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Article

Decision Support Method for Dynamic Production Planning

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Abstract: Small and medium-sized engineering production companies face challenges that are related to unpredicted rapid changes of availability of the work force, materials and equipment. Those challenges are especially difficult to solve for companies focusing on unit or batch production and when they are collaborating with customers who require short lead times. A four-month observation was carried out in a metal processing company in Lithuania to understand the most common rising problems and developing solution for computerised decision support systems. It was discovered that the company needs a computerised "employee centred" system for the improvement of the allocation of tasks to employees. Such a need proved to be the most urgent one, especially during pandemics. An algorithm for the analysis and automated allocation of the employees' tasks has been developed and tested. The proposed algorithm is universal and may be applied in different SMEs for engineering production.

Keywords: production planning; decision support method; production engineering

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1. Introduction

Every production company seeks the best performance to maintain competitiveness. However, each day, production faces different challenges. In few last years, the lives of manufacturing companies have become more dynamic than ever, and this was caused by pandemics, energetic issues, political desicions and other factors which could not be planned or predicted. These turbulences are more effective to SMEs (small and medium-sized enterprises), and so flexibility and having fast response times are vital for such companies [1,2]. To accomplish faster production times, the more efficient use of raw materials and having automated processes of Industry 4.0 and the digitalization of their systems helps [3–5]. As well, having faster delivery times, improved quality of the products, increased customization and financial factors such as cost reduction, revenue growth and increased productivity are key factors to start using tools of Industry 4.0 [6]. However, it might sound easily achievable, but small and medium-sized companies cannot afford smart ERP systems, cloud manufacturing or automated production lines, and as a result it is much harder to implement digitalization or automation procedures [7–9]. SMEs often limit themselves only with such tools such as Cloud computing or Internet of Things [10], virtual factory, smart manufacturing or digital factory applications [11–13]. In different literature studies, cyber physical systems, cloud-based freeware or knowledge management is described as optional help for the SMEs [14,15]. Using only part of the possible newest solutions, the SMEs cannot obtain the interconnectivity and integration that they need in these times [16]. Such companies as much more likely to produce unique and non-recurring orders, and thus, their production processes cannot be simplified or unified [17]. In [18], the advantages of mass customization are described as a strength of the SMEs. To control such processes, production planning and control (PPC) systems are used, but they should be transformed to smart production planning and control (SPPC) systems [19,20]. SPPC systems require real-time management systems, dynamic production planning and autonomous execution control [21]. Thus, there is a great need to help and improve the performance of the SMEs companies since in most economies, SMEs take precedence [22]. That is why this article focuses on the decision support algorithm which could be adapted to production, and especially, it could improve "employee centred" companies which are mostly small or medium-sized.

2. Methodology

2.1. Information about the Case Study Company

For this research, the main data were collected from a metal processing company. This company is in Lithuania and its total number of employees during the examination was 75. This is categorized as a medium-sized company. This company produces furniture components such as metal tube legs, brackets, frames for shelves, tables and others. In total, more than 500 different article numbers for their products are active because company's production is defined by its customers' needs. It accepts small or individual sample orders and also provides metal processing services such as turning, punching, cutting and finishing. Such production tasks are different each day, and flexibility, having a quick response and adaptability are key factors. This company is a part of a group of more than 20 companies, and it is a supplier to them as well as for other companies that are all over Europe. Since the final products of this company are sold to other production companies, any delay in their delivery is unaccepted because that would cause production problems in the other companies. In such business models, a precision and accuracy are highly required. At the moment, all of the equipment is serviced by employees, and no robotic or automated line is available.

In this company, the monitoring of the production lasted for 4 months—from January to April of 2022. This was conducted to understand and confirm the main emerging problems. The company works in three shifts, each of them having 18 employees that work during the production. Different data were gathered to have as much information for further investigations as possible—every shift, every operation and every product was included in this. As seen in Figure 1, the absence of workers was a leading problem, mainly due to isolation and seasonal flus. Another issue, which ended up being ranked in the second place, was a delay of the delivery of the components. A significant increase in this issue was noticed in March since this company lost the relationship with its main suppliers from Ukraine. The third problem was machinery failures. Since the company works in three shifts and for five days a week, the machinery should be in the best condition to provide an uninterrupted workflow. The last section was about the changes in orders, and more specifically the changes by the customers. This issue was connected with the situation in Europe—the customers of this company are furniture producers, and they faced challenges with the supply of other components, thus, they cancelled and changed the dates for the open orders.

To create a workflow and test program, a specific product and its production was selected. It is a metal furniture leg (Figure 2). The furniture leg is made of a steel tube, a punched metal plate, a threaded stud and a plastic cap. These kind of furniture legs are lacquered or painted, and finally, they are packed in plastic bags according to the client, one by one or in kits.

There are 7 main technological operations to produce such furniture leg:

- Cutting operation (1);
- Punching operation (2);
- 1st welding operation (3);
- 2nd welding operation (4);
- Finishing operation (5);
- Assembling operation (6);
- Packaging operation (7).

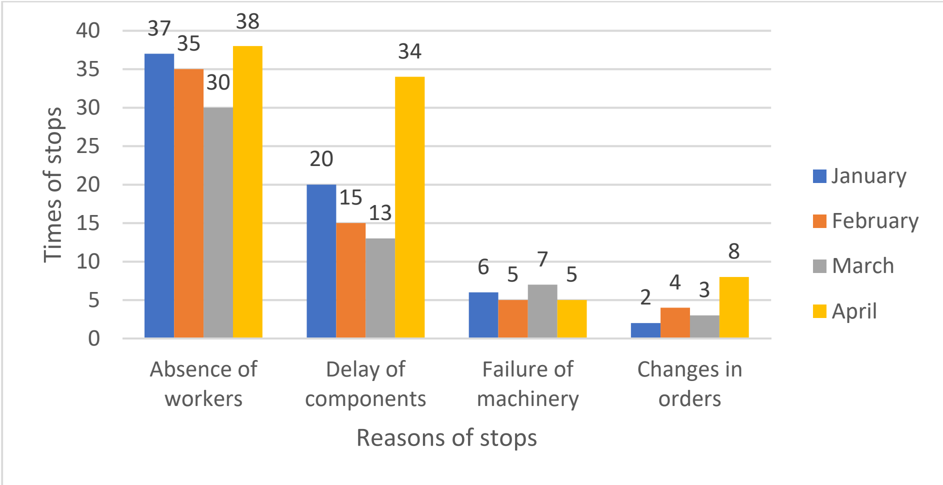

Figure 1. Observation results: issues of production stops.

