_3D sta pokazali zelo nizko standardno deviacijo, kar kaže na visoko natančnost meritev (Tabela 2).

Tabela 2. Procesni podatki za kazalnik funkcij

Kazalnik	LSL	Target	USL	Sample Mean	Sample N	StDev(Within)	StDev(Overall)
Funkcija_2L	152	*	168	160,090	50	1,96692	1,95691
Funkcija_2D	152	*	168	159,888	50	2,04022	2,02984
Funkcija_3L	152	*	168	160,116	50	1,00621	1,00109
Funkcija_3D	152	*	168	160,194	50	0,99799	0,99292

Opomba. LSL (Lower Specification Limit) predstavlja spodnjo mejo specifikacije, ki jo določa kupec ali konstruktor. Target označuje ciljno vrednost, ki jo kupec ali konstruktor želi doseči. Pogosto se nahaja med LSL in USL ter ni nujno enaka srednji vrednosti. USL (Upper Specification Limit) predstavlja zgornjo mejo specifikacije, ki jo določa kupec ali konstruktor. Sample Mean predstavlja povprečno vrednost izmerjenih podatkov. Sample N predstavlja število izmerjenih podatkov. StDev (Within) predstavlja standardni odklon vzorca. StDev (Overall) predstavlja standardni odklon celotnega procesa. Specifikacija kupca določa vrednost gradienta kjerkoli LSL in USL. Kljub temu, da so dovoljene vrednosti gradienta kjerkoli v tem območju, je zaradi centričnosti tehnološkega procesa najprimerneje, da se vrednost gradienta nahaja sredi med LSL in USL.

Tabela 3 prikazuje izračun potencialne zmogljivosti (*ang.* potential capability) in zmogljivosti znotraj območja (*ang.* within capability) za vsako spremenljivko, ki se nanaša na funkcije (Funkcija_2L, Funkcija_2D, Funkcija_L3 in Funkcija_3D). Potencialna zmogljivost odraža popolno usklajenost procesa s specifikacijami izdelka, medtem ko zmogljivost znotraj območja ocenjuje dejansko zmogljivost procesa glede na spremenljivost podatkov znotraj območja specifikacij.

Vsaka spremenljivka ima dve vrednosti za zmogljivost znotraj območja: CPL za spodnjo mejo specifikacije in CPU za zgornjo mejo specifikacije. Zmogljivost znotraj območja se izračuna kot razmerje med razdaljo med mejo specifikacije in standardnim odklonom znotraj območja.

Poleg tega tabela 3 prikazuje še Cpk, ki je pokazatelj skladnosti procesa s specifikacijami. Vrednost Cpk, ki je manjša od 1,33, kaže, da proces ni skladen s specifikacijami, medtem ko vrednost nad 1,67 kaže, da je proces skladen s specifikacijami.

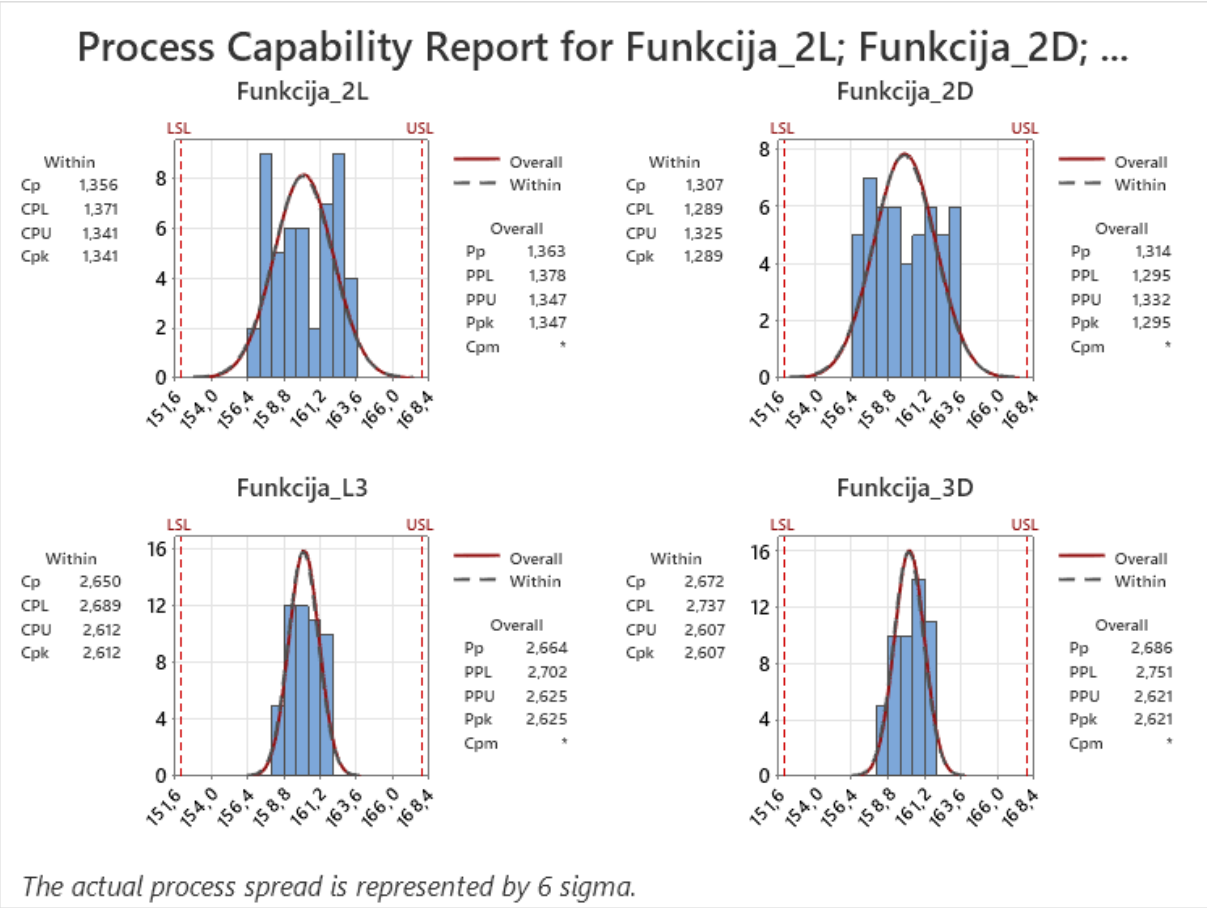
Glede na podatke v tabeli 3 lahko vidimo, da so vrednosti potencialne zmogljivosti in zmogljivosti znotraj območja za funkcije po optimizaciji 3 višje kot po optimizaciji 2. Poleg tega so vrednosti Cpk za funkcije po optimizaciji 3 višje kot 1,33, kar kaže, da so vrednosti funkcij po optimizaciji 3 skladne s tehnično specifikacijo.

Tabela 3: Potencialne zmogljivosti in zmogljivosti znotraj območja za kazalnik funkcij

Kazalnik	**Cp**	**CPL**	**CPU**	**Cpk**
Funkcija_2L	1,356	1,371	1,341	1,341
Funkcija_2D	1,307	1,289	1,325	1,289
Funkcija_3L	2,650	2,689	2,612	2,612
Funkcija_3D	2,672	2,737	2,607	2,607

Opomba. .Cp označuje razmerje med standardnim odklonom procesa in toleranco (razliko med zgornjo in spodnjo mejo specifikacije), CPL in CPU označujeta odstotek vrednosti, ki so manjše od spodnje meje specifikacije oziroma večje od zgornje meje specifikacije, Cpk pa označuje kazalnik kritične procesne zmožnosti v primerjavi s sredino toleranc. Specifikacija zahteva, da je Cpk večji od 1,67 (6 Sigma).

Slika 3 nazorno prikazuje izboljšane kazalnike Cpk Funkcija_L3 in Funkcija_3D v primerjavi s Funkcija_2L in Funkcija_2D. Po tretji optimizaciji smo dosegli Cpk vrednosti, ki so izpolnjevale zahteve specifikacij, pri čemer smo to dosegli tako na levi kot desni strani. Ta slika ponuja pregledno vizualno primerjavo in olajša razumevanje rezultatov analize.



