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IMPACT OF ENTERPRISE MATURITY ON THE IMPLEMENTATION OF SIX SIGMA CONCEPT

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Abstract
Six Sigma as the continuation of comprehensive quality management TQM is of interest to many enterprises. Unfortunately, not everybody successfully implements quality improvement projects using Six Sigma tools. This approach requires proper preparation in many areas of the company's operation, including: organization of processes, establishing measures, employee engagement and creating conditions for continuous improvement. The goal of the article is to present on the case study the idea of using the organizational maturity model for production management to assess a readiness of organization to implement Six Sigma. The case study presents a company maturity level diagnosis and a successful project of quality and productivity improvement using the Six Sigma concept, confirming that the organization's maturity model is the appropriate tool for assessing multi-faceted preparation for successful implementation of Six Sigma projects.

Keywords
continuous improvement, six sigma, maturity model, maturity levels, production management.

Introduction

Six Sigma concept is considered a TQM development aimed at improving the quality and productivity of enterprises through actions aimed at reducing special and common causes of process variability. It uses advanced mathematical statistics tools.

Six Sigma implementation in the organization is associated with introduction of measures of the level of meeting customers requirements, which means that the features that determine the level of products quality perceived by customers become measurable and its improvement can be tracked.

Six Sigma is a set of techniques and advanced tools based on mathematical statistics that should be implemented in a prepared environment. As Six Sigma is based on a process approach, it seems that a maturity models derived from the CMMI process maturity model (Capability Maturity Model Integration) [1] would be a good measure to verify the organization's readiness for implementing Six Sigma.

Maturity models are used to diagnose the organization. They allow to determine the level of organization's maturity based on the good practices assigned and followed within the process areas. It is not possible to reach a higher maturity level without effective implementation of good practices assigned to lower maturity levels.

The article presents the essence and instrumentation of the Six Sigma concept. The idea of the process maturity model of the organization, particular levels of maturity and good practices used in production management, assigned to these levels are characterized. Also locations of Six Sigma concepts and tools in the model are shown with indication of methods and tools which should be implemented before implementation of Six Sigma to ensure a success of productivity and quality improvement projects implemented using the Six Sigma instrumentation. Theoretical considerations are illustrated with a case study.

Six Sigma concept

The idea and principles

Six Sigma comes from the TQM concept. Nowadays it is more and more often regarded as an off-road management concept and defined as a comprehensive and flexible program designed to reduce defects, lower costs, save time, and improve customer satisfaction. Six Sigma is a comprehensive system – a strategy, a discipline and a set of tools – for achieving and sustaining business success. It is a strategy because it focuses on total customer satisfaction. It is a discipline because it follows formal improvement model called DMAIC and it is a discipline for it, and it is a discipline for it and it is a formal set of statistical tools [2].

Six Sigma was created on the basis of other quality management concepts [3]. At the beginning of activities aimed at improving quality, mainly through control, was the use of the SPC tool (Statistical Process Control) on a large scale. Then, quality assurance tools, such as FMEA, were used and quality management strategies implemented based on many of the previous management concepts. Six Sigma was heavily inspired by TQM and zero defects [4]. At the and it could be said that it is a disciplined approach for improving manufacturing or service processes applying different tools and techniques [5].

Six Sigma assumes a continuous improvement of customer satisfaction, which translates into the organization's profit by improving the quality level. The measure of the process quality level of is the sigma value, which informs about the number of defects per million opportunities – DPMO. Table 1 contains the indicated sigma quality levels depending on the DPMO.

Table 1
Sigma quality levels depending on DPMO [6].

Indicator	Sigma level					
	1	2	3	4	5	6
Acceptable error number [DPMO]	697 700	308 537	66 807	6210	233	3.4
Share of products that meet the requirements [%]	30.9	69.2	93.3	99.4	99.98	99.9997

Table 2
Six Sigma phases – DMAIC methodology [8].

