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Innovation in the Production Process: Conditions in Line with the Production Schedule

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Abstract:

Purpose: *Efficient implementation of the production process is important nowadays. The form of production is important from the point of view of meeting the conditions in which operations are assigned to individual positions in accordance with the production process, based on the schedule of a given production.*
Approach/Methodology/Design: *The literature on production processes was reviewed according to manufacturing techniques. The conditions of production feasibility were verified, together with the verification of the matching of employees and the degree of use of working time. The following formulas were used to achieve the above objective, production programme of final products, cooperation products, production of spare parts, repeatability of parts in the product, shortage rate and number of assortments of finished products.*
Findings: *The combination of the above-mentioned elements at the same time makes it possible to identify innovations, as so far no one has analyzed this issue in a simultaneous manner. Immediate solutions are indicated.*
Practical Implications: *In the literature on the subject no one has assumed all these activities at once. There was also no numerical connection in this area.*
Originality/Value: *The originality is given by the timing of the links between the individual process steps, which allows it to be considered innovative.*

Keywords: *Innovation, production, evaluation, production system, management.*

JEL classification: *O30, R38, G32, M11.*

Paper Type: *Research study.*

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1. Introduction

The functioning of all kinds of production processes nowadays is one of the essential elements of the organization's efficient functioning. It would be sufficient to maintain the proper structure of basic management functions, which planning plays at the very beginning. And then organizing and controlling. Although at this stage, and in principle at every stage, we cannot exclude motivating (Rosenblatt and Lee, 1986). The feasibility of the production process was assessed by asking a question in the form of Hypothesis 1 - Are the conditions of feasibility of production fulfilled? Hypothesis 2 - Is the number of employees appropriate? and Hypothesis 3 - Does their working time utilization rate meet the relevant feasibility standards?

At the very beginning, it is worth adding that the production form is important in terms of meeting the conditions in which operations are assigned to positions in accordance with the production process is based on a schedule for the production in question (Wojtaszek and Miciuła 2019).

2. Production Processes

Production is one of the basic elements of a company's economic activity, adapting the resources and forces of nature to human needs. In today's world, the demand for goods and services dictates the size, structure, and method of sale. Production is created to meet the needs of buyers (Rosenblatt and Lee, 1986). By the term production process, we mean a planned set of intentional actions prepared for production starting from taking the base material (material) from the warehouse through individual stages of technological, transport, control and storage operations (as well as natural processes) up to and including the sentence of the finished product prepared to create the finished material, later usually the product. The production process consists of manufacturing process, research and development, production preparation and distribution process.

Table 1. *Stages of the production process*

Production process	
Research and development process	Customer needs analysis Capital accumulation and financial finalization of development works Forecasting and planning of company development Developing a company strategy Preparation of production Preparation of resources Analysis and improvement of the production process and products Evaluation analysis of customer needs
Testing process and manufacturing process	Basic processing of inputs articles
	Auxiliary Machine operation, power supply and material, waste disposal

	Administrative support Orderly HEALTH AND SAFETY
Distribution process and customer service	Preparation of products for distribution, product distribution, product service, recycling and regeneration, handling of product life cycles

Source: *Jałowiec et al., 2020, Wojtaszek and Miciuła, 2019.*

The research and development process consists of performing activities preparatory to production in terms of design, technology and organization aimed at performing the manufacturing process, where it is transformed into devices. The distribution process consists in building distribution channels for the customer and after-sales service (Laosirihongthong and Dangayach, 2005). The core business of manufacturing companies is to produce products that meet the expectations of the future buyer (customer). The buyer pays a certain price for the good, and the customer, as a manufacturer (producer), generates revenue from sales. In the modern world and turbulent market tendencies, we are not sure that a company will make a profit even in a situation of flawless or exemplary business operation (Dangayach and Deshmukh, 2001). The manufacturing process is a part of several specific process activities, such as: basic, auxiliary, and service processes. Basic manufacturing processes make it possible to manufacture products whose sale is the main source of the company's income.

However, in the sphere of the company's basic activity. We distinguish a few processes, such as development of a concept of a new product, meeting the known needs of customers or creating new needs, design of a new product and manufacturing processes, ensuring appropriate quality and reliability of the product, production of the product together with technical control and acceptance (Niu *et al.,* 2019).

