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MANAGEMENT OF THE PRODUCTION CYCLE IN REAL-TIME MODE

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Abstract. *The scope of the article proved that an effective management production cycle of the economic activity subject will be able to provide the mutual connection between internal system production events of cycles and moments using events, critical sections, channels of movement, etc. Thus, the article is oriented on the description of peculiarities of the management production cycle in real-time mode. Peculiarities of management of production cycle in real-time mode systemically growing in five sections. The production cycle management specifics section reveals the specific shift of attention from the classical algorithm of the production cycle to the complex set of algorithms around which operations of planning, organization, and control of the duration of the technological cycle are formed. The peculiarities of the management production cycle in real-time mode section systematically described the peculiarities of production cycle management with the built-in real-time system. The technology of intersystem production events of one cycle to time moments section described synchronized production operations specifics, which are part of the production process carried out about a particular subject of work by a group of workers at the same workplace. The technology of intersystem production events of different cycles to time moments section described specifics of a batch of parts movement in production according to synchronized time-critical operations (which are finished parts of the technological process). The technology of intersystem production events interlinking of cycles of simple process at consecutive and parallel-sequential types of motion section described the specifics of batch of parts movement in the production process in the time of the related operations.*

Key words: *production cycle; time moments; economic activity subject; finished products.*

Introduction.

Within the framework of the outlined research, the production cycle management of the economic activity subject is considered a systematic process for planning, organization, and control of the operational time from the beginning to the end of the production process. It means the time interval during the labor objects launched into production into finished products transformed. Therefore, the defined management should be directed to improve the basic parameters of such a cycle, in particular, the process cycle time (Ttex), the number of operations (m), the average operating time (tMO), and the natural process time (te). These parameters are relevant for both the same product and for a certain number of products if they are produced at the same time.

1. Production cycle management specifics.

Given the specifics of the production cycle (PP), in the theory of its management, the planning, organization, and control processes should be quite simple at first glance because they are implemented only within the framework of a simple, classical algorithm:

$$PP=Ttex+m*TMO+te, \quad (1);$$

At the same time, in practice, production cycle management is quite difficult if changed in part of the improvement of the process cycle duration parameters. The main difficulty depends on the type of the labor objects movement (which can be consecutive, parallel, or parallel-sequential), and on other parameters differ by high dynamics of time changes (for example, the number of operations in the technological process, transmission party size, artificial standard time on the i-operation, etc.). The dependence we have given results in the shift of attention from the classical algorithm of the production cycle to the complex set of algorithms around which operations of planning, organization and control of the technological cycle duration are formed (Fig. 1).

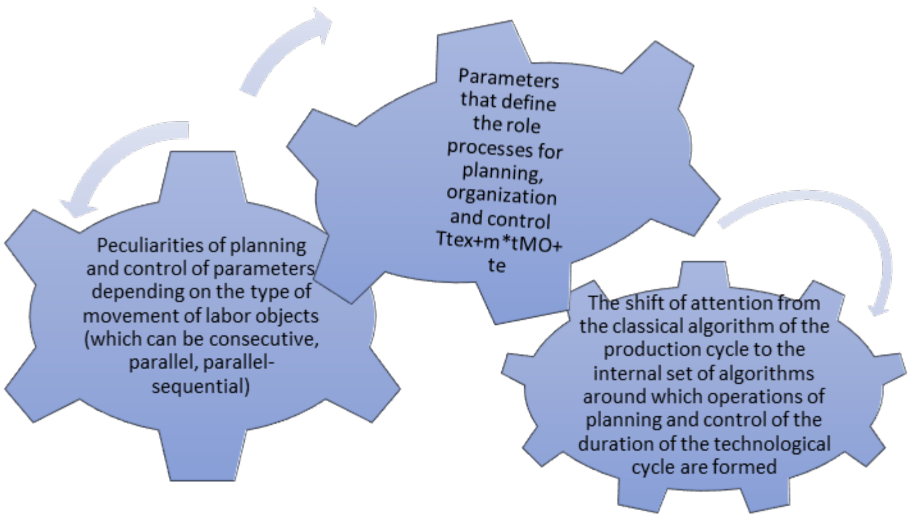

Fig. 1. Dependence of production cycle on complex algorithms set, operations of planning, and control of process cycle duration are formed

A source: *formed based on* [1; 5]

