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Inconsistencies in the Production Process Resulting From the Employment Structure

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PLANNING THE DURATION OF THE PRODUCTION PROCESS

One of the basic objectives set by engineers during the planning of the production process is the correct location of all operations, treatments and other activities related to the manufacturing process underway (Burduk, et al 2019, Gawlik, et al., 2017). Properly executed stage, which is the planning of the production process, should allow to indicate the exact moment of starting and ending the production process, as well as to determine where, by whom and with the use of which devices selected operations forming part of the production process should be implemented. Production planning should be implemented based on data on, inter alia, the production capacity that the company has at the time of commencement of a given production or (in the case of long-term planning) the capacity that it will have in the future (Kotowska at. al 2017, Górecka at al. 2017, Paprocka at. al 2017, Kutschenreiter-Praszkiewicz 2016).
In order to determine the basic information that allows proper planning of production is to determine the duration of production (punctuality). Defining the theoretical times takes place at the process planning stage by calculating the time of execution of individual activities performed in the framework of each production operation (Leong at al. 1990). The reason for the inability to accurately estimate the duration of production operations, especially in the case of non-automated production, is a large number of independent factors hindering the unambiguous qualification and determining the amount of possible delays. In a large number of cases, methods for estimating the duration of selected stages of the production process are determined on the basis of analytical and computational methods (such as, among others, MTM I and MTM II elementary movements) and analytical and measurement methods (e.g. timing or photo of the working day) and exploration of historical data Unfortunately, however, in a large number of cases there are large discrepancies between the theoretical times of the production process and sometimes the real time (Marlock, at al. 2017, Pawlak & Miranowicz, 2017, Brokranz & Landau 2012.

The occurrence of the underestimation of the duration of the production process is particularly evident in production plants specializing in serial production of a parallel or series-parallel system. In the case of a parallel system, the element being executed immediately after the completion of a particular operation is immediately transported to another workstation, the workstation is used for further actions aimed at making the final element. The station receiving the element should be ready for immediate implementation of the given operation, Fig. 1.

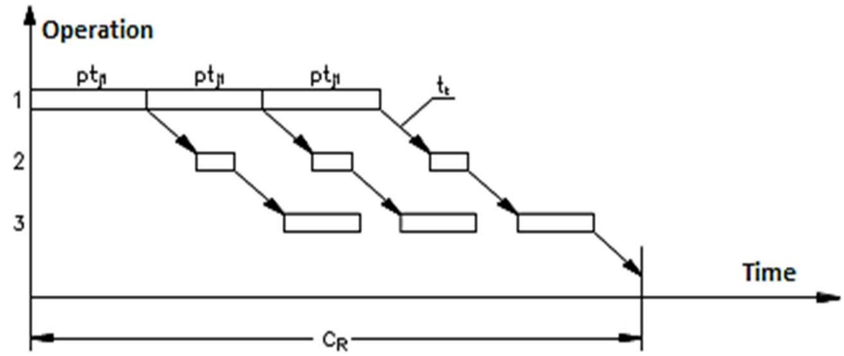

Fig. 1 Parallel system

Source: (Pawlak, Nowacki 2017)

When the duration of individual operations is equal to or is a multiple of a number of operations taking place in shorter time series, it can be concluded that the applied parallel flow implements the principle of continuity of the flow of elements. In other cases, there is a need for machine downtimes whose working rhythm is determined by the duration of the previous production task. In order to reduce losses related to downtime of particular positions, attempts should be made to align the rhythms of operation of all production units or to minimize the occurrence of time intervals arising between operations (Pająk, 2016, Lisowski & Kozłowski 2016, Pawlak & Nowacki 2017).

Assumptions:

t_j – unit time of the operation, p – size of the transport lot, t_t – time of the transport operation, Cr – total duration of the parallel flow Csr – total duration of the serial-parallel flow.

Serial-parallel system

The basic feature of the serial-parallel system is to run production continuously, while reducing the level of generated inter-operable stocks. For this purpose, the workplace waiting to perform the machining process does not wait for the entire batch of elements produced in the previous workplace, and starts working as soon as possible. In this case, there is a need to synchronize tasks consisting (depending on the case considered) immediately joining the job or delaying it, Fig. 2 (Pająk, 2006, Pawlak & Nowacki, 2017).

The development of a precise schedule taking into account the location of particular operations over time is based mainly on the theoretical synchronization of their work time. A meticulously prepared schedule that allows to obtain serial-parallel flow is difficult to implement.