Ancillary manufacturing processes are logistic activities of the company providing the basic processes with necessary resources: employees with appropriate qualifications, equipment, appropriate premises. Auxiliary manufacturing products are used for the company's own needs (Hopkinson and Dicknes, 2003). The service processes are designed to meet the needs of the company: maintenance, repairs of fixed assets, administration of employees in terms of human resources (wages, working time records), health and safety at work and securing assets (Edvardsson and Olsson, 1996). Manufacturing processes may be classified according to other criteria: manufacturing techniques, technological features, means of work used and technological phases, as shown in Table 2. The organization of the manufacturing process is also influenced by the way workstations are linked in the process. The organization of the course of work subjects can be divided into non-rhythmic forms (non-rhythmic, universal), where the direction of the flow of work subjects is variable, which indicates that each workstation cooperates with different positions. This usually concerns production specialization of technological nature using the same method of processing. Production is used when a production order requires specialist technical equipment together with a low level of capital investment.

Table 2. *Types of manufacturing process by manufacturing technique*

Breakdown criterion **Type of manufacturing process**	**The essence of the manufacturing process**
Mining	Extraction of material goods from land, water and air: extraction of coal, oil; also logging from forest, fishing; extraction from air gases such as nitrogen, helium
Processing	Processing of raw materials into completely different products with altered physicochemical properties: oil processing, metallurgy, processing of energy resources in essential forms of energy.
Machining	Causing a change in the shape and characteristics of the surface or internal structure of products made of different materials. The following operations are used in machining processes: shaping, heat or thermo-chemical treatment, surface treatment and physico-chemical treatment
Assembly	They are intended to consist of two or more the number of elements.
natural and biotechnological	They cause changes in structure and properties of materials. These include processes involving the use of biologically active organisms for manufacturing products as a result of so-called biotechnology.

Source: *Hernandez-Matias, J.C., Vizán, A., Hidalgo, A., Ríos, J. 2006. Evaluation of techniques for manufacturing process analysis. Journal of Intelligent Manufacturing, 17(5), 571-583.*

Table 3. *Types of manufacturing process due to the complexity of the process*

Simple	Compiled
Used in the manufacture of homogeneous products and low complexity	Used in highly complex production. The product is usually made within several technological phases

Source: *ElMaraghy, W., ElMaraghy, H., Tomiyama, T., & Monostori, L. 2012. Complexity in engineering design and manufacturing. CIRP annals, 61(2), 793-814.*

Unusual forms of production organization require the employment of highly qualified and rhythmically (streamlined, repetitive) personnel. Pipeline forms of production organization are aimed at the best possible adaptation of the manufacturing plant to the requirements of the production process, to carry out the process without interruptions and interruptions. Production activities in this type of production enterprises are propitiatory in a continuous manner, i.e., directly after the execution of Individual Activities, where they are later transferred to the next stage of the production process. The form of this production reduces the inter-operational stocks and indicates the employment of workers with lower qualifications. Specialization of workstations and employees working on them allows to achieve higher work efficiency and stabilized quality of products. As far as the production is streamlined, it looks like that the workstations are arranged according to the subject structure, i.e., identical with the order of technological operations performed (Urbanic and ElMaraghy 2006).

The rhythmic form of production distinguishes detailed aspects of production subforms, such as, asynchronous stream, synchronous stream, forced-beat brook, automated brook. In an asynchronous stream there is no continuity in the production process, and in a synchronous stream there is. Forced-beat and automated stream were separated according to the criterion of the degree of mechanization, of the movement of products between production stands performing subsequent technological operations. In the asynchronous stream the execution times of individual operations are not equal and do not constitute a multiple of the duration of other operations. In a synchronous stream, the synchronization of operations results in a constant connection of workstations, with their full use and complete uniformity of the production process (Brezina and Weiss, 2000).