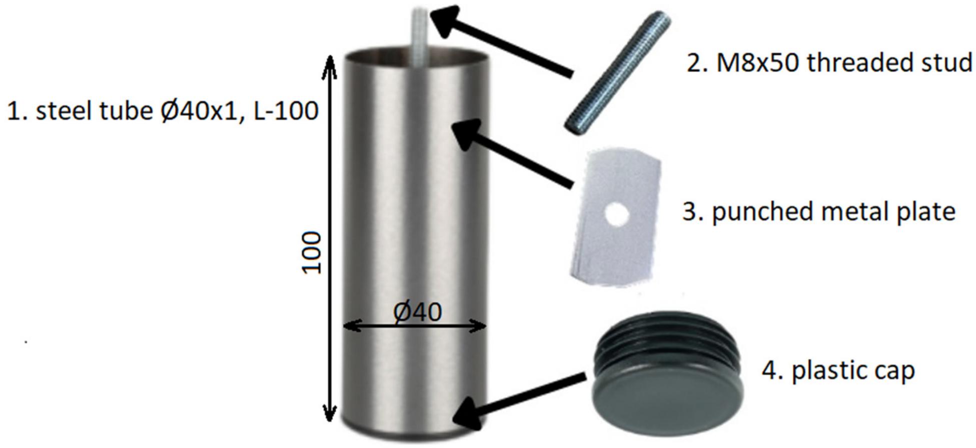

Figure 2. Steel metal furniture leg—D40 × L100 mm.

Each of these operations were performed by an employee, any absence caused a delay. Since production is rapidly changing, every employee had a main specific task to perform but they also had to learn how to cover different tasks. To gather data about the employees' skills and level of knowledge of the operations, matrix of skills was developed (Table 1). This helped to speed up a reaction time when a change was needed—making this process automatic is the main goal. As well, this matrix differentiated the salary of the workers—workers with more skills had a bigger coefficient. An employee can have 4 different levels of skills—from 0 to 1. In the investigated company, this ranking of skills is confirmed by the production manager, and it is based on the opinion about the abilities of each employee. Even though this might be subjective, it is the only way viable method that is available at the moment.

Table 1. Matrix of skills.

E. No.	1	2	3	4	5	6	7	Main Operation
1	0.5	0.5	0.75	0.75	0	1	1	Welding
2	0.5	0.5	0.75	0.75	0	1	1	Welding
3	0.5	0.5	0.75	0.75	1	0.75	1	Welding
4	0.25	0.5	0.75	0.75	0	0.75	1	Welding
5	0.25	0.25	0	0	0	1	1	Packaging
6	0	0	0	0	0	1	1	Packaging
7	0	0	0	0	0	1	1	Packaging

Table 1. *Cont.*

E. No.	1	2	3	4	5	6	7	Main Operation
8	0	0	0	0	0	1	1	Packaging
9	0	0	0	0	0	1	1	Assembling
10	0	0	0	0	0	0.75	1	Assembling
11	0	0	0	0	0	0.75	1	Assembling
12	0.5	0.5	0	0	0	1	1	Assembling
13	0.5	0.5	0	0	1	1	1	Finishing
14	0.5	0.5	0	0	1	0.75	1	Finishing
15	1	0.75	0	0	0	0.75	0.75	Punching
16	1	1	0	0	0	1	0.75	Punching
17	1	1	0	0	0	1	0.75	Cutting
18	1	1	0	0	0	1	1	Cutting

2.2. Workflow

Based on this conducted information, a workflow was created. The workforce algorithm is presented in Figure 3. The workflow reflects the situation in the observed factory, but it could be adapted to a different company by changing the questions.

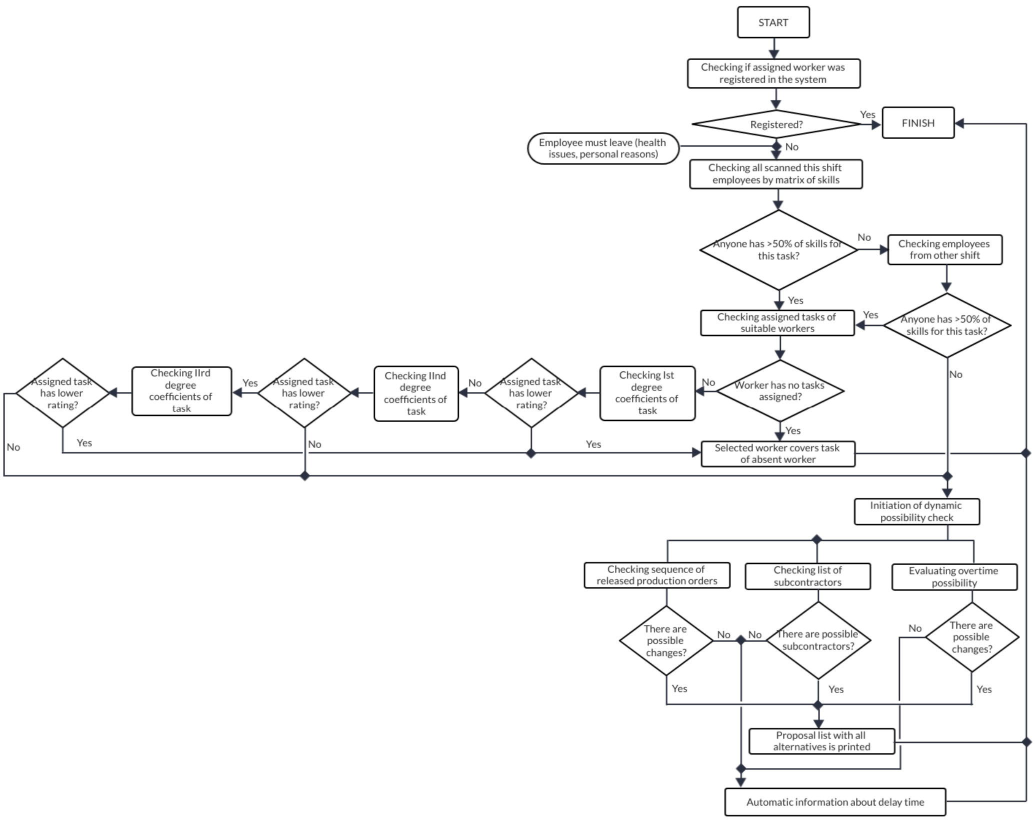

Figure 3. Workflow of presence of employees.

