DOI: 10.5604/01.3001.0053.9494
Volume 119 • Issue 2 • August 2023
Journal of Achievements in Materials and Manufacturing Engineering
International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

The role of technology in industry according to the BOST method

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ABSTRACT

Purpose: Data for analysis and scientific interpretation was obtained by conducting a qualitative study in an industrial setting, using the BOST questionnaire – Toyota management principles in questions. The foundation of the research was the Eastern, particularly Japanese philosophy of the approach to production, expressed in the participation of the entire workforce in the evaluation and improvement of activities occurring during the manufacture of products.

Design/methodology/approach: The paper will present the results relating to Toyota management principles 1 and 2. Arithmetic averages will be calculated for the sets of scores obtained. They are the basis for the being the material result of the production process. For investigations, the 3x3 matrix, after some modification, will be used to assess the relationship between technological capabilities and product competitiveness. The structure of the map described by the technological capabilities and competitiveness of the product gives information on the desirability of manufacturing the product in question.

Findings: The paper will examine the relationship between the capabilities of technology and the competitiveness of the products of a metalworking company in light of selected Toyota principles. The opinion of production personnel is an important factor in the process of evaluating technology to increase the competitiveness of the products obtained.

Research limitations/implications: In the research, employees of the operational level, i.e. the part of the crew that is directly involved in shaping products and creating quality, were used to obtain data on the evaluation of the course of production processes.

Practical implications: The technology implemented by specific machines serves to produce a specific product, which is the material result of the production process. The material result should be transformed into a financial result, which is determined by the number of units of the product sold.

Originality/value: The product of a given enterprise, according to the laws of the free market, should be better, cheaper, etc., than the product of another enterprise.

Keywords: Production technology, Rule of technology, Method of optimisation of production

Reference to this paper should be given in the following way:

S. Borkowski, M. Szota, A. Baryłka, T. Bajor, J. Przybytniowski, The role of technology in industry according to the BOST method, Journal of Achievements in Materials and Manufacturing Engineering 119/2 (2023) 80-85. DOI: https://doi.org/10.5604/01.3001.0053.9494

1. Introduction

Machines and equipment [1], irrespective of the type of human activity, implement a specific technology [2], giving the products certain characteristics (shape, dimension, physical-chemical properties, usability, etc.) [3]. The product characteristics (in addition to the price) may determine the manufacturer's existence on the market [4]. There is, therefore, a definite relationship between the characteristics of a product (quality) and its competitiveness in the market. On the other hand, existing technologies are not 100% utilised. The gap can be referred to as technological capabilities, which are absolutely conditioned by the innovativeness of the technology and the training of the operators [5,6]. An important factor here is the technology learning within the technology portfolio and the improvement of processes by the operators [7,8].

The paper will examine the relationship between the capabilities of technology and the competitiveness of the products of a metalworking company in the light of selected Toyota principles [9]. The opinion of production personnel is an important factor in the process of evaluating technology to increase the competitiveness of the products obtained.

According to Toyota, technology development is one factor describing management principle 1. An important element in the production process is the reliability of the technology, and this issue is addressed in management principle 2 according to Toyota concerning the course of the production process [10,11]. The result of these two factors, development and reliability, can be technology capabilities assessing the existing state of technology operation in a given company. The technology implemented by specific machines serves to produce a specific product, which is the material result of the production process. The material result should be transformed into a financial result, which is determined by the number of units of the product sold. According to the laws of the free market, the product of a given enterprise should be better, cheaper, etc., than the product of another enterprise (competitor).

2. Research methodology, characteristics of the companies surveyed

It is planned [12-14] to carry out research in 10 companies. The results obtained in the research are classified into independent and dependent variables. The independent variables are the characteristics of the respondents [11], the characteristics of which are presented in Table 1. The characteristics of the respondents are gender (MK), education (WE), age (WI), seniority (SC), mobility (MR), and mode of recruitment (TR).

The dependent variable is the importance ratings of the respondents, the type of which and how they were obtained are as follows. In order to obtain data on the importance of the factors describing Toyota management principles as interpreted by the BOST method [10,11], a questionnaire was conducted among operational-level employees. A set of

Table 1.
Characteristics of the respondents. General characteristics. Source: [11]

Symbol	Designation of features and their characteristics					
	MK	EC	WI	SC	MR	TR
1	Man	<Secondary	< 30	< 5	1	Normal
2	Woman	Secondary	31 – 40	6 to 10	2	Transfer
3		Higher I	41 – 50	11 to 15	3	Finances
4		Higher II	51 – 55	15 to 20	4	
5			56 – 60	21 to 25	5	
6			61 – 65	26 to 30	6	
7			> 66	31 to 35		
8				> 36		

questions describing a specific Toyota principle is called an area. The given paper will present the results relating to Toyota management principles 1 and 2. Arithmetic averages will be calculated for the sets of scores obtained, which are the basis for the construction of factor importance series.

Principle 1.
Base management decisions on a long-range concept – even at the expense of short-term financial performance.
Area E2. A set of factors describing Toyota's management principle 1.
Rank the importance of the factors determining the development concept of your company. Enter 1; 2; 3; 4; 5; 6; 7 (7 being the most important factor) in the box [10,11].

DK		Customer welfare
IP		Product innovation
JC		Cooperation with partners
ZP		Eliminating waste
SP		Autonomy and responsibility of employees
RT		Technological developments
PR		Nurturing a company culture

Principle 2.
Create a continuous and smooth process for uncovering problems.
Area E3. A set of factors describing Toyota's management principle 2.
Rank the importance of production process factors. Enter 1; 2; 3; 4; 5; 6 (6 being the most important element) in the box [10,11].

CP		Continuous disclosure of problems
PE		Interruption of production when a quality problem is detected
SZ		Standard tasks, processes, documents
EU		Downward power of attorney
ST		Using only reliable technology
SW		Use of visual inspection

On the other hand, a 3x3 matrix, after some modification, will be used to assess the relationship – technological capabilities versus product competitiveness. The structure of the map described by the technological capabilities and competitiveness of the product gives information on the desirability of manufacturing the product in question.

The structure of the map described by the technological possibilities and the competitiveness of the product gives information about the purposefulness of producing a given product. The map in the literature is called a 3x3 matrix. In the case of testing the importance of significance, the technological potential and competitiveness of a product, the scale of evaluation is determined by the literature; it is "9" because it is required by the subjective matrix (3x3). The output for the 3x3 matrix is obtained from the BOST survey. For instance, it is area E4b, where the following request is addressed to respondents:
Area E4b. On a scale of 1 to 9, evaluate the competitiveness of the product and the technological potential of the manufacturing process.
1 – small, 9 – large

TK		Product competitiveness
TW		Technological potential

The version of the 3x3 matrix used in the BOST method is presented in Figure 1. In the original by Lowe P. [4], the X-axis is represented by technological capabilities and the Y-axis by market position. In the presented research, the Y-axis represents the competitiveness of a product. For substantive reasons, the matrix zones are numbered from 1 to 9 in the circular version, and additionally, the axes are marked with letter symbols. It follows from the name of the matrix itself that the adopted rating scale must be divisible by 3.