The algorithm features cause the content of the production cycle management to be complicated in the part of the duration of the technological cycle of economic activity subjects are presented in Table 1

The above-mentioned algorithmic features of Ttex definition are formed depending on the specifics of the party processing cycle and peculiarities of its movement in the technological cycle form rather complex, ramped, rapidly changing operational structures. It is possible to state that effective production cycle management of the economic activity subject necessary to ensure the interrelation of internal system production events of cycles to the moments (through events (processes, streams), critical sections, channels of movement, etc.). It is possible if production cycle management through software products uses a built-in response system to events in the external relation to the production system environment or its influence of production cycles within the necessary time limits (or real-time system). In particular, such software products include MS Project, Wrike, Hive, Trello, and A2B. The peculiarities of production cycle management in the real-time mode are given in Fig. 2.

Table 1 - Algorithm-specific features of production cycle management in the part of the process cycle duration

Type of labor movement	Algorithm-specific features of Ttex determine the content of planning and control of labor objects movement	Options that must be added	
		controlled	planned
Consecutive	based on algorithm action $n \times m \sum i = 1tiCi,$ Where: m - the number of operations in the technological process; n - the number of parts in the party; CI- accepted number of jobs for the i-operation, od; ti- the artificial standard time for the i-operation, min.	the scheme of movement, the operations number in the technological process; the number of jobs involved for the i-operation; the time for the i-operation; the size of the transport (transmission) party, samples	average, maximum and minimum standard time for the execution of the i-operation, min; number of jobs (machines) for the i-operation; number of operations in the technological process;
Parallel	based on algorithm action (n-p) $\times$timax Ci+p$\times$m∑i=1ti$\times$Ci, Where: m - the number of operations in the technological process; n - the number of parts in the party; CI- accepted number of jobs for the i-operation, od; ti max –the maximum artificial standard time on the i-operation, min.; p- the size of the transport lot, samples.		
Parallel-sequential	based on algorithm action n$\times$m∑i=1tiCi-(n-p) $\times$m-1∑i=1(tki$\times$Ci), Where: m - the number of operations in the technological process; n - the number of parts in the party; CI- accepted number of jobs for the i-operation, od; ti max –the maximum artificial standard time on the i-operation, min.; p- the size of the transport lot, samples; t_{ki}- minimum time between k-th of adjacent operations taking into account the number of equipment units, minutes.	«…», related operations taking into account the number of equipment units	minimum and average time between k-th of adjacent operations taking into account the number of equipment, units

A source: *formed based on* [1; 3; 4]

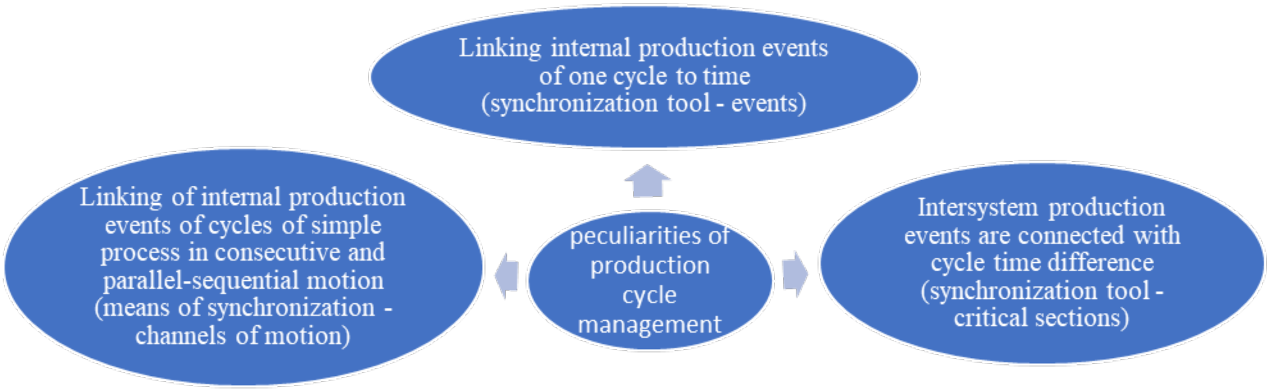

Fig. 2. Peculiarities of management of production cycle in real time mode

A source: developed on the basis of [1; 2; 5]

The advantages of such an approach are detailed and fast planning, organization, and control of each production cycle, depending on the scheme set of products movements in the technological process, number of production operations, and other parameters, outlined in Table 1. The result is a reduction of the break in working hours (divided into breaks of the party and waiting).