The information about whether an employee came to work or left the production site was received automatically because everyone must scan a personal card. The system was notified about employees personal data such as their name, surname and the time when the check-in and check-out was performed. If the system did not get notification about an employee, it automatically initiates further steps wherein the matrix of skills was needed. The algorithm checked whether someone on that shift had more than 50% of the skills of the absent employee.

However, even if there is a worker who is skilled enough, the system must run a three-stage evaluation process to evaluate which task is more important—the one that employee was performing at the time or the one which has no assigned employee. To run this evaluation, different factors should be evaluated.

This specific company has selected 5 factors of production importance:

- Delivery date;
- The need of this task (technological operation) for further production processes;
- Quantity;
- Clients ranking;
- Extra requirements (i.e., it is sample order for large quantities; parts should be sent to subcontractor; etc.).

Table 2 presents the values of the factors that evaluate the importance of each indicator. The closer to 1 that is value is, the more important it is according to this specific company.

Table 2. Values of selected factors.

Factor	Value	Degree
Delivery date (f_1)	0.8	1
The need of this task for further processes (f_2)	0.9	1
Quantity (f_3)	0.75	2
Clients ranking (f_4)	0.7	2
Any extra addition requirement (f_{n})	0.2	3

The equation for the calculation of each coefficient value V is as follows:

$$V = \sum_{n}^{1} f_n \cdot v_n, \quad (1)$$

where, *vn* is the value of factor for the specific task and *fn* is the factor value itself. Both of the values are confirmed by the production manager, and they are based on an expert opinion.

However, in real life, another situation could appear when there is no available or skilled enough employee to make this production reconfiguration. Then, the algorithm initiates the Dynamic decision support (DDS) module. In this module, the main additional external information is evaluated to give a proposal. For example, in case there was no available employee to cover the needed task, then the DDS module would check the possible changes in production orders, available subcontractors, or overtime possibilities. It is important for a company to import all of the data such as contacts, working hours, or lead times from the subcontractors so that the system can automatically check whether there is a solution or not. Figure 4 presents the DDS module for machinery workflow.

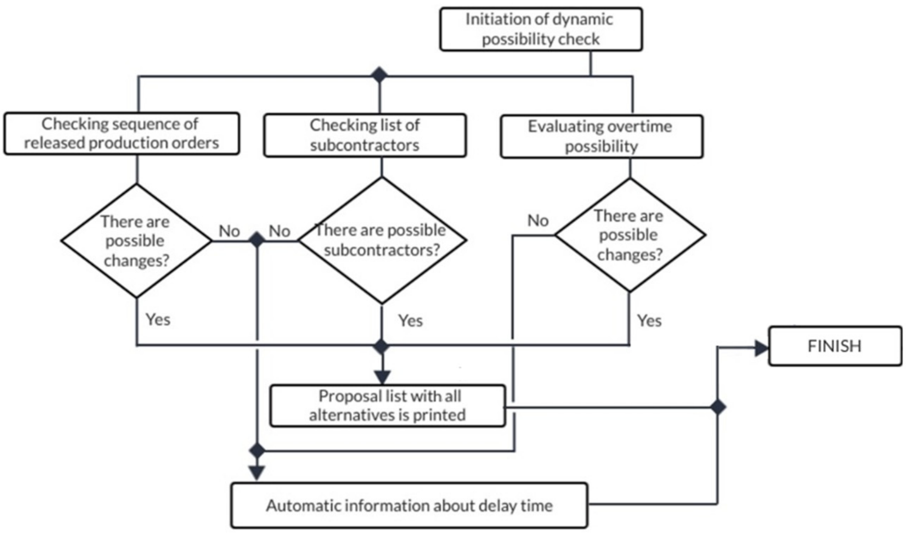

Figure 4. Dynamic Decision Support Module for presence of employees.

2.3. Workflow Check

To ensure that the workflow is usable and adaptable to real life situations, the tests were performed in Excel program (Figure 5). The test was based on the data from the company and it recreated a situation that occurred.

Matrix E	Matrix M	Matrix T	TN	ON	EN	Is EN=1?	E*M*T				
Machinery	Material	Task	Order	Operation	Employee	Employee	Can employee work?	Is task performed?	Result	If Result is 0, additional check:	Final result
1	1	1	1	3	1	1	1	1	2	If J & H columns = 0, then no further steps, if no - looking for an employee	1 = there is an available employee
1	0	1	2	3	2	1	0	0	1		1 = there is an available employee
0	1	1	3	4	3	1	0	0	1		1 = there is an available employee
1	1	1	4	4	4	0	1	0	0		0 = we need to cover this employee
1	1	1	5	6	5	1	1	1	2		2 = no further steps
1	1	1	5	6	6	1	1	1	2		2 = no further steps
0	1	1	6	6	7	1	0	0	1		1 = there is an available employee
1	1	1	6	6	8	1	1	1	2		2 = no further steps
1	1	1	5	7	9	1	1	1	2		2 = no further steps
1	0	1	5	7	10	0	0	0	0		0 = no further steps
0	1	1	6	7	11	1	0	0	1		1 = there is an available employee
1	1	1	6	7	12	1	1	1	2		2 = no further steps
1	1	1	5	5	13	1	1	1	2		2 = no further steps
1	1	1	6	5	14	1	1	1	2		2 = no further steps
1	1	1	7	2	15	1	1	1	2		2 = no further steps
1	1	1	8	2	16	1	1	1	2		2 = no further steps
1	0	1	7	1	17	1	0	0	1		1 = there is an available employee
1	1	1	8	1	18	1	1	1	2		2 = no further steps

Figure 5. Results of the algorithm testing.

The "Matrix E", "Matrix M" and "Matrix T" columns represent the availability of equipment, materials, and task, respectively—if any of these are missing, then the employee cannot work even if he is at work. Each employee has an assigned task (operation) and an order number ("TN" and "ON" columns). An employee number is provided in "EN" column. The values in "Is EN = 1?" column is used to check whether an employee is at work. The results in "Result" column can be as follows:

- "1" means that an employee is in reserve and is available for any work because there is no possibility for them to work due to lack of materials, equipment or other reasons;
- "2" means that everything has gone according to the plan;
- "0" has two meanings: either nothing should be done because there is no employee and there is no task, and either there is a need to look for someone to cover this task. The replacement is needed in case when values in H column is equal to "1".
- The next step is to find someone with the required skills to cover the task. For this, the matrix of skills is used. When the company has an employee who could cover the task, there is a need to check if the initially planned task is more or less important. To do that, a three-stage evaluation process is initiated.