Slika 3. Poročilo Cpk za funkcije

Rezultati (Tabela 4) kažejo, da je pri optimizaciji 2 na levi strani (Dimenzijska_ustreznost_2L) standardni odklon znotraj vzorca 4,27897, kar presega zahtevano specifikacijo. To pomeni, da optimizacija 2 ni zadostila tehničnim zahtevam za dimenzijsko ustreznost. Podobno je rezultat tudi na desni strani (Dimenzijska_ustreznost_2D), kjer standardni odklon znotraj vzorca znaša 3,99365.

Po drugi strani pa je pri optimizaciji 3 dosežena zadostna dimenzijska ustreznost, saj so standardni odkloni znotraj vzorca za Dimenzijska_ustreznost_3L in Dimenzijska_ustreznost_3D le 0,82414 in 0,70193. Poleg tega so vrednosti za obe strani skladne s tehnično specifikacijo.

Vrednosti standardnega odklona znotraj vzorca merijo, kako dobro so vzorci razporejeni okoli povprečne vrednosti. Manjši kot je standardni odklon, boljše so dimenzijske ustreznosti. Prikazan je tudi standardni odklon za vse vzorce (*ang.* StDev(Overall), ki meri splošno variabilnost procesa in je podoben standardnim odklonom znotraj vzorca.

Skupaj gledano, rezultati kažejo, da je bila optimizacija 2 neuspešna pri doseganju zadostne dimenzijske ustreznosti, medtem ko je optimizacija 3 dosegla zahtevane standarde.

Tabela 4. Procesni podatki za kazalnik dimenzijske ustreznosti

Kazalnik	LSL	Target	USL	Sample Mean	Sample N	StDev(Within)	StDev(Overall)
Dimenzijska_ustreznost_2L	132,05	*	145,95	138,300	50	4,27897	4,25719
Dimenzijska_ustreznost_2D	132,05	*	145,95	138,720	50	3,99365	3,97333
Dimenzijska_ustreznost_3L	132,05	*	145,95	139,044	50	0,82414	0,81995
Dimenzijska_ustreznost_3D	132,05	*	145,95	139,062	50	0,70193	0,69836

Opomba. LSL (Lower Specification Limit) predstavlja spodnjo mejo specifikacije, ki jo določa kupec ali konstruktor. Target označuje ciljno vrednost, ki jo kupec ali konstruktor želi doseči. Pogosto se nahaja med LSL in USL ter ni nujno enaka srednji vrednosti. USL (Upper Specification Limit) predstavlja zgornjo mejo specifikacije, ki jo določa kupec ali konstruktor. Sample Mean predstavlja povprečno vrednost izmerjenih podatkov. Sample N predstavlja število izmerjenih podatkov. StDev (Within) predstavlja standardni odklon vzorca. StDev (Overall) predstavlja standardni odklon celotnega procesa. Višja standardna deviacija pomeni, da so podatki bolj razpršeni okoli srednje vrednosti, kar kaže na večjo variabilnost procesa. Nižja standardna deviacija pa pomeni manjšo razpršenost podatkov in boljše nadzorovan proces. Standardna deviacija prispeva k izračunu Cpk in oceni sposobnosti procesa za proizvodnjo izdelkov znotraj določenih specifikacijskih zahtev.

Iz tabele 5 lahko razberemo, da je procesni kazalnik dimenzijske ustreznosti za optimizacijo 2L in 2D (leva in desna stran) prenizek. Vrednosti kazalnikov Cp, CPL, CPU in Cpk so pod 1 kar kaže na to, da proces ne izpolnjuje tehničnih zahtev. Na drugi strani pa so vrednosti kazalnikov za optimizacijo 3L in 3D zelo visoke in presegajo 2. To kaže na to, da so dimenzije proizvoda v skladu s tehnično specifikacijo in da proces dobro izpolnjuje zahteve.

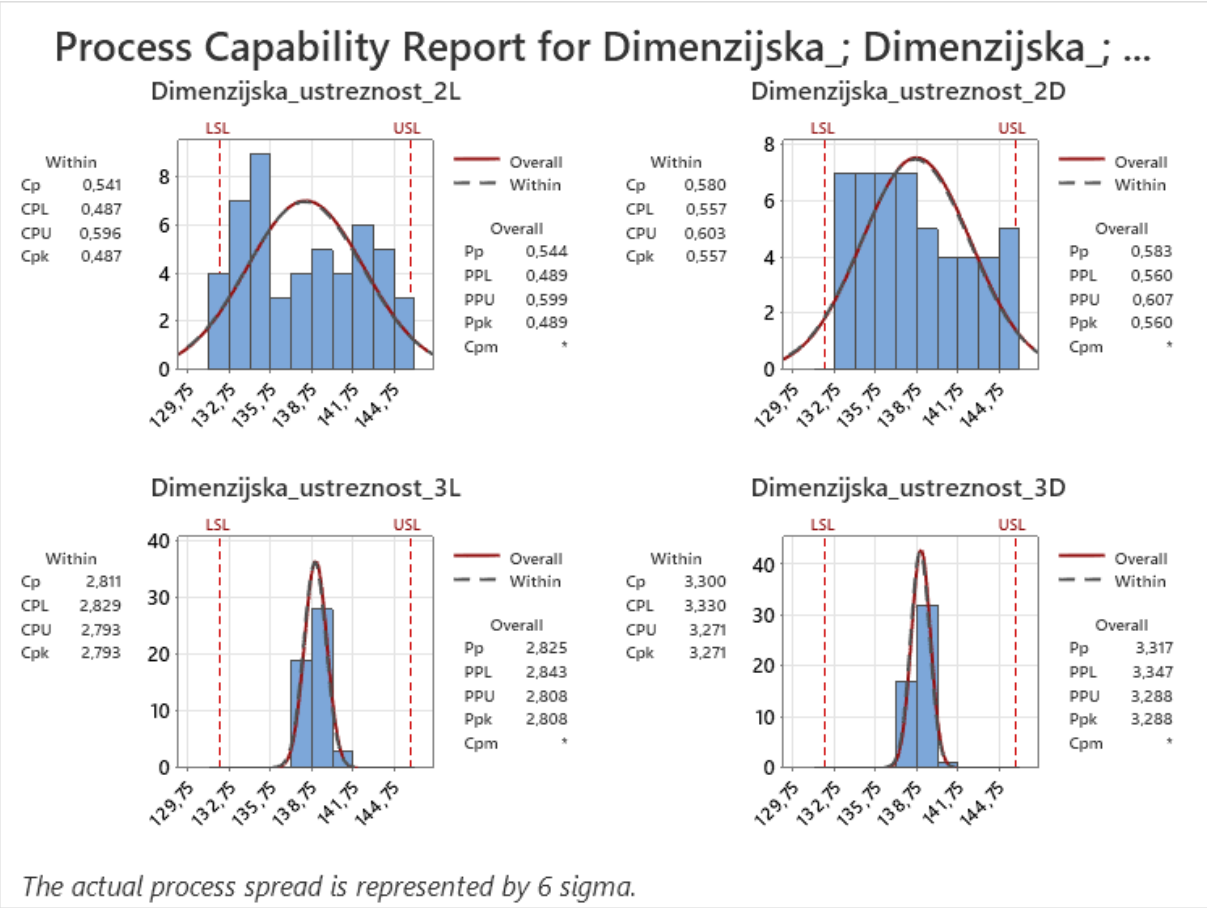
Poleg tega lahko opazimo, da je vrednost standardnega odklona celotnega procesa (StDev(Overall)) manjša pri optimizaciji 3L in 3D kot pri optimizaciji 2L in 2D, kar pomeni, da je proces manj variabilen in bolj stabilen pri optimalnih nastavitvah 3.