2. Peculiarities of management of production cycle in real-time mode

Peculiarities of production cycle management based on software products, which have a built-in real-time system, solve problems.

1. Intersystem production batch of one cycle to time moments (synchronization tool - operational events). This feature automates and synchronizes the processes of planning, organization, and production control. Within the framework of such processes, the following are synchronized: 1) the duration of the technological cycle of processing a details part; 2) the details parts movement; 3) the actual standard time of execution of each technological operation. At that, it is possible to output the general schedule and deviations from the schedule of the production cycle (at that these operations are carried out regardless of what restrictions have processes (tasks) of real-time systems (deadline, latency or jitter);

2. Linking internal production batch to time cycles (synchronization tool - critical sections/operations). Within the framework of such processes, the following are synchronized: 1) the duration of technological cycles of processing a batch of parts (including interoperating time for each transmission details party); 2) the parallel movement of details parts; 3) the norms or the actual time of execution of each technological operation. At that, it is possible to withdraw the parallel general schedule and deviation from the schedule of the production cycle.

3. Interlinking of the internal production batch of cycles of a simple process in consecutive and parallel-sequential types of motion (means of synchronization - motion channels). Within the framework of such processes, the following are synchronized: 1) the duration of technological cycles of processing a *details* part (including the duration of adjacent operations); 2) parallel-sequential details parts movement; 3) the rules or the actual time of each technological operation execution. It is possible to output the general cycle schedule at the parallel-sequential form parties in production movement.

3. Technology of intersystem production events of one cycle to time moments

The technology of intersystem production events of one cycle to time moments t is carried out on the operational events synchronized (or production operations, which are part of the production process, carried out to a particular subject of work by a group of workers in the same workplace). Note that each operating system event is an object for synchronization of execution of production processes in 2-th condition located - signal (the event is now) and non-signal (the event is in standby mode).

Let us consider management features of the production cycle in real-time on the example of Solid Group LLC on condition MS Project software product use. For example, MS Project defines in one click the duration of the technological cycle for gearboxes production under the brand POLAT GROUP REDUKTOR (PGR). It is assumed that each production batch will consist of 50 gearboxes. The intersystem production batch of the cycle is connected to the moments by parameterization of their consecutive movement in production according to the operations synchronized in time 1-8. In particular, it is: operations of aluminum case gearboxes manufacturing – operations 1-4); strength of the case check (operation 5); placement of transmission elements in the case (operation 6); case sealant (operation 7); general assembly of the case (operation 8). The condition of the cycle is to bring operations to such a flow when they are carried out in a certain order allowing avoiding competition or mutual blocking. In such conditions, MS Project automatically parameterizes the technological process of gearbox production in the form of a table (Table 2).

Table 2 - Standard time and other parameters of operations on gearbox production, LLC Salt Group, 2022

event number	operations of aluminum case gearboxes manufacturing				strength of the case check (operation 5)	placement of transmission elements in the case (operation 6)	case sealant (operation 7)	general assembly of the case (operation 8)	Breaks in party playing
	case (operation 1)	wheels (operation 2)	shafts (operation 3)	bearing supports (operation 4)					
Standard time, min.	12	3	2	5	8	10	2.5	6	2
Number of machines per operation	2	1	1	1	1	2	1	1	-
View of the movement of the gearbox detail (consecutive movement n✕tiCi)	Ttex=800(122+31+21+51+81+102+2,51+61) =800✕37,5=30000 хв								

A source: developed on the basis of Solid Group Ltd. data in the MS Project environment

In the MS Project environment, the production cycle organization schedule is a visualization function within which the cycle informatio can be output with time-bound. In our case, the process of drawing the schedule is based on the algorithm:

$$N \times tiCi, \qquad (2).$$

So it is possible to set the parameters of the cycle planning by the number of parts in the party and the number of jobs on the I-operation (fig. 3).

Obvious that the link between internal production and time events takes place with the production operations synchronization process. It automates the calendar planning process (the production cycle schedule above already contains the time of technological operations). The MS Project cycle schedule within a calendar system details the component necessary for carrying out concrete work operations from work into finished product transformation. At the same time, the preparatory and final stages need to plan.