After this, we tested and proved that algorithm was working and gave correct results, and then, further tests were made using Matlab. In order to start the program, some information was required. A manual data upload methos was only used in this test model because the idea is that information about equipment, materials and employees will be added in the system in real time.

2.4. Mathematical Transformation

To create a method that is based on previous tests, a mathematical transformation was performed. Matrix $P1$ shows the initial day plan:

$$P1 = (p1_{ij}),\ i = \overline{1,\ k},\ j = \overline{1,\ 6}, \tag{2}$$

In this case, k = 18 since there are 18 employees.

$$P1 = \begin{pmatrix} 1 & 1 & 1 & 1 & 3 & 1 \\ 1 & 0 & 1 & 2 & 3 & 2 \\ 0 & 1 & 1 & 3 & 4 & 3 \\ 1 & 1 & 1 & 4 & 4 & 4 \\ 1 & 1 & 1 & 5 & 6 & 5 \\ 1 & 1 & 1 & 5 & 6 & 6 \\ 0 & 1 & 1 & 6 & 6 & 7 \\ 1 & 1 & 1 & 6 & 6 & 8 \\ 1 & 1 & 1 & 5 & 7 & 9 \\ 1 & 0 & 1 & 5 & 7 & 10 \\ 0 & 1 & 1 & 6 & 7 & 11 \\ 1 & 1 & 1 & 6 & 7 & 12 \\ 1 & 1 & 1 & 5 & 5 & 13 \\ 1 & 1 & 1 & 6 & 5 & 14 \\ 1 & 1 & 1 & 7 & 2 & 15 \\ 1 & 1 & 1 & 8 & 2 & 16 \\ 1 & 0 & 1 & 7 & 1 & 17 \\ 1 & 1 & 1 & 8 & 1 & 18 \end{pmatrix} \quad (3)$$

The corresponding elements of the columns of the matrix $P1$ can take on certain values:

$$P1_{i,1} = \begin{cases} 0, \textit{equipment is available}, \\ 1, \text{equipment is not available}; \end{cases} \quad (4)$$

$$P1_{i,2} = \begin{cases} 0, \textit{materials are missing}, \\ 1, \textit{aterials are in stock}; \end{cases} \quad (5)$$

$$P1_{i,3} = \begin{cases} 0, \textit{no task is assigned}, \\ 1, \textit{task is assigned}; \end{cases} \quad (6)$$

The assigned task number is presented in the fourth column. In this case, m = 8 since there are 8 different production orders that run through this shift:

$$P1_{i,4} = \overline{1,\ m,} \quad (7)$$

The operation number is in the 5th column. In this case, n = 7 since there are 7 different production operations:

$$P1_{i,5} = \overline{1, n,} \quad (8)$$

The last column describes the number of employees. In this case, k = 18:

$$P1_{i,6} = \overline{1,\ k,} \quad (9)$$

The first check of the plan is whether all of the employees have come to work. The data are entered by simulating the real situation. A new matrix S is created:

$$S = (s_{ij}),\ i = \overline{1,\ k,}\ j = \overline{1,\ 4,} \quad (10)$$

$$S = \begin{pmatrix} 1 & 1 & 1 & 2 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 1 & 1 & 2 \\ 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 2 \end{pmatrix} \quad (11)$$

The corresponding elements of the columns of the matrix S can have certain values:

$$S_{i,1} = \begin{cases} 0, employee\ is\ absent, \\ 1,\ employee\ is\ working; \end{cases} \quad (12)$$

Another check should define if the employee is able to start a new operation, has all of the materials, the equipment is properly working, and they have an initial task that has been allocated to them. To do that, the data from matrix $P1$ are needed:

$$S_{i,2} = P1_{i,1} \cdot P1_{i,2} \cdot P1_{i,3} = \begin{cases} 0, employee\ can\ not\ work, \\ 1,\ employee\ can\ work; \end{cases} \quad (13)$$

The third column of matrix S shows whether the planned task is performed. Even if $S_{i,2} = 1$, but $S_{i,1} = 0$, it is not possible to perform a task as the assigned employee is not at work:

$$S_{i,3} = S_{i,1} \cdot S_{i,2} = \begin{cases} 0,\ task\ is\ not\ performed, \\ 1, task\ is\ performed; \end{cases} \quad (14)$$

According to the values that are received in first three columns, the result column appears:

$$S_{i,4} = S_{i,1} + S_{i,3} = \begin{cases} 0, \\ 1, \\ 2, \end{cases} \quad (15)$$

The result 1 means that employee is in reserve, the result 2 means that no changes are needed and if the result is equal to 0, an additional check is needed to see if $S_{i,2}$ is equal to 0 (no actions required) or 1 (replacement is needed).

Then, matrix C was created:

$$C = \begin{pmatrix} 1 & 2 & 0,50 & 0,50 & 0,75 & 0,75 & 0,00 & 1,00 & 1,00 \\ 2 & 1 & 0,50 & 0,50 & 0,75 & 0,75 & 0,00 & 1,00 & 1,00 \\ 3 & 1 & 0,50 & 0,50 & 0,75 & 0,75 & 1,00 & 0,75 & 1,00 \\ 4 & 0 & 0,25 & 0,50 & 0,75 & 0,75 & 0,00 & 0,75 & 1,00 \\ 5 & 2 & 0,25 & 0,25 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 6 & 2 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 7 & 1 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 8 & 2 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 9 & 2 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 10 & 0 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,75 & 1,00 \\ 11 & 1 & 0,00 & 0,00 & 0,00 & 0,00 & 0,00 & 0,75 & 1,00 \\ 12 & 2 & 0,50 & 0,50 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \\ 13 & 2 & 0,50 & 0,50 & 0,00 & 0,00 & 1,00 & 1,00 & 1,00 \\ 14 & 2 & 0,50 & 0,50 & 0,00 & 0,00 & 1,00 & 0,75 & 1,00 \\ 15 & 2 & 1,00 & 0,75 & 0,00 & 0,00 & 0,00 & 0,75 & 0,75 \\ 16 & 2 & 1,00 & 1,00 & 0,00 & 0,00 & 0,00 & 1,00 & 0,75 \\ 17 & 1 & 1,00 & 1,00 & 0,00 & 0,00 & 0,00 & 1,00 & 0,75 \\ 18 & 2 & 1,00 & 1,00 & 0,00 & 0,00 & 0,00 & 1,00 & 1,00 \end{pmatrix} \tag{16}$$