Phase	Description	Steps
D	**Defining the problem and launching a project leading to find the solution** Developing a plan for improving the company's performance	– business analysis of the project (goals and critical points) – booking of resources with the sponsor – setting up a team (roles and responsibilities) – work schedule – identification and description of processes – defining the customer's voice (requirements)
M	**Measurement of process performance** It is based on measuring the company's systems and processes – measuring the current state, setting goals	- process map (general and detailed) – identification and selection of variables – data collection plan – evaluation of the measuring system (measuring instruments, type of measurement, recording) – initial process capability (determination of non-compliance level, DPMO, sigma level)
A	**Data analysis and identification of improvement opportunities** Processing the data collected from the previous phase and comparing them to certain patterns, objectives or established initial process abilities	– analysis of correlation between variables – verification of hypotheses – elaboration of a list of root causes of the problem – identification of sources of variation
I	**Process improvement** Introducing a change that will improve the current quality status – it can be the improvement of the process or the business management system	– generating solutions – evaluation and choice of solution – risk assessment – action plan – implementation of the solution
C	**Control** Monitoring the key process features in the enterprise to provide the intended capabilities, specific values of key variables and standardization of best practices	– evaluation of the results obtained – setting a new standard – creation of a control plan – assessment of business results – closing the project

"Sigma level" refers to the standard deviation of the population. If the distribution of a given characteristic is described by a normal distribution, then the sigma level determines the number of times the standard deviation of a given feature falls into the middle of the tolerance field [6]. The level "6 sigma" means that in the occurrence of a given feature, only 3.4 errors will occur per million events. An example could be production, in which there were 3.4 deficiencies per million parts produced.

Tending to maintaining processes at a level 3.4 defects per million possibilities (at the level of "six sigmas"), should take place using known and available tools and methods of quality improvement and problem-solving to reach the most effective applications [7].

Leading processes to a specific sigma level takes place using the DMAIC cycle (D – Define, M – Measure, A – Analyze, I – Improve, C – Control) characteristic for the Six Sigma concept [8]. Activities in the relevant phases are shown in Table 2.

The realization of the Six Sigma project is carried out in accordance with the cycle presented in Table 2. Precisely defined schedule and carefully selected methods for each stage, allow for effective elimination of variability in the process and improve a level of customer satisfaction.

An impact of Six Sigma implementation on productivity improvement

The statement "improving the quality improves productivity" [9] is known already for a long time. It indicates a significant impact of pro-quality approaches on production management.

The variability is an inherent feature of manufacturing processes. A part of the variability is natural, embedded in the process and should be expected even if there were no disturbances in the process. It is caused by the so-called common factors. The second type of variation is special variability, caused by specific factors that have disrupted the process [10]. This variability means that some manufactured products do not meet the requirements set out in the specification, i.e. they "do not fall" within the tolerance limits. Presented in article case study is related with manufacturing and engineering in one of global companies. Traditionally, engineering problems have been formulated to handle uncertainty [...] and the concepts of six sigma can be defined in an engineering design context as reliability and robustness [11]. The six sigma helps to take the process into conformance to customers' requirements' with keeping the process at zero defect level and meeting all the specification of product/service all the time without variability [12].

The use of quality management tools in the organization allows to reduce the risks from the emerging variability inside and outside the enterprise. The combination of rules, standards and pro-quality approaches such as TQM, SPC or Six Sigma affects the culture and organization of work. Statistical process control reduces the number of deficiencies. The systemic approach to quality assurance through the system of audits increases the responsibility for quality. But the goal is so-called quality management, where all employees are involved in the continuous improvement of quality in all spheres of the company's operation, able to use auxiliary methods and tools, including mainly statistical ones.

Six Sigma methodology is a synthetic combination of the mentioned approaches to quality management. It helps people to achieve the needs of the market [13]. In this way, Six Sigma contributes to maintaining the organization in constant readiness to act and respond to emerging changes.

