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# ASSESSMENT OF THE PRODUCTION PROCESS ORGANIZATION IN THE METAL INDUSTRY - CASE STUDY

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**Abstract:** The article provides a detailed case study illustrating the practical application of BOST surveys while focusing on the third principle of Toyota. This particular principle underscores the importance of achieving an even distribution in production to mitigate fluctuations and ensure the smooth functioning of the production process. The article delves into a comprehensive analysis of how this principle is implemented in real-world scenarios, exploring its effects on production efficiency and elucidating the advantages gained from the elimination of downtime and the prevention of excessive inventory buildup. Moreover, the article offers a discussion on examples of applications across various industries, shedding light on practical strategies for implementing the third Toyota principle. The goal is to not only optimize production processes but also enhance flexibility and adaptability to evolving demand patterns. The article concludes by examining the pivotal role of this principle within the broader context of operational excellence and the development of more efficient production systems. The research in focus centers around a company operating in the metal industry. Through the utilization of BOST questionnaire surveys, production workers within the company expressed their perspectives, revealing which factors they deemed most crucial. The analysis of research results takes various forms, including tables, histograms, radar charts, and several statistical tools. The overarching objective of this analysis is to identify and present the most critical factors by constructing significance sequences based on the obtained results. The findings obtained for small and medium-sized enterprises align with results from similar tests conducted in different business settings, indicating a level of consistency and applicability across various organizational contexts.
**Keywords:** BOST method, Toyota management principle, production process, statistical analysis

## 1. INTRODUCTION

The contemporary approach to production management has found inspiration in the revolutionary model developed by the Japanese automotive giant – Toyota (Gao and Low, 2015). The Toyota Production System (TPS), also known as the Toyota Production System, has not only become a benchmark for efficiency in the automotive industry but also a significant source of inspiration for businesses worldwide (Ulewicz et al. 2013). The Toyota model has not only become an icon in the automotive industry but also a source of inspiration for companies seeking to improve their production processes, increase efficiency, and enhance flexibility in adapting to changing market conditions (Amasaka, 2012). The Toyota Production System is based on scientific principles and assumes that all separate elements work well for the benefit of the entirety (Liker and Franz, 2011). Toyotarity is a concept which is legally protected by confirming the date. This document contains the following definition of Toyotarity: “Toyotarity is defined as a scientific study of human-machine and human-human 17 interactions with regard to process-based approach and Japanese culture, especially that of Toyota, aimed at continuous improvement with the use of knowledge” (Borkowski, 2012). The fundamental research tool of Toyotarity is the BOST method. It presents the management principles of Toyota in the form of distinct sets of issues that describe specific principles. These sets are referred to as "areas. The BOST method describes Toyota’s management principles with its characteristic factors. Each of these principles described with an appropriate set of factors. Toyota’s management principles are divided into sections that contains a set of factors describing principles: 1; 2; 3; 4; 6; 7; 14 and elements of the roof of Toyota’s house. BOST studies are aimed to prove that in enterprises operating in Poland, irrespective of conducted activity, the employees unconsciously use management principles, about which perhaps they never heard. Respondents may assess the significance of a given factor by placing one of the numbers within the range of scale in an appropriate box (A preliminary condition for classification of the companies to BOST study was confirmed information about implementation of Toyota management principles in the workstations in analyzed company. The researched company is a producer of car parts manufacturer. All products have safety certificates confirming the compliance of the products with the applicable standards and the high quality of the manufactured products (Ohno, 2008). In today's dynamic business environment, companies are seeking innovative methods to improve their management and production processes. In this context, the management principles introduced by Toyota, known as the Toyota Principles, represent an exceptionally valuable model (Borkowski et al., 2013). However, to fully leverage the potential of these principles, it is essential to utilize the appropriate tools. One such tool is the BOST method (Selejdak, 2015) .