The corresponding elements of columns of the matrix C can take on certain values:

$$C_{i,1} = \overline{1,\ k}, \tag{17}$$

$$C_{i,2} = S_{i,4}, \tag{18}$$

$$C_{i,j} = \begin{cases} 0; \\ 0.25; \\ 0.5; \\ 1 \end{cases}, \tag{19}$$

$j = \overline{3,\ 9}$ because there are 7 operations, and each employee has specific knowledge that can be used for the task. It represents the information from Table 1.

As in this specific example, there were two absent employees—No. 4 and No. 10, but only the employee No. 4 needed a replacement. Firstly, the program scans the employees with $C_{i,2} = 1$ because they are free to the cover task that was initially planned for employee No. 4. They need to have enough skills for operation No. 4, which was the operation that was assigned to an absent employee. In this example, two employees are available—No. 2 and No. 3. If there were no one available from $C_{i,2} = 1$ list, then the $C_{i,2} = 2$ list would be checked. The one that would have lower task ranking position would cover the task.

In this specific case, there are 8 different tasks. Each of them has two Ist degree values, two IInd degree values and IIIrd degree values, and thus, matrix OW is created:

$$OW = \begin{pmatrix} 1 & 0.10 & 0,11 & 0,05 & 0,08 & 0,82 & 0,21 & 0,13 & 0,82 \\ 2 & 0,12 & 0,13 & 0,21 & 0,21 & 0,09 & 0,25 & 0,42 & 0,09 \\ 3 & 0,81 & 0,05 & 0,55 & 0,37 & 0,00 & 0,86 & 0,92 & 0,00 \\ 4 & 0,15 & 0,12 & 0,15 & 0,07 & 0,00 & 0,27 & 0,22 & 0,00 \\ 5 & 0,75 & 0,65 & 0,24 & 0,89 & 0,00 & 1,40 & 1,13 & 0,00 \\ 6 & 0,88 & 0,50 & 0,18 & 0,89 & 0,00 & 1,38 & 1,07 & 0,00 \\ 7 & 0,79 & 0,47 & 0,49 & 0,41 & 0,75 & 1,26 & 0,90 & 0,75 \\ 8 & 0,20 & 0,39 & 0,58 & 0,25 & 0,00 & 0,59 & 0,83 & 0.00 \end{pmatrix} \tag{20}$$

The corresponding elements of the columns of the OW matrix can take on certain values:

$$OW_{i,1} = \overline{1,\ m}, \tag{21}$$

$$OW_{i,2} = \overline{0,1,} \tag{22}$$

This is factor f_1 from Table 1.

$$OW_{i,3} = \overline{0,1,} \tag{23}$$

This is factor f_2 from Table 1.

$$OW_{i,4} = \overline{0,1,} \tag{24}$$

This is factor f_3 from Table 1.

$$OW_{i,5} = \overline{0,1,} \tag{25}$$

This is factor f_4 from Table 1.

$$OW_{i,6} = \overline{0,1,} \tag{26}$$

This is factor f_5 from Table 1.

$$OW_{i,7} = OW_{i,2} + OW_{i,3}, \tag{27}$$

This is the overall first-degree tasks ranking coefficient.

$$OW_{i,8} = OW_{i,4} + OW_{i,5}, \tag{28}$$

This is the overall second-degree tasks ranking coefficient.

$$OW_{i,9} = OW_{i,6}, \tag{29}$$

This is the overall third-degree production tasks ranking coefficient. Now the condition is being checked. If

$$OW_{x,7} > OW_{i,7}, \tag{30}$$

where x is absent employee and i is employee which covers this task and whose $S_{i,4} = 2$, then, the decision is that the employee i changes to the x employee. Otherwise, 2nd degree check is initiated and if

$$OW_{x,8} > OW_{i,8}, \tag{31}$$

then, the employee i changes to the x employee. Otherwise, the DDS is initiated.

In this part, the mathematical background is presented which is needed to transform this method to the Matlab program and test it further. The tests showed that algorithm is correct and solves the described problem—the absence of employees. The received results from tests in the Matlab program are presented in the following section.

3. Results

All of received the data are up to date so that the program with the rearranged production plan can adapt in a short time. Since the investigated production company works in three shifts, the production manager is only available 8 hours per day, so this kind of software gives a solution and changes the existing production plan when it is based on real situations. The created method includes the selection of the working plan; the working day could be divided into two or one production plans for the employees. This is important since the production often has quantities which are only planned for half of the shift.

In the first case, the machine of the 1st operation is not working, and the company has all of the materials. All of the employees are at work. The visual result of the initial data is shown in Figure 6. Each operation has its own colour—red represents the cutting operation, green represents the punching operation, the 1st welding operation is dark blue, the 2nd welding operation is light blue, the finishing one is purple, the assembly one operation is yellow and the packaging one is black. If for any reason operation could not be performed, then the box is not filled with colour. The outline of the box shows the operation that was assigned. If there is a star-shaped box, it means that the employee is absent and the outline colour represents the operation which was assigned to this employee.