The system combination of different cycle schedules in time allows for controlling the breaks of the parties (in particular, those that arise because of the details of the gearboxes processed in batches). At the same time, the party breaks are calculated not separately but together with the duration of all technological operations, forming a technological cycle.

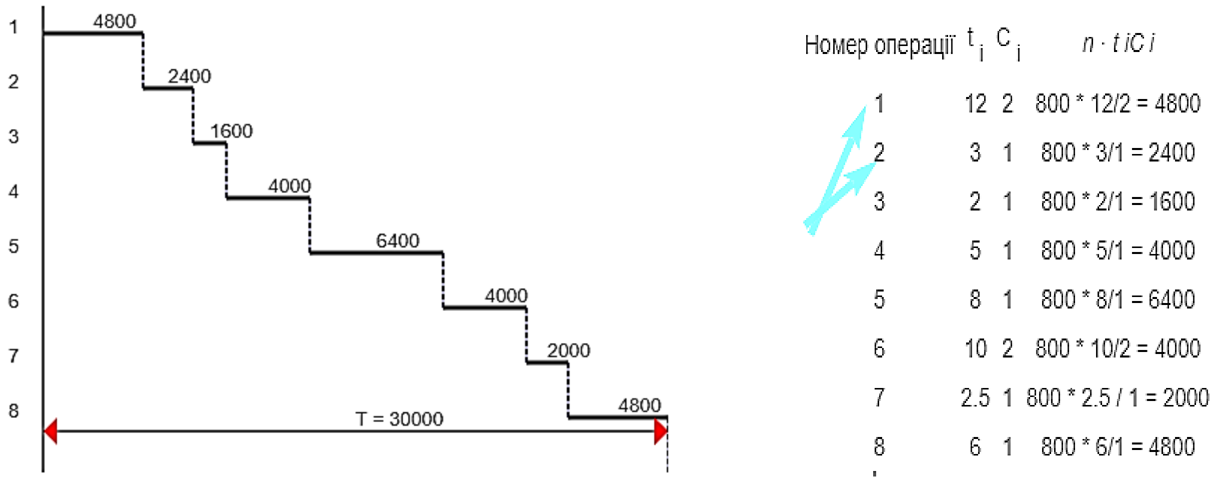

Fig.3. Schedule of cycle at consecutive form of gearbox movement in production of Solid Group, 2022

Note: * n - the number of parts in the party; CI- accepted number of jobs for the i-operation, od; ti- the artificial standard time for the i-operation, min.

A source: developed on the basis of Solid Group Ltd. data in the MS Project environment

4. Technology of intersystem production events of different cycles to time moments

The technology of intersystem production events of different cycles to time moments is carried out at parameterization of their paralyzed movement in production according to critical operations synchronized in time (which are finished parts of the technological process). Accordingly, for the example of Solid Group LLC, the following critical technological operations (1-6) are allocated several gearboxes movement in production: preparation for production (critical operation 1); production entrance (critical operation 2); primary collection (critical operation 3); testing of useful action coefficient (critical operation 4); testing of roll angular velocity (critical operation 5); final testing of the transmission number (critical operation 6). The presence of such operations allows the simultaneous execution of a certain critical set of production operations for the defective product. It is assumed that the time requirements for critical technological operations will be different than for normal production events (Table 3). At those critical operations are performed on a single unit of equipment.

Also, the average interoperating time for each transmission batch of reducers is determined will allow for to combination of the movement of parties in time. To see the combination of the paralyzed schedule of the cycle in time, the cycle duration to express in working days. For synchronization of different production cycles, we translate minutes for hours: PP= 1036/60 = 17,27 hours, hours in days: PP h =1,08 months. At the same time, the schedule of parallel cycles at the consecutive gearbox movement in the production of Solid Group LLC will have the appearance shown in Fig. 4.

According to the results, the system combination of different cycle schedules in time allows: 1) to control the party breaks in all parallel parties (in particular, those that arise because the details to gear reducers are processed by the parties); 2) to provide a uniform flow of critical technological operations.