## 2. METHODOLOGY OF RESEARCH

The metal industry is an economic sector encompassing diverse enterprises engaged in the production, processing, and treatment of metals. It is characterized by significant diversity, including the production of non-ferrous and colored metals, as well as finished metal products. In this industry, one can find metallurgical plants, foundries, machining facilities, producers of metallurgical products, structural components, and companies specializing in the manufacturing of tools, machinery, and metal equipment. The metal industry plays a crucial role in various sectors of the economy, as it supplies the raw materials and components necessary for the production of a wide range of products (Klimecka-Tatar and Ingaldi, 2022). It includes both large corporations and smaller enterprises providing metal processing services. The development dynamics of this industry often depend on global market conditions, technological innovations, and the demand for metal products in various industrial sectors. The surveyed company specializes in the production of precision metal elements, such as parts for machinery, tools, and metal constructions. It also offers comprehensive metal processing services, including turning, milling, bending, laser cutting, and welding, using modern technologies

and CNC machines. The company supplies products to various industries, including the automotive, construction, and machinery sectors. It operates on a medium scale, serving both individual customers and businesses in the southern Poland region. The company invests in cutting-edge technologies to ensure high quality and precision for its customers. It utilizes advanced CAD/CAM systems and numerically controlled machines. Building close relationships with local businesses, the company provides tailored metal solutions and participates in community projects. It maintains a team of experienced specialists in metal processing, including engineers, technologists, and machine operators. Having quality certificates confirming compliance with industry standards enhances customer trust. The company also strives for continuous improvement and innovation, keeping abreast of the latest trends in the industry to maintain competitiveness in the market. Employees of company were asked to fill out a survey, which allowed for the analysis of the BOST study. The analysis of one of the principles will be presented in the work - the E4 area, which is one of the Toyota Management Principles. Area E4 concerns the organization of the production system. Respondents had to answer the question:
The organization of the production system ensures: In the box, enter 1, 2, 3, 4 (4 being the most important element).

| | | |
|---|---|---|
| DZ | | Deliveries on customer "demand" |
| MM | | Maximum utilization of machines, people |
| PZ | | Formation of product stocks |
| BS | | Quick order processing |

The extensive questionnaire survey targeted the production workers within the researched enterprise, which specializes in the production of metal products. The inclusion of 40% of production staff in the survey was a deliberate choice to ensure a comprehensive and representative sample. This sizable group of directly involved production workers plays a crucial role in the operational processes of the company. By focusing on this specific demographic, the survey aims to gather insights directly from those who contribute to the day-to-day production activities. This approach enhances the reliability and relevance of the collected data, allowing for a more accurate and targeted analysis of the key areas within the surveyed enterprise (Knop and Mielczarek, 2018).
Circular charts illustrate the characteristics of respondents. Due to the specific nature of production, men constitute 72% of those surveyed, while women make up 28%. Employees with vocational education represent 28%. The next group consists of employees with secondary education, comprising 16% of the total. Employees with higher education make up the majority at 56%. In Fig. 1c, data regarding the age of respondents is presented. Employees up to 30 years old constitute 6%, while those in the age range from 31 to 40 years represent 44% of respondents. In the age group from 41 to 50 years, respondents account for 19%. Those in the age group from 51 to 55 years make up 25%. Employees with up to five years of experience constitute 31%, while in the range from 6 to 10 years, employees represent 16%. Fig. 1e indicates that for 31%, it is the second employment, and for 38%, it is the third employment. Fig. 1e shows how respondents were employed in the company. The largest group, constituting 66%, consists of employees hired on a regular basis, 13% were hired through transfer, and 22% were employed due to better financial conditions.