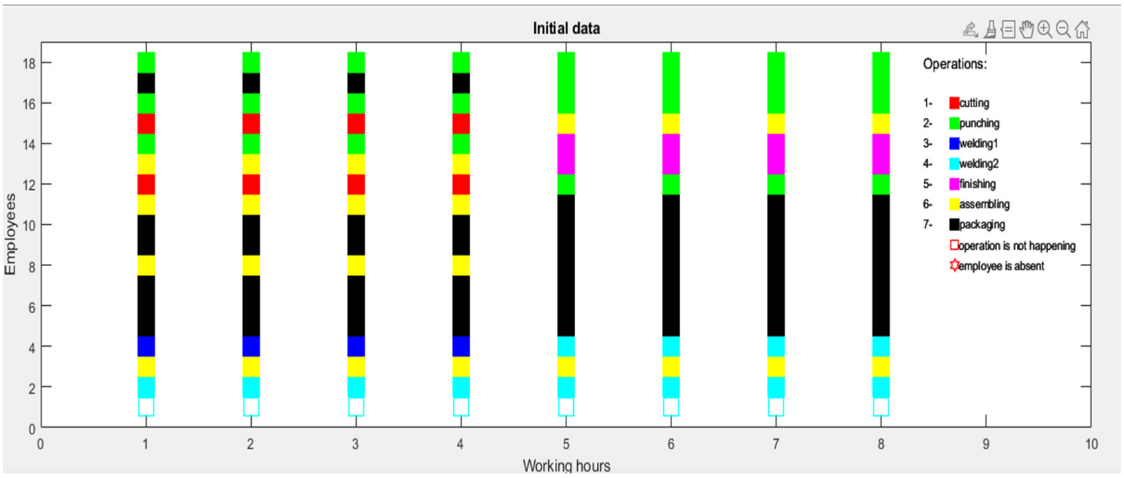

Figure 6. Initial data, 1st case.

The results are that the production plan stays as it was in the beginning of this case analysis. The first employee will remain in reserve. Figure 7 shows the visual presentation of the results.

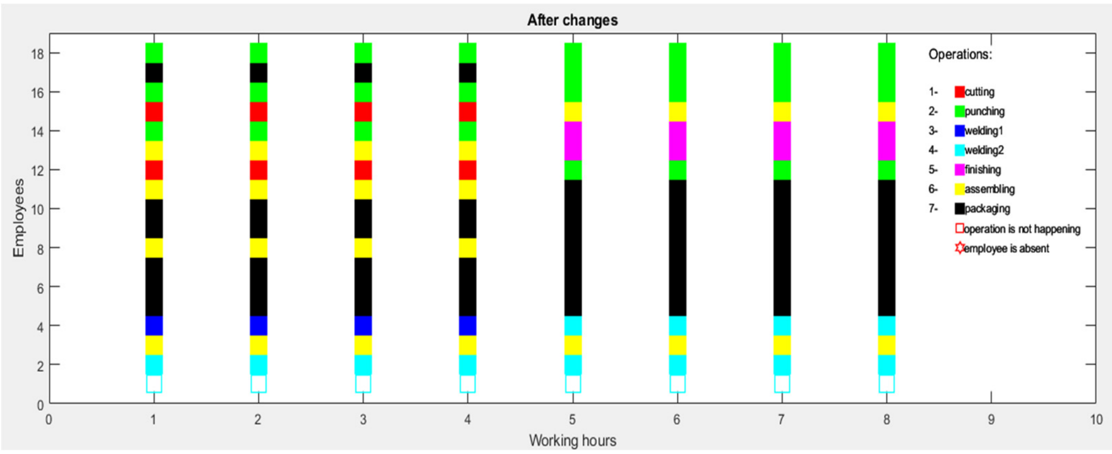

Figure 7. Data after changes, 1st case.

When the program starts, as mentioned, it requests for the data about the equipment, materials and employees that are available at the moment and the daily plan of production. For the second example, the initial data show that two machines stopped working, the 1st task was not performed due to lack of materials, the working plan is 8 h and two employees were absent (Figure 8). The program immediately gives a solution that employees No. 9 and No. 10 must be changed. Three other employees could perform the tasks of the absent ones—employees No. 5, No. 17 and No. 18. The system first gives the proposal to use those employees who were not able to work due to a lack of machinery and materials. The system proposes that they perform the operations instead of the absent ones, and only in the case that these are not suitable for the operation, it suggests someone from employee list that has tasks which has been already allocated.

```
Command Window
Number of machines forced to stop due to critical condition:2
Number of operations forced to stop due to lack of materials:1
Working plan: 1 - 8 hours continuously; 2 - changing each 4 hours:1
Number of absent employees:2
***************************************
9 employee must be changed
5 employee changes 9
17 employee changes 9
18 employee changes 9

 Select who changes absent 9 employee 17
---------------------------------------
10 employee must be changed
5 employee changes 10
18 employee changes 10

 Select who changes absent 10 employee 5
---------------------------------------
fx >>
```

Figure 8. Entered information, 2nd case.

To automatically select one of the employee of several that are available, an additional coefficient was created—the employee effectiveness coefficient. As this program seeks to optimize the production, changing the employees at random is not be the best solution. Thus, an employee effectiveness coefficient will be calculated by evaluating:

- The time period that is required for an employee to start doing a specific task (technological operation)—even if the employee has enough skills to cover task, maybe this task was performed by them a long time ago, and therefore, remembering and preparing for the task will take more time when they are compared to some other employee;
- The productivity of the employee in the certain technological operation—at the same time, a different person will perform different amount of valuable tasks, and this should be evaluated to reach maximum performance;
- The quality—the information of rejected parts/scrap from production is collected so that everyone has the data about the percentage of the inappropriate parts. It is better to select an employee who has a better quality coefficient for a specific product.

The visual presentation of the data that were entered, and the selection of the employee is shown in Figure 9.

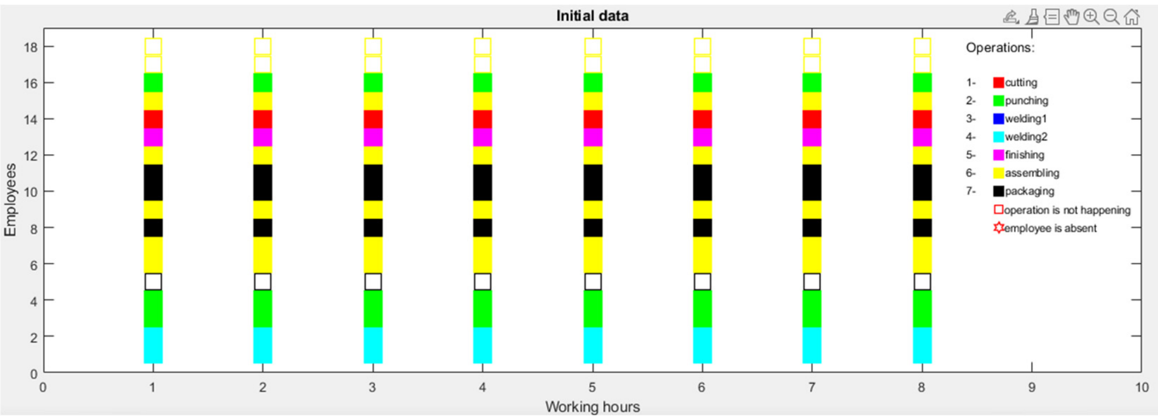

Figure 9. Initial data, 2nd case.