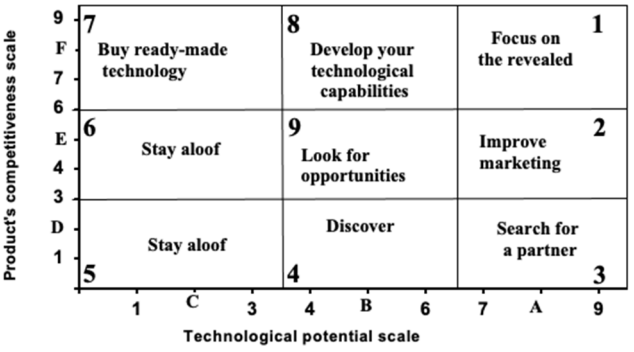


Fig. 1. General characteristics of matrix 3*3. Source: [4]

To assess similarity or lack thereof, Thurstone's method of comparative evaluations [15-17] is most often used to build a one-dimensional metric preference scale of the factors under study. It involves comparing each characteristic (factor) with each other, and based on the results, a preference scale is created. A problem has arisen in relation to the results of the BOST method, which is that the number of scores varies from company to company. The document [18] presents an equivalent tool to the comparison scale under the name of the striae scale. The basis for constructing the bifurcation scale and its structure is the arithmetic averages of the importance ratings of the factors. In contrast, the publication [19] proposes the following

zones of both scales and similarity criterion: 0 – least preferred, 0 – 20 weakly preferred, 21 – 40 moderately preferred, 41 – 50 moderately preferred, 61 – 80 strongly preferred, 81 – 100 very strongly preferred,100 – most strongly preferred. Similarity criterion: 4 factors – 18; 5 factors – 16; 6 factors – 14; 7 factors – 12; 8 factors – 10; 9 factors – 8; 10 factors – 7; 11 factors – 6; 12 factors – 5% of the scale length.

The research was conducted in a group of 10 companies from the metal industry operating in the Silesian Voivodeship; each company is identified in the article using code names to preserve anonymity. A total of 327 respondents took part in the survey.

Enterprise M is a company operating mainly in the metal industry. Enterprise M can provide tooling facilities for manufacturing plants with press shops and tooling up to 5000 kg. The company specialises in the production of tooling for plastic treatment. It produces wood and wood-based materials elements as part of its activity in the field of casting models.

The company M1 is a dynamically developing company in the fastener industry. The company provides solutions for leading domestic and foreign producers using fasteners and fastening systems. The product range of the M1 company is used in many industries. The recipients are large industrial and commercial companies, as well as individual customers. The company is continuously working on expanding and improving its offer, putting the welfare and satisfaction of its customers first. The basic offer of the company includes fasteners manufactured according to domestic and foreign standards. Years of experience and professionalism in the field of fasteners are the advantages of the M1 company.

Enterprise M1 is a production, service and trade enterprise. It is one of the leading and recognised Polish companies producing steel screens from corrugated wires and meshes. The high position in the industry has been achieved through many years of experience in the field of steel screen production.

The M2 company provides complete service in the field of optimal product selection depending on the needs, taking into account individual requirements through production and offering the finished product. The high quality of our products, timely execution of orders and short time of order execution are the advantages of M2 enterprise.

The priority is the continuous development of the company and the individual products manufactured in it. The company cooperates with permanent suppliers to whom high requirements are set, by whom the company has no problems meeting the expectations of its customers. Competitiveness in the market also results from the reliability, honesty and integrity on which our company's operations are based.

For several years, the M3 company has been producing screws, bolts for gutter clamps, double-threaded screws, metric pins, wall anchors, hooks, hex keys, rivets, screws and atypical fasteners for the construction, furniture and automotive industries. It also produces potting screws, bolts and pins made of all kinds of materials, including stainless, acid-resistant materials and in grades. It also galvanises screw products and metal elements on pendants up to 3 metres long.

The M4 company offers processing of sheets, profiles and flat bars based on modern technologies. Operating both as a manufacturer and subcontractor increases customers' competitiveness and profitability. It offers a comprehensive service from design through production to delivery logistics. It has a modern machine park and its own design office. Owing to the experienced staff, it guarantees short delivery times, serialisation adapted to the customer's needs, and favourable prices combined with advantageous payment terms. The core competencies include producing power cabinets, electrical and electronic enclosures, frames, covers, cassettes, battery shelves, containers, brackets and terminals – including component assembly. Concern for the environment is deeply embedded in the company. All standards for waste selection and disposal are fulfilled based on partnership agreements. 100% of the metal waste generated during production is recycled.

The M5 company produces highly adjustable collars and metal containers for storage and transport. The company also manufactures many other metal products and structures according to entrusted or own documentation. The products are painted in various RAL colours, and hot dip galvanised at the customer's request. In order to meet the needs of the market, the company is constantly expanding its existing assortment while ensuring competitive prices and favourable sales conditions. The fundamental goal of the company is to satisfy customer requirements and to execute orders on time.

Enterprise M6 specialises in the production of fasteners, which is carried out using modern technologies, the method of plastic working and machining using numerically controlled machines (CNC). The company's primary goal is to offer a wide range of high-quality fasteners. Equipping the control department with a specialised measuring microscope, which allows accurate checking of the geometry of the thread outline, and with a testing machine connected to the IT system, they enable the generation of test reports.

The M7 company specialises in metalworking, including turning, gear milling, grinding and machining. It produces elements according to the documentation provided by the customer or a pattern made of regular steel, quality steel, non-ferrous metal alloys or plastics. According to the

recipient's wishes, it produces elements and ready-made components from entrusted or own material. The M7 company has been adapting to the needs of a changing market for many years. Introducing optimal technological solutions translates into lower production costs. The employees are qualified and experienced staff with competencies confirmed by the authorisations and certificates.

The M8 company has over 30 years of experience in designing and producing special tools made of tungsten carbide and quality steel. It is one of the leading suppliers of special tools for many companies and concerns. It employs qualified staff with many years of experience in this industry. The company's products are manufactured on high-class machines using the highest-quality semi-finished products. The M8 company is equipped with high-class measuring instruments for producing dies and tools in a given order. The machine park is modernised continuously, making the products quickly while maintaining high accuracy. The M8 company has extensive experience in electrical discharge machining. Wire EDM is performed on high-class Japanese numerically controlled machines.

The M9 enterprise was established in 1990 with the Polish-origin capital. From the very beginning, the company was focused on dynamic development, and it remains valid all the time. This strategy enabled it to become currently one of the largest Polish producers of perforated sheets, expanded metal, wire mesh welded from round and profiled wires, industrial screens, as well as structures and products containing screens. It continually invests in the latest equipment, educates employees and develops the production base. Those activities allow us to constantly expand our offer and produce products with better and better parameters at more competitive prices. The company has its own design office, and a well-equipped tool room and machining department are additional advantages.

3. Characteristics of respondents

In the case of the gender structure of the respondents (Tab. 2), it can be read that, in general, most respondents are men. They make up between 63% and 100% of the workforce. Such a structure of respondents is typical for heavy industry, which includes the metal industry.

From the data in the columns on respondents' education (WE) in Table 3, it can be seen that in only one of the companies surveyed, 6% of respondents have the lowest level of education. Some of them (from 0% to 62%) have a secondary education, while the two largest groups are respondents with a first degree (from 31% to 60%) and those with a second degree (from 12% to 43%).

