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Applying a New Method to the Location of the Machines on a Manufacturing Line

Olga-Ioana Amariei, Codruța-Oana Hamat

In this article, we started from a case study in which we wanted to develop a proprietary design methodology of lower rank production systems, using several softwares. Due to its complexity, the study is truncated, making it the subject of some specialized articles. In this article the placement of a minimal number of machines is achieved, on which the technological flow can be achieved unidirectionally, by applying a new method - AOI method.

***Keywords**: technological flow, AOI method, available time, workload, machines placement.*

Short introduction

A new method is tried, that can be applied easier than the classical ones. The method has the same objective as the fictive ranges method, achieving the placement of a minimal number of machines, on which the technological flow can be done unidirectionally. The order of operations from the technological process, the volume of production, as well as the standardized unitary time (in min – machine) on each operation is presented in the form of a table, exactly as in the case of applying the fictive ranges method (tab. 2).

Materials and methods

In the case study that was achieved, the problem was not designing an industrial production system, but of several lower rank production systems (SPRI), placed in the hall of an enterprises production section.

When achieving the project two essential conditions were placed by the enterprises management:

- The new placement should consider the decommissioning of a space from a production section; here being the necessary equipment to ensure the power supply of the machines.
- In the new placement only the existing equipments will be used, resulting from the decommissioning of other production halls.

From the analysis of the sorting software, it shows that the main products that are about to be made in the refurbished section are the ones presented in table 1.

Table 1. Manufacturing software

Nr. crt.	Product name	N_T [min/piece]	Q [piece/year]	Material	SPRI
1.	Threaded bolt 1	64	352	OLC35N	1
2.	Threaded bolt 2	35	2304	OL35CR	
3.	Threaded bolt without head	128	128	OL50	
4.	Bolt without head	85	128	OL50	
5.	Nipple 1	100	2200	X12Cr13QT650	2
6.	Nipple 2	90	2200	X12Cr13QT650	
7.	Stub	21	4400	X12Cr13QT650	
8.	Nut	37	4400	X12Cr13QT650	
9.	Fixing bush	25	24960	OLC35N	
10.	Buffer	35	24960	OLC35N	
11.	Coupling GS type A PN 160	6	2200	-	3
12.	Coupling GS type B PN 160	4	2200	-	

After completing the first four stages of SPRI design, and namely: SPRI analysis; determining the processing type; establishing the production resources and determining the grouping mode of machines, the reached conclusion was that the grouping method according to the characteristics of the types of spatial placement is cellular placement. The last two steps are the placement of machines and ordering of products. The present paper represents a part from the fifth step of SPRI design, namely achieving the placement of machines using an own method - AOI, which will be applied only in SPRI 2. Some remarks must be made, namely, numbering activities with letters from I to O and of landmarks with P21-P26 is due to the fact that this paper refers to the second SPRI. To not occupy too much space in this paper with the presentation of each activity and the machines allocated to them, we will go directly to the steps of the AOI method which are presented further.

Step 1. Input data of the problem. The sequence of the technological operations and the unitary time norms are presented in table 2.

We start from numbering activities, starting with the first activity (activity I), to which the order number 1 is assigned, and then until the last activity (activity O). Then the technological itinerary of each product is written as follows:

P21: 1-2-3-5-6
P22: 1-3-5-4-3-6-5
P23: 1-2-4-3-6-4
P24: 1-4-4-5-6-7
P25: 1-2-5-3-3-6-7
P26: 3-1-2-4-3-6-7

Table 2. Input data of the problem

Operation order nr.	Nipple 1 P21		Nipple 2 P22		Stub P23		Nut P24		Fixing bush P25		Buffer P26	
	Type of activ.	Tu [min/ piece]	Type of activ.	Tu [min/ piece]	Type of activ.	Tu [min/ piece]	Type of activ.	Tu [min/ piece]	Type of activ.	Tu [min/ piece]	Type of activ.	Tu [min/ piece]
1	I	20	I	15	I	5	I	10	I	3	K	7
2	J	15	K	12	J	3	L	10	J	1	I	7
3	K	25	M	20	L	5	L	2	M	5	J	4
4	M	30	L	5	K	3	M	15	K	7	L	7
5	N	10	K	10	N	3	N	8	K	7	K	7
6	-	-	N	8	L	2	O	2	N	2	N	2
7	-	-	M	15	-	-	-	-	O	1	O	1
Vol.prod.	2200		2200		4400		4400		24960		24960	

Step 2.Establishing the initial position of the work places. To be able to calculate the average positioning of the activities (tab.3), we sum the order numbers of each activity, and the value is divided to the number of occurrences of that activity in the itineraries of the products.