Tabela 5. Potencialne zmogljivosti in zmogljivosti znotraj območja za kazalnik dimenzijske ustreznosti

Kazalnik	Cp	CPL	CPU	Cpk
Dimenzijska_ustreznost_2L	0,541	0,487	0,596	0,487
Dimenzijska_ustreznost_2D	0,580	0,557	0,603	0,557
Dimenzijska_ustreznost_3L	2,811	2,829	2,793	2,793
Dimenzijska_ustreznost_3D	3,300	3,330	3,271	3,271

Opomba.Vrednost Cp predstavlja razmerje med tolerančnim intervalom in standardnim odklonom procesa, medtem ko kazalnika CPL in CPU prikazujeta, kako dobro proces izpolnjuje specifikacijo v spodnjem in zgornjem delu tolerance. Vrednost Cpk predstavlja manjšo vrednost med kazalnikoma CPL in CPU, kar kaže na to, da je proces omejen z manjšim od obeh tolerančnih intervalov Specifikacija zahteva, da je Cpk večji od 1,67 (6 Sigma).

Slika 4 prikazuje vrednosti kazalnikov Cp, CPL, CPU in Cpk za vsako od štirih spremenljivk. Ti kazalniki so grafično predstavljeni na sliki, kar omogoča boljše razumevanje njihovih vrednosti. Iz slike 4 je jasno razvidno, da so vrednosti Cp, CPL, CPU, in Cpk za optimizacija 3L in 3D veliko višje v primerjavi z optimizacija 2L in 2D, kar pomeni, da je optimizacija 3 bolje izpolnila tehnične specifikacije.



Slika 4. Poročilo Cpk za dimenzijska ustreznost

Manjša standardna deviacija znotraj vzorca pomeni, da so izdelki v skladu z ozkimi tolerancami in ustrezajo tehničnim zahtevam.

Kazalnik skladnosti ocenjuje, kako dobro izdelki ustrezajo predpisanim specifikacijam po UN/ECE R87 (UN/ECE 2010). Ta kazalnik pomaga razumeti, kako pogosto se pojavijo razlike med dejanskimi izdelki in njihovimi specifikacijami. Za naše raziskovalne namene ni pomembna regulativa UN/ECE R87 (UN/ECE 2010), saj določa le, katere specifikacije morajo izdelki izpolnjevati, da veljajo za skladne.

Iz tabele 6 je razvidno, da optimizacija 2 ni skladna z tehničnimi zahtevami, saj so vsi kazalniki skladnosti (Skladnost_2L in Skladnost_2D) presegli zgornjo mejo tehnične specifikacije (USL). Standardne deviacije znotraj vzorca so relativno visoke za obe funkciji, kar kaže na visoko variabilnost izdelkov. Na drugi strani pa so funkciji Skladnost_3L in Skladnost_3D dosegle veliko višje vrednosti kazalnikov skladnosti, kar kaže na to, da sta optimizaciji 3 skladni s tehničnimi zahtevami, ki jih predpisuje UN/ECE R87. (UN/ECE 2010). Standardne deviacije znotraj vzorca za funkciji Skladnost_3L in Skladnost_3D so precej nizke, kar kaže na bolj skladne izdelke.

Tabela 6. Procesni podatki za kazalnik skladnosti

Kazalnik	LSL	Target	USL	Sample Mean	Sample N	StDev(Within)	StDev(Overall)
Skladnost_2L	142,12	*	157,08	149,314	50	1,93578	1,92593
Skladnost_2D	142,12	*	157,08	149,102	50	2,17079	2,15974
Skladnost_3L	142,12	*	157,08	149,580	50	0,63374	0,63052
Skladnost_3D	142,12	*	157,08	149,628	50	0,62243	0,61926

Opomba. LSL (Lower Specification Limit) predstavlja spodnjo mejo specifikacije, ki jo določa kupec ali konstruktor. Target označuje ciljno vrednost, ki jo kupec ali konstruktor želi doseči. Pogosto se nahaja med LSL in USL ter ni nujno enaka srednji vrednosti. USL (Upper Specification Limit) predstavlja zgornjo mejo specifikacije, ki jo določa kupec ali konstruktor. Sample Mean predstavlja povprečno vrednost izmerjenih podatkov. Sample N predstavlja število izmerjenih podatkov. StDev (Within) predstavlja standardni odklon vzorca. StDev (Overall) predstavlja standardni odklon celotnega procesa. Višja standardna deviacija pomeni, da so podatki bolj razpršeni okoli srednje vrednosti, kar kaže na večjo variabilnost procesa. Nižja standardna deviacija pa pomeni manjšo razpršenost podatkov in boljše nadzorovan proces. Standardna deviacija prispeva k izračunu Cpk in oceni sposobnosti procesa za proizvodnjo izdelkov znotraj določenih specifikacijskih zahtev.

V Tabeli 7 so rezultati kazalnika skladnosti za štiri spremenljivke (Skladnost_2L, Skladnost_2D, Skladnost_3L in Skladnost_3D). Vrednost Cpk se osredotoča na skladnost procesa glede na specifikacije. Za proces, da velja za skladen mora biti Cpk vsaj 1,67. Če je vrednost manjša to kaže na večje variacije.

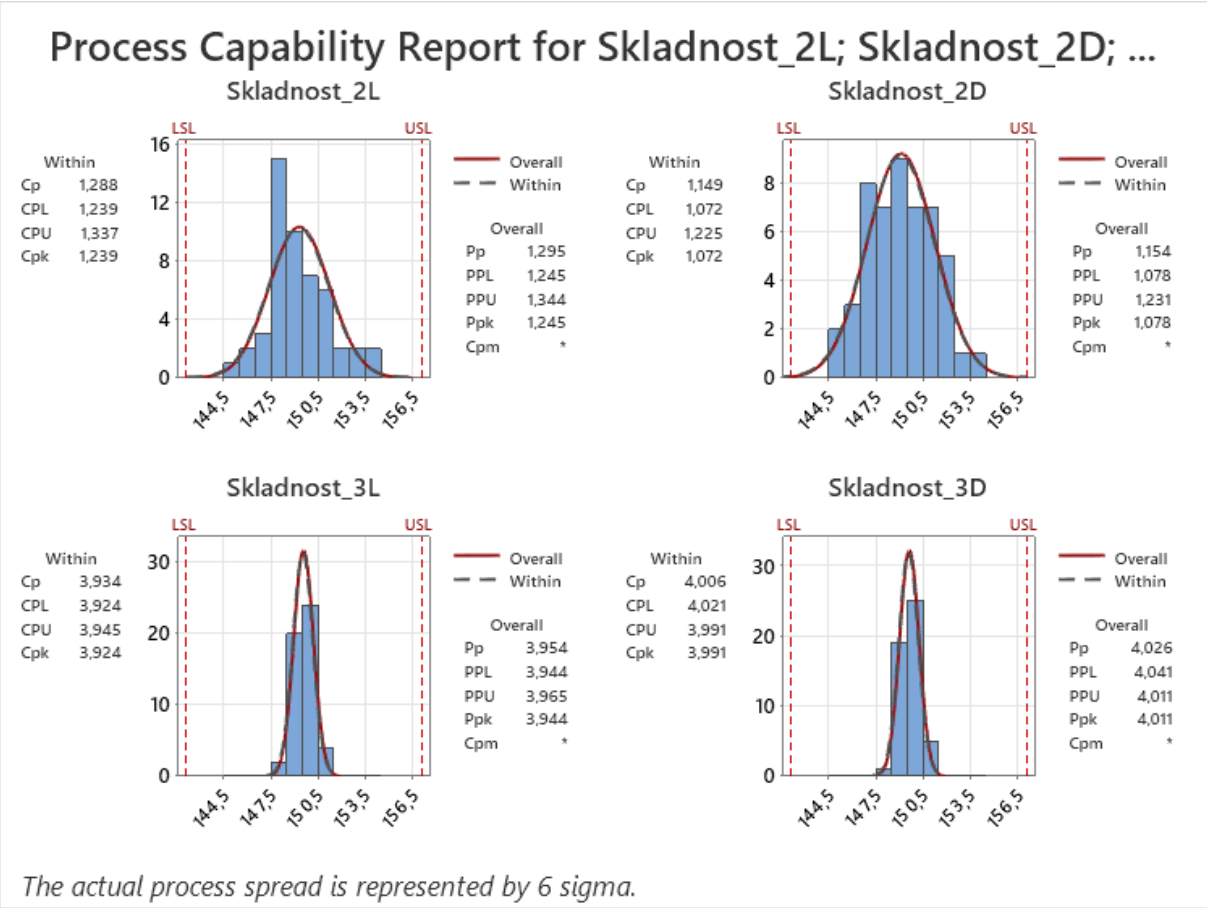
Iz Tabele 7 lahko vidimo, da za Skladnost_2L in Skladnost_2D Cpk ne dosega 1,67, kar pomeni, da proces ni skladen in obstajajo večje variacije. To je zahtevalo izboljšave v tehnološkem procesu. Po tretji optimizaciji je Cpk za Skladnost_3L in Skladnost_3D presegel 1,67, kar kaže na skladnost procesa in manj kot 0,6% izdelkov, ki ne ustrezajo specifikacijam po UN/ECE R87 (UN/ECE 2010).