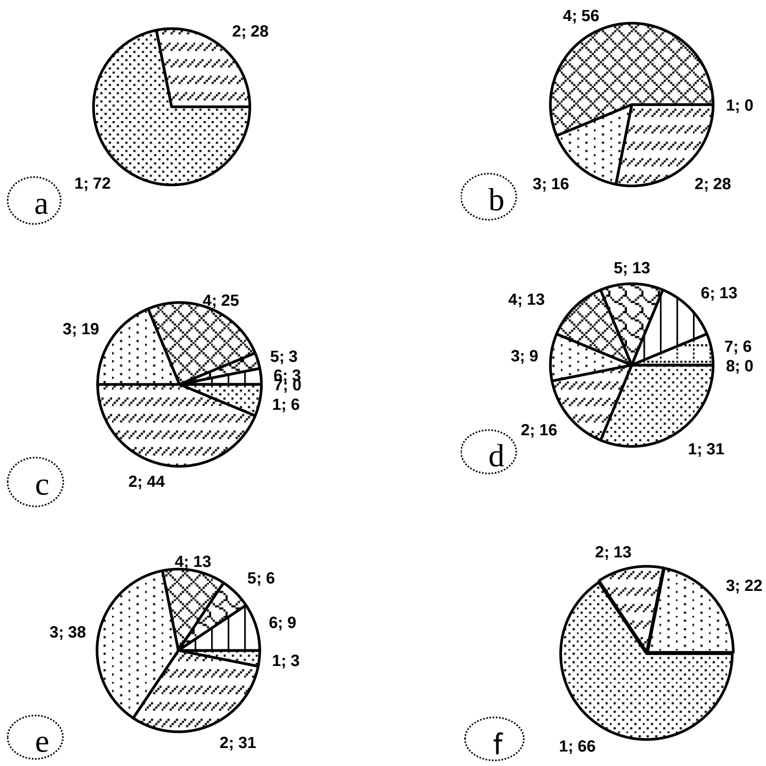


Fig. 1. Circular charts – percentual characteristics of respondents considering: a) gender, b) education, c) age, d) tenure, e) mobility, f) employment status

## 3. GRAPHIC PRESENTATION OF RATES STRUCTURE

Fig. 2 depicts radar charts describing the structure of ratings for the importance of factors in the organization of the production system for each factor belonging to E4 area. In Fig. 2a, the structure of importance ratings for the "on-demand" customer delivery factor (DZ) is presented. 12.5% of respondents rated this factor as “1”. The majority, 59.4% of respondents, rated the factor as “4”. In Fig. 2b, the structure of importance ratings for the factor of Maximum utilization of machines and people (MM) is shown. 25% of respondents each gave a rating “1” and “2”. 37.5% of respondents rated this factor as “3”.In Fig. 2c, the structure of importance ratings for the factor of the Formation of product stocks (PZ) is presented. The highest percentage of respondents, 37.5%, gave a rating “1”. 28.1% of respondents gave it a rating ‘2’. In Fig. 2d, the structure of importance ratings for the factor Quick order processing (BS) is shown. 25% of respondents gave it a rating “1”. 31.3% of respondents gave it a rating “2” and 37.5% gave a rating “3”, and only 6.3% of respondents gave a rating “4”. Fig. 2e illustrates the average distribution of importance ratings for factors that make up the assurance of the organization's production system. According to respondents, the most important assurance is the factor Deliveries on customer "demand" (DZ) with 31.9%. In second place, 23.7% is the factor of Maximum utilization of machines and people (MM).

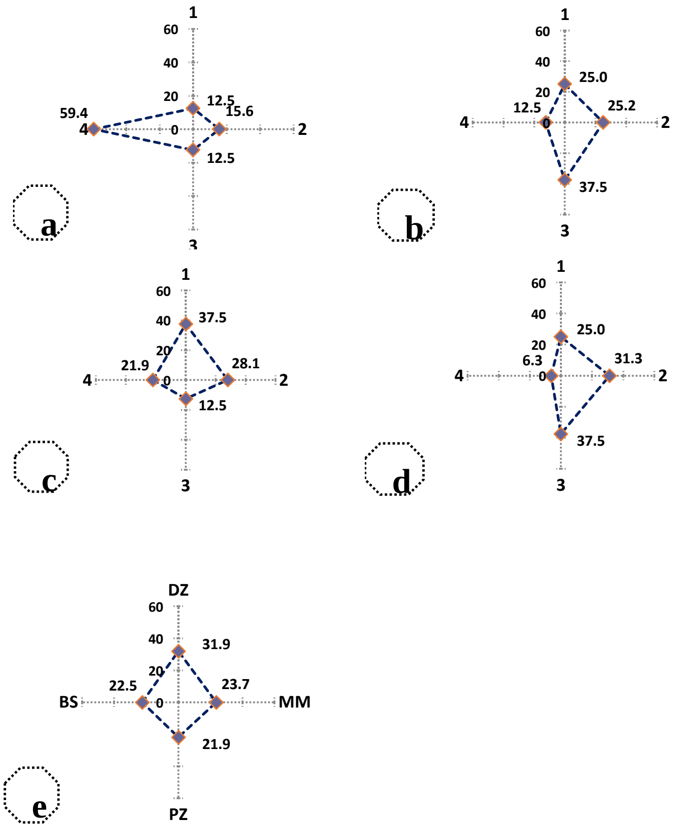


Fig. 2. Radar charts - structure of importance ratings for factors in area E4: a) DZ, b) MM, c) PZ, d) BS, e) average