Table 2.
Gender of respondents (MK). Percentage characteristics. Source: own elaboration

MK	M	M1	M2	M3	M4	M5	M6	M7	M8	M9
Man	84	79	100	77	71	94	63	65	85	77
Woman	16	21	0	23	29	6	37	35	15	23

Table 3.
Education of respondents (WE). Percentage characteristics. Source: own elaboration

EC	M	M1	M2	M3	M4	M5	M6	M7	M8	M9
<Secondary	0	0	0	0	0	0	0	0	6	0
Secondary	29	44	62	32	37	33	14	0	41	34
Higher I	48	38	31	55	49	43	43	60	41	43
Higher II	23	18	7	13	14	24	43	40	12	23

Table 4.
Age of respondents (WI). Percentage characteristics. Source: own elaboration

WI	M	M1	M2	M3	M4	M5	M6	M7	M8	M9
< 30	3	6	21	23	20	15	34	25	21	26
31 – 40	13	18	31	35	29	12	23	25	26	20
41 – 50	48	32	10	19	14	24	17	20	26	9
51 – 55	13	21	10	6	11	27	6	13	15	14
56 – 60	16	6	3	10	9	12	11	5	9	17
61 – 65	0	0	0	0	0	0	0	0	0	0
> 66	3	9	10	0	0	0	3	3	3	3

The age structure of employees (respondents) is an important element of human resources management for the employer; the decisive majority should be between 30 and 55 years of age. Such a range in the BOST method includes three age ranges. Table 4 data shows that the proportion of respondents in such a range varies between 43% and 74%. It should be noted that in companies with a high share (>70%) of employees in the 30-55 age range, the youngest employees are less than 10% and, conversely, in companies with less than 50% of employees in the surveyed range, there are more than 15% young people. The results of the research showed that in the surveyed enterprises, there is no age group among the respondents in the range of 61-65 years; in three enterprises (M3, M4, M5 there are also no respondents above 66 years of age, those three enterprises have in the structure of respondent people under 30 years of age at a level in the limit of 15-23%. The proportion of respondents aged 56-60 ranges from 3-17%, while those aged 66+ range from 0-10%.

An important personal characteristic of employees during human resource management is the seniority of the employees in relation to the respondents, as shown in Table 5. Assuming that an employee is capable over 20 years of work to acquire and improve the required, unfortunately changing, professional skills and does not fall into the dominance of routine, then in the range of 6-25 years of seniority, the share of respondents is 78; 74; 74; 67; 60; 78; 63; 64; 83; 54% respectively for the companies surveyed, a spread of as much as 23%. The maximums of the percentage shares fall within the analysed seniority range, but for the different ranges: 6-10 (1), 11-15 (5), 16-20 (3), 21-25 (1), with the number of companies in brackets (in the case of company M9, this is a local maximum).

Skill acquisition also occurs as a result of changing employers (occupational mobility). The structure of the occupational mobility of respondents is shown in Table 6. The data analysis in Table 6 shows that in six enterprises, respondents are employed for the first time, the current enterprise is the first employer for them, their share is more than 20%, and in three, the share is more than 30%. The maximum percentage share (over 40%) is for respondents who have previously worked in one other company; it applies to two companies. Regarding respondents who previously worked in two other companies, the range of their share is 9-31%, a narrower range (9-24%) applies to respondents who previously worked in three other companies, and an even narrower range (9-17%) applies to respondents who previously worked in four other companies. Table 6 data shows that 9 out of 10 companies have respondents working in their current job for a minimum of six, the maximum share being 15%.

Business managers regulate the structure of their workforce through appropriate human resources management. The fastest way to change the workforce structure is by admitting new employees. It is to the mode of admission that one of the personal characteristics of the respondents in the

Table 5.
Length of service of respondents (SC). Percentage characteristics. Source: own elaboration

SC	M	M1	M2	M3	M4	M5	M6	M7	M8	M9	
< 5	0	3	3	13	14	3	17	20	6	9	8,8
6 – 10	13	9	9	19	6	12	23	20	18	17	14,6
11 – 15	13	18	18	39	29	15	17	28	26	17	22
16 – 20	39	29	29	3	14	21	17	8	24	11	19,5
21 – 25	13	18	18	6	11	30	6	8	15	9	13,4
26 – 30	16	6	6	13	9	9	6	8	9	17	9,9
31 – 35	3	9	9	3	17	9	9	8	0	17	8,4
> 36	3	9	9	3	0	0	6	3	3	3	3,9

Table 6.
Mobility of respondents (MR). Percentage characteristics. Source: own elaboration

MR	M	M1	M2	M3	M4	M5	M6	M7	M8	M9
1	16	21	14	16	23	33	14	35	21	31
2	23	26	21	42	23	15	20	18	41	29
3	23	21	21	16	31	18	31	13	9	11
4	19	12	24	13	11	15	20	15	15	9
5	13	6	17	6	6	15	9	8	15	14
6	6	15	3	6	6	3	6	13	0	6

Table 7.
Mode of admission of respondents (TR). Percentage characteristics. Source: own elaboration

TR	M	M1	M2	M3	M4	M5	M6	M7	M8	M9
Normal	52	56	48	52	48	52	49	52	47	37
Transfer	26	29	14	16	29	18	17	23	24	26
Finances	23	15	38	32	23	30	34	25	29	37

BOST method is devoted. As a result of many years of refinement, three variants of such a trait have been established, which are presented in Table 7, together with data for the surveyed companies. In the normal mode (advertisement, casting, acquaintances), more than 40% (except for company M9) have been accepted, with an average of 49.3%. On a transfer basis, an average of 22.2% are admitted (range 14-20%), with financial conditions 28.6% (range 15-38%). The information presented shows that management shapes the structure of hired employees, as a large share of the admission mode (15-38%) is the option with the financial conditions.

Summarising the information obtained on the structure of the respondents' characteristics, it can be concluded that:

- it is specific to each enterprise, no case of an identical structure of a given characteristic in two or more enterprises has been identified,
- the management of metalworking companies has chosen to employ women to fill their workforces, while in order to ensure an appropriate staffing structure, they have used the labour market drain by offering higher wages to specialists (a high proportion of employees with financial conditions,
- the metal industry uses modern technologies, and therefore, the proportion of employees in the workforce is high (no less than 38%),
- the age structure of the respondents indicates that the implementation of production processes is guaranteed, as most of them fall within the range of years (31-55) of effective work. The existence of an age group above 66 years indicates problems in terms of employment opportunities for younger people,
- the respondents stated high occupational mobility is a positive factor in improving workers' skills and implementing production processes.

4. Technology development in a forward--looking business management concept

For each set of importance ratings of the factors describing Toyota's management principle 1, an arithmetic mean was calculated [19]. The results obtained are presented graphically in Figure 2.