Tabela 7. Potencialne zmogljivosti in zmogljivosti znotraj območja za kazalnik skladnost

Variable	Cp	CPL	CPU	Cpk
Skladnost_2L	1,288	1,239	1,337	1,239
Skladnost_2D	1,149	1,072	1,225	1,072
Skladnost_3L	3,934	3,924	3,945	3,924
Skladnost_3D	4,006	4,021	3,991	3,991

Opomba. Cp označuje razmerje med standardnim odklonom procesa in toleranco (razliko med zgornjo in spodnjo mejo specifikacije), CPL in CPU označujeta odstotek vrednosti, ki so manjše od spodnje meje specifikacije oziroma večje od zgornje meje specifikacije, Cpk pa označuje kazalnik kapacitete procesa v primerjavi s sredino toleranc. Specifikacija zahteva, da je Cpk večji od 1,67 (6 Sigma).

Slika 5 prikazuje vrednosti kazalnikov Cp, CPL, CPU, in Cpk za vsako od štirih spremenljivk. Ti kazalniki so grafično predstavljeni na sliki, kar omogoča boljše razumevanje njihovih vrednosti. Iz slike 5 je jasno razvidno, da so vrednosti Cp, CPL, CPU, in Cpk za Skladnost_3L in Skladnost_3D veliko višje v primerjavi s Skladnost_2L in Skladnost_2D, kar pomeni, da je optimizacija 3 izpolnila tehnične specifikacije.



Slika 5. Poročilo Cpk za skladnost

V primerjavi med optimizacijama 2 in 3 smo primerjali Cpk, OEE in ROI kar prikazuje tabela 8. Rezultati kažejo, da optimizacija 2 ni zadostila tehničnim zahtevam, saj so bile njene vrednosti Cpk, OEE in ROI nižje v primerjavi z optimizacijo 3. Pri optimizaciji 3 smo dosegli bistveno višje vrednosti Cpk in OEE, kar je prineslo tudi večji ROI v primerjavi z optimizacijo 2.

Kazalniki Cpk, ki se nanašajo na funkcije, dimenzije in skladnost so se po optimizaciji 3 občutno izboljšale, kar je ključnega pomena za zagotavljanje kakovosti izdelka.

Kazalnik OEE je prav tako pokazal izboljšanje, kar kaže na večjo učinkovitosti proizvodnje. Optimizacija 3 je izboljšala vse tri komponente OEE, kar pomeni večjo razpoložljivost opreme, večjo produktivnost in višjo kakovost izdelkov. Prav tako se je znatno povečal ROI, kar kaže na uspešno naložbo z večjimi koristmi od začetnih stroškov.

Tabela 8. Povzetek rezultatov optimizacij Cpk , OEE in ROI

	Optimizacija 2	**Optimizacija 3**
Cpk	**<2**	**>2**
Funkcije	1,31	2,61
Dimenzije	0,52	3,03
Skladnost	1,16	3,96
OEE		
OEE	78,36	85,41
Razpoložljivost	89,66	91,98
Produktivnost	89,81	92,10
Kakovost	97,07	98,60
ROI	2.915.182,27 €	7.978.259,00 €

Opomba. Pri izračunu ROI smo upoštevali različne stroške, vključno z razvojem, izdelavo orodij, pripravami, industrializacijo, zagonskimi, obratovalnimi in stroški nekakovosti. Po optimizaciji2 smo porabili še 1,5 k€ za izboljšave.. To je zmanjšalo stroške obratovanja in stroške nekakovosti izdelkov, kar je upravičilo večjo investicijo.

Optimizacija 3 je stala nekaj več kot 1,5 milijona evrov, vključno z nadgradnjo in izboljšavami proizvodnih naprav z testiranjem. Kljub začetnim stroškom se je naložba izplačala zaradi povečane učinkovitosti in izboljšane kakovosti. To je privedlo do večjih prihodkov in manjših operativnih stroškov. Naša analiza kaže visok ROI po tretji optimizaciji v primerjavi z drugo, kar potrjuje, da so bili začetni stroški upravičeni.

4.2 Rezultati preverjanja H1

Na podlagi rezultatov linearne regresijske analize smo ugotovili, da obstaja statistično značilna povezava med Cpk in OEE. Višji Cpk pomeni boljši OEE, kar je ključno za avtomobilsko industrijo, saj redno spremljanje Cpk izboljšuje OEE (Baciarello & Schiraldi, 2015, str. 3). Poleg tega so tudi drugi dejavniki, kot je izobraževanje zaposlenih (Neely, Gregory, & Platts, 1995, str. 84), vplivali na OEE v tej industriji. Prav tako so pomembni upravljanje kakovosti, pristop k vzdrževanju ter uporaba tehnologije (Scagliarini, 2018, str. 2).

Rezultati preverjanja H1 kažejo, da so vrednosti spremenljivke OEE_L3 razpršene okoli povprečne vrednosti, medtem ko so vrednosti spremenljivk Funkcije_3L, Dimenzijska ustreznost_3L in Skladnost z dokumentacijo_3L relativno blizu povprečne vrednosti. Te ugotovitve nakazujejo na močnejšo povezanost kazalnikov OEE s kazalniki Cpk kot s spremembami v drugih fazah tehnološkega procesa.

H1 predpostavlja statistično značilno povezavo med Cpk in OEE. Za preverjanje te hipoteze smo uporabili kazalnike po drugi in tretji optimizaciji. V našem regresijskem modelu smo vključili vse kazalnike Cpk, vključno z merjenjem ponovljivosti, prikazanim s kazalniki funkcij, dimenzijske ustreznosti in skladnosti z dokumentacijo. Odvisna spremenljivka je bila

OEE, ki smo jo predstavili z razpoložljivostjo, produktivnostjo in kakovostjo. Enak regresijski model smo uporabili tudi za kazalnike po tretji optimizaciji, saj so bili ti kazalniki skladni s specifikacijo (Enačba 3.1).

V analizi povezav med spremenljivkami smo se zanašali na uporabo Pearsonove korelacije (Tabela 9). Ta statistična metoda nam je omogočila, da smo kvantitativno ovrednotili linearno povezanost med numeričnimi spremenljivkami ter ocenili stopnjo te povezanosti (Hair et al., 2014, str. 379).

Opazili smo, da med OEE_L3 in Funkcijami_3L (Tabela 9) obstaja negativna korelacija (-0,327), kar pomeni, da višja ocena Funkcij_3L običajno sovpada z nižjo oceno OEE_L3. Prav tako smo ugotovili nizko negativno korelacijo med OEE_L3 in Dimenzijsko ustreznostjo_3L (-0,012), kar kaže na povezavo med dimenzijsko ustreznostjo in kakovostjo proizvodnje, vendar je ta povezava šibkejša. Poleg tega smo zaznali negativno korelacijo med OEE_L3 in Skladnostjo z dokumentacijo_3L (-0,267), kar pomeni, da boljša skladnost z dokumentacijo običajno sovpada z nižjo oceno OEE_L3.

Korelacija med Funkcijami_3L in Dimenzijsko ustreznostjo_3L je zelo nizka (-0,051) in ni statistično značilna (p-vrednost = 0,362). To kaže na nekaj povezanosti med tema dvema spremenljivkama, vendar statistično ni potrjena. Kljub temu, ker smo že potrdili zadostitev zahtev specifikacije s Cpk v Minitabu, ta korelacija lahko služi kot začetna točka za morebitne nadaljnje raziskave ali preiskave povezave med njima, če bi se pojavila potreba po bolj podrobni analizi.