The key feature of the Six Sigma concept is the use of a process approach and measurability. By collecting data on the key metrics (quality, price and delivery) and analyzing such data the organization can identify areas for continuous improvement. Process efficiency measurers are based on the degree of meeting customer requirements. At the beginning, Six Sigma helps to identify the expected results (key parameters, key values for the customer), which are defined in the specifications or documentation of the process, and then provide tools to measure them. In subsequent stages, it allows to refer the collected data to the values identified at the beginning and position them appropriately within the defined limits and tolerances. At this point, the parameterization of the Six Sigma concept is visible: the process is diagnosed using the parameter "sigma level". By analyzing the collected data, it is possible to assess the effectiveness of processes and identify areas for improvement, as well as to define measurable goals to be achieved expressed by the "sigma level". Precise parameterization of the process using the "sigma level" and focus on achieving tangible results allow [13]:

- differentiate and identify types of quality costs that appear in the diagnosed processes;
- to quantify the quality costs in order to confirm the need for improvement, and to further establish a benchmark (sigma level) which indicates the priorities for action for project teams in the organization;
- transform processes that are facing serious problems and increase the rate of improvement of or-

ganization's productivity in relation to the competitors and improve the degree of meeting the growing expectations of customers.

The justified and well-thought-out application of the Six Sigma concept in organization with the appropriate advancement of production processes allow to achieve the quality leverage, i.e. bring quality improvement while bringing benefits to clients and organizations [13].

The key to applying the Six Sigma concept in organization is its proper preparation. Oakland states that "Six Sigma organizations, in addition to focusing on customer satisfaction, in continuous improvement, are responsive to change" 14]. So how to assess whether the company is properly prepared to implement the Six Sigma concept? It seems that the appropriate tool for assessing this multi-faceted preparation for successful implementation of Six Sigma projects is the organization's maturity model.

Production management maturity model

Structure of the production management maturity model

Maturity models were developed as a response to the need of measuring a progress achieved by the organization as a result of continuous improvement. They constitute an attempt of a quantitative evaluation of qualitative features [15]. The maturity model is a framework of tools and practices, enabling a comprehensive appraisal of organization's key competencies in managing and improving crucial factors leading to the established goals [16].

The typical structure of the maturity model is formed by four connected elements which are presented in Fig. 1 [17]:

Maturity level – degree of process improvement across a predefined set of process areas, in which all goals in the set are attained.

Process area – a cluster of related practices in an area that, when implemented collectively, satisfy a set of goals considered important for making significant improvement in that area.

Objectives (generic and specific goals) – characteristics, that must be present to satisfy that process area.

Best practices (generic and specific) – a set of methods and tools assigned to process areas, the effective implementation of which will allow to meet the objectives and then achieve a certain level of maturity.

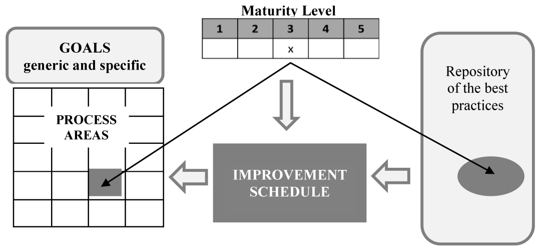


Fig. 1. The general structure of maturity model [18].

Maturity of the organization is determined by verifying compliance with the requirements (targets) set for individual process areas in connection with the degree of implementation of good practices assigned to the process areas, which can be equated with the scope of competences and skills. The most commonly used rating scale in maturity models is the discrete scale from 1 (the lowest level) to 5 (the highest level).

Maturity models are formulated for different organizations (business and administration) and for different areas (quality management, production management, project management, knowledge management, risk management, etc.). A term maturity level in the field of production management, derived from CMMI, is denoting how advanced an organisation is in organising and managing its production processes. The levels are called production maturity levels. Specific levels are outlined in Table 3.

Table 3
Production maturity levels [19].

No of Level	Maturity Levels	Short characteristics
Level 1	performed production processes	targets are met (adequate products are manufactured in the right quantity and on time) – but these processes are not iterative or predictable, which makes it impossible to control progress
Level 2	managed production processes	production targets are met as a result of implementing plans and progress is monitored for consistency with plans
Level 3	defined production processes	production targets are met in processes defined (described) in line with the process approach parameters
Level 4	quantitatively managed production processes	quantitative and qualitative targets and performance control tools have been defined for individual processes and their constituents (operations)
Level 5	optimised production processes	processes are continuously improved and adapted to changing environment and corporate strategy

Individual levels of maturity are achieved due to the implementation of good practices assigned to individual levels in the organization.

Assignment of best practices to maturity levels

Table 4 shows the best practices used in production management systems LM, TQM, TPM, TOC, Six Sigma, and Kaizen according to the production maturity level.