Arithmetic averages were used to construct the validity series; they are of the form:

- – company M

(DK, IP, **RT**) > WK > ZP > PR > SP (1)

- – company M1

DK > IP > **RT >** ZP > WK > SP > PR (2)

- – company M2

DK > IP> PR > WK > ZP > **RT >** SP (3)

- – company M3

DK > IP > ZP > WK > SP > PR > **RT** (4)

- – company M4

IP >DK > **RT >** WK > ZP > (SP, PR) (5)

- – company M5

DK > IP > WK > **RT >** PR > ZP > SP (6)

- – company M6

(DK, IP) > ZP > WK > PR > SP > **RT** (7)

- – company M7

DK > IP > WK > ZP > PR > SP > **RT** (8)

- – company M8

DK > IP > WK > **RT** > SP > ZP > PR (9)

- – company M9

IP > PR > (DK, WK) > ZP > SP > **RT** (10)

Summarising the above, it can be seen that the factors:

- *Customer well-being* (**DK**) came first in 8 out of 10 cases and second and third on one occasion each,
- *Product innovation* (**IP**) appeared in first place twice and came second in 8 out of 10 cases,
- *cooperation with co-operators* (**JC**) took third place four times fourth place five times, and fifth place only once in 10 cases,
- *trust in employee relations* (**ZP**) ranked third and fourth three times each, and fifth and sixth twice,
- *employee autonomy and responsibility* (**SP**) ranked fifth 5 times, sixth 3 times, and seventh 2 times,
- *technology development* (**RT**) ranked first once, third, fourth and seventh twice each, and sixth 3 times,
- *nurturing* company *culture* (**PR**) once second third place, and twice each third, fourth, fifth, sixth and seventh place.

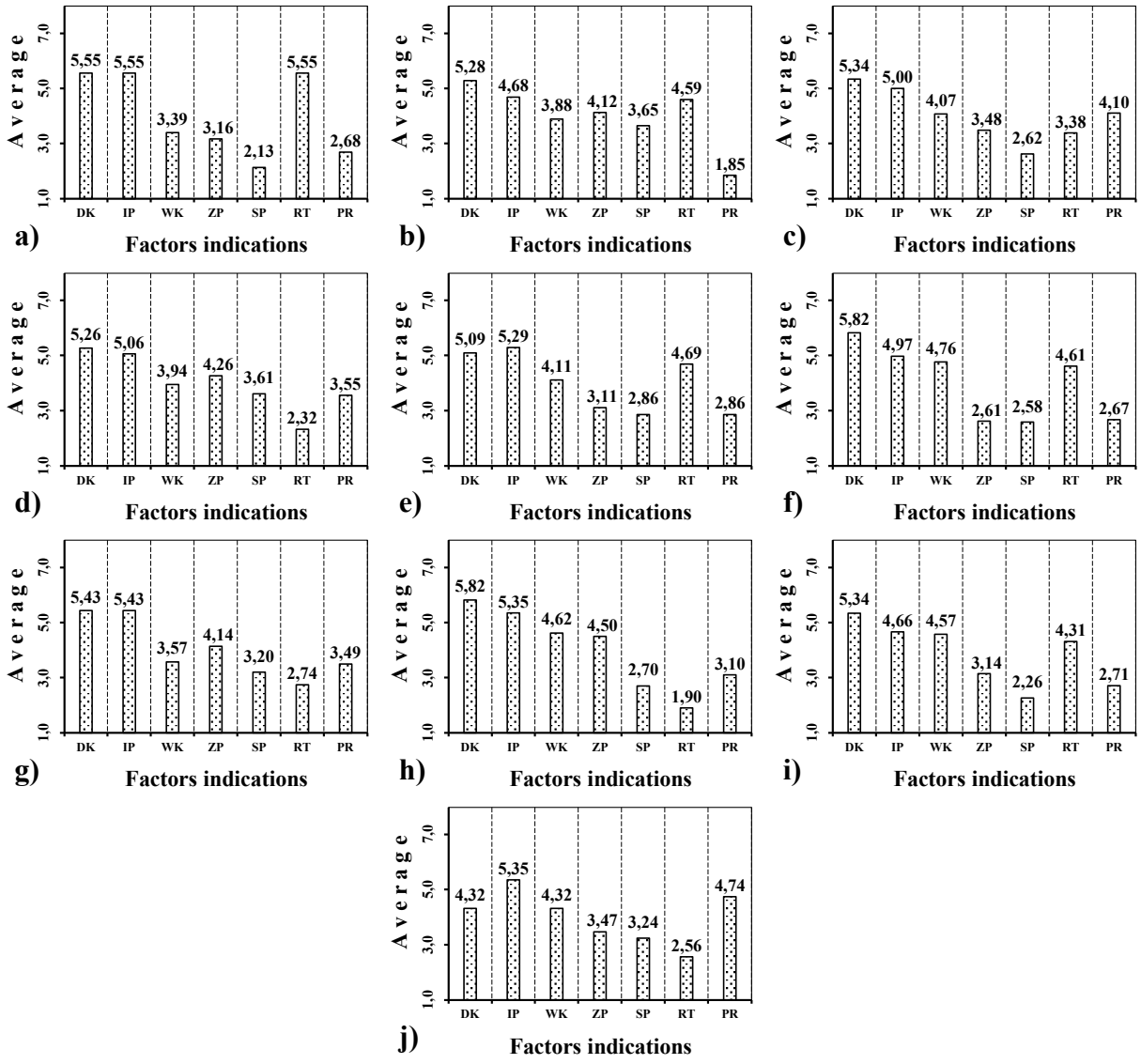


Fig. 2. Comparison of mean scores for factors describing principle 1. Applies to companies: a) M, b) M1, c) M2, d) M3, e) M4, f) M5, g) M6, h) M7, i) M8, j) M9. Source: own study

Overall, we can see that only the factor of *customer well-being* (**DK**) stands out above the others, appearing most often in first place (8/10). The factor *product innovation* (**IP**) appeared in second place most often (8/10). The other factors were pushed to lower places, with *cooperation with cooperators* (**WK**) and *trust in relations with employees* (**ZP**) appearing in third place. Thus, the factors of *customer well-being* (**DK**) and *product innovation* (**IP**) are the most important for the construction of the development concept of the surveyed companies. The subjective factor – *technology development* (**RT**) – was ranked first only once (albeit non-self-contained with two other factors) and as many as four times last. Such a diversity of places occupied by this factor allows us to think that technology development does not appear to employees as one of the most important elements of the company's strategy in the surveyed companies.

The above analysis provided information on the importance of the subject factor technology development (**RT**) compared to the other factors of area E2. A bifurcation scale (Fig. 3) was used to determine the preference for the technology development **(RT) factor** in individual companies.