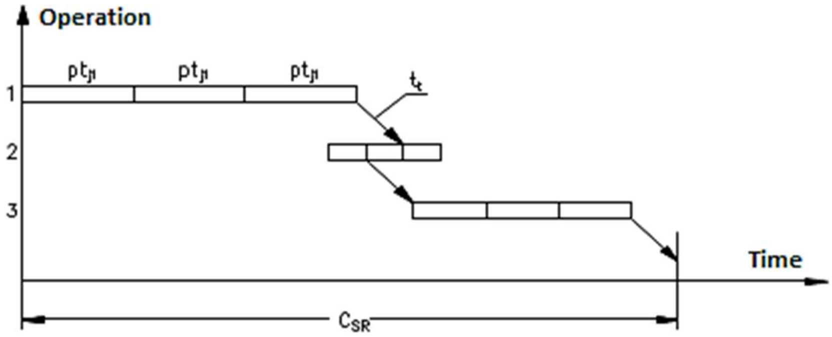

Fig. 2 Serial – parallel flow

Source: (Pawlak, Nowacki 2017)

Random events, such as: untimely delivery of materials, machine failures or mistakes made by production personnel, may result in a longer time of a given operation, which is directly related to the risk of colliding of actual tasks with events scheduled in the schedule. The lack of full synchronization of events resulting from the delay or possible inability to undertake the operation at the exact time set prevents the implementation of a properly functioning serial-parallel flow.

The occurrence of time delays on any of the existing production operations carried out with a parallel or serial-parallel system determines the delay of the entire production process, the generation of intermediate stocks and the difficulty in estimating the company's production capacity. In production processes with such characteristics, identification and analysis of the reasons for underestimating the duration of the production process is one of the basic activities allowing to determine the reasons for their occurrence. The activities causing the factors determining underestimation depend, inter alia, on the type of production process, the level of complexity of production operations carried out as part of the analyzed production process, production volume, material flow organization applied between the various operations included in the process, skills and qualifications of employees and the structure of their employment.

The paper presents an analysis of the production process of the underestimation of the duration of the production process, taking into account the employment structure in the manufacturing company. The analyzes allow to determine the level of underestimation of operations of the production process depending on the form of employment (steel workers – employed under a contract of employment in the production plant, and temporary workers employed by temporary work agencies), identification of the reasons for the underestimation of individual production positions and the length of their time occurrence.

ANALYSIS OF THE UNDERESTIMATION OF THE DURATION OF THE PRODUCTION PROCESS

The production process carried out in a serial-parallel system was analyzed. The production process consists of 9 production operations marked with A-I symbols, implemented on separate production cell. The period covered by the analysis was 2 months (February and March) on three working changes. Table 1 shows the number of the production cell, its name and the theoretical time of the production operation, calculated using the MTM 1 method.

Table 1 The duration of production operations

Designation of the production cell	Theoretical duration of operation [s]
A	650
B	212
C	200
D	350
E	225
F	202
G	340
H	120
I	240

In order to analyze the causes of time delays occurring over time, identification of causes that underestimate the manufacturing process was taken into account, including the underside and its duration on a particular change. Table 2 shows the causes of delays in the production process, recorded during the period of time analyzed. Each delay cause has a code defined by the manufacturer.

Table 2 Causes of delays

Code of the cause	Description of the cause
4000	Service (over-standard service time)
4002	Start from the standstill
4004	Over-standard setting time
4007	Technical failure of the machine
4009	The difference for service
4011	Material defect

Table 3 The number of employees and the level of underestimation of the duration of the production process – February

February – Week 1			
Employees:	Permanent	Temporary	Total
Number of employees	156	68	224
Percentage of employees	70%	30%	
The sum of ineffective time	189,06	371,02	560,08
Percentage of ineffective time	34%	66%	
February – Week 2			
Employees:	Permanent	Temporary	Total
Number of employees	148	69	217
Percentage of employees	68%	32%	
The sum of ineffective time	165,12	389.1	554,22
Percentage of ineffective time	35%	65%	
February – Week 3			
Employees:	Permanent	Temporary	Total
Number of employees	152	66	218
Percentage of employees	70%	30%	
The sum of ineffective time	201,2	278,8	480
Percentage of ineffective time	42%	58%	
February – Week 4			
Employees:	Permanent	Temporary	Total
Number of employees	171	71	242
Percentage of employees	71%	29%	
The sum of ineffective time	191,3	243,7	435
Percentage of ineffective time	44%	56%	

In order to analyze the production process in terms of occurring delays causing underestimation of the production process due to the employment structure, the percentage share of permanent employees - employment contract for the work in the production plant and temporary workers by temporary work agencies was analyzed, taking into account the level of generated by them underestimates, Table 3, 4.