Table 4 shows that effective implementation of solutions using the Six Sigma is possible in organizations that have fully achieved at least the third level of production maturity. To implement the DMAIC effectively the standardization with full process documentation and processes maps with description should be implemented at least. Some improvements tools should be also used like VSM, 5S, Kaizen and Maintenance System. The relation between production maturity level for selected organization and implementation of Six Sigma tools will be wider described in Sec. 4.

Table 4
Assignment of best practices maturity levels [20].

Maturity level	Methods and tools used at a given level
1. Performed production processes	• vaguely defined product quality parameters connected with customers' demands • using employees' tacit knowledge • general control
2. Managed production processes	• complete documentation (construction, technological and organizational) • 5S – sorting, setting in order, shining, standardization • machine maintenance standards – autonomous maintenance • quality goals and standards for key processes (e.g. Cp, Cpk) • work standardization (operational standards for workstations) • production planning • employee training system • initial level of the Kaizen system
3. Defined production processes	• production and supply process maps • VSM – identification and value stream mapping • waste identification and elimination • workstation layout adjusted to the processes' requirements • quality assurance system (e.g. ISO, HACCP, QS, TS etc.) • cooperation with suppliers guarantees a constant level of quality of materials and components • collecting data on quality for using in the future • maintenance system (prevention, diagnostics and autonomous maintenance schedules) • Kaizen – problem identification and solving
4. Quantitatively managed production processes	• productivity and quality measures established • SPC – identification of special causes of process variation • DMAIC (Six Sigma) • OEE – overall equipment effectiveness • SMED – quick set-up • visual management • presentation of productivity and quality performance • pull system – kanban • supplier partnering • Kaizen – continuous problem solving
5. Optimized production processes	• process re-engineering – value stream optimization • implemented Kaizen in the whole organization • benchmarking – aiming to get the best results in one's field • SPC – identification of common causes of process variation • DMAIC (Six Sigma) • teamwork, culture of productivity • pull system, one piece flow • TPM – no equipment failures

Table 5
The assignment of Six Sigma steps to production maturity level (source: own studies).

Maturity level	Steps of Six Sigma implementation
1. Performed production processes	Some quality data is recorded in the company (especially customer scraps and complaints), but the goals are achieved based on the intuition and unprocessed experience of employees – no requirements and specifications; No use of statistical tools; Lack of illustration and interpretation of process current state – processes are unrepeatable and unpredictable – no quality goals have been set; Inability to identify and interpret the concept of process variability – a process out of control.
2. Managed production processes	The variability of process results is known and understood in the company – possible identification of the variability causes (normal and special) – reference to the established construction, technological and organizational documentation The company's goals are realized through the implementation of plans built based on the ability to identify and predict the "behaviors" of the process The organization determines the Cp and Cpk capability indicators in relation to final products and based on the interpretation of the value of 6σ scale assesses the key production processes – the process is supervised in terms of compliance with the plan and corrected in case of deviation (corrective measures are undertaken).
3. Defined production processes	Most of the processes have been defined (inputs, outputs, stages and results of the process are known) and assessed in terms of the level of ability to meet the requirements on 6σ scale and DPMO At this stage, the processes are described in more detail and carried out more precisely – a level of capacity satisfying at a given stage was determined and due to this production goals are achieved (in accordance with the requirements of the process approach).
4. Quantitatively managed production processes	The measures and quantitative and qualitative objectives were established for individual processes and their component parts (operations). Processes are managed based on the observation of process variability using specific statistical tools – SPC cards – which are used to detect special causes of variability. Attempts to carry out projects using the DMAIC methodology.
5. Optimized production processes	The company has implemented and fully used SPC, not only to measure the obtained results, but also to their continuous improvement in accordance with the DMAIC cycle. SPC is used to identify special and common causes of variability, reduce their impact on the process and achieve next level on the 6σ scale. The use of SPC allows you to adapt to changing environmental conditions and set the directions of the organization's strategy.

Six Sigma and the production maturity level

The structured approach to process improvement following the Six Sigma concept allows the assignment of the methods and tools used to appropriate maturity levels. The assignment of activities and statistical tools for the Six Sigma concept to levels of maturity is provided in Table 5.