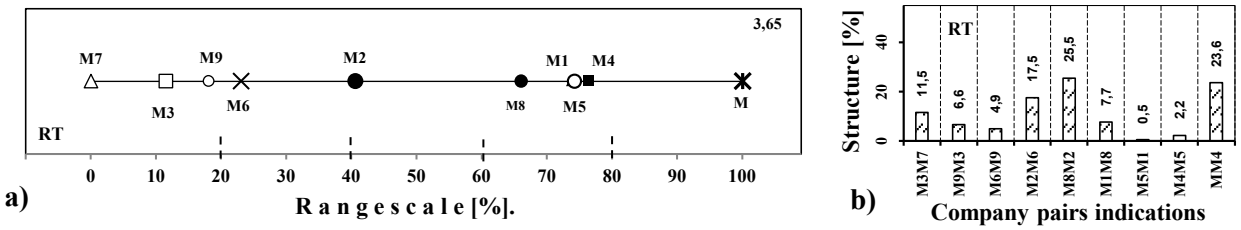


Fig. 3. Preference analysis of the factor technology development (RT) in the surveyed companies, (a) distribution of companies on the straddle scale, (b) structure of the straddle scale

The data of Figure 3a indicate that the factor of technology development (**RT**) by the respondents is least preferred in enterprise M7, while it is most strongly preferred in enterprise M. The difference in average ratings for these enterprises is 3.65. Two clusters of enterprises can be observed: the first one – M3, M9, M9 (located in the zones: weak and moderate preference), M6, the second one – M8, M1, M5, M4 (located in the zone of strong preference). The data of Figure 3b shows that in the first grouping of companies, respondents decided that the factor of technology development (**RT**) shows similarity in preference in companies: M9 and M3 and M6 and M9 (distances are less than 7%). On the other hand, in the grouping of four enterprises, it is in three of them, M4, M5, and M1 that there was similarity in the preference of the factor technology development (**RT**) – the sum of distances is 2, 7% which is less than 7% (similarity criterion). The analysis of the data in Figure 3 shows that the management of enterprises M7, M3, M, M6, and M2 have received a direction of action in the field of improvement of technology development. The direction of technology development activities in enterprises: M8, M1, M5, M4, M especially M.

5. The importance of using only reliable technology in the process of continuous and smooth disclosure of problems

Figure 4 shows the structure of the average importance ratings of the factors describing Toyota management principle 2 (area E3). Based on the importance series, it is possible to infer the priorities for organising a continuous and smooth process of problem disclosure from the employee's perspective.

The averages were used to build importance series of factors, describing Toyota management principle 2 for:

- M

SW > **ST > SH >** PE > CP > EU (11)

- M1 companies

SH > **ST >** SW > PE > CP > EU (12)

- M2 companies

CP > SZ > PE > **ST >** SW > EU (13)

- M3 companies

CP > SW > SZ > **ST >** EU > PE (14)

- M4 companies

ST > CP > SW > SH > PE > EU (15)

- M5 companies

CP > **ST >** PE > SW > SH > EU (16)

- M6 companies

CP > PE > SZ > **ST >** EU, SW (17)

- companies M7

CP > PE > SW > SZ > PE > **ST** (18)

- M8 companies

EU > CP > PE > **ST >** SH > SW (19)

- M9 companies

PE > CP > EU > **ST > SH >** SW (20)

In general terms it can be seen that:

- *The continuous problem disclosure* (**CP**) *system* ranked first in 5 out of 10 cases and second in 3 cases,
- *interrupting production when a quality problem is detected* (**PE**) appeared only once as the first in the ranks of the processes, documents (**SZ**) appeared only once in first place and once in second place, third place was taken by this factor on 3 occasions,
- *standardised tasks, processes, documents* (**SZ**) appeared only once in first place and once in second place; third place was taken by this factor three times,
- *downward empowerment* (**EU**), according to respondents, is not very important, only in one establishment such a factor ranked first in a row and only once in third place,
- *The use of only reliable technology* (**ST**) is the factor that underlines the importance of technology for the

production process, only once does this factor appear as the most important in a row, it came second in 3 cases,

- *The use of visual inspection* (**SW**) appeared only once in first place and once in second place; third place was taken by this factor on 3 occasions.

Thus, the factor *continuous problem disclosure* (**CP**) is the most important for the production process according to production workers. The next factors perceived as important are the *use of only reliable technology* (**ST**), the *standardisation of process tasks and documents* (**SZ**) and *the use of visual control* (**SW**). The least important factor turns out to be the factor of *giving downward proxy* (**EU**).

The subjective factor use of only reliable technology (**ST**) is preferred by respondents in the surveyed enterprises as shown in Figure 5. It is least preferred in enterprise M7, most preferred in enterprise M4, both of which show no similarity to the others. The remaining eight enterprises are distributed on a spread scale between 0-80%, this means no enterprise (except for the most strongly preferred enterprise M4) in the zone of very strong preference.

Comparing the data of Figures 3 and 5, it should be noted that both the factor of technology development (RT) and the factor of using only reliable technology (ST) are the least preferred in the same company (M7) involved in surface

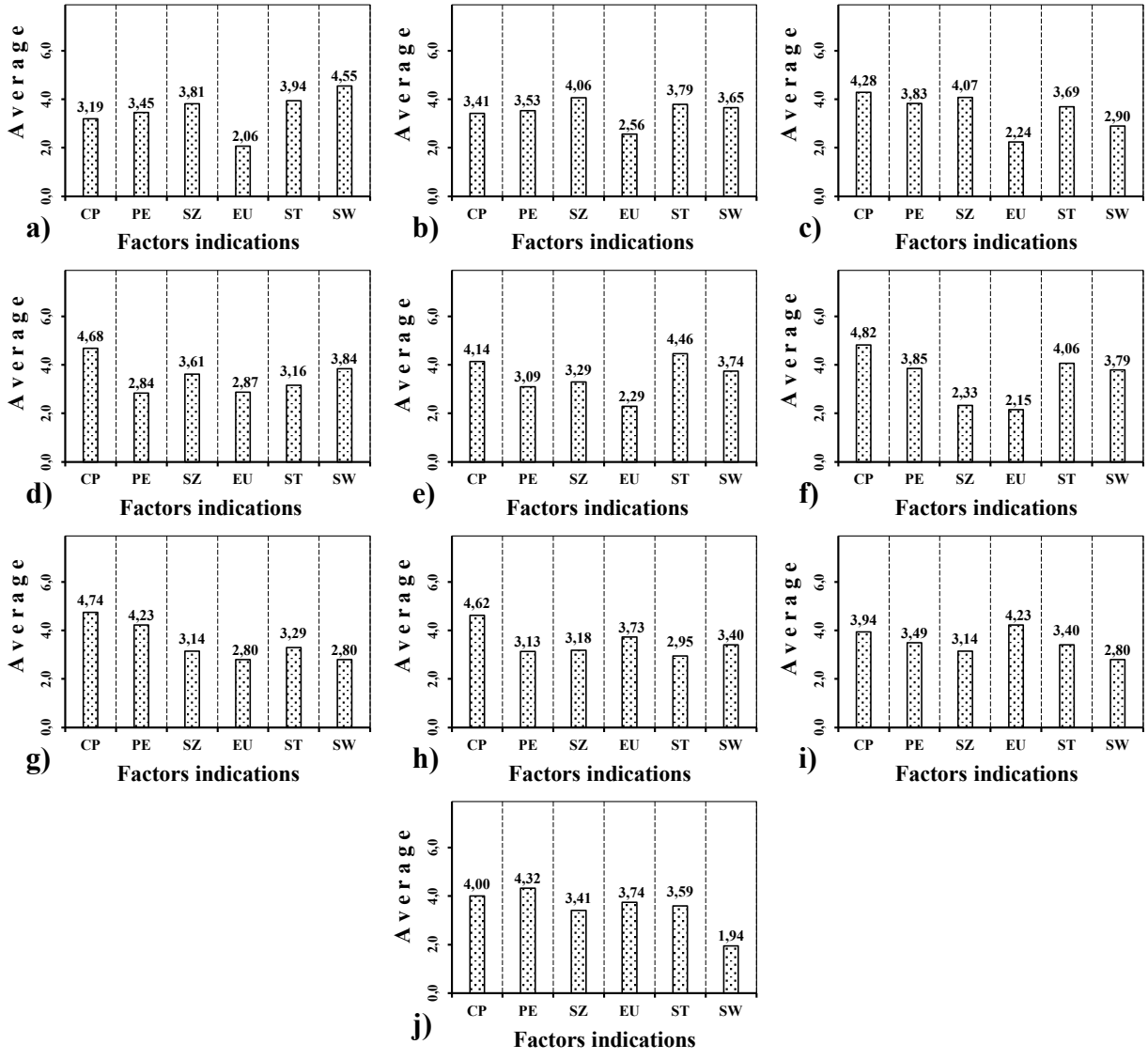


Fig. 4. Comparison of mean scores for factors describing principle 2. Applies to companies: a) M, b) M1, c) M2, d) M3, e) M4, f) M5, g) M6, h) M7, i) M8, j) M9. Source: own study