Production on customer demand, also known as made-to-order manufacturing, is a crucial factor influencing the efficiency and flexibility of production processes. This significant element involves tailoring production to the individual needs of the customer, contributing to the development of a strong and competitive business profile. Production on customer demand is a key factor that not only promotes the individualization of products but also influences the efficiency, flexibility, and competitiveness of the enterprise .

## 4. CORRELATIONAL ASSESSMENT OF E4 PRINCIPLES FACTORS

The correlation between two variables is a measure of the connection occurring between these variables. The value most often indicates the strength of the interdependence of two variables within a range. It should be noted that a value close to zero not always signifies a lack of relation, but only a lack of a linear relation between variables (Knop, 2018). The obtained significance rates for factors describing the third Toyota management principle, along with the respondents' descriptions, served as the basis for defining the relationships between these sets of results. These relationships were presented in the form of graphs (Fig. 3). Each graph characterizes the occurrence and type of correlation between a specific response and gender, education, age, seniority, mobility, and type of employment. The adopted approach includes three levels of significance (α) - 0.05, 0.1, and 0.2. This choice is influenced by the fact that in this type of test, the issue of correlation is not addressed.

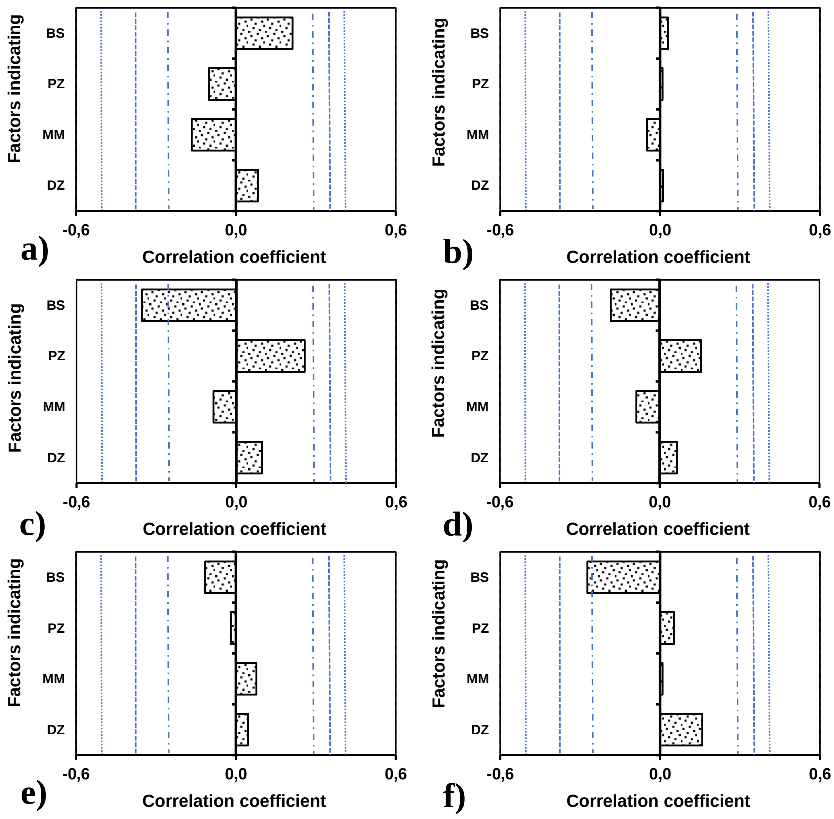


Fig. 3. Principle 3. Correlation graphs of ratings for factors in the E4 area based on respondents' characteristics: a) gender, b) education, c) age, d) work experience, e) mobility, f) employment status. α = 0.2 (inner lines), α = 0.1 (middle lines), α = 0.05 (outer lines)