The lists of tools presented in description of Six Sigma implementation steps (Table 5), show the appropriate sequence of implementing statistical tools depending on the level of maturity already achieved.

Case study

The case study aim is to show that effective implementation of solutions using the DMAIC cycle and a full set of statistical Six Sigma tools is possible in organizations that have fully achieved at least the third level of production maturity and in which good practices have been implemented, such as (based on Table 4):

- Descriptions and processes maps;
- Standardization and full process documentation;
- VSM – identification of the value stream and elimination of losses;
- 5S;
- Kaizen system – identification and problem solving;
- Maintenance system.

The described example of a quality improvement project based on Six Sigma approach comes from enterprise manufacturing industrial automation devices. In general, considered company is the global one, which offers products through four segments: cooling, heating, drives and power solutions. The company has 69 factories and 50 sales companies in every region of the world, employing 26 000 people. The considered case study comes from Polish site of the company, the refrigeration and cooling segment. The factory is divided into 5 production departments and in each of them on production lines where in total c.a. 900 operators are working. The data used in further part of this chapter comes from production process where water regulating valves are manufactured.

The production line consists of 6 workstations with U-shape layout. The production is medium-lot, which means that several types of products are produced on the line. The products flow sequentially through the stations. One operator per shift is working at this subassembly line (one operator on 6 workstations). The average time of manufacturing the products is three minutes (assuming low value of machine failure indicator and excellent quality and availability of all production components). The main problems identified with Pareto diagram that occur at production line are: machine breakdowns, additional control, sorting, reworks and high scrap ratio. Most of them are connected with quality problems: process variability and lack of repeatability over time.

It was identified that considered production processes have implemented good practices mentioned at the beginning of this chapter. Based on checklist consists of all good practices defined in Table 4 and Table 5, it was assessed that processes maturity level is placed at the third level so it is possible to try implement more advanced improvement tool like Six Sigma.

The factor that initiated the improvement process was the unstable production process, manifested by the lack of repeatability in obtaining key characteristics during production process of element A, to be included in a product X – kind of a switch. This led to the loss of functionality of the product X. It did not switch as required by the customer. It was a signal for the management to pay attention for the requirements specified in the element A production process specification. In order to solve the problem with the DMAIC methodology, an interdisciplinary team with the participation of research and development engineers was established. The team acted as described below.

Define. The project began with defining and verifying requirements for element A and product X. Based on the details of the SIPOCR process map (Supplier, Inputs, Process, Output, Customer, Requirements), input and output variables of the process were defined and their mutual influence was determined. The key parameter of the process was weight of the element A which was referred to the requirements from the product specification (defined weight tolerances for element A). Until that time, after starting the production of element A, the first three pieces from the production order had been controlled. If the first three pieces of the order were in the given tolerances, only one per 20 pieces had been controlled. The observations showed that the item's weight of many pieces were out of tolerance and unrepeatable. Moreover, the X products with such pieces completely lost their required functionality.

Measure. In the measurement phase, a plan for data collection and control of element A was developed. Based on the collected and recorded data, the waste in the process was verified (using the Pareto-Lorenzo chart) and referred to the quality standards for this area. The representative sample of 30 measurements was selected from entered register and analyzed using the Minitab statistical program.