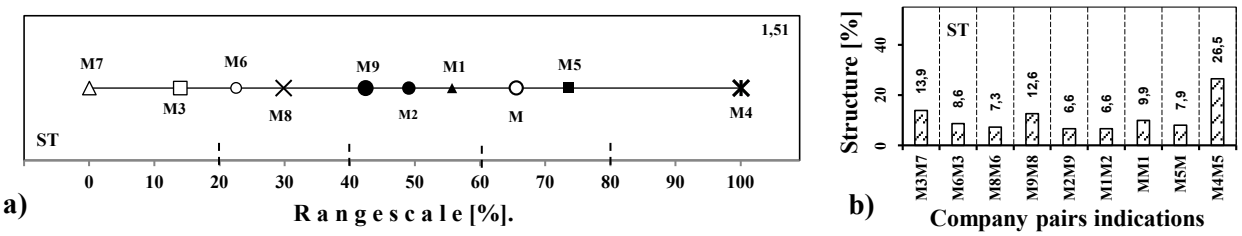


Fig. 5. Preference analysis of the factor use of only reliable technology (ST) in the surveyed companies, (a) distribution of companies on the straddle scale, (b) structure of the straddle scale

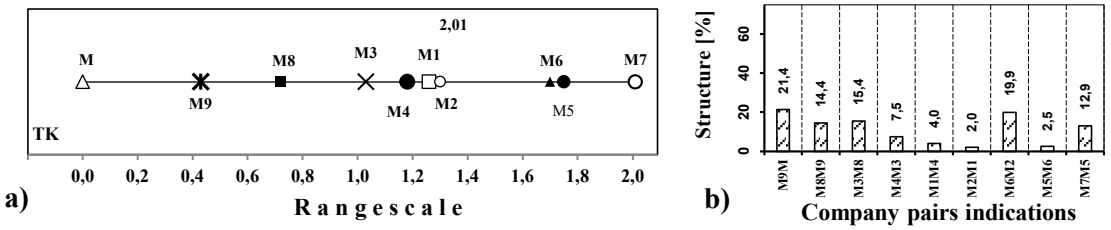


Fig. 6. Comparison of product competitiveness factor (CT) preferences in the surveyed companies: a) distribution of companies on the straddle scale, b) structure of the straddle scale. Source: own elaboration

treatment. This fact suggests a lack of operator interference in the operation of surface treatment equipment. In enterprise M4 (Fig. 3), the ST factor is most preferred, while for the RT factor, this enterprise is in the strong preference zone. Further analysis shows that the enterprise (M) with the most preferred RT factor (Fig. 3) is in the strong preference zone for the (ST) factor. Hence, the conclusion: the improvement of the development of technology (RT) and the use of only reliable technology (ST) are delineated by the actions of the enterprises: tool plant (M), or offering sheet, profile and flat bar machining (M4).

6. Importance of the factors describing the 3x3 matrix in the companies surveyed

In the case of the results concerning the 3x3 matrix, a comparison of the importance of the factors describing the matrix above, will be presented using a bifurcation scale. The factor technological potential (TW) preference in the surveyed companies (Fig. 6) shows two characteristic clusters. In one of them (in the weak preference zone – 0-20%), there are five companies: M1, M9, M2, M4, M.

The TW factor is the least preferred in enterprise M1, the preference being similar to the one in enterprise M9. On the other hand, the preference in enterprise M9 shows similarity to the preference in the mentioned enterprise M1 and enterprises M2 M4, as the sum of the distances M9-M2 (4.5), M2-M4 (0.9) is 5.4 < 8%. The second grouping, comprising two enterprises, M3 and M8, is in the middle zone of preference (40-60%), with the TW factor similarly preferred in the mentioned companies. Analysing the enterprises in which the factors TK TW are extremely preferred, it should be stated that the TK factor is the least preferred in enterprise M. In contrast, in the enterprise, the TW factor is more appreciated (on the scale, it took place with a coordinate of 16.4%). The TK factor is the most preferred in company M7, also highly preferred in the company (it took place on the scale with a coordinate of 87.3%); it is in the very strongly preferred zone. The TW factor is least preferred in enterprise M1; such a preference is similar to that in enterprise M9. As can be seen from Figure 7a in enterprise M1, the factor TK is strongly preferred. The TW factor is most preferred in enterprise M6.

The combined influence of the two factors on the structure of the 3x3 matrix can be determined by analysing the distribution of factor pairs on the matrix, i.e., the importance given by each respondent. The percentage of the number of factor pairs in each matrix zone was calculated for all ten companies. The results obtained in the form of a dichotomous scale are shown in Figure 8. The distribution of the zones of the matrix on the axis of the dichotomous scale (Fig. 8a) indicates the existence of 3 groupings, two containing two zones, each one containing five zones. Zone '1' by respondents is the most preferred, showing similarity in percentage to zone '8' (similarity criterion for 9 factors – 8%).

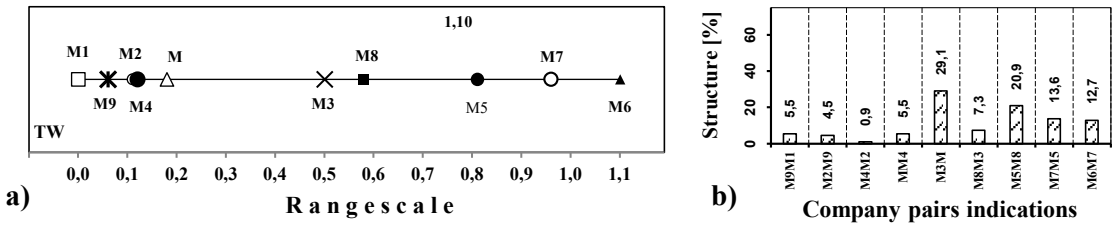


Fig. 7. Comparison of the preference of the factor technological potential (TW) in the surveyed companies, (a) distribution of companies on the bifurcation scale, (b) structure of the bifurcation scale. Source: own elaboration