Tabela 9. Korelacije med OEE L3 in Cpk L3

Correlations					
		OEE_L3	Funkcije_3L	Dimenzijska ustreznost_3L	Skladnost z dokumentacijo _3L
Pearson Correlation	OEE_L3	1,000	-0,327	-0,012	-0,267
	Funkcije_3L	-0,327	1,000	-0,051	0,760
	Dimenzijska ustreznost_3L	-0,012	-0,051	1,000	0,609
	Skladnost dokumentacijo_3L	z-0,267	0,760	0,609	1,000
Sig. (1-tailed)	OEE_L3	.	0,010	0,468	0,030
	Funkcije_3L	0,010	.	0,362	0,000
	Dimenzijska ustreznost_3L	0,468	0,362	.	0,000
	Skladnost dokumentacijo_3L	z0,030	0,000	0,000	.
N	OEE_L3	50	50	50	50
	Funkcije_3L	50	50	50	50
	Dimenzijska ustreznost_3L	50	50	50	50
	Skladnost dokumentacijo_3L	z50	50	50	50

Opomba: velikost vzorca N = 50.

Rezultati v tabeli 9 kažejo negativno povezanost med OEE L3 ter Funkcijami_3L, Dimenzijsko ustreznostjo_3L in Skladnostjo z dokumentacijo_3L, kar nakazuje, da izboljšanje teh kazalnikov lahko prispeva k izboljšanju OEE L3. Opazimo tudi pozitivno povezanost med Funkcijami_3L in Skladnostjo z dokumentacijo_3L, kar kaže, da izboljšanje enega kazalnika lahko koristi tudi drugemu. Kljub temu so kazalniki v analizi šibko povezani, kar nakazuje, da bi jih bilo smiselno obravnavati neodvisno. Pomembno je tudi vedeti, da korelacija ne nujno odraža vzročne povezave med spremenljivkami, temveč zgolj statistično povezanost.

Tabela 10 prikazuje rezultate regresijske analize za odvisno spremenljivko OEE_L3, ki meri operativno učinkovitost, ter neodvisni spremenljivki Skladnost z dokumentacijo_3L in Dimenzijska ustreznost_3L. Spremenljivka Funkcije_3L je bila izključena iz modela, ker ni pokazala statistično pomembne povezave s spremenljivko OEE_L3.

Tabela 10. Regresijska analiza neodvisnih spremenljivk Cpk in odvisne spremenljivke OEE

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0,328[a]	0,108	0,070	8,04053	0,108	2,841	2	47	0,068	2,032

a. Predictors: (Constant), Skladnost z dokumentacijo_3L, Dimenzijska ustreznost_3L
b. Dependent Variable: OEE_L3; Uporabljena je metoda Enter

Determinacijski koeficient (R Square) (Tabela 10) v našem modelu znaša 0,108, kar pomeni, da le 10,8% variabilnosti v spremenljivki OEE_L3 lahko pojasnimo s Skladnostjo z dokumentacijo_3L in Dimenzijsko ustreznostjo_3L. Ta nizek koeficient kaže, da naš model nima močnih napovedovalcev za OEE_L3.

Prilagojen determinacijski koeficient (*ang.* Adjusted R Square) z vključitvijo števila napovednih spremenljivk v model potrjuje nizko pojasnjevalno moč našega modela (0,070). To pomeni, da trenutne napovedne spremenljivke ne zadostujejo za zadovoljivo razlago variabilnosti v OEE_L3.

Poleg tega so korelacije med napovednimi spremenljivkami in OEE_L3 nizke, kar kaže, da med njimi ni močne povezanosti. To podpira ugotovitev, da naš model nima močnih napovedovalcev za OEE_L3. Vendar pa nizki rezultati ne pomenijo nujno, da je analiza nepomembna. V določenih primerih bi lahko namigovali na potrebo po iskanju drugih dejavnikov ali boljših napovedovalcev za OEE_L3.

Nizke korelacije kažejo na stabilnost tehnološkega procesa kakor tudi neobčutljivost procesa na manjše spremembe in podpirajo ugotovitve Cpk analize z Minitab, kar je pomembno za dosledne prihodnje rezultate.

V regresijski analizi za napoved OEE_L3 (Tabela 11) z uporabo spremenljivk Skladnost z dokumentacijo_3L in Dimenzijska ustreznost_3L opazimo naslednje:

- Dimenzijska ustreznost_3L ima pozitiven vpliv na OEE_L3 (Beta = 0,241), vendar ni statistično značilna.
- Skladnost z dokumentacijo_3L negativno vpliva na OEE_L3 (Beta = -0,414) in je statistično značilna.
- Konstanta (562,982) je tudi statistično značilna.
- Med Skladnostjo z dokumentacijo_3L in Dimenzijsko ustreznostjo_3L obstaja negativna korelacija (-0,609), kar kaže na njuno obratno povezanost.

Poleg tega statistika kolinearnosti (*ang.* Collinearity Statistics) kažejo, da ni resnih težav z večkratno kolinearnostjo, saj so tolerance in VIF v sprejemljivih mejah (Hair et al., 2014).

Tabela 11. Koeficienti OEE L3 in kazalniki Cpk L3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	562,982	274,896		2,048	,046	9,962	1116,001					
	Dimenzijska ustreznost_3L	2,447	1,767	0,241	1,385	,173	-1,107	6,002	-0,012	0,198	0,191	0,629	1,591
	Skladnost z dokumentacijo_3L	-5,474	2,298	-0,414	-2,382	0,021	-10,097	-0,851	-0,267	-0,328	-0,328	0,629	1,591

a. Dependent Variable: OEE_L3

Rezultati analiz Cpk in regresijske analize jasno kažejo, da je ključno optimizirati naš tehnološki proces, da dosežemo ustrezno raven kazalnikov Cpk, ki morajo biti najmanj 1,67 (VDA 2011), kot zahteva tehnična specifikacija UN/ECE R87 (UN/ECE 2010) ter visoko raven OEE, ki bi idealno morala biti čim bližje 100. Čeprav že dosežena vrednost OEE okoli 85 (Tabela 8) nakazuje na odlično uspešnost proizvodnje je naš cilj doseči najvišjo možno vrednost OEE ob hkratnem zagotavljanju dimenzijske ustreznosti in skladnosti z dokumentacijo.

H1, ki trdi, da obstaja povezava med Cpk in OEE, je bila potrjena. Funkcije_3L so se izkazale kot ključen dejavnik pri napovedovanju vrednosti OEE_L3. Glede na to priporočamo, da se osredotočimo na izboljšanje funkcij v proizvodnem procesu, saj imajo največjo korelacijo na izboljšanje OEE. Hkrati pa ne smemo zanemariti pomembnosti dimenzijske ustreznosti in skladnosti z dokumentacijo, saj tudi te igrajo svojo vlogo, čeprav ne toliko kot funkcije.

4.3 Rezultati preverjanja H2

H2 trdi, da obstaja statistično značilna povezava med ROI in Cpk. Za preverjanje te hipoteze, smo izvedli regresijsko analizo, kjer smo temeljito preučili regresijski model, korelacijsko

matriko in korelacijske koeficiente. Analizo kazalnikov Cpk smo izvedli s pomočjo programske opreme Minitab, medtem, ko smo regresijsko analizo izvedli s programom SPSS.

Uporabili smo podatke o kazalnikih Cpk in ROI ter oblikovali regresijski model (enačba 3.2). Analizo smo izvedli na podlagi kazalnikov po drugi in tretji optimizaciji ter vključili vse kazalnike Cpk (funkcije, dimenzijska ustreznost in skladnosti z dokumentacijo) in ROI v naš regresijski model. Za natančno analizo povezav med temi spremenljivkami smo prav tako preučili korelacijske koeficiente.