3. Assessment of Production Capacity

The following study contains the basic calculations for the airRDI filter operating system, which include, production programme, large batches, number and location of workstations, the number of necessary production workers, the length of the production cycles. The production site where similar items are made by different technologies is one of the basic forms of production organization, which has the following features: reverting to previously used workplaces, changes in direction, the product routes intersect each other in an inter-operative manner, the individual details contribute to the load on the workstation, the most used sequence of details, serial, serial parallel. The production form meets the following conditions the operations are assigned to individual positions, the sequence of operations on each position is normatively determined and it repeats itself rhythmically and production is controlled based on a pattern, for example: schedule, production tact. Parts selection and selection of assortments necessary for the production were made based on technological documentation and overall sketches of the parts by performing the following calculations. In the first step, a calculation of the annual production programme of individual parts was:

$$P_{czi} = (\sum_{n=1}^{a_g} P_{fi} \cdot d_i + P_k + P_z)(1+b)$$

- P_{fi}- programme of production of final products
- P_k- the cooperation products programme
- P_z- spare parts manufacturing programme
- d_i- the repeatability of parts in the product
- b- deficiency rate
- a_g- number of finished product assortments

After substituting the appropriate data, we obtained:

P_A= (1500*3+500+500)(1+0,02)=5610 (arts/year)
P_B= (2000*2+1500+700)(1+0,02)=6324 (arts/year)
P_C= (2000*2+1000+700)(1+0,02)=5814 (arts/year)
P_D= (1500*3+1000+700)(1+0,02)=6324 (arts/year)
P_E= (1000*3+1000+500)(1+0,015)=4567,5 (arts/year)

The relevant data were received:

The relevant data were received:

	Nr. rys. części	P_f (arts/year)	di (arts/year)	P_k (arts/year)	P_z (arts/year)	B %	P_{czi} (arts/year)
1	**A**	1500	3	500	500	2	5610
2	B	2000	2	1500	700	2	6324
3	C	2000	2	1000	700	2	5814
4	D	1500	3	1000	700	2	6324
5	E	1000	3	1000	500	1,5	4568

The technology was established and identified, and technology cards were developed

Lp.	R1	R2	R3	R4	R5	R6	R7	R8	m	m_r
A	10	20	30	40	50	70	-	-	6	6
B	-	10,20	30	-	40,70	60	-	-	6	4
C	-	20	30,40	-	50	70	10	-	6	5
D	10	20	40,50	-	60	80	-	-	6	5
E	-	20	30	-	60	40	10	50	6	6
Total									30	26

The markings: m- number of operations m_r- number of generic operations

Lp.	R1			T2			R3			R4			R5			R6			R7			R8			Σtpz	Σtj
	op	tpz	tj	op	tpz	tj	op	tpz	tj	op	tpz	tj	op	tpz	tj	op	tpz	tj	op	tpz	tj	op	tpz	tj		
A	10	0,40	0,65	20	0,30	0,25	30	0,40	0,10	40	0,40	0,10	50	0,10	0,10	70	0,60	0,60	-	-	-	-	-	-	2,2	1,8
B	-	-	-	10 20	0,45 0,25	0,25 0,25	30	0,24	0,10	-	-	-	40 70	0,90 0,90	0,10 0,10	60	0,50	0,60	-	-	-	-	-	-	3,24	1,4
C	-	-	-	20	0,50	0,25	30 40	0,70 0,40	0,10 0,10	-	-	-	50	0,60	0,12	70	0,50	0,60	10	0,40	0,25	-	-	-	3,1	1,42
D	10	0,40	0,25	20	0,50	0,25	40 50	0,40 0,40	0,10 0,10	-	-	-	60	0,80	0,10	80	0,50	0,65	-	-	-	-	-	-	3,0	1,45
E	-	-	-	20	0,30	0,20	30	0,68	0,10	-	-	-	60	0,15	0,10	40	0,30	0,60	10	0,45	0,30	50	0,41	0,35	2,29	1,65
Suma					-	0,80	0,90	-	2,3	1,45	-	3,22	0,70	-	0,40	0,10	-	3,45	0,62	-	2,4	3,05	-	0,85	0,55	-

The marking: op- operation t_{pz}- preparatory and final time t_j- unit time

4. Verification of General Capacity Conditions

The conditions for a specialized filter are as follows:
$\rho_{śr}$: 0,65-0,85, f: 2-10 ,$r_{opśr}$: 0,1-0,5

Checking the value of the technological and organizational similarity factor. This coefficient illustrates the degree of coverage of a set of homogeneous job groups by technological marches of objects.