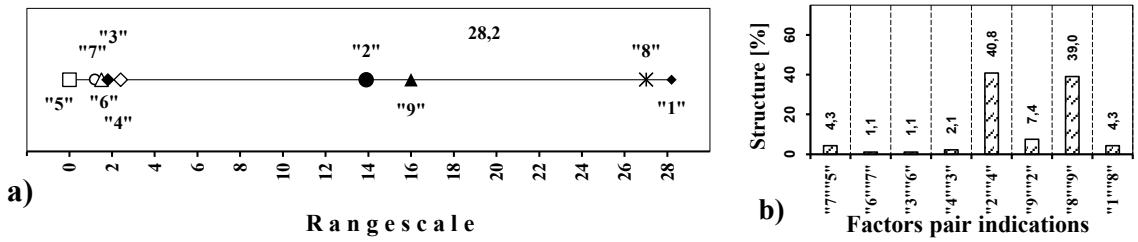


Fig. 8. Comparison of the preferences of pairs of factors: technological potential (TW) and product competitiveness (TK) in the surveyed companies, (a) distribution of zones on the bifurcation scale, (b) structure of the bifurcation scale. Source: own elaboration

In the second grouping are zones: "9" and "2." they are placed in the middle zone of the preference scale of the divergence; they show similarity with respect to each other in terms of percentage share (the difference is 7.4% < 8%) because the distance between them is smaller than the criterion. The zones forming the five-factor grouping show similarity with respect to each other in terms of percentage share. Such a grouping is in the weak preference zone. As the data of Figure 8b indicate, the distance between the groupings of the zones of the 3x3 matrix is approximately 40%.

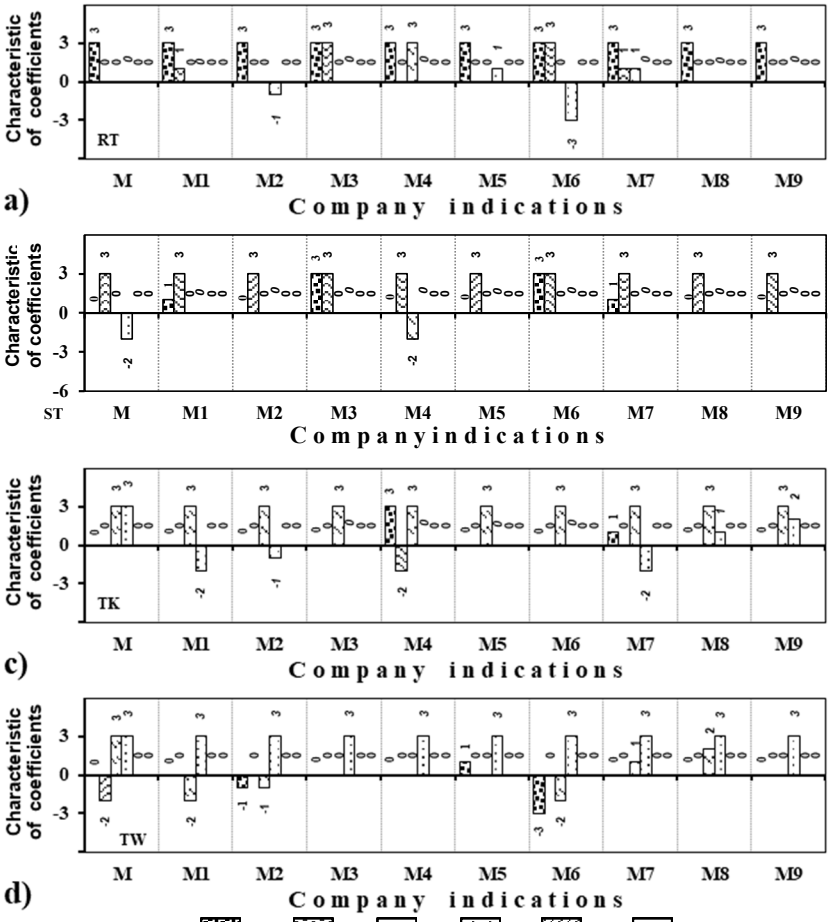
7. Correlation analysis

The effect of respondents' characteristics on the subject ratings of the four factors: RT, ST, TK, and TW, are shown in Figure 9 [20]. The figure data indicate that:

- at least one of the respondents' characteristics shaped the evaluation level of the analysed factors in the surveyed companies,
- for each of the factors analysed, positive correlations prevail, RT 19/2, ST 16/2, TK 19/3, TW 20 20/6 (numerator overall, denominator negative correlation),
- the maximum number of correlations is 3 and relates to three factors: technology development (RT), product competitiveness (TK), technological capability (TW),
- there are characteristics of the respondents that influence the ratings of the subjective factors in all the surveyed companies at the adopted three α levels; this is a positive relationship:
- the gender of the respondents (MK) influences the level of ratings for the technology development (RT) factor,
- the education of respondents (EC) shapes the ratings of the factor use of only reliable technology (ST),
- the age of respondents (WI) influences the level of ratings for the product competitiveness factor (CT),
- seniority (SC) shapes the assessment level of the technological capability factor (TW),
- the most influential respondent characteristic is gender (19 correlations, of which 2 are negative); two respondent characteristics: mobility (MR) and mode of recruitment (TR), did not show any influence on the evaluations of subjective factors in the surveyed companies.

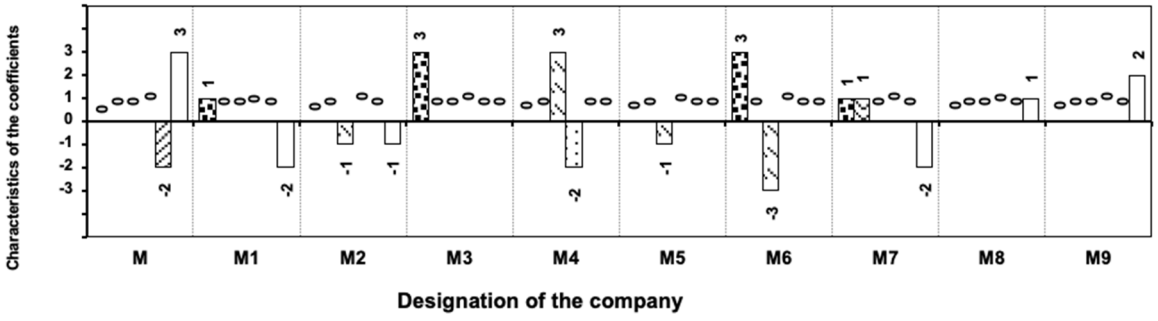
Subject factors with symbols RT, ST, TK, and TW form the following six pairs: ST–RT, TK–RT, TW–RT, TK–ST, TW–ST, and TW–TK. It is easy to see that each factor occurs three times. The results of the correlation analysis (Fig. 10) are as follows:

- the TW–TK factor pair shows a correlation in six companies; it is the most correlationally active factor pair; in two companies, it is the only correlation between the subject factors,



1; 2; 3 number of statistically significant coefficients. (+) positive correlation, (–) negative correlation

Fig. 9. Influence of respondents' characteristics on the importance ratings of the factors: a) technology development (RT), b) use of only reliable technology (ST), c) competitiveness of the product (TK), d) technological capabilities (TW) in the surveyed companies. Source: own study



1; 2; 3 number of statistically significant correlation coefficients. (+) positive correlation, (-) negative correlation

Fig. 10. Summary of the results of the correlation analysis between the subject factors. Refers to RT, ST, CT, and TW factors. Source: own elaboration

- the number of cases in which one of the subjective factors is present is RT – 7, ST – 5, TW – 10, TK – 8. In practice, this means that the technological capabilities (TW) of companies are determined by the importance of technology development (RT) and the use of only reliable technology (ST), among others. In contrast, the competitiveness of a product (TK) depends on the other three subjective factors, i.e., technology development (RT), use of only reliable technology (ST) and technological capability (TW),
- correlation was found for 28.3% of cases. In four enterprises producing small metal products (M3), metal containers and high-set extensions (M5), carbide products (M8), and structures and products containing screens (M9), there is only one correlation relationship between the subject factors. The highest number of such correlations (three) is found in the surface treatment company (M7), with two correlations each in the other five companies.