Table 3 - Standard time and other parameters of critical operation movement of parties' gearboxes in production of Solid Group, 2022 p.

critical operation number	preparation for production (critical operation 1)	production entrance (critical operation 2)	primary collection (critical operation 3)	testing of useful action coefficient (critical operation 4)	testing of roll angular velocity (critical operation 5)	final testing of the transmission number (critical operation 6)
Standard time, min.	1.7	2.1	0.9	4.3	2.8	0.7
Average interoperating time per transmission party, min.	2	2	2	2	2	2
work variability	for eight hours					
Motion parallelization algorithm	(n-p)ti_{max}✕Ci+p✕m∑i=1tiCi+m·t= (200-20)✕4,31+20✕ (1,71+2,11+0,91+4,31+2,81+0,7 1)+6✕2 = 774 +250+ 12=1036 min.					

A source: developed based on Solid Group Ltd. data in the MS Project environment

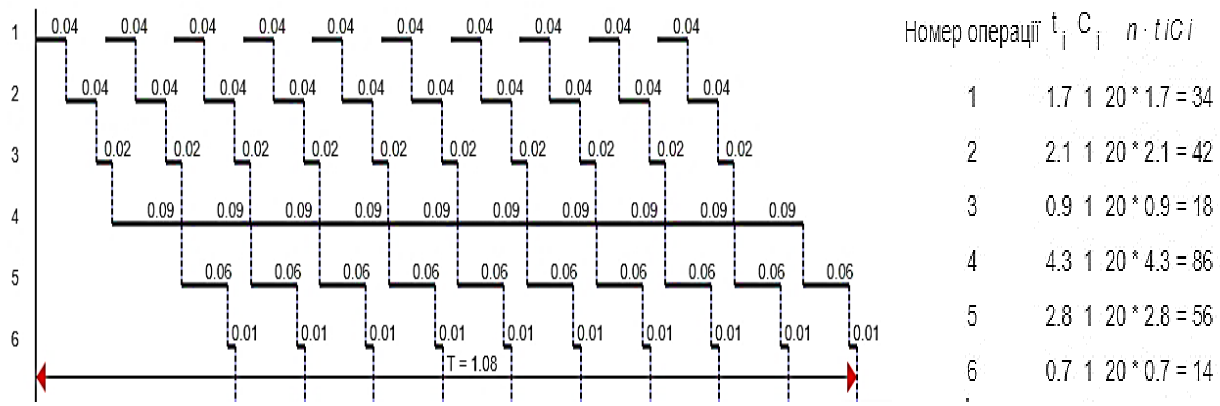

Fig. 4. Schedule of Pparalyzed cycles at consecutive gearbox movement in production of LLC Solid Group, 2022

Note:
* n – кількість деталей у партії; C_i- прийнята кількість робочих місць на *i*-ї операції, од; t_i- норма штучного часу на *i*-ї операції, хв.;
A source: developed based on Solid Group Ltd. data in the MS Project environment

5. Technology of intersystem production events interlinking of cycles of simple process at consecutive and parallel-sequential types of motion

The technology of intersystem production events interlinking cycles of the simple process with consecutive and parallel-sequential movements in time-synchronized related operations.

The operation of such a synchronization process and its specificity can be traced to the example of Solid Group Ltd., namely the content of the party gearbox movement of 180 units, with the size of the transmission party of 30 units. At that, it is assumed to have synchronized movements 1-7: receipt into the production of workpieces for the gearbox production and testing of workpiece strength (movement 1); receipt into the production of gear reducer wheels and testing of workpiece strength (movement 2); receipt into the production of rolls and supports and testing of workpiece strength (movement 3); receipt into the production of finished gear case bodies and testing of its strength (movement 4); receipt into the production of transmission elements, assembly of the case (movement 5); receipt into the production of seals, general assembly and testing of the case (movement 6); transfer of finished goods to the warehouse (movement 7). For such movements of parts in the gearbox production, MS Project for organization planning and control of the production cycle automatically parameterizes the adjacent operations of movement in the point table form (table 4).

Table 4 - Time and other parameters on the related operations of the gearbox movement in the production of Solid Group, 2022

number of parts movements in production (adjacent operations of movement)	receipt into production of workpieces for the gearbox production and testing of workpiece strength (movement 1)	receipt into production of gear reducer wheels and testing of workpiece strength (movement 2)	receipt into production of rolls and supports and testing of workpiece strength (movement 3)	receipt into production of finished gear case bodies and testing of its strength (movement 4)	receipt into production of transmission elements, assembly of the case (movement 5)	receipt into production of seals, general assembly and testing of the case (movement 6)	transfer of finished goods to the warehouse (movement 7)
Standard time, min.	4.6	9.9	3.1	11.4	3.0	6.8	1
Parallel-sequential movement:	n×m∑i=1tii-(n-p)×m-1∑i=1(tkiCi)=180(4,6 +9,9 +3,1+11,4 +3 +6,8 +1)-(180-30)(4,6+3,1+3,1+3+3+1)+7×60 =7164-2670 +420 = 4914 min.						