Table 4 The number of employees and the level of underestimation of the duration of the production process – March

March – Week 1			
Employees:	Permanent	Temporary	Total
Number of employees	147	58	205
Percentage of employees	72%	28%	
The sum of ineffective time	232,2	322,4	554,6
Percentage of ineffective time	42%	58%	
March – Week 2			
Employees:	Permanent	Temporary	Total
Number of employees	174	66	240
Percentage of employees	73%	28%	
The sum of ineffective time	220,2	310,1	530,3
Percentage of ineffective time	42%	58%	
March – Week 3			
Employees:	Permanent	Temporary	Total
Number of employees	176	57	233
Percentage of employees	76%	24%	
The sum of ineffective time	199,9	256,8	456,7
Percentage of ineffective time	44%	56%	
March – Week 4			
Employees:	Permanent	Temporary	Total
Number of employees	132	38	170
Percentage of employees	78%	22%	
The sum of ineffective time	93,9	261,3	355,2
Percentage of ineffective time	26%	74%	

In the analyzed period, an average of around 28% employees employed by temporary work agencies generated around 61% underestimation. In order to present the scale of the problem regarding the occurring delays, depending on the employment structure of employees, the average delay time per employee in a given week is presented in Figures 3 and 4.

The highest average level of delays generated by temporary employees in a particular week occurred in the 4th week of March and amounted to 6.88 [h] with a lag time of only 0.71 [h] in the case of permanent employees.

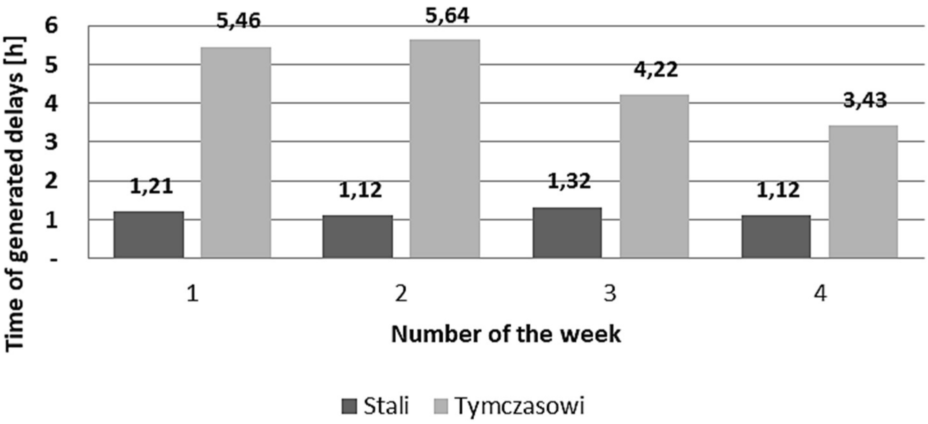

Fig. 3 Average time of delay per employee [h] – February

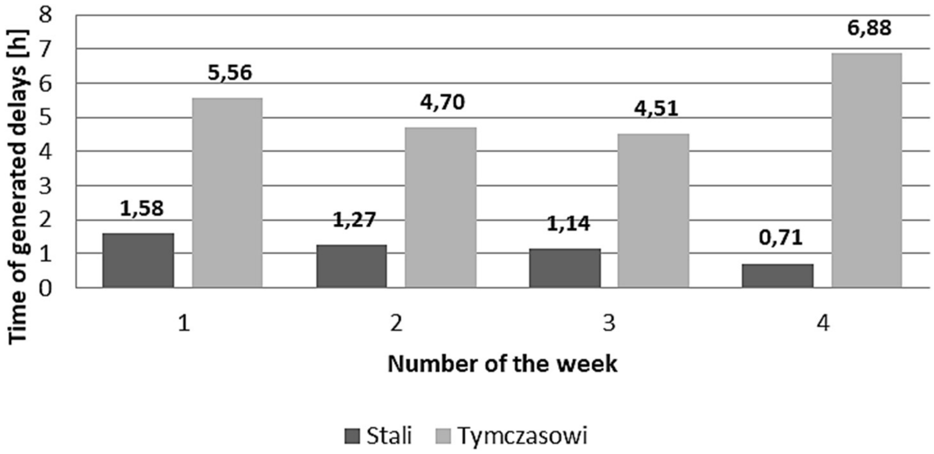

Fig. 4 Average time of delay per employee [h] – March

As a result of the analysis of the data showing the differences in the delay of the production process generated by temporary employees with respect to temporary employees, a detailed analysis of the distribution of underscore causes occurring at individual production cells was made, Table 5.