Table 3. Activities positioning

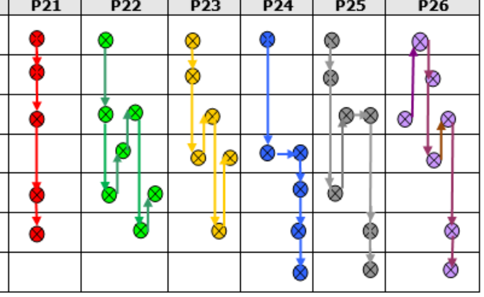
Type of activ.	Order number	LANDMARKS						Average positioning	Position
		P21	P22	P23	P24	P25	P26		
I	1	1	1	1	1	1	3	8/6=1,33	1
J	2	2	3	2	4	2	1	14/6=2,33	2
K	3	3	5	4	4	5	2	23/6=3,83	3
L	4	5	4	3	5	3	4	24/6=4	4
M	5	6	3	6	6	3	3	27/6=4,5	5
N	6	-	6	4	7	6	6	29/6=4,83	6
O	7	-	5	-	-	7	7	19/3=6,33	7

The theoretical placement of machines is as follows: 1-2-3-4-5-6-7, meaning I-J-K-L-M-N-O.

Step 3. Analysis of product circuits and elimination of returns. We notice returns in flow at the landmarks presented in table 4.

Table 4. Graphical representation of technological flows (1)

Op. no.	Activities		Trajectories of technological flows					
	M.T.	No.	P21	P22	P23	P24	P25	P26
1	I	1						
2	J	1						
3	K	1						
4	L	1						
5	M	1						
6	N	1						
7	O	1						



A table is made (tab.5), which has the purpose to present the technological trajectories of the products, compared to the theoretical order already established, according to table 3, which helps to eliminate the returns in flow.

Table 5. Overviews of the placement order of machines

Nr. crt.	Theoretical order	Flow return	P21	P22	P23	P24	P25	P26
1	-	**K**	-	-	-	-	-	K
2	**I**	-	I	I	I	I	I	I
3	**J**	-	J	-	J	-	J	J
4	**K**	-	K	K	-	-	-	-
5	**L**	-	-	-	L	L	-	L
6	-	**K**	-	-	K	-	-	K
7	**M**	--	M	M	-	M	M	-
8	-	**L**	-	L	-	-	-	-
9	-	**K**	-	K	-	-	K	-
10	**N**	-	N	N	N	N	N	N
11	-	**L**	-	-	L	-	-	-
12	-	**M**	-	M	-	-	-	-
13	**O**	-	-	-	-	O	O	O

Tables 6 and 7 can be used instead of table 5.

Table 6.

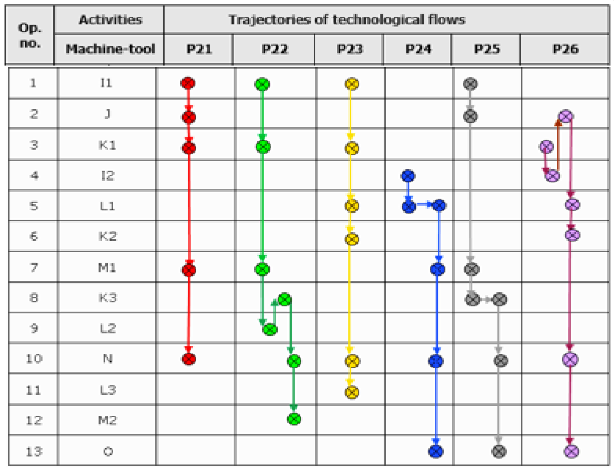
	LANDMARK NAME			
	P22	**P23**	**P25**	**P26**
Flow returns	M→L;L→K; N→M	L →K; N→L	M→K	K→I; L→K
Additional machines	L, K, M	K, L	K	I, K
Operation order nr.	4, 3, 5	3, 4	3	1, 3

Additional machines are added for the activities where return points appear, and namely, I, K, L, M (tab.6). It starts with activity I, for which it is supplemented with a machine, which is placed after the machine on which activity K is performed and thus the return from K→I is eliminated, in flow P26. Next, the returns are eliminated in the trajectories of products P22 and P23 (L →K), then returns M→K, M→L, N→L and N→M, according to table 7.