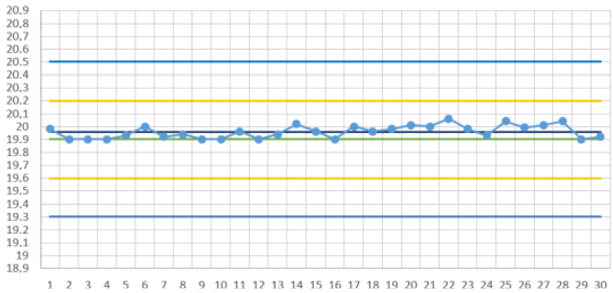
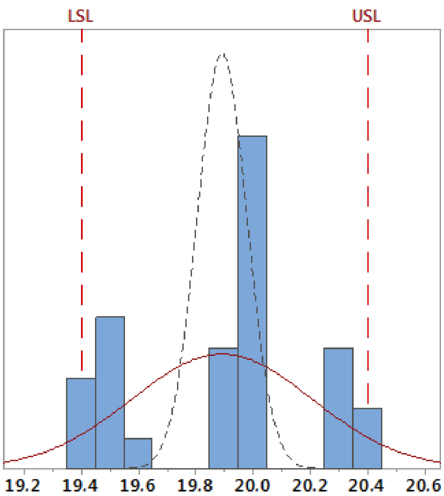
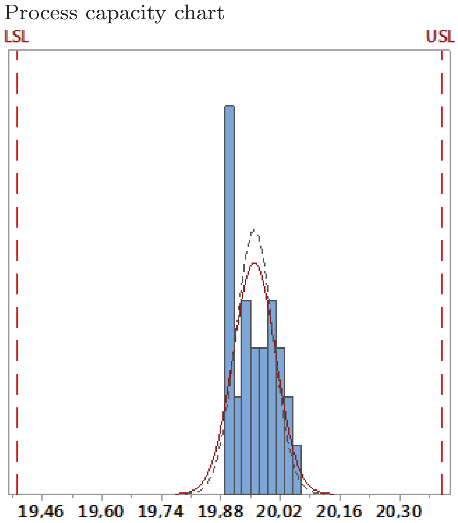
Analyse. Based on the collected data, the process capability was analyzed. It was noticed that the weight of element A in the production process is unrepeatable and the process is unstable (the values of C_p and P_p and C_{pk} and P_{pk} are not similar). The process is stable when the values of short-term (C_p and C_{pk}) and long-term indicators (P_p and P_{pk}) are similar to each other. In addition, among 30 samples there were values outside the tolerance limits. In this situation, steps have been taken to determine whether the source of variability in the process is caused by special causes or whether it is due to common reasons. Based on existing process maps, the team created and analysed a C&E matrix (Cause and Effects Matrix) and identified that the source of variability are special causes: element weight in 96.5% was within tolerance and 3.5% outside.

A control card has been created by taking the tolerance limits as the upper and lower control limits. A clear trend of several consecutive events was clearly visible above and below the expected value of the process, which indicated the existence of a special reason for variability. The use of the existing PFMEA and building a detailed map of the SIPOCR process helped to find the reason, which indicated that the possible cause of the problem lies with the supplier of material. The weight of component A was increased by contamination resulted from the supplier's treatment, what affected on disorder work of the product X.

Improve. To confirm the hypothesis about the effect of impurities on the weight result of element A, in the improvement phase, special samples (free of impurities) were prepared. The analysis of the data showed that the process complies with the requirements and the characteristic of element A is in tolerance after the removal of special reasons. In addition, it was observed that the functionality of X product was restored. The claim process in accordance the method used to solve the problem – the 8D process was initiated at the supplier of a component A to avoid such problem in the future.

Control. The last step within the DMAIC cycle was the assessment of the ability to meet the requirements on the 6σ scale. After eliminating the cause of variation the element A reached a normal distribution and the DPMO dropped to 0. The level of short- and long-term ability was determined for element A ($C_p = 3.79$, $P_p = 3, 32$). It was decided that C_p and $P_p > 3.0$ are accepted as satisfactory. Establishing a satisfactory level of process capability was only a starting point for further actions to ensure quality. The original frequency of controlling the weight of the element turned out to be unsatisfactory. Therefore, it was decided to introduce SPC cards, with upper and lower control limits (LCL = 19.6, UCL = 20.2, 6 sigma level (6 * standard deviation from the nominal value)) and upper and lower specification limit (USL = 20.5, LSL = 19.3). The element A control plan has been updated by introducing weighting every tenth piece in the process. In this way, in the event of emergence of variation in the process, operators, observing the entries on the SPC card, informed the persons responsible for the process in advance. Thanks to this action, the chance to eliminate the source of variation with success is greater. Collecting data on SPC cards is the starting point for further improvements. It allows identification of special causes of variability and facilitates data collection. The results of the Six Sigma project are shown in Table 6.

Table 6
Comparison of the state before and after applying Six Sigma (SS) solutions.