In Fig. 3a, the influence of gender on the assessment of factors in the E4 area is depicted. Factors such as Deliveries on customer "demand" (DZ) and Quick order processing (BS) obtained positive correlations, while factors like Maximum utilization of machines and people (MM) and formation of product stocks (PZ) showed negative correlations. Fig. 3b illustrates the impact of education on the assessment of factors in the E4 area. Factors such as Deliveries on customer "demand" (DZ), Formation of product stocks (PZ), and stockless system (BS) achieved a slight positive correlation. On the other hand, the factor of Maximum utilization of machines and people (MM) obtained a negative correlation. Fig. 3c presents the influence of age on the assessment of factors in the E4 area. Factors like Formation of product stocks (PZ) and Deliveries on customer "demand" (DZ) achieved positive correlations. The factor of Maximum utilization of machines and people (MM) obtained a negative correlation, and Quick order processing (BS) also reached a significant negative correlation at the α = -0.1 level. In Fig 3d, the impact of work experience on the assessment of factors in the E4 area is illustrated. The factor of the formation of product stocks (PZ) and Deliveries on customer "demand" (DZ) achieved a positive correlation. The factor of Maximum utilization of machines and people (MM) obtained a negative correlation, as well as the stockless system (BS). Fig. 3e shows the influence of mobility on the assessment of factors in the E4 area. Factors like the formation of product stocks (PZ) and Quick order processing (BS) received a negative correlation. Meanwhile, factors like Deliveries on customer "demand" (DZ) and Maximum utilization of machines and people (MM) showed a positive correlation.

In Fig. 3f, the impact of employment status on the assessment of factors in the E area is presented. Factors like the Formation of product stocks (PZ), Maximum utilization of machines and people (MM), and Deliveries on customer "demand" (DZ) have a positive correlation. Quick order processing (BS) achieved a significant negative correlation at the α = 0.2 level. Lack of influence of individual features of respondents is clearly a result of forming enterprise culture, great dispersion of rates or a small test sample.

## 5. STATISTICAL ANALYSIS OF THE RESULTS

In the statistical analysis of the studied area, five tools were employed: arithmetic average, standard deviation, the coefficient of variation, skewness, and excess coefficient. These statistical tools were applied with the aim of illustrating the distribution of evaluations for individual factors.

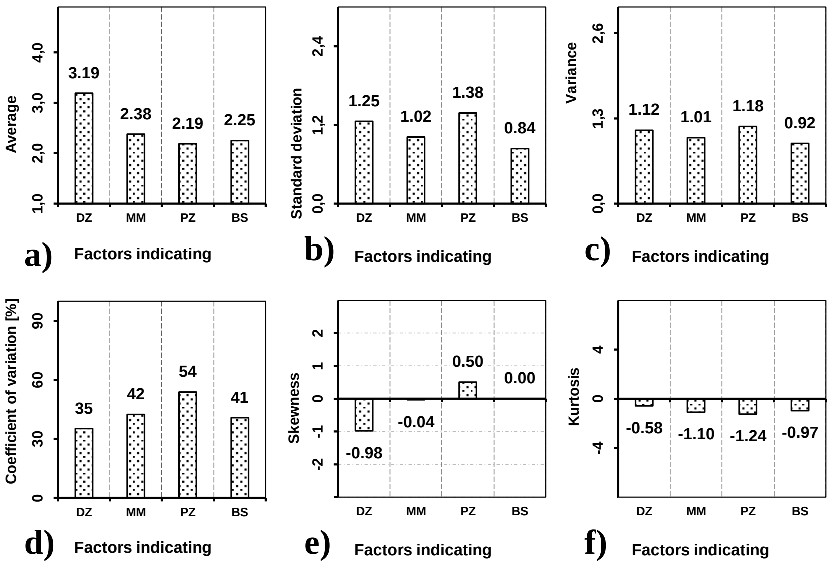


Fig. 4. Principle 3. Comparison: a) average, b) variance, c) standard deviation, d) coefficient of variation, e) skewness, f) kurtosis for factors in the E4 area