As it is shown in Figure 10, the selected employee No. 17 covers the task that was previously planned for the employee No. 9. Employee No. 9 had to perform an assembly operation (indicated by yellow colour) so the employee No. 17 is coloured in yellow. The same applies to the absent employee No. 10—the employee No. 5 covers the packaging operation (indicated by black colour). So as a result, only employee No. 18 stays in reserve.

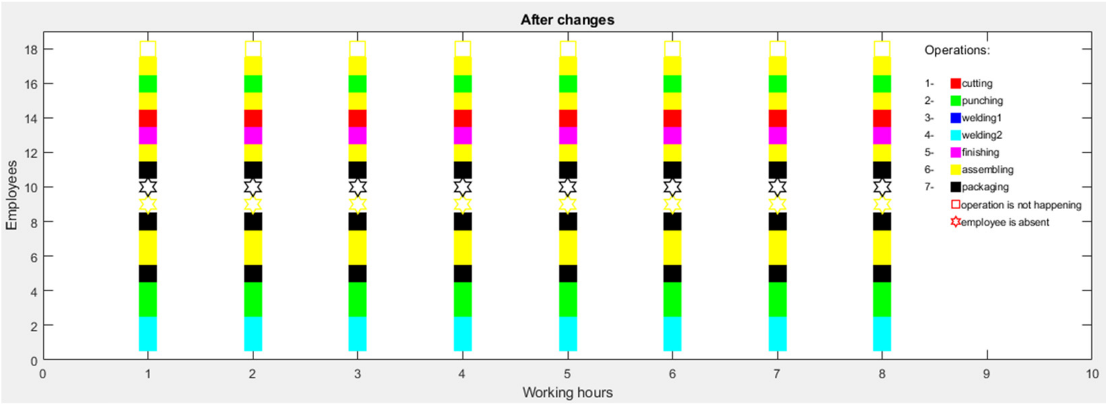

Figure 10. Data after changes, 2nd case.

There is a need to test a situation wherein all of the machines are working, and all of the materials are in place. In that case, a simulated situation is when no employees are in reserve, and thus, the selection for an absent employee is made from someone who has been allocated the task. For the selection, the task rating is initiated, and the production tasks importance coefficients are used. The input data for this specific situation are shown in Figure 11. The program selects the optimal change of the employees.

```
Command Window
Number of machines forced to stop due to critical condition:0
Number of operations forced to stop due to lack of materials:0
Working plan: 1 - 8 hours continuously; 2 - changing each 4 hours:2
Number of absent employees:1
***************************************
8 employee must be changed
There is noone free who can change absent employee
Optimal replacement 5
---------------------------------------
***************************************
8 employee must be changed
There is noone free who can change absent employee
Optimal replacement 5
---------------------------------------
fx >>
```

Figure 11. Entered information, 3rd case.

Since the working plan for this specific case is 4 hours, the program finds an optimal replacement for the first and for the second part of the day (shift). In this case, it is employee No. 5 who was completing a packaging operation. According to the plan, employee No. 8 was also assigned to the packaging operation. The initial plan is shown in Figure 12.

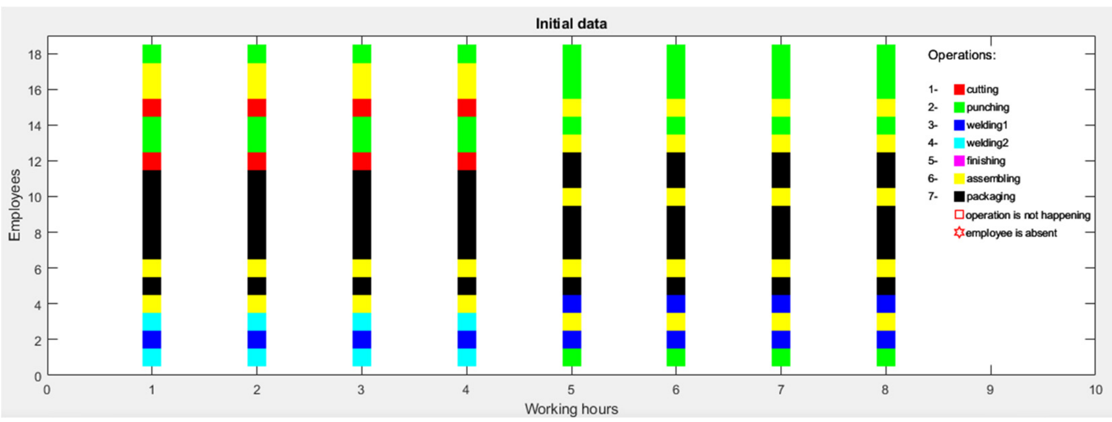

Figure 12. Initial data, 3rd case.

That means that the system checked the possible employees and selected the one that was working with least necessary operation. There were several other employees who could cover this task because based on the skills matrix, the packaging operation is commonly known to most of the employees. That is why task ranking coefficients need to be carefully selected by the authorities so the program could automatically solve such cases without additional questions being asked (additional data input is required). As a result, the task of employee No. 5 will not be processed (Figure 13).

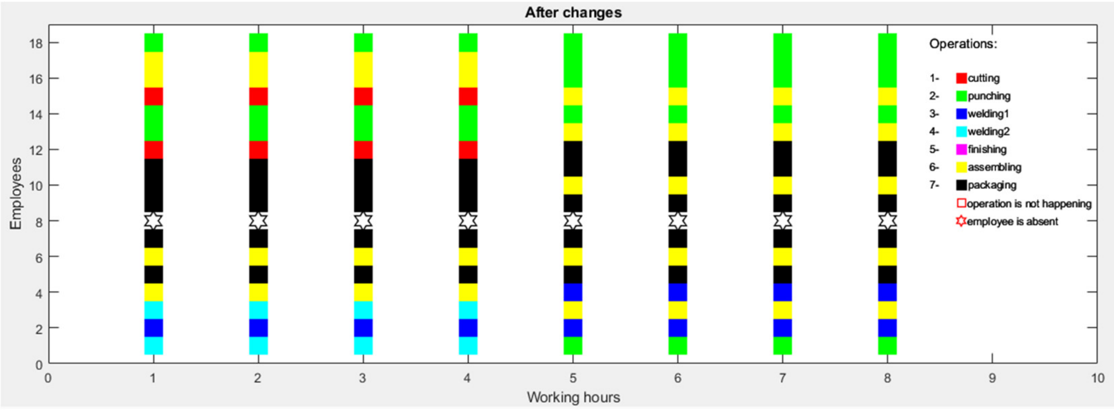

Figure 13. Data after changes, 3rd case.

