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ANALYSIS OF PRODUCTIVITY BASED ON PRODUCTION LINE BALANCING

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Abstract: *An important and significant source of competitiveness for enterprises is the productivity, which is the ability to produce more output with the same or less input. This paper proposes an analysis and a model for productivity improving for production line (assembly line), using the relations between indicators that characterize production processes, such as: tact time, cycle time, number of posts (or jobs), loading volume of production. The paper give the model and the guidance lines for the right way of improving productivity, to adopt strategies and decisions to perform better from the production function point of view.*
Key words: *productivity, line balancing, tact time, cycle time*

1. INTRODUCTION

Productivity is the measure on production efficiency. While productivity is the amount of output produced relative to the amount of resources that go into the production, efficiency is the value of output relative to the cost of inputs used. Productivity improves when the quantity of output increases relative to the quantity of input.

Labour productivity is generally held to be the same as the "average product of labour" (average output per worker or per worker-hour, in physical or price/value terms).

Productivity, in production, is the relationship between output of goods and services and the inputs of resources used in the production process. A change in productivity is characterized by a shift of the production function and a change to the output/input relation (Saari, 2005):

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \tag{1}$$

2. PRODUCTION LINE BALANCING. CASE STUDY

Production line balancing supposes preparing following steps (Guerra, 2009):

- breakdown of technological processes in operation, phases, transitions;
- determination of phases succession and predecessors (precedence rules);
- repartition of each phase to an workplace/workstation or worker in order of their execution;
- the concomitant execution of operations at all workplace and with a rhythm of the tact time.

Tact time is the time or pace necessary for a product component to be produce at one workplace of the production line and is the maximum time from all operations/phases time (Co, 2009). In table 1 we have an example, from our case study, of line balancing with a tact time of 5 minutes.

The problem here is to determine the optimum tact time for a maximum productivity and for a production volume that is effective for a given enterprise. For this we can use the break-even points (the volume of production), between which the enterprise is profitable.

Phase no	Precedence phase	T [min/pcs]	T accum. [min/pcs]	Loading [%]	Jobs no.
1	-	0.93	0.93	93.8%	I
2	1	0.85	1.78		
3	2	0.91	2.69		
4	3	1.10	3.79		
5	4	0.90	4.69		
6	5	0.95	0.95	90.8%	II
7	6	0.90	1.85		
8	7	0.95	2.80		
9	8	0.79	3.59		
10	9	0.95	4.54		
11	10	0.80	0.80	92.8%	III
12	11	1.00	1.80		
13	12	1.02	2.82		
14	13	1.02	3.84		
15	14	0.80	4.64		
16	15	1.02	1.02	90.8%	IV
17	16	0.78	1.80		
18	17	1.02	2.82		
19	18	1.01	3.83		
20	19	0.71	4.54		
21	20	0.90	0.90	96.8%	V
22	21	1.02	1.92		
23	22	1.00	2.92		
24	23	1.02	3.94		
25	24	0.90	4.84		
26	25	1.00	1.00	50.0%	VI
27	26	0.90	1.90		
28	27	0.60	2.50		

Tab. 1. Example of line balancing with a tact time of 5 min

In our case study, the values of these two points are given by the enterprise and are 23000 and 40000 products per year. These correspond to a tact time from 3 to 5.1 minutes, as can be seen in the table 2, based on the following equations:

$$Q = \frac{Tt}{t}\,[\text{products/ year}] \tag{2}$$

$$N = \frac{\text{Cycle time}}{t}\,[\text{jobs}] \tag{3}$$

$$\text{Loading} = \text{No of jobs} \cdot t\,[\text{min/ job}] \tag{4}$$

$$\text{Loading rate} = \frac{\text{Loading}}{\text{Cycle time}}\,[\%] \tag{5}$$

$$W = \frac{Q}{N}\,[\text{pcs / job} \cdot \text{year}] \tag{6}$$

Where: Tt is the time available in a year (in our case is 118560 minutes/year); Q is the volume of the production per year; W is the productivity; N is the number of jobs/workplace or workstations; t is the tact time. The minimum tact time in our case is 1.1 minutes, which is maximum of all phase's time. The total cycle time for production line is 25.75 minutes.

In table 2 are presented the theoretical values of: number of jobs, loading per job, loading rate, quantity and productivity for each phase, this is when we do not consider the real duration of each phase. For the real values of productivity for our study case, we have the results presented in table 3, with the differences calculated from the theoretical values.