After the substitution to the pattern we get: $\rho_{śr} = \frac{26}{8 \cdot 5} = 0{,}65$

So, this indicator is within the range.
Calculate the coefficient of variation of works using the following formulae:

$$f = \frac{m_g}{r_g}$$

- m_g - number of operations
- r_g - number of posts

$$r_g = \frac{\sum_{i=1}^{a_g} P_{czi} \cdot T_{ji} \cdot (1 + g_i)}{F_{mn} \cdot \eta_n}$$

T_j - unit time
P_{cz} - annual programme of parts
- proportionality factor of the share of time tpz in total labour intensity, was adopted: q=0,05

F_{mn} - machinery and nominal fund
$F_{mn}=F_k-F_w$
F_k - calendar fund
F_w - leisure fund

Information: 5-day working week and 2 working shifts were adopted
ηn- normative workload factor taking into account necessary provisions for organisational losses, adopted: $\eta_n=0{,}85$
The relevant data were received:

We calculate the coefficient of variation of works f:

$$r_g = \frac{(5610 \cdot 1{,}8 + 6324 \cdot 1{,}4 + 5814 \cdot 1{,}42 + 6324 \cdot 1{,}45 + 4568 \cdot 1{,}65) \cdot 1{,}05}{4240 \cdot 0{,}85} =$$

$$\frac{46110{,}204}{3604} = 12{,}79 \cong 13$$

5. Calculation of the Repeatability of Workstations

$$d_r = \frac{r_g}{r_r}$$

- r_g - number of posts
- r_r - number JGS

$$d_r = \frac{13}{8} = 1{,}625$$

It should be noted that the condition is met: $d_r < 3$

Checking the value of the completion rate:

$$e = \frac{\sum_{i=1}^{a_g} m_{czgi}}{\sum_{i=1}^{a_g} m_{czi}}$$

- m_{czgi} - number of operations
- m_{czi} - total number of operations

$$e = \frac{30}{40} = 0{,}75$$

When analyzing the possibility of division JP_I. The e indicator for smaller units is an important element guiding the further action programme. When the division results in a significant deterioration of the coefficient below e=0,9-0,7 this leads to an abandonment of the division.

6. Determining the Economic Size of the Batch, the Rate of Production of the Parts, Unit Rhythm, Batch Rhythm, etc.

Economic production volume

$$n_{ek} = \frac{T_{pz}}{q \cdot T_j}$$

- T_{pz}- the preparation and completion time of the operation
- T_j- unit time of individual operations
- q- współczynnik udziału Tpz

The coefficient takes values 0,02-0,15

After the data was substituted, the following results were obtained for individual details:

$$n_{ek}(A) = \frac{2{,}2}{0{,}02 \cdot 1{,}8} = 61{,}11 \approx 61 \qquad n_{ek}(D) = \frac{2{,}7}{0{,}02 \cdot 1{,}55} = 93{,}54 \approx 93$$

$$n_{ek}(B) = \frac{3{,}24}{0{,}02 \cdot 1{,}4} = 115{,}71 \approx 116 \qquad n_{ek}(E) = \frac{2{,}29}{0{,}02 \cdot 1{,}65} = 69{,}39 \approx 69$$

$$n_{ek}(C) = \frac{3{,}1}{0{,}02 \cdot 1{,}42} = 109{,}15 \approx 109$$

Calculation of the component production rate:

$$p = \frac{P_{cz}}{F_{mn}} \text{ pieces/year}$$

P_{cz}- annual parts production programme
F_{mn}- nominal machine fund

After substitution, the following results were obtained, and the following results were obtained for the individual parts:

$$R_j = \frac{1}{p} \qquad p_{śr} = \frac{25640}{4240} = 6{,}75$$

$$p_A = \frac{5610}{4240} = 1{,}32$$

$$p_B = \frac{6324}{4240} = 1{,}49 \qquad p_D = \frac{6324}{4240} = 1{,}49$$

$$p_C = \frac{5814}{4240} = 1{,}37 \qquad p_E = \frac{4568}{4240} = 1{,}07$$

Determination of unit rhythm: where:
p- production rate

After substitution, we get it:

$$R_{jśś} = \frac{1}{6{,}75} = 0{,}15$$

For the individual parts, it was obtained:

$$R_j(A) = \frac{1}{1{,}32} = 0{,}75 \qquad R_j(D) = \frac{1}{1{,}49} = 0{,}67$$

$$R_j(B) = \frac{1}{1{,}49} = 0{,}67 \qquad R_j(E) = \frac{1}{1{,}07} = 0{,}93$$

$$R_j(C) = \frac{1}{1{,}37} = 0{,}73$$

Calculation of the series rhythm

$$R_s = n_{ek} \cdot R_j$$

- N_{ek}- economic lot size
- R_j- bar

After inserting the data, it was calculated:

1.1 Determining the corrected series rhythm Rs`

Lp.	R_s	R_s`	$\lvert R_s$-R_s`$\rvert$	R_s``
A	45,75	48	0,75	45
B	77,72	96	-12,27	90
C	79,57	96	-10,43	90
D	62,31	96	-27,69	90
E	64,17	96	-25,83	90
Total	76,97			

Establishing the rhythm of production, correcting the size of the batches, transport batches and checking the feasibility of production.

Determining the production rhythm and multiplication factor $R_g = R_{s\max}$

Based on the calculations, it was obtained: $R_g = 96$

Using the formula: $k_r = \dfrac{R_g}{R_s^{`}}$

k_r - the number of starts for the individual details, the natural number, a sufficiently small number of equals, determines the repeatability of batch rhythms in the production rhythm

After substitution, the following results were obtained:

$$k_r(A)=\frac{96}{48}=2$$
$$k_r(B)=\frac{96}{96}=1$$
$$k_r(C)=\frac{96}{96}=1$$
$$k_r(D)=\frac{96}{96}=1$$
$$k_r(E)=\frac{96}{96}=1$$

Establishing the organisational size of the batch (arts/lot)

$$n_{org}=R_s^{`}\cdot p$$

Received:

$$A \rightarrow n_{org}=46\cdot 1{,}32=60{,}72\approx 64$$
$$B \rightarrow n_{org}=96\cdot 1{,}49=143{,}4\approx 144$$
$$C \rightarrow n_{org}=96\cdot 1{,}37=131{,}52\approx 132$$
$$D \rightarrow n_{org}=96\cdot 1{,}49=143{,}4\approx 144$$
$$E \rightarrow n_{org}=96\cdot 1{,}07=102{,}92\approx 104$$

Determining the size of transport batches

$$n_{tr}=\frac{n_{org}}{k_t}$$

- n_{org}- organisational batch size
- k_t- number of transport lots (3-5), for our needs assumed k_t=4

After the replacement, we got the results:

$$A \rightarrow n_{tr}=16$$
$$B \rightarrow n_{tr}=36$$
$$C \rightarrow n_{tr}=33$$
$$D \rightarrow n_{tr}=36$$
$$E \rightarrow n_{tr}=26$$

Verification of the production feasibility conditions from the following relationship:

F_{mn}- nominal machine fund
$R`_s$- corrected series rhythm
n_{org}- organisational batch size
P_{cz}- annual parts production programme

After the substitution we received the following results:

$$A \rightarrow \frac{4240}{48}\cdot 64\geq 5610,\quad 5653{,}3\geq 5610$$
$$B \rightarrow \frac{4240}{96}\cdot 144\geq 6324\quad 6360\geq 6324$$
$$C \rightarrow \frac{4240}{96}\cdot 132\geq 5814\quad 5830\geq 5814$$
$$D \rightarrow \frac{4240}{96}\cdot 144\geq 6324\quad 6360\geq 6324$$
$$E \rightarrow \frac{4240}{96}\cdot 104\geq 4568\quad 4593{,}3\geq 4568$$

Hypothesis 1 is fulfilled, which indicates that, based on the above calculations, the conditions for production feasibility were found to be fulfilled. Summary table of previous calculations for individual details is as follows:

Lp	Sym	P_{cz} [art./year]	p [art./year]	R_j [pence/art]	T_{pz} [min]	T_j [min]	q	n_{ak} [art]	R_s [pence/art]	R_s` [pence/art]	k_r	R_g [pence/art]	n_{org} [art/pa]	n_{tr}	k_t
1	A	5610	1,32	0,75	2,2	1,8	0,02	61	45,75	48	2	96	64	16	4
2	B	6324	1,49	0,67	3,24	1,4	0,02	116	77,72	96	1	96	144	36	4
3	C	5814	1,37	0,73	3,1	1,42	0,02	109	79,54	96	1	96	132	33	4
4	D	6324	1,49	0,67	2,7	1,55	0,02	93	63,31	96	1	96	144	36	4
5	E	4568	1,07	0,93	2,29	1,65	0,02	69	64,14	96	1	96	104	26	4

Determining the number of positions in JGSs according to the load capacity of each operation. Calculating the number of workstations:

t_{pz}- preparatory and final time
n_{org}- organisational batch size
t_j- unit time
R_s - corrected series rhythm

$$r_{op}(A)=\frac{0{,}60+64\cdot0{,}60}{48}=0{,}812$$
$$r_{op}(B)=\frac{0{,}50+144\cdot0{,}60}{96}=0{,}905$$
$$r_{op}(C)=\frac{0{,}50+132\cdot0{,}60}{96}=0{,}830$$
$$r_{op}(D)=\frac{0{,}50+144\cdot0{,}65}{96}=0{,}980$$
$$r_{op}(E)=\frac{0{,}30+104\cdot0{,}60}{96}=0{,}653$$
$$r_{obl}=4{,}180$$
$$r_{przyj}=5$$

$$r_{op}(C)=\frac{0{,}40+132\cdot0{,}25}{96}=0{,}348$$
$$r_{op}(E)=\frac{0{,}45+104\cdot0{,}30}{96}=0{,}329$$
$$r_{obl}=0{,}677$$
$$r_{przyj}=1$$
$$r_{op}(E)=\frac{0{,}41+104\cdot0{,}35}{96}=0{,}384$$
$$r_{obl}=0{,}384$$
$$r_{przyj}=1$$

Calculation of the utilization rate for workstations:

$$\eta_r=\frac{r_{obl}}{r_{przyj}}$$

- r_{obl}- calculated number of posts
- r_{przyj}- number of posts adopted

$$R1\to\eta_r=\frac{1{,}254}{2}=0{,}627 \qquad R5\to\eta_r=\frac{0{,}895}{1}=0{,}895$$
$$R2\to\eta_r=\frac{1{,}984}{2}=0{,}992 \qquad R6\to\eta_r=\frac{4{,}180}{5}=0{,}836$$
$$R3\to\eta_r=\frac{1{,}592}{2}=0{,}796 \qquad R7\to\eta_r=\frac{0{,}677}{1}=0{,}677$$
$$R4\to\eta_r=\frac{0{,}070}{1}=0{,}070 \qquad R8\to\eta_r=\frac{0{,}384}{1}=0{,}384$$

Determining the number of direct production workers and the rate of utilisation of their working time. We use the following patterns:

$$L_x=r\cdot z$$

L_x- number of employees
r- number of posts
z- number of changes

$$\eta_r=\frac{r_{obl}\cdot z}{L_x}$$

η_L- employees' working time utilisation rate
By submitting the relevant data we received:

Planning is one of the most important management functions without it there is no proper organization, motivation, and control. These are some of the basic elements that significantly influence the proper production process. In this paper we evaluate the simple mass production of a specific, concrete final good.

7. Conclusion

Hypothesis 1 was confirmed, indicating that the production feasibility conditions are met, and hypothesis 2 was also confirmed, indicating that the number of employees is appropriate, and hypothesis 3 was confirmed, indicating that their working time utilisation rate meets appropriate feasibility standards. The production programme was found to be correct, the size of batches, the number of and the layout of workstations, the number of necessary production workers and the length of production cycles. In turn, the production site where similar items are made by different technologies was assessed as one of the basic forms of production organization.

No anomalies were detected regarding conversion to previously used workstations, changes in direction and routes of products intersect each other in an inter-operative manner. The production form meets the conditions in which operations are assigned to particular positions, and the order in which operations are performed on each position is determined in a normative way and is repeated rhythmically, where - the production process is controlled on the basis of a practice-based model with a traditional schedule for the production in question.

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