Z regresijsko analizo smo ugotovili, da med ROI3 ter Funkcije3, Dimenzijska ustreznost3 in Skladnost z dokumentacijo3 obstajajo šibke korelacije (Tabela 12). Korelacija med ROI3 in Funkcije3 je pozitivna, vendar zelo nizka (0,072), medtem ko je korelacija med ROI3 in Dimenzijska ustreznost3 negativna, a prav tako zelo nizka (-0,027). Poleg tega je korelacija med ROI3 in Skladnost z dokumentacijo pozitivna, vendar tudi zelo nizka (0,040).

Vendar pa je pomembno opozoriti, da so vse p-vrednosti višje od običajne ravni pomembnosti 0,05. To pomeni, da ni statistično značilnih korelacij med temi spremenljivkami. Na podlagi teh rezultatov ni dovolj dokazov za podporo hipotezi H2 samo z regresijsko analizo, ki trdi povezanost med ROI in navedenimi kazalniki. To je pričakovano, saj smo namerno izbrali kazalnike, ki naj bi imeli zelo nizke ali celo odsotne korelacije, kar potrjuje pravilno izbiro kazalnikov za našo analizo.

Tabela 12. Korelacijska matrika, hipoteza 6 – ROI_3L in kazalniki Cpk, optimizacija 3

Correlations

		ROI3	Funkcije 3	Dimenzijska ustreznost3	Skladnost z dokumentacijo
Pearson Correlation	ROI3	1,000	0,072	-0,027	0,040
	Funkcije3	0,072	1,000	-0,051	0,760
	Dimenzijska ustreznost3	-0,027	-0,051	1,000	0,609
	Skladnost z dokumentacijo	0,040	0,760	0,609	1,000
Sig. (1-tailed)	ROI3	.	0,311	0,427	0,393
	Funkcije3	0,311	.	0,362	0,000
	Dimenzijska ustreznost3	0,427	0,362	.	0,000
	Skladnost z dokumentacijo	0,393	0,000	0,000	.
N	ROI3	50	50	50	50
	Funkcije3	50	50	50	50
	Dimenzijska ustreznost3	50	50	50	50
	Skladnost z dokumentacijo	50	50	50	50

Ti rezultati potrjujejo predpostavko, da izboljšanje funkcionalnosti izdelka, dimenzijske ustreznosti in skladnosti z dokumentacijo pozitivno vpliva na donosnost organizacije. Na podlagi teh ugotovitev lahko sklepamo, da je hipoteza 2 potrjena. To pomeni, da obstaja povezava med ROI in Cpk, kar je ključno za dolgoročni uspeh proizvodnih organizacij, saj višji Cpk kaže na višji ROI.

Izhajajoč iz rezultatov (Tabela 13) je pomembno dejstvo izredno nizek determinacijski koeficient (R Square), ki znaša le 0,006. To pomeni, da lahko le 0,6 % variabilnosti v donosnosti naložbe (ROI3) razložimo s pomočjo izbranih neodvisnih spremenljivk. Hkrati pa je prilagojen determinacijski koeficient (*ang.* Adjusted R Square) negativen, kar je ključno za razumevanje teh rezultatov.

Negativna vrednost prilagojenega determinacijskega koeficienta pomeni, da Cpk v regresijskem modelu ne zanesljivo pojasnjuje variabilnosti ROI3. To kaže, da obstajajo verjetno drugi, pomembnejši dejavniki, ki vplivajo na donosnost naložbe, a jih ta model ne vključuje. Skratka, Cpk, Skladnost z dokumentacijo in Dimenzijska ustreznost3 niso ključni napovedovalci za ROI.

Tabela 13. Regresijska analiza neodvisnih spremenljivk Cpk in odvisne spremenljivke ROI3

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	0,075[a]	0,006	-0,037	79,89634	,006	0,133	2	47	0,875	2,344

a. Predictors: (Constant), Skladnost z dokumentacijo, Dimenzijska ustreznost3
b. Dependent Variable: ROI3; Uporabljena je metoda Stepwise

Kazalnik Funkcije3 (Tabela 14) je bil izločen iz regresijskega modela (metoda Enter), saj ga je program SPSS prepoznal kot statistično nepomembnega in potencialno problematičnega zaradi visoke korelacije z drugimi spremenljivkami. Kljub temu, da Dimenzijska ustreznost3 in Skladnost z dokumentacijo3 statistično pomembno vplivata na donosnost naložbe (ROI3), pa pojasnjujeta le majhen odstotek njene variabilnosti, kar nakazuje prisotnost drugih pomembnih dejavnikov, ki niso zajeti v tem modelu.

Tabela 14. Korelacije kazalnikov, hipoteza 2 – ROI3 na neodvisne spremenljivke Cpk (regresijska analiza)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1057,250	2731,559		,387	,700	-4437,939	6552,439					
	Dimenzijska ustreznost3	-7,715	17,558	-,081	-,439	,662	-43,037	27,607	-,027	-,064	-,064	,629	1,591
	Skladnost dokumentacijo 3	z11,031	22,833	,089	,483	,631	-34,903	56,964	,040	,070	,070	,629	1,591

a. Dependent Variable: ROI3

Rezultati v tabeli 14 kažejo, da nobena od neodvisnih spremenljivk ni pomembno prispevala k napovedi odvisne spremenljivke ($p > 0,05$). Konstanta v modelu je 1057,250, kar pomeni, da se ROI3 giblje okoli te vrednosti, ko sta neodvisni spremenljivki enaki nič. Standardizirani koeficienti (*ang.* Standardized Coefficients beta) za obe neodvisni spremenljivki sta majhna in negativna, kar kaže na njuno omejeno vlogo pri napovedovanju ROI3. Kolinearnostne statistike pa kažejo, da ni velikih težav s kolinearnostjo med spremenljivkami (toleranca in VIF sta enaka 1,591).

Tabela 15 kaže na negativno korelacijo med neodvisnima spremenljivkama Dimenzijska ustreznost3 in Skladnost z dokumentacijo3, vendar analiza ni potrdila njunega statistično pomembnega prispevka k napovedi ROI3. To nakazuje, da drugi dejavniki, ki niso obravnavani v regresijski analizi, igrajo ključno vlogo pri razumevanju donosnosti naložbe.

Tabela 15. Korelacije kazalnikov, hipoteza 2 – ROI3 in kazalniki Cpk, optimizacija 3

Coefficient Correlations[a]

Model			Skladnost dokumentacijo	zDimenzijska ustreznost3
1	Correlations	Skladnost z dokumentacijo3	1,000	-,609
		Dimenzijska ustreznost3	-,609	1,000
	Covariances	Skladnost z dokumentacijo3	521,333	-244,325
		Dimenzijska ustreznost3	-244,325	308,275

a. Dependent Variable: ROI3

Analiza Cpk in njegova povezanost z ROI3 v naši raziskavi sta razkrila zanimive ugotovitve. Čeprav so korelacijski koeficienti med Cpk in ROI3 pokazali šibko povezavo med tema spremenljivkama, to ne pomeni, da povezave ni. Nadaljnje analize (Cmk analiza za procese vijačenja, lepljenja in končne kontrole; Critical Machine Capability - Cmk), se v okviru metodologije Six Sigma uporablja za izboljšanje kakovosti procesov v organizacijah Pyzdek (2003) ki so bile izvedene, so potrdile, da je povezava med Cpk in ROI3 izrazito močna in jasno

vidna. To pomeni, da smo uspešno potrdili hipotezo H2, ki je predvidevala povezanost med Cpk in ROI3.

To dejstvo nas vodi do pomembnega zaključka: čeprav so korelacijski koeficienti lahko majhni in neznačilni, ne pomenijo nujno odsotnosti povezave med kazalniki. Pomembno je razumeti, da šibka korelacija ne izključuje možnosti, da sta spremenljivki povezani, vendar morda nista linearno povezani. V našem primeru, kljub šibki korelaciji med ROI3 in Cpk, smo lahko z gotovostjo potrdili hipotezo 2, saj je Cpk pomembno povezan z ROI (Tabela 8).