Before SS tools implementation	After SS tools implementation
Central line: 19.9 g Tollerances: 19.4–20.4 g	Central line: 19,9 g Tollerances: LSL = 19.3 g, USL = 20.5 g, LCL = 19.6 g, UCL = 20.2 g
No control charts	Control chart 
DPMO = 33333.00 Sigma level = 3	DPMO = 0 Sigma level = 6
$\mu = 19.89$	$\mu = 19.96$
Process capacity indicators $C_p = 1.91$, $P_p = 0.53$, $C_{pk} = 1.88$, $P_{pk} = 0.52$ $C_p \neq P_p$, $C_{pk} \neq P_{pk}$, $p < 0.005$	Process capacity indicators $C_p = 3.79$, $P_p = 3.32$, $C_{pk} = 3.34$, $P_{pk} = 2.29$ $C_p \approx P_p$, $C_{pk} \approx P_{pk}$, $p = 0.028$
Process capacity chart 	Process capacity chart 

Proper preparation of the company, both in the area of implementation of Six Sigma tools and in other process areas was the key to achieving the success of the Six Sigma project in an industrial automation enterprise. The identification of the achieved level of production maturity and the Six Sigma tools used in the case study is presented in Table 7.

Table 7
The diagnosis of production maturity level in industrial automation enterprise (source: own study).

Production maturity level	Steps of Six Sigma – tools implementation	Diagnosis
1. Performed production processes	Forms for registering qualitative data	Forms to collect data: order number, order size, weight of A element, operator number, date
	Registration of qualitative data	Registration of element A weight (3 first pcs control, then every 20th pcs from an order)
2. Managed production processes	Illustration and interpretation of events in processes and identification of process variability	30 trials selection; data analysis in statistical program Minitab
	Process capacity establishment	Capability analysis based on normal distribution); C_p (1.91) and C_{pk} (1.88) calculation – instable process; 3 sigma level identification
	Relating the established capacity to the requirements of construction, technological and organizational documentation	Requirements for element A: 19.4–20.4; 3% out of tolerance; high process dispersion, unrepeatable process
	Establishing action plans to look for variability (normal and special)	Team cooperation in identifying variability Analysis of data from the process – searching for causes of variability in relation to design requirements
3. Defined production processes	Analysis and definition of key elements of the indicated process with the use of statistical tools	Recording registration data on the control card, using the VSM tools, building the SIPOCR (detailed process map), using the C&E matrix, analysis and identification of waste on the Pareto-Lorenzo chart
	Process variability identification	Identification of the special variability cause (the weight of the components delivered to the process contained contaminations from the supplier's treatment)
	Detailed description of the process and more precise way of production	Manufacturing of samples free of contaminations (5S implementation); Process led into tollerance (new indicators $C_p = 3.79$, $C_{pk} = 3.34$) DPMO = 0, sigma level = 6 Process goal: Cp and $P_p > 3.0$
4. Quantitatively managed production processes	Verification of process measures and quantitative and qualitative goals definition	The key process measure stay the same (weight expressed in grames) Quality goal: C_p and $P_p > 3.0$
	Verification and update of statistical tools usage	SPC introduction: new control plan (every 10 pcs in process) change of upper and lower limit specification (LSL = 19.3 g; USL = 20.5 g)
	Action with DMAIC cycle	Define – product requirements and problem identification Measure – collect data acc. to established plan Analyse – process capacity and variability identification Improve – variability elimination Control – SPC introduction
5. Optimised production processes	SPC implemented and used to normal and special process variability identification	Collecting data with SPC – possibility to identify special process variability *Identifying normal variability with SPC – still at implementation*
	Systematic improvement of processes with the DMAIC	*Still at implementation*

The assessment of the company's readiness for implementation Six Sigma places the analyzed organization on the fourth maturity level. Implementation of the DMAIC cycle and Six Sigma tools is possible when the organization reaches at least level three – defined processes, i.e. the precondition is met in the analyzed example. From the DMAIC methodology point of view it is important because its cycle begins with "defining": requirements for the product, defining the problem, setting up a team. Next, goes to the measurement phase, where the standards to map the process are used, the current state is established and the base line determined. In the next phase, the identified problem is analyzed with the use of statistic tools (capability studies, normality test, DPMO) and the plan to search for the source of variation is created. The next step, is the improve phase deals with finding a cause of variability and bringing the current state to compliance with the requirements for the process and the product. The last phase (control) equips the process with tools for monitoring and identification of variability. However, achieving the highest level of maturity of the analyzed organization is impossible due to the lack of systematic use of DMAIC in daily life of enterprise. Also, the SPC card system requires to be used not only to identify special causes, but also common causes of variation. These two points are being implemented.