8. Summary

Data for analysis and scientific interpretation were obtained by conducting a qualitative study in an industrial setting, using the BOST questionnaire – Toyota management principles in questions. The foundation of the research was the Eastern, particularly Japanese, philosophy of the approach to production, expressed in the participation of the entire workforce in the evaluation and improvement of activities occurring during the manufacture of products. In the research, employees of the operational level, i.e., the part of the crew that is directly involved in shaping products and creating quality, were used to obtain data on the evaluation of the course of production processes.

The personal characteristics (independent variable) of the surveyed part of the workforce (respondents) were the independent variables and included gender (2), education (4), age (7), length of service (8), mobility (6) and mode of entry (3), with the number of options in brackets. Respondents were asked to rank the factors describing principle one and principle two of Toyota management and to rate the competitiveness of products and the technological capabilities of the manufacturing process (3x3 matrix). In this way, by assigning numerical values to the descriptive factors, the research has the character of a qualitative-quantitative study. The arithmetic averages made it possible to construct factor importance series for the management data according to Toyota's principles in specific companies, of which there were 10, all from the metal industry.

A total of 15 dependent variables were used to carry out the work, seven describing principle one of management according to Toyota, six describing principle two and two related to the 3x3 matrix. In this set of factors, four of them: technology development (RT), use of only reliable technology (ST), competitiveness of the product (TK) and technological capability of the manufacturing process (TW) were called subjective factors.

Production personnel (respondents) by ranking the values of the factors describing the first and second principles of management according to Toyota and assessing the importance of the factors of the axis of the 3x3 matrix, expressed their opinion on the usefulness of the Toyota approach in interpreting the BOST method to study the functioning of the production process.

The analysis of the data on the structure of respondents' characteristics yielded the following information:

- they were predominantly male (79.5%),
- usually holding a first degree (45.1%),
- a significant number of the respondents surveyed are employees under the age of 55, and in general, the number of employees under this age represents around three-quarters of the workforce,
- employees with between 6 and 20 years of seniority predominated,
- half of the employees have already changed jobs three times,
- in half of the cases, they were taken on as normal. However, there is a group of respondents who placed financial conditions during employment.

Taking into account the information mentioned and the details in the body of the work, it should be emphasised that the managers, regardless of the production profile, manage human resources appropriately. In order to fill the working positions, it was decided to employ women (j), people with higher education (although this is not required by the working position, it is especially true for employees negotiating financial conditions), to employ without secondary education, to employ pensioners (over 66 years old).

Respondents showed a high level of understanding of the survey, with the number of wrong answers rising from 2.5% (company M7) to 10.4% (company M1), with an average of 4.9%.

The analysis carried out allows us to conclude that the nature of the companies' activities influences the level of importance of the factors describing the first and second principles of management according to Toyota. Such an influence is made apparent in the average ratings of the values of the factors, which are the basis for the construction

of the series used. No two identical factor importance series and 3x3 matrix structure were found.

In the far-reaching management concept of enterprises (Toyota's management principle one), customer welfare (DK) and product innovation (IP) is decisive. The customer good factor stands out above the others, appearing most often in first place (8 out of 10 companies). The product innovation factor came in second most often (8 out of 10 cases). The subject factor – technology development (RT) – appeared in first place only once (albeit non-self-consciously, as it was with two other factors), in third, fourth and seventh place twice and in sixth place three times. Generalising, such a diversity of places occupied by this factor allows us to think that technology development does not appear to employees as one of the most important elements of the company's strategy in the surveyed companies. The most subjective is preferred in enterprise M, followed by enterprises M4, M5, and M1, located in the strong preference zone of the divergence scale; they show similarity with respect to each other regarding preference values.

In the process of continuous and smooth disclosure of problems in the production process (Toyota management principle two), the most important factor is continuous problem disclosure (CP). It occurs most often in first place and second place, together with the subjective factor of using only reliable technology (ST). The subject factor uses only reliable technology (ST), ranked second three times and fourth five times in a row and can, therefore be considered the second most important factor compared to the other factors. The factor use of only reliable technology (ST) is most preferred in enterprise M4, followed by M5, M, M1. Enterprises M5 and M are in the zone of strong preference on the scale of the striatum (they show similarity to each other with respect to preference values), while enterprise M1 is located in the zone of medium preference of the striatum scale.

The preference of the factor technological potential (TW) in the surveyed enterprises shows that it is, in the opinion of the respondents, the most important in the fasteners enterprise (M6), followed by the surface treatment enterprise (M7) (very strong preference zone), the metal containers and high-set extensions enterprise (M5) (strong preference zone), the carbide products enterprise (M8) (medium preference zone). The preference values of the mentioned companies do not show any similarity to each other. The factor of product competitiveness (TK) is most preferred in the surface treatment enterprise (M7), followed by the metal containers and high-set extensions enterprise (M5) and the fasteners enterprise (M6) (very strong preference zone; they show similarity to each other in terms of preference values) and the screens and meshes enterprise (M2) (strong preference zone).

The assessments of the factor pairs describing the 3x3 matrices are mainly located in zone '1' (98 cases), zone '8' (94 cases), zone '9' (70 times), zone '2' (68 times), with the 3x3 matrix zones '1' and '8'and '2' and '9' showing similarity in the percentage distribution of CT and TW factor pairs.

A characteristic effect of respondents' characteristics on the ratings of the subjective factors in all the companies analysed was shown that women give higher ratings than men (MK) of the importance of the factor technology development (RT). With the increase in respondents' education (WE), the factor use of only reliable technology (ST) obtains higher ratings. The older the respondents are (WI), the higher the factor product competitiveness (TK) ratings. Respondents with increasing seniority (SC) rate the importance of the factor of technological capability (TW) higher. Mobility (MR) and mode of recruitment (TR) did not impact the ratings of the subject factors in the surveyed companies.

When examining the correlations between the importance ratings of the four subject factors, correlations were found for 28.3% of the cases. Out of 30 cases of correlation relationships for each factor, it was shown that the factor technological capability (TW) has 10 of them, the factor product competitiveness (TK) 8, the factor technology development (RT), seven and the use of only reliable technology (ST) 7. It was found out that the factor of technological capability (TW) of enterprises is conditioned by the importance of technology development (RT) and the use of only reliable technology (ST), among others. This relationship is of practical importance in the field of production management, and such a decision boils down to undertakings for the improvement of the factors: technology development (RT) and the use of only reliable technology (ST). A signpost for the improvement of the first factor (RT) could be activities in a toolmaking company (M), while the factor (ST) could be activities in a company offering sheet, profile and flat bar machining (M4).

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