A source: developed based on Solid Group Ltd. data in the MS Project environment

For synchronization among the neighboring operations of gears production: 1) we choose the least: Min(4,6;9,9) = 4,6; min(9,9;3,1) = 3,1; min(3,1;11,4) = 3,1; min (11,4;3) = 3; min(3;6,8) = 3; min(6,8;1) = 1; 2), we translate minutes for hours: PP= 81,9 hours, hours in days: PP =5,12. At the same time, the schedule of parallel and consecutive cycles during the gearbox movement in the production of Solid Group Ltd. will have the appearance shown in Fig. 5.

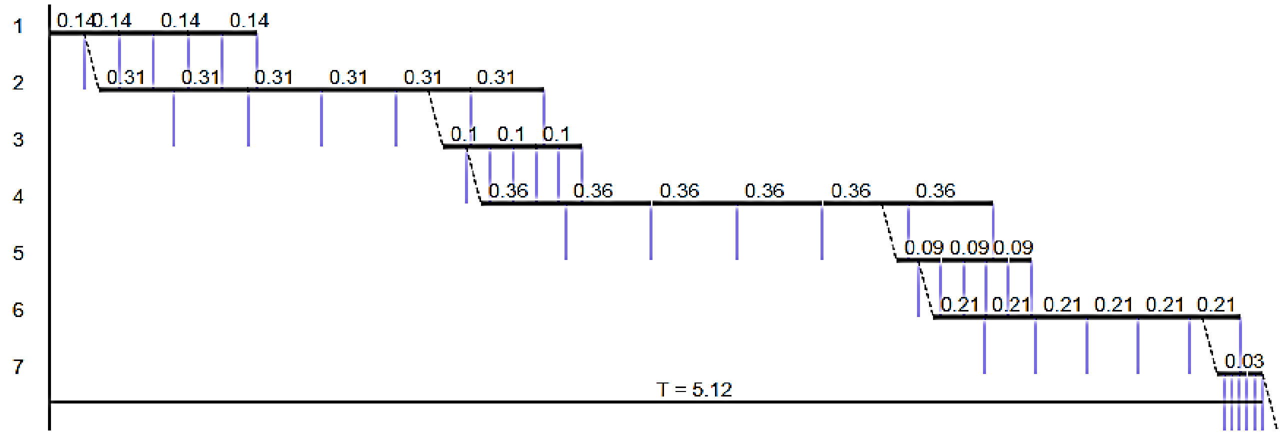

Fig. 5. Schedule of the cycle at parallel-sequential batches movement in the gearbox production for Solid Group, 2022

A source: developed based on Solid Group Ltd. data in the MS Project environment

According to the obtained data, it is obvious that the given schedule is formed based on the fixed duration of adjacent operations and the following groups of irregularities: 1) scheduling of a schedule within which the previous operating cycle is smaller than the next cycle (or $T_{опi} \leq T_{оп(i+1)}$). The beginning of the movement for the next neighboring operation after the transfer party movement on the previous operation is over; 2) the previous operating cycle is larger than the next cycle. ($T_{опi} > T_{оп(i+1)}$). It is actual, if it is necessary to transfer the last transport party. The processing time of the remaining parts of the batch is postponed to the left. The beginning of the first detail indicates the moment when the transport track from the previous operation must be transferred to this operation.

Summary and conclusions.

Effective management of the production cycle of the economic activity subject will ensure the interrelation of the internal system production events of cycles and time moments events, critical sections, movement channels, etc. For this purpose, such management should be carried out through software products use, which have a built-in system of response to events in external relation to the production system environment or influence on the environment of production cycles within the necessary time limits (or system of real-time).

It is the management of the production cycle, with the built-in real-time system, that solves problems: linking the internal production events of one cycle to the moments (synchronization tool - operational events); linking the internal production events to the moments (synchronization tool - critical sections/operations); linking of internal production events of cycles of a simple process with consecutive and parallel-sequential types of motion (means of synchronization - channels of motion).

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