Earning power modeling for make to order manufacturing system

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Abstract: — In this paper we propose a calculation for job Earning Power which is an effective tool for making decisions about accepting or outsourcing the job. The company will keep only those jobs that bring favorable Earning Power and the other ones are given to other manufacturing companies for execution. The manager can easily make a selection of more favorable jobs for its company.

Keywords:— Control of manufacturing system, Order level of manufacturing system, Earning power

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1. Introduction

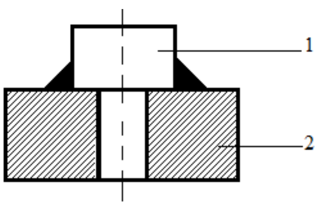
In order to better represent the specified goal of manufacturing process we propose (as a novelty) as a criteria the Earning Power (EP). By definition, Earning Power is an operating income divided by total assets. Each order have a manufacturing system specific, including all the workstations covered by order. The order is formed from manufacturing jobs. At job level *EP* we understand the relation between price difference and cost for job processing and the amount of products from job asset and operation time to accomplish the job (relation 1). Costs necessary to accomplish the job is the sum of costs for the transactions that make the job.

$$EP_{ij} = \frac{P_{ij} - \sum_{k} c_{ijk}\left(p_{jkn}\right)}{\sum_{k} A_{ijk} \cdot t_{ijk}\left(p_{jkn}\right)} \qquad \left[\frac{Euro}{Euro \cdot min}\right] \qquad (1)$$

where: P_{ijk}, c_{ijk}, A_{ijk}, t_{ijk} are the price, cost, asset and time for each operation.

Fig. 1. Manufacturing part: 1- rod, 2- plate

In order to determine EP we must estimate: cost, time, asset, and price. In this paper, cost and time will be estimated by



some techniques based on analytical modeling, neuronal modeling, or modeling by k-nearest neighbour regression. We consider that we have to manufacture the part from Fig. 1 and the manager must decide whether to accept this order. The technological process needed to process the part consists of the following operations: turning, drilling and welding. In order to evaluate the order EP we have to calculate job EP and operation EP. To do this, the order will be divided in job 1 (rod 1, Fig. 1) and job 2 (plate 2, Fig. 1). To perform job 1 it is necessary to use the turning operation. For job 2 we need drilling and welding operations. For job 1 containing a single operation, EP's job is just the EP for turning operation presented in [1].

2. Job Modeling

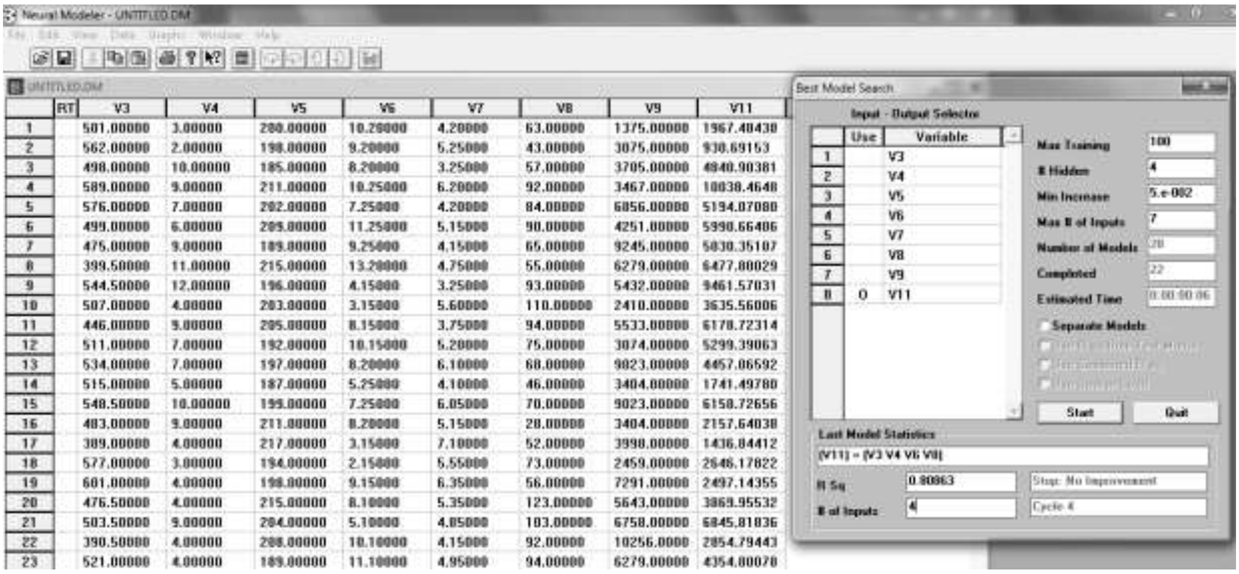
Welding operation for job 2 is modeled by a Neural Network technique. "Best NN model" or the best model provided by a neuronal network is a practical modality to find out causality relations between variables in order to be able to determine the variable clusters [2], [3]. Using neuronal network to compare variables (each by each) we obtain sets/clusters of variables that are in causal relationship. Procuring clusters is a computer application, training the network with all its database values and determining those variables that have causality relations. From database of welding operation variables (Table 1) which we note with *v1*, *v2*,…,*v12*, we'll take into consideration column 12 containing values of variable *v11*- cost of welding operation. By a neuronal network, are determined the best relationships with the other columns.