Average also known as the mean, is a value that represents the center of a distribution of numerical data. In Fig. 4a, the average ratings for factors in the E4 area are presented. The factor with the highest average rating is Deliveries on customer "demand" (DZ) with a score of 3.19. The lowest average ratings are assigned to the factor Formation of product stocks" (PZ) - 2.19. Standard deviation is a measure of the spread of data around the mean in a given data set. It is an indicator that tells us how much values in the set deviate from the mean. The larger the standard deviation, the greater the spread of data, and the smaller it is, the more concentrated the data is around the mean. Fig. 4b illustrates the standard deviation of ratings for factors in the E4 area, where the highest deviation is observed for the Formation of product stocks (PZ) - 1.38, and the lowest for Quick order processing (BS) - 0.84. Variance is a statistical measure that quantifies the amount of dispersion or spread in a set of data points (Uçurumc et al., 2016). It calculates the average of the squared differences from the mean of a data set (Knop et al., 2019). Fig. 4c shows the variance of ratings for factors, with the lowest value for Quick order processing (BS) - 0.92 and the highest for Formation of product stocks (PZ) - 1.18. The coefficient of variation (CV) is a statistical measure used to assess the relative variability or dispersion of a set of data points in comparison to the mean. The coefficient of variation (Fig. 4d) is the biggest for Formation of product stocks (PZ) - 54. The measurement of skewness is a classic coefficient of asymmetry: (0.0 - 0.4) - very weak distribution asymmetry, (0.4 - 0.8) – weak distribution asymmetry, (0.8 - 1.2) - moderate distribution asymmetry, (1.2 - 1.6) - strong distribution asymmetry, (more than 1.6 – very strong distribution asymmetry). Fig. 4e presents the statistical determinant - skewness, where the factor Formation of product stocks (PZ) has a positive skewness, while Deliveries on customer "demand" (DZ) have negative skewness. Positive skewness indicates right-skewness, and negative skewness indicates left-skewness. Kurtosis is a statistical measure that describes the shape, sharpness, or peakedness of a probability distribution. It provides information about the tails and extremes of the distribution compared to a normal distribution In Fig. 4f, kurtosis of ratings for factors in the E4 area is presented, where all factors exhibit a negative excess coefficient. This statistical tool confirm that distribution of results is logical and can be helpful for evaluation actual state in enterprise.

## 6. COMPARISON OF THE STRUCTURE OF RATINGS AND THE IMPORTANCE OF FACTORS

In Fig. 5a, a comparison of the structure of factor ratings is presented in the form of a histogram, while Fig. 5b depicts a comparison of the importance of factors in rating scales, also in the form of a histogram.

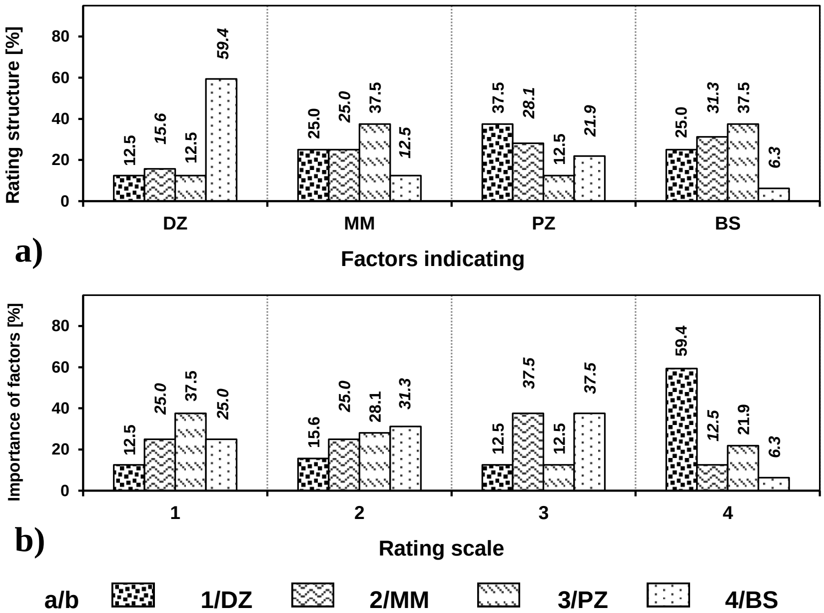


Fig. 5. Principle 3. Histograms. Comparison: a) structure of factor ratings, b) importance of factors in rating scales