Pri analizi Cpk smo ugotovili, da je ključno upoštevati več faktorjev, kot so velikost vzorca, variabilnost podatkov, stabilnost procesa in specifikacijske zahtevama za kakovost izdelka. Pravilna obdelava podatkov je nujna za zanesljive rezultate. Vključevanje nadzornih ukrepov v proces ter upoštevanje okolijskih dejavnikov lahko izboljša procesno zmogljivost. Te ugotovitve odpirajo možnosti za nadaljnje raziskave, ki bi lahko bolj podrobno preučile vpliv teh dejavnikov na Cpk in ROI ter identificirale najboljše prakse za izboljšanje procesnih zmogljivosti. V prihodnjih študijah bi bilo smiselno preučiti, kako večji vzorec poveča natančnost ocene Cpk, kako variabilnost podatkov vpliva na Cpk, ter kako stabilnost procesa in specifikacijske zahteve vplivajo na izboljšanje Cpk in posledično na ROI. Prav tako bi bilo koristno raziskati različne metode za analizo Cpk ter kako meritve in metode vplivajo na rezultate. Vključevanje nadzornih ukrepov v proces in upoštevanje okoljskih dejavnikov bi lahko prav tako pomagalo razviti smernice za izboljšanje zmogljivosti procesa v različnih poslovnih okoljih.

5 Razprava

Dosedanje raziskave o merjenju uspešnosti so omejene na kratkotrajne analize podatkov. Kljub temu je ključno izvajati redke dolgoročne raziskave z dinamičnim pristopom za napredek v teoriji na tem področju (Janeš, 2014, str. 205). V okviru raziskave smo razvili sistem za monitoring PTP, ki omogoča temeljito spremljanje in analizo ključnih kazalnikov uspešnosti, vključno s Cpk, OEE in ROI (Slika 1).

V raziskavi smo izkoristili potenciale industrije 4.0 za avtomatizacijo meritev (Majstorović, Mačužić, Šibalija, Stojadinović, & Živković 2015, str. 379). Razvili smo sistem za merjenje PTP, ki omogoča monitoring procesne uspešnosti in hitro odzivanje na odstopanja. S sodobnimi tehnologijami smo avtomatizirali meritve in analize, kar je znatno izboljšalo natančnost in hitrost odločanja. Naš sistem za spremljanje ključnih kazalnikov uspešnosti, vključno s Cpk, OEE in ROI, predstavlja preboj v optimizaciji procesov. Kljub izzivom v drugi fazi smo zaznali vzpostavljanje pozitivnega trenda v uspešnosti, odpirajoč vrata za nadaljnje raziskave o vplivu večje avtomatizacije meritev v okviru industrije 4.0 na dolgoročno uspešnost organizacij.

Raziskava je potekala skozi več faz optimizacije. Kljub prizadevanjem in dosežkom v drugi fazi optimizacije, kjer smo dosegli izboljšave, nismo še dosegli optimalnih rezultatov (VDA, 2011). Opazili smo vzpostavljanje pozitivnega trenda v uspešnosti, kar je spodbudno. Druga faza optimizacije je prinesla opazne izboljšave v vseh spremljanih kazalnikih.

Pri tretji fazi optimizacije smo dosegli izrazito izboljšanje kazalnika Cpk. Vrednosti Cpk so se zvišale na 2,61 (Slika 3), dimenzije so dosegle 3,03 (Slika 4), in skladnost je narasla na 3,96 (Slika 5). Ti rezultati so neposredno prispevali k izboljšanju skladnosti z zahtevami specifikacij UN/ECE R87 (UN/ECE 2010) in zmanjšanju variabilnosti v procesih, kar je ključnega pomena za zagotavljanje končne kakovosti izdelka (VDA 2011).

Kazalnik OEE smo s tretjo optimizacijo izrazito izboljšali. Konkretno se je OEE povečal na 85,41%, kar odraža višjo razpoložljivost opreme, produktivnost na ravni 92,10%, in izjemno visoko kakovost izdelkov na 98,60% (Tabela 8). V nadaljevanju, tretja faza optimizacije je prinesla znatno povečanje donosa naložbe (ROI). Začetna vrednost ROI je znašala 2.915.182 € in se je povečala na 7.978.259 € (glej tabelo 8). To impresivno povečanje potrjuje, da so koristi, dosežene v tretji fazi optimizacije, presegale začetne stroške, kar nedvoumno kaže na uspešnost te naložbe.

Šibke korelacije med kakovostjo izdelka in donosnostjo nakazujejo na kompleksno naravo njune povezave. Naša študija dodaja novo perspektivo k raziskavam kakovosti izdelka in donosnosti (Agostini, Nosella, & Soranzo, 2017, str. 1155).

Rezultati naše analize kažejo, da se začetni stroški optimizacije (De Felipe & Benedito, 2017, str. 5) običajno povrnejo skozi izboljšanje učinkovitosti in kakovosti, kar vodi do večjega prihodka in/ali zmanjšanja stroškov.

Naši rezultati so v skladu s prejšnjimi raziskavami o povezavi med kazalniki kakovosti izdelka in donosnostjo naložbe (Bititci et al., 2011, str. 872). Kljub šibkim korelacijam pa vprašanja o metodologiji in kriterijih za merjenje teh kazalnikov ostajajo odprta. Podobno ugotovitev je pokazala študija, ki sta jo izvedla Barnes in Hinton (2008, str. 53).

Skupaj z navedenimi omejitvami naša raziskava prispeva k boljšemu razumevanju povezave med kakovostjo izdelka, merjenimi kazalniki ter donosnostjo organizacije (Wysocki, 2004, str. 165)

6 Zaključek

Preliminarni rezultati raziskave izpostavljajo ključno vlogo sistema za monitoring PTP pri izboljšanju organizacijske učinkovitosti. Z meritvijo kazalnikov, kot so ROI, OEE in Cpk, smo optimizirali PTP ter opazili pozitivne spremembe v delovanju in kakovosti proizvodnje.

Prepoznali smo pomanjkanje raziskav, ki se ukvarjajo s tehničnimi kazalniki PTP, kar nas pripelje k ugotovitvam nekaterih avtorjev, kot so Kaplan in Norton (2006), Neely, Gregory in Platts (1995) ter Santori in Anderson (1987). Naša raziskava dokazuje, da zgolj finančni kazalniki niso zadostni in da je ključno meriti tudi tehnološke procese za izboljšanje proizvodne in poslovne uspešnosti. Naša raziskava poudarja nove vidike, zlasti pri upoštevanju tehničnih kazalnikov PTP, ki predstavljajo pomembno dopolnitev k finančnim kazalnikom in prinaša ključna spoznanja o korelacijah med tehnološkimi kazalniki Cpk, OEE in finančnim kazalnikom ROI ter njihovi korelaciji na uspešnost organizacij v avtomobilskem sektorju.

Hipoteza H1 je bila potrjena z Minitab, kar dokazuje povezavo med Cpk in OEE. Višje vrednosti Cpk so nakazovale na izboljšano usklajenost funkcij, dimenzij in splošne kakovosti izdelka, s čimer se je posledično povečala učinkovitost proizvodnje. Nizke korelacije v regresijski analizi so kazale na stabilnost tehnološkega procesa in njegovo neobčutljivost na manjše spremembe, kar podpirajo ugotovitve Cpk analize z uporabo programa Minitab. To je igralo ključno vlogo pri zagotavljanju rezultatov.

Hipoteza H2 je sistematično raziskovala korelacijo med Cpk in ROI pri čemer je potrdila izrazito povezanost med tema kazalnikoma, kljub morebitni šibkosti povezave. Navkljub nizkim korelacijskim koeficientom, ki izhajajo iz regresijske analize, je ključno razumeti, da šibka povezava ne izključuje možnosti obstoja korelacije med omenjenima spremenljivkama. Nadaljnje analize in uporaba metodologije Six Sigma je potrdila obstoj izrazite korelacije med Cpk in ROI. Povečanje vrednosti Cpk je bistveno prispevalo k povečanju ROI, ki je ključni dejavnik poslovne uspešnosti organizacije, kar je potrdila tudi ta raziskava.