t [min/pcs]	No of jobs	Load [min/job]	Loading rate [%]	Q [pcs/year]	W [pcs/job]
3.0	9	27	95.40	39520	4392
3.1	9	27.9	92.30	38246	4250
3.2	9	28.8	89.40	37050	4117
3.3	8	26.4	97.50	35928	4491
3.4	8	27.2	94.70	34871	4359
3.5	8	28.0	92.00	33875	4235
3.6	8	28.8	89.40	32934	4117
3.7	7	25.9	99.40	32044	4578
3.8	7	26.6	96.80	31200	4458
3.9	7	27.3	94.30	30400	4343
4.0	7	28.0	92.00	29640	4235
4.1	7	28.7	89.70	28918	4132
4.2	7	29.4	87.60	28229	4033
4.3	6	25.8	99.80	27573	4596
4.4	6	26.4	97.50	26946	4491
4.5	6	27.0	95.40	26347	4392
4.6	6	27.6	93.30	25774	4296
4.7	6	28.2	91.30	25226	4205
4.8	6	28.8	89.40	24701	4117
4.9	6	29.4	87.60	24196	4033
5.0	6	30.0	85.80	23712	3952
5.1	6	30.6	84.20	23248	3875

Tab. 2. Theoretical productivity based on tact time

t [min/pcs]	No of jobs	Δ No of jobs	Δ Loading rate [%]	W [pcs/job]	Δ W [pcs/job]
3	10	1	-9.54%	3952	-440
3.1	10	1	-9.23%	3825	-425
3.2	10	1	-8.94%	3705	-412
3.3	10	2	-19.51%	3593	-898
3.4	9	1	-10.52%	3875	-484
3.5	9	1	-10.21%	3764	-471
3.6	9	1	-9.93%	3660	-457
3.7	8	1	-10.10%	4006	-572
3.8	8	1	-12.10%	3900	-558
3.9	8	1	-20.19%	3800	-543
4	7	0	-9.35%	4235	0
4.1	7	0	-9.13%	4132	0
4.2	7	0	-8.92%	4033	0
4.3	7	1	-22.97%	3939	-657
4.4	7	1	-22.44%	3850	-641
4.5	7	1	-13.62%	3764	-628
4.6	7	1	-13.33%	3682	-614
4.7	6	0	0.00%	4205	0
4.8	6	0	0.00%	4117	0
4.9	6	0	0.00%	4033	0
5	6	0	0.00%	3952	0
5.1	6	0	0.00%	3875	0

Tab. 3. Real productivity based on tact time

In figure 1, 2 and 3 we present, dependent on tact time, the variations of productivity (theoretical and real from the study case), volume of production (quantity of products produced) and the loading rate (theoretical and real from the study case).

We can see from the figures that the real values are lower that the theoretical ones, but the differences are generally not high (one job or a maximum of 23% for loading rate). The maximum of productivity is for tact time of 4 minutes, with 7 workplaces and a loading rate of 82.61%.

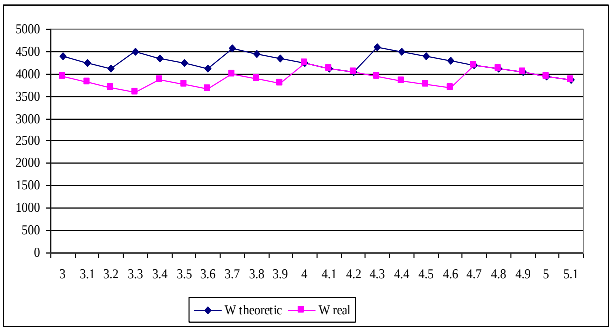

Fig. 1. Theoretical and real productivity (W)

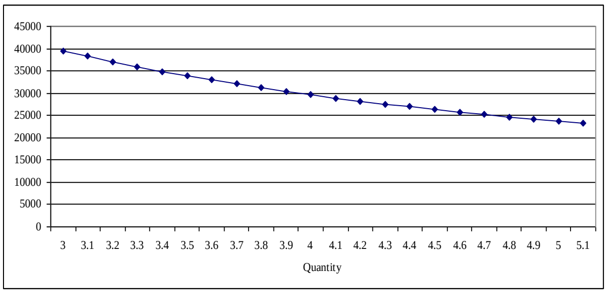

Fig. 2. Volume of production (Q)

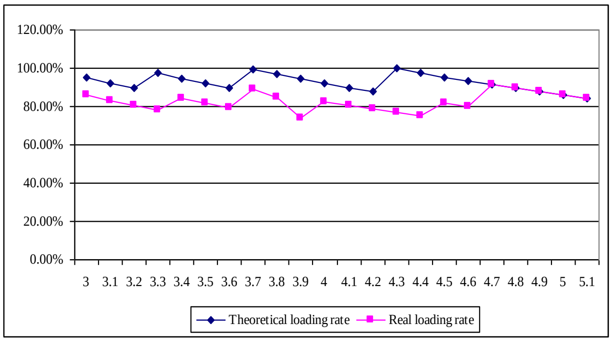

Fig. 3. Theoretical and real loading rate

3. CONCLUSIONS

With all this information on a dashboard (Co, 2006), production managers can decide the optimum way of line balancing, for a maximum of productivity, or for a maximum of workplace loading, minimum of workers, maximum of quantity needed (maybe more important for a certain period of time).

The next step will be the benchmarking of this productivity with key competitors on the market, to see if enterprise is competitive (Porter, 1990). But the limitations here is the fact that every competitor has unique/specific type and organization of production process and the comparison is difficult and maybe with irrelevant results.

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