Table 7. Theoretical placement of machines after eliminating the returns in flow

Flow returns	Theoretical placement of machines
K→I	I J K I L M N O
L→K	I J K I L K M N O
M→K	I J K I L K M K N O
M→L	I J K I L K M K L N O
N→L	I J K I L K M K L N L O
N→M	I J K I L K M K L N L M O

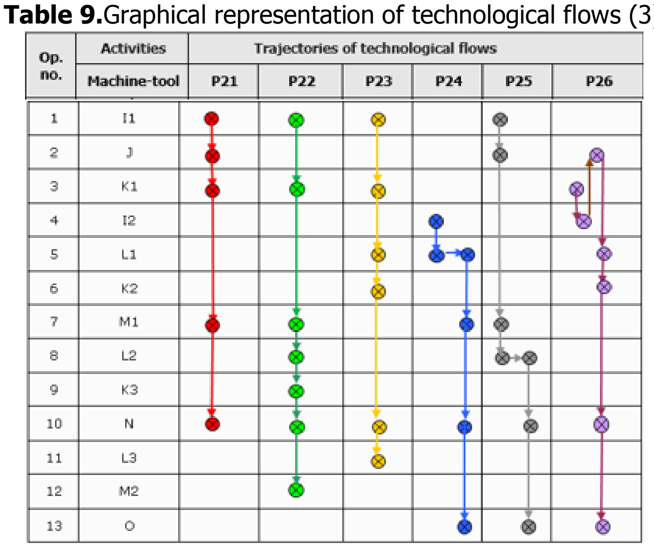
Table 8. Graphical representation of technological flows (2)



There are still two returns remaining in the flow of products P22 and P26. To eliminate the return from L→K, from flow P22, we just inverse the two machines (L2 and K3) between them (table 8).

Eliminating the return from flow P26 (tab.9), from I2→J, is done by inserting a machine for activity K in front of machine I1. This is done by changing the place of machine K2, the only machine attached to activity K that does not influence the final arrangement of machines, respecting the straight line principle.

Table 9. Graphical representation of technological flows (3)



Step 4. Workload analysis of machines. After streamlining the technological flows of the products, next we check the workload of the machines. For this we must take into account table 2, which contains the data regarding the volume of production, as well as the operating times, necessary data to establish the workload of each machine, presented next in table 10. The available time fund was established to be 3840 hours/year, which means 230.400 min/year. In table 10 we can observe that at positions 2(I1), 7(M1) two machines are needed, and position 9(K3), requires 3 machines. On the basis of this table we can see that at position 5(I2), the total processing times are very low. On this machine we can still process 186.400 min/year, and at K2 and M2 remains a difference of 55.680 min/year, respectively 197.400 min/year.

Table 10. Calculating the total processing times

Op. no.	Activ. / MT	Trajectories of technological flows						Total time required
		P21	P22	P23	P24	P25	P26	
1	K2	-	-	-	-	-	174720	174720
2	I1	44000	33000	22000	-	74880	174720	348600
3	J	33000	-	13200	-	24960	99840	171000
4	K1	55000	26400	-	-	-	-	81400
5	I2	-	-	-	44000	-	-	44000
6	L1	-	-	-	52800	-	174720	227520
7	M1	66000	44000	-	66000	124800	-	300800
8	L2	-	11000	22000	-	-	-	33000
9	K3		22000	13200	-	349440	174720	559360
10	N	22000	17600	13200	35200	49920	49920	187840
11	L3	-	-	8800	-	-	-	88000
12	M2		33000	-	-	-		33000
13	O	-	-	-	8800	24960	24960	58720

There must be a "compensation" between the machines from the same activity (tab.11).