S potrditvijo hipotez med raziskavo smo prinesli konkreten odgovor na raziskovalno vprašanje "Kakšna korelacija obstaja med tehnološkimi kazalniki Cpk in OEE ter finančnim kazalnikom ROI?". Naše ugotovitve jasno kažejo, da obstaja pozitivna korelacija med višjimi vrednostmi Cpk in OEE ter finančnim kazalnikom ROI.

Z zaključki dosedanjih raziskav poudarjamo ključno vlogo sistema za merjenje PTP pri učinkovitem upravljanju procesne tehnološke uspešnosti v avtomobilski industriji. Verjamemo, da bo razvoj in uporaba tega sistema prinesla izjemne koristi avtomobilski industriji, kar bo vodilo k izboljšanju obvladovanja procesov in povečanju konkurenčnosti na trgu.

Monitoring tehnoloških procesov v avtomobilski industriji predstavlja pomemben prispevek k stroki in znanosti, pri čemer se osredotočamo na učinkovito upravljanje PTP. Ključno področje naše raziskave je razvoj sistema za monitoring PTP ter raziskovanje povezave med za nas ključnima kazalnikoma uspešnosti in sicer OEE in ROI pri čemer so pomembno vlogo v raziskavi predstavljale tudi Cpk analize.

V raziskavi izpostavljamo, da so Cpk analize ključno orodje za merjenje in izboljšanje uspešnosti tehnoloških procesov v avtomobilski industriji. Te analize omogočajo natančno merjenje, če procesi ustrezajo specifikacijam izdelkov kar vodi k izboljšanju kakovosti in zanesljivosti izdelkov ter zmanjšanju tveganj in stroškov. Naša raziskava potrjuje, da obstajajo pomembne korelacije med kazalniki Cpk ter OEE in ROI. To poudarja izjemno pomembnost učinkovitega merjenja in upravljanja procesne tehnološke uspešnosti v avtomobilski industriji.

Razvijali smo sistem za merjenje PTP, ki omogoča celovit pregled procesne uspešnosti in hitro odzivanje na morebitna odstopanja. Z uporabo sodobnih tehnologij smo avtomatizirali meritve in analize, kar je izboljšalo natančnost in hitrost odločanja. Obenem opozarjamo, da večina obstoječih sistemov za merjenje uspešnosti poslovnih procesov temelji na finančnih kazalnikih, medtem ko je merjenje procesne tehnološke uspešnosti manj razvito. Naš sistem za merjenje

PTP je prispeval pomemben korak k celovitemu razumevanju in nadzoru uspešnosti procesov, še posebej na tehnološkem področju.

V raziskavi se pojavljajo omejitve, ki lahko vplivajo na posploševanje rezultatov na druge organizacije. Omejitev je, da je raziskava osredotočena le na eno proizvodno organizacijo, kar dvomi o smiselnosti raziskave, kot opozarja Ivanko (2007). Vendar pa Flyvbjerg (2006) trdi, da študije primera omogočajo posploševanje na druge organizacije.

Za izboljšanje razumevanja in upravljanja kazalnikov uspešnosti smo uporabili triangulacijo z različnimi metodami zbiranja podatkov. Čeprav ta metoda zagotavlja zanesljive rezultate pa ostajajo druge omejitve, kot so časovne in finančne. Rezultati v raziskavi so trenutno v preliminarni fazi, saj še niso vključeni kazalniki Cmk, zato nadaljujemo analizo, da bi dobili celovit vpogled v korelacije med kazalniki. Tovrstna raziskava zahteva vztrajnost in strokovno znanje za obdelavo obsežnih podatkov, ki razkrivajo dolgoročne učinke optimizacije in sprememb na proizvodne procese.

Potencialno področje za nadaljnje raziskave predstavlja poglobljena analiza korelacij med kazalniki proizvodnih procesov in finančnimi rezultati organizacij. Takšna analiza bo lahko ponudila praktične rešitve za izboljšanje PTP in finančnih rezultatov. Za to analizo bi lahko uporabili statistične analize ali sodobne metode, kot so umetna inteligenca (AI) in strojno učenje, vključno z naprednimi modeli globokega učenja, na primer nevronske mreže. Nevronske mreže so sposobne avtomatično prepoznati kompleksne vzorce in povezave med različnimi spremenljivkami.

Nadaljnje raziskave lahko vključujejo tudi primerjalne analize med različnimi industrijami s katerimi bi dognali univerzalne strategije za izboljšanje učinkovitosti proizvodnje in poslovanja v različnih sektorjih.

Raziskava izpostavlja pomembno vlogo sistema za monitoring PTP pri izboljšanju organizacijske učinkovitosti, poudarja korelacijo med tehničnimi kazalniki, kot so Cpk in OEE, ter finančnim kazalnikom ROI ter hkrati nakazuje potrebo po nadaljnjem raziskovanju teh odnosov in razvoju naprednih analitičnih metodologij.

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Robert Pavlin izkušen strokovnjak za menedžment projektov in upravljanje timov z magisterijem strojništva ter več kot dvajsetletnimi izkušnjami v gospodarstvu. Trenutno zaključuje doktorski študij na področju menedžmenta. Njegove kompetence obsegajo menedžment projektov, inženiring, inovacije in strojništvo. Robert je prepoznan kot vizionar, ki oblikuje uspešne ekipe in navdihuje sodelavce na vseh ravneh organizacije. S svojim znanjem in izkušnjami prispeva k uspehu organizacij, ki sledijo odličnosti in trajnostni rasti, ter je izjemno učinkovit pri doseganju odličnih rezultatov, sprejemanju strateških odločitev in učinkoviti komunikaciji.

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Aleksander Janeš je izredni profesor za področje menedžmenta na Fakulteti za management, Univerze na Primorskem. Njegovo projektno delo obsega vodenje in sodelovanje pri več kot 35 strokovnih in znanstvenih projektih v gospodarstvu in visokem šolstvu. Je izkušen strokovnjak in raziskovalec na mestu programskega direktorja magistrskega študija Management. Njegove strokovne in raziskovalne izkušnje in interesi vključujejo različne perspektive sistemov projektnega vodenja in merjenja poslovanja, (zelenih, modrih, trajnostnih) poslovnih modelov in upravljanja poslovnih procesov ter orodij upravljanja na področju digitalizacije in menedžmenta procesov, inkluzivnega izobraževanja in veščin ter mladih in medijev. Njegova bibliografija na področju menedžmenta in organizacijskih ved obsega 209 del od tega 87 znanstvenih del.

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Abstract:
Monitoring Technological Processes in the Automotive Industry

Research Question: What is the relationship between the technological indicators Cpk and OEE and the financial indicator ROI?
Purpose: The purpose of the study was to enhance the understanding and management of key performance indicators (Cpk, OEE, and ROI) in the automotive industry. The research aimed to develop a tool for precise monitoring of the PTP system in the automotive industry, including the analysis of preparation and assembly processes and the determination of measurable performance indicators.
Background and Originality: The purpose of this research was to enhance the understanding and management of key performance indicators (Cpk, OEE, and ROI) in the automotive industry. The uniqueness of the research stems from its emphasis on process technological performance and the digitization of measurements, both of which are crucial in today's industry.
Method: The study was based on a case study approach, involving data analysis, the utilization of the Cpk measurement system, and the maintenance of a tracking log. The theoretical framework relies on measuring process technological performance and its impact on financial outcomes.
Results: In the third phase of optimization, significant improvements were recorded, including higher values of Cpk, OEE, and ROI. These improved indicators led to compliance with product specification requirements and simultaneously increased the operational efficiency of production. Automation of measurements enabled rapid detection of deviations in processes and real-time adjustment of measurements.
Society: Preliminary research results already provide a significant contribution to the automotive industry by emphasizing the crucial role of measuring business and technological performance systems and automation in improving operational efficiency. This can support enhanced process management and add value to social responsibility and environmental protection.
Limitations/Further Research: Limitations of the research include constraints related to the case study, time, and finances. For further research, it is recommended to delve into correlations between process technological performance indicators and financial outcomes and extend the study to other industries.

Keywords: measurement, business processes, technological processes, performance indicators, Cpk (process capability), OEE (overall equipment efficiency), ROI (return on investment), monitoring system, automotive industry.