It is determined the best dependence relationships with the columns *v3*– length of welding seam, *v4* – number of passes, *v6* – rate of welding and *v8* – number of pieces (Fig. 2). The result will be a cluster of variables (*v3*, *v4*, *v6*, *v8*). Using the data from cluster of variables database a neuronal network is trained. The trained network is a search model and by interrogation, we can find out the value for variable that interest us to know, *v1*– operation cost.

Then, the same steps will be followed but comparing the column 10 that has values for variable *v9* – time of welding operation with the other columns. It will result a cluster of variables, which becomes the pair (*v3*, *v4*, *v6*). Trained network is a search model and by interrogation, we can find out the value for variable that interest us to know, *v1*– operation time. Knowing the cost, time, asset and price gained through negotiation with the client for welding operation, is calculated the Earning Power for welding operation with relation (2) and get the value tables (Table 2) for different values of rate of welding. Asset's estimation is not difficult because in the balance sheet there is enough accurate and updated information.

Table 1. Sequence from the table of welding operation variables

Item Nr.	Material type	Welding type	Length of welding seam [mm]	Nr. of passes	Current intensity [A]	Rate of welding [mm/s]	Quantity of welded wire [m]	Nr. of pieces	Welding time [s]	Energy consumption [KW/h]	Operation cost [Euro]	Waste quantity [Kg]
-	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12
1	OL 52	corner	501	3	200	10.2	4.2	63	1375	10.521	78.9	15.781
21	OL 37	corner	503.5	9	204	5.1	4.85	103	6758	52.898	388.9	77.791
40	OL 52	corner	490	4	197	8.2	4.60	59	11243	12.656	96.3	19.273
52	OL 42	corner	515	10	188	9.2	5.20	52	2459	27.970	223.1	44.633
64	OL 52	corner	521	11	191	8.15	4.1	92	6066	55.947	439.3	87.875