The factor Deliveries on customer "demand" (DZ) mostly received a rating of “4”, gathering 59.4% and was considered the most important factor according to the respondents. Additionally, 15.6% of respondents rated this factor as “2”. Ratings of “3” and “1” for this factor received 12.5% of the respondents' votes each. The factor Maximum utilization of machines and people (MM) was rated by the highest percentage of respondents, with 37.5% giving it a rating of “3”. Ratings “1” and “2” were given by 25% of respondents. The factor Formation of product stocks (PZ) was rated as “1” by 37.5% of respondents. 28.1% of respondents gave it a rating “2”. The factor Quick order processing (BS) received a rating “1” from 25% of respondents, 31.3% gave it a rating “2”, 37.5% rated it as “3”, and only 6.3% rated it as “4”. Fig. 5b pertains to the importance of factors in rating scales in the E4 area. Rating “1” was most frequently assigned to the factor Formation of product stocks (PZ), with a factor importance of 37.5%. The factors that were second most often rated 1, with an importance of 25% each, are Maximum utilization of machines and people (MM) and Quick order processing (BS). Rating “4” was most frequently, as much as 59.4%, assigned to the factor Deliveries on customer "demand” (DZ). Next is the factor Formation of product stocks (PZ) with an importance of 21.9%. Following that are the factors Maximum utilization of machines and people (MM) with an importance of 12.5%, and the least frequently rated factor as 4 is Quick order processing (BS), which received only 6.3%.

## 7. SUMMARY

Using a pull system in production involves delivering products promptly, ensuring customers receive what they expect in the requested quantities and within a specified timeframe. This concept is formulated as a set of factors, the significance of which was assessed by respondents. This ensures that products are manufactured or delivered precisely when and in the quantities requested by customers. The goal is to align production closely with customer needs and preferences, fostering efficiency and customer satisfaction. The significance sequences of factors describing Toyota's third management principle are a fascinating aspect. These sequences follow a logical order determined by the organization of the production of a specific product. The results obtained, coupled with their multidimensional analysis, affirm the precision of the selected factors that delineate Toyota's third management principle. The demonstrated high "sensitivity" of these results underscores their effectiveness in assessing the existing conditions within the enterprise. The order in which these factors are deemed significant reveals a thoughtfully structured approach aligned with the intricacies of organizing the production process for a particular item. The results obtained and their in-depth analysis not only validate the appropriateness of the chosen factors but also provide a comprehensive understanding of how they contribute to Toyota's third management principle. The sensitivity exhibited by these results highlights their effectiveness in accurately evaluating the current state and dynamics within the enterprise, offering valuable insights for strategic decision-making. he role of organizing a production system in the metal industry is crucial for the efficiency, quality, and competitiveness of the enterprise. Organizing a production system involves a series of activities aimed at optimizing processes, resources, and the production structure to achieve maximum performance and effectiveness. The production system in the metal industry must be tailored to the specific nature of this sector, considering the diversity of processes, casting, metal processing, and the production of finished metal products. his can contribute to identifying key areas for the functioning of the enterprise, particularly for small and medium-sized enterprises. The research results align with those from similar enterprises. The analyzed fragment highlights the diversity in the significance of factors describing the third Toyota management principle. This demonstrates the efficacy of the presented BOST method in assessing the production process of high-quality goods. According to respondents, the proposed set of factors has been structured in a manner typical of an enterprise producing metal products. The established significance sequence of factors describing the third management principle is logical, confirming the accuracy of their selection. These research findings can be applied to other small and medium-sized enterprises. It's worth noting that production on customer demand is a crucial element that received a high rating and is a significant factor influencing the efficiency and flexibility of production processes. Furthermore, the analysis of age, work experience, and employment mode provides additional context regarding the assessment of individual factors. The final summary indicates that the metal industry has its specific characteristics and challenges, and the applied statistical tools are helpful in understanding and evaluating this area. The insights from the analysis can serve as a starting point for improving production processes in the company and contribute to research on management in the metal industry.

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