Conclusion

The case study illustrates the successfully implemented project of improving quality and productivity which was implemented with the Six Sigma concept based on the company's level of production maturity diagnosis. Achieving success in implementing Six Sigma solutions is dictated by the use of an

Table 8
Production maturity level identification based of Six Sigma tools usage (source: own studies).

Production maturity level	Six Sigma tools dedicated to individual levels of organization maturity
1. Performed production processes	Data collecting plan Continuous and snapshot observation (creating forms for registration) Process mapping (creating simple forms for data collecting)
2. Managed production processes	Process Map, Value Map Value analyse, economic analyse Pareto-Lorenz chart, waste analysis Box plot Basic statistical tools (histogram, process capacity, C_p, C_{pk}, correlation) DPMO and sigma level identification 5 × Why Ishikawa diagram Data collection and control plan (frequency, quantity, devices, type of measurement)
3. Defined production processes	Project Charter FMEA basic Brainstorm Histogram, normal distribution, capability analysis Control charts Simple Poka-Yoke solutions MSA (Measurement System Analysis) for key process elements (repeatability and reproducibility >30%)
4. Quantitatively managed production processes	SPC Some machines have Poka-Yoke solutions MSA for selected process steps (repeatability and reproducibility 10–30%) Full quality documentation (PFMEA, CP, Flow Charts) Statistical tools (multivariate tools, hipothesis tests, regression, correlation, ANOVA, variance analysis Experiment (plan Shainin or Taguchi) DOE (Design of Experiments) 5S, Standardization
5. Optimised production processes	All machines have Poka-Yoke MSA for all process steps (repeatability and reproducibility <10%) All tools from DMAIC methodology are used Simulations, benchmarking TPM Customer requirements analysis (KANO, QFD model) Creating organizational structures with appropriate competence levels in the field of SS (Green Belt, Black Belt etc.)

appropriate approach and appropriate methods and techniques. If the implementation of the solution is to be effective, it is necessary to select and apply statistical methods and tools to improve the current state appropriate to the level of production processes maturity in the enterprise.

The production maturity model used in the case study shows that the improvement of the company's results is possible through the implementation of strictly defined stages: the transition from processes managed effectively to optimized processes. With reference to the organization presented in the case study, it is clearly visible that in order to move to the highest level of maturity, the process areas of the company should be properly prepared. Only after implementation of solutions and tools required on a lower levels, it would be possible to improve and optimize processes using the higher-level methodologies. Based on the case study and an analysis of the maturity model in production management, Table 8 provides a link between the level of organization maturity and the usage of Six Sigma tools.

Most of the authors, including Lunau [21], assigns Six Sigma tools to the stages of the DMAIC structure. The result of the case study is the division of Six Sigma tools according to the maturity level of the production processes and the competencies of employees according to next achieved levels of maturity. Most of the tools (methods and techniques) of Six Sigma are specific practices and they are recommended for implementation at fourth level maturity. However, Six Sigma also uses generic best practices, which should be implemented when the company achieves lower maturity levels and which provide a foundation for more advanced tools.

Masaaki Imai [22] have already claimed that it is impossible to optimize a process that does not have a standard and requirements, i.e. it is not defined. When implementing the tools of the DMAIC methodology, characteristic of the Six Sigma concept, it is necessary for the organization to achieve at least the maturity third level. It is not possible to effectively use all the tools of the DMAIC cycle at the first and second level of the organization's maturity in the area of production management. The key competences of the organization for the implementation of Six Sigma are value stream mapping, Kaizen system and standardization based on complete process documentation.

The presented case study shows the impact of production maturity of the enterprise on the successful implementation of the improvement project based on six sigma concept and tools. This may be the starting point for formulation the further research hypothesis and carrying out a more extensive quantity research.

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