Table 5 Causes of delays on selected production cells

	Name of the production cell	The cause February	The cause March
Permanent	A	4004, 4007, 4002	4004, 4007, 4002
Temporary		4004, 4007, 4002	4004, 4007
Permanent	B	4011	4000, 4011
Temporary		4000, 4004, 4011	4000, 4004, 4011
Permanent	C	4009	4008, 4009
Temporary		4009, 4008	4008, 4009
Permanent	D	-	4009
Temporary		4008, 4009, 4011	4009, 4011
Permanent	E	4011, 4008	4008, 4009
Temporary		4008, 4009, 4011	4008, 4009, 4011
Permanent	F	4000	4000, 4004
Temporary		4000, 4004, 4008	4000, 4004
Permanent	G	4004, 4007, 4002	4004, 4007, 4002
Temporary		4002, 4007, 4011, 4004	4002, 4007, 4011, 4004
Permanent	H	-	4009
Temporary employees		4004	4004, 4009

After the analysis, it was found that in a large number of cases, there was a greater number of reasons for delays in the case of employees hired by temporary work agencies at individual production cells. The largest disproportion in the number of occurring causes of undervaluation occurred in the production cell B in the entire analyzed period, in the case of permanent employees the only occurring cause of underestimation was material defect, while in the case of temporary workers: material defect, over-standard service time, over-standard setting time.

In order to determine the level of time differences between temporary and permanent employees during the delay at individual production cells, Tables 6 and 7 were prepared, specifying the exact time of delays, all underestimation reasons occurring at the selected production cell.

Table 6 Delays occurring at selected production cells – February

Underestimation of the time, permanent employees – February [h]								
Cause	**Production cell**							
	A	**B**	**C**	**D**	**F**	**G**	**H**	**I**
4004	32						64	
4007	48						34	
4000						109		
4009		118	142					
4011					62			
4002	12						45	
Underestimation time, temporary employees – February [h]								
Cause	**A**	**B**	**C**	**D**	**F**	**G**	**H**	**I**
4004	67	21					58	35
4007	158						32	
4000		112				154		
4009		164	210	39	15			
4011					81		13	
4002	86						131	
Ineffective time generated by permanent employees	93	118	142	0	62	109	143	0
Ineffective time generated by temporary employees	313	298	210	39,2	97	154	234	35

Table 7 Delays occurring on selected production cells – March

Underestimation of the time, permanent employees – March [h]								
Cause	**Production cell**							
	A	**B**	**C**	**D**	**F**	**G**	**H**	**I**
4004	28						32	
4007	37		28				23	
4000		21				131		
4009		111	159		78			9
4011				21	59			
4002	10						36	
Underestimation time, temporary employees – March [h]								
Cause	A	**B**	**C**	**D**	**F**	**G**	**H**	**I**
4004	68						46	10
4007	120	12					32	
4000		112				151		
4009	10	130	179	39	15	26		23
4011					81		13	
4002							80	
Ineffective time generated by permanent employees	76	111	187,7	21	137	131	92	9
Ineffective time generated by temporary employees	198	255	179,3	39	97	177	171	33

As a result of the comparative analysis of inefficient time generated by permanent and temporary employees, it was found that in the verified period of time, in each of the production cells, the delay time in relation to the assumed one was larger in the case of temporary employees. In the analyzed period, the highest level of occurring delays occurred on the production nest A and B, and the main reason for the underestimation was the "difference in service" – not meeting the time standards calculated at the planning stage of the production process.

CONCULSION

The complexity of the production planning process is caused by a huge number of factors seemingly independent, impeding precise definition of the duration of individual operations, and determining the actual production capacity of the

company. Statistical analysis of data obtained on the basis of continuous control of the manufacturing process allows in many cases identification of key reasons that cause a high level of underestimation. In the described case, the underestimation of the duration of the production process generated by production workers (temporary and permanent) was subject to analysis.
The calculations carried out in a given time interval clearly indicate a large time discrepancy in the case of temporary employees, causing numerous delays in the production process. The occurring undervaluation causes numerous downtimes and makes it impossible to determine the actual production capacity of the company. Obtained results may lead to removal of reasons for delays or the introduction of corrective actions aimed at reducing the impact of their impact on the duration of the production process.

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Abstract.
Underestimating the duration of the production process is one of the basic factors determining the occurrence of delays in the duration of individual operations included in the production process. Occurrence of underestimation of production time brings many negative effects, which include, among others: underestimation of the company's production capacity, accumulation of intermediate stocks, impeded planning of the production process (scheduling of the production process) and increase of production costs. The problem of erroneous estimation of the duration of the production process is most often found in production plants specializing in serial or mass production, implemented in a parallel or series-parallel system. The basic causes that underestimate the duration of the production process include errors in production scheduling, incorrect determination of durations of individual operations carried out as part of the analyzed production process, complexity of production operations and employment structure. The occurrence of delays in the production process can also be affected by accident events that generate underestimation and costs for the enterprise (including social and economic costs). In many cases, many algorithms are used to reduce underestimation and optimization and scheduling of the entire production process. The publication presents an analysis of the production process in which the duration of the production process is underestimated, taking into account the employment structure in the manufacturing company. The analyzes allow to determine the level of underestimation of operations of the production process depending on the form of employment (steel workers – employed under a contract of employment in the production plant, and temporary workers employed by temporary work agencies), identification of the reasons for the underestimation of individual production positions and the length of their time occurrence.

Keywords: production, production planning, underestimation