Table 11. Balancing total times

Op. no.	Activ. / MT	Trajectories of technological flows						Total time required
		P21	P22	P23	P24	P25	P26	
1	K1	-	-	-	-	-	174720	174720
2	I1+I2	44000	33000	22000	44000	74880	174720	392600
3	J	33000	-	13200	-	24960	99840	171000
4	K2	55000	26400	-	-	-	174720	256120
5	I2	-	-	-	~~44000~~	-	-	44000
6	L1	-	-	-	52800	-	174720	227520
7	M1	66000	44000	-	66000	124800	-	300800
8	L2	-	11000	22000	-	-	-	33000
9	K3	-	22000	13200	-	349440	~~174720~~	384640
10	N	22000	17600	13200	35200	49920	49920	187840
11	L3	-	-	8800	-	-	-	8800
12	M2	-	33000	-	-	-		33000
13	O	-	-	-	8800	24960	24960	58720

The two machines used in activity I, can be brought together to position 2, from table 12, because it does not affect with anything the flow of product P24. Anyway, the problem of machine I2 was solved when machine K2 was inserted on the first position, but in the case of activity K, things are more complicated, because there are two possibilities of adjustment of the total processing times between machines. The first can be moving machine K2 from position 1 to position 4, along K1 (tab.11), but this thing is ruining again the principle of the straight line. For the second possibility of placement of machines in activity K, we require a new "castling" that needs to happen between L1 and K1. Thus we adjust the flow P26, transferring 174720 minutes of processing from machine K3 to machine K2. We now note the machines in the order they appear in the table, according to table 11. In table 11 we can see a higher total necessary time than the one available (230400 min/year), at position 2, where there are two machines for activity I, and also at position 4, where besides machine K2, a K3 machine needs to be distributed. At position 7, there are two machines necessary to deploy activity M, and at position 9, there are also two machines used for activity K. To facilitate calculations, next we transfer the tables to Excel and we obtain the workload, broken down, on each machine. The workload is generally good, except machines L2 and L3, with 14,32%, and 3,82%. There are also the machines M3 and O with a really low percent of 14,32%, and 25,49%.

Table 12. Graphical representation of the technological flows (5)

Op. no.	Activ./ MT	Trajectories of technological flows						Grade loading %
		P21	P22	P23	P24	P25	P26	
1	K1						⊗	75,83
2	I1	⊗	⊗		⊗	⊗		85,02
3	I2			⊗			⊗	85,38
4	J	⊗		⊗		⊗	⊗	74,22
5	L1				⊗ ⊗		⊗	98,75
6	K2						⊗	75,83
7	K3	⊗	⊗					35,33
8	M1		⊗			⊗		73,26
9	M2	⊗			⊗			57,29
10	L2		⊗	⊗				14,32
11	K4			⊗		⊗		81,56
12	K5		⊗			⊗		85,38
13	N	⊗	⊗	⊗	⊗	⊗	⊗	81,53
14	L3			⊗				3,82
15	M3		⊗					14,32
16	O				⊗	⊗	⊗	25,49

Step 5. Establishing the final position of the work places. According to the data presented in the table done in Excel, a graphical representation of the techno-

logical flows of the products that are about to be manufactured on L2 is built, shown in table 12.

Conclusions

In this case study that was performed, at the placement of machines step, this was achieved with the dedicated heuristically methods, and an own method, which were then compared with the results offered by the WinQSB software, after applying the CRAFT algorithm. Specifically, for the placement of the machines in SPRI 1, the chain method was applied, and then it was checked with the CRAFT method, the manner of spatial placement of the machines. Because the type of production prevalent on SPRI 2 is that of large series, to establish the position of machines on this line, the fictive ranges method was used. Before applying the CRAFT algorithm, using the WinQSB software, as in the previous case, at the placement of machines in SPRI 1, it was calculated with an own method - AOI, method presented in this paper, then a comparative study was performed between these two methods. After completing the placement of machines on the production line SPRI 2, it was found that there is a lower workload on some machines, and at others, extremely low, which led to the idea of abandoning the organization in multivariate flow and adopting the cellular organization.

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Addresses:

- Lect. Dr. Eng. Olga-Ioana Amariei, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, o.amariei@uem.ro
- Prof. Dr. Eng. Codruța-Oana Hamat, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, c.hamat@uem.ro