All of these automatic changes in production not only provide an immediate response for the situation that occurs at that time, but it can also be used for proposals of future improvements. The collected data could give a proper result to develop further strategic actions. This is a future research topic to develop how this method could work not only in a daily background, but also provide sufficient data for management. The displayed data could present which technological equipment or operations need upgrading or to plan the development of the employees' skills.

While modelling possible situations, the program was activated 200 times. As the company has three shifts and the program is activated every time, it obtains an update on the equipment, materials or employees 200 times, which could possibly be achieved in approximately 2 months. This test presented the results of how often each employee did not come to work, and these data are presented in Figure 14.

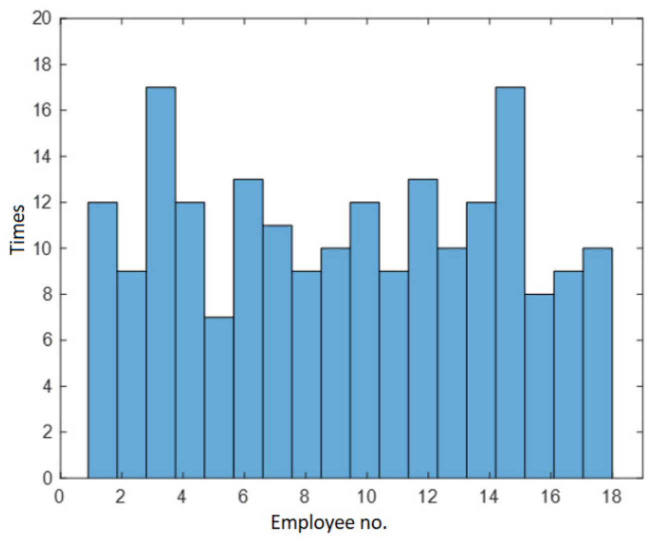

Figure 14. Number of absences after 200 program activations.

From this test, the company could find that employees No. 3 and No. 15 were absent 17 times out of 200 times. Employee No. 3 is a welder so there are only few employees with such skills, and possibly, they have been assigned welding operation tasks. The data that indicate that in two months, this employee was absent for almost 10% of working days could indicate a need to make strategical changes. The additional generated statistics present the frequency of the replacements of each employee (Figure 15).

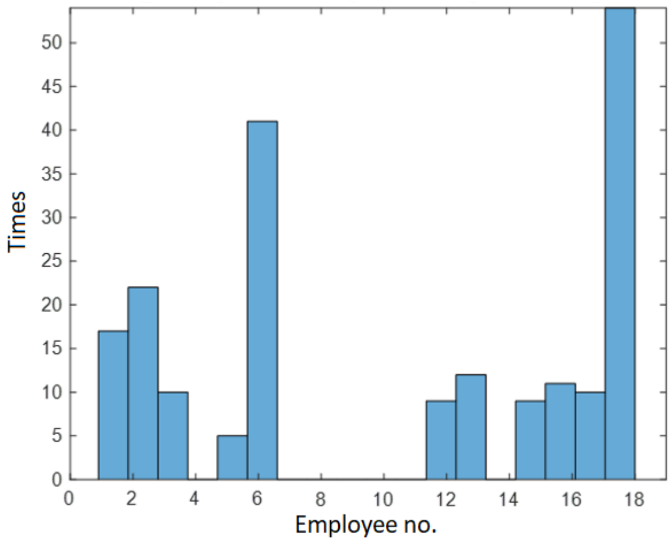

Figure 15. Number of changes after 200 program activations.

These data shows that employee No. 18 was involved in about 25% of all of the cases. Originally, this employee as assigned to cutting operation tasks. However, seven employees have not changed their tasks with another employee's during these test runs. The reasons for this should be checked, and if they cannot change theirs with other employee due to them having a lack of knowledge in another operations, this could show a need of trainings. This would reduce the load of employee No. 18, and the cutting operation (which is the starting operation in the production process) could proceed without interruptions. As well, it is possible that this employee was covering other tasks because he was in reserve or did not have the equipment or materials. In such a case, different solutions could be carried out. Having these statistics still cannot predict the occurrence of future stops or absences. Thus, the necessity of such a decision support method is needed. Each day has a different case, and this proves the dynamic of production and existing problem of SME companies that without advanced ERP systems, no other accessible solution can be provided.

4. Conclusions and Discussion

There is not a single day without unpredicted cases in the production industry, and this might not be a huge problem for large companies with ERP systems, mass production and advanced technologies. However, small and medium-sized companies face these problems differently. Production in such business is based on them having small batches and a wide range of products. The manufacturing is based on the work of the employees, and they do not have an accessible program to control the situation. That is why this article presents a decision support method for an "employee centred" company.

The case study in a medium-sized metal processing company was made, and the observations of 4 months gave a solid background to start the development of such a method. Having access to real life data presented the possibility to check the created method and obtain sufficient data. This also presented the ability to make future recommendations and proposals.

The created algorithm requires several coefficients—the production task importance coefficients, the data about the skills and the employee effectiveness coefficient will be added. The algorithm solves unpredicted situations and either gives a straight command to the workers or presents possible solutions.

In the future, this algorithm will be adapted for replanning equipment, the reconfiguration of the task sequence in case of machinery failure, the lack of materials, etc. This method is universal and could be easily used for equipment and materials in the same way it was used for employees. The statistics might be used to make strategical decisions about the improvement to the machinery, the training of employees, a change in suppliers, etc. After the investigation, a recommendation for the companies is to pay more attention to factors which are confirmed only by the production manager. To avoid subjective assessments, automatization should be discussed for coefficients such as the level of skills. The higher levels can be only gained when the automatic quality control for specific task exceeds the target value. A step before automatization could lead to a periodical competence verification which should be carried out to understand the existing level of skills. In this case, the evaluation would be connected to a specific value, but not to the personal opinion.

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