	RT	V3	V4	V5	V6	V7	V8	V9	V11
1		501.00000	3.00000	200.00000	10.20000	4.20000	63.00000	1375.00000	1967.40430
2		562.00000	2.00000	198.00000	9.20000	5.25000	43.00000	3075.00000	930.69153
3		498.00000	10.00000	185.00000	8.20000	3.25000	57.00000	3705.00000	4840.90381
4		589.00000	9.00000	211.00000	10.25000	6.20000	92.00000	3467.00000	10038.4648
5		576.00000	7.00000	202.00000	7.25000	4.20000	84.00000	6856.00000	5194.07080
6		499.00000	6.00000	209.00000	11.25000	5.15000	90.00000	4251.00000	5990.66406
7		475.00000	9.00000	189.00000	9.25000	4.15000	65.00000	9245.00000	5030.35107
8		399.50000	11.00000	215.00000	13.20000	4.75000	55.00000	6279.00000	6477.80029
9		544.50000	12.00000	196.00000	4.15000	3.25000	93.00000	5432.00000	9461.57031
10		507.00000	4.00000	203.00000	3.15000	5.60000	110.00000	2410.00000	3635.56006
11		446.00000	9.00000	205.00000	8.15000	3.75000	94.00000	5533.00000	6178.72314
12		511.00000	7.00000	192.00000	10.15000	5.20000	75.00000	3074.00000	5299.39063
13		534.00000	7.00000	197.00000	8.20000	6.10000	68.00000	9823.00000	4457.06592
14		515.00000	5.00000	187.00000	5.25000	4.10000	46.00000	3404.00000	1741.49780
15		548.50000	10.00000	199.00000	7.25000	6.05000	70.00000	9023.00000	6158.72656
16		483.00000	9.00000	211.00000	8.20000	5.15000	28.00000	3404.00000	2157.64038
17		389.00000	4.00000	217.00000	3.15000	7.10000	52.00000	3998.00000	1436.84412
18		577.00000	3.00000	194.00000	2.15000	5.55000	73.00000	2459.00000	2646.17822
19		601.00000	4.00000	198.00000	9.15000	6.35000	56.00000	7291.00000	2497.14355
20		476.50000	4.00000	215.00000	8.10000	5.35000	123.00000	5643.00000	3869.95532
21		503.50000	9.00000	204.00000	5.10000	4.85000	103.00000	6758.00000	6845.81836
22		390.50000	4.00000	208.00000	10.10000	4.15000	92.00000	10256.0000	2854.79443
23		521.00000	4.00000	189.00000	11.10000	4.95000	94.00000	6279.00000	4354.00070

Fig. 2. Neural Model

$$EP_{ijk} = \frac{P_{ijk} - c_{ijk}\left(p_{jkn}\right)}{A_{ijk} \cdot t_{ijk}\left(p_{jkn}\right)}\left[\frac{Euro}{Euro \cdot min}\right] \qquad (2)$$

Table 2. EP values for different rate of welding

Rate of Welding [mm/s]	Earning Power [%/h]
2.2	0.005206
3.2	0.028903
4.2	0.038126
5.2	0.039392
6.2	0.036163
7.2	0.030261
8.2	0.022651
9.2	0.013768
10.2	0.003928
11.2	-0.00673
12.2	-0.01816

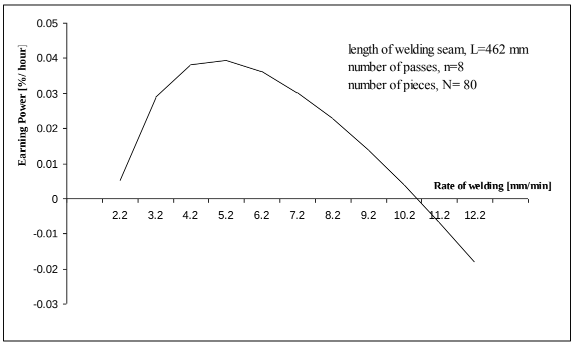


Fig. 3. The variation of the Earning Power depending on rate of welding

Using data from table 2, we obtained a curve of EP variation depending on rate of welding considered as control parameter for welding process (Fig. 3). After analyzing the diagram from Fig. 3, we can emphasize that there is a maximum value for EP for a certain rate of welding, optimal rate of welding. Therefore, when we are welding the rate of welding can be adjusted so that the efficiency of operation becomes maximum and the economical effect on company will be maximum too. It is made a control of welding operation. Drilling operation for job 2 will be modeled by data mining technique. We will be using a computer program named Visual FoxPro and C_{++} that needs the mathematical library called MatLab. For start we'll take a random sequence from drilling operation database (Table 3), where we can find the notations *vi*, with *i=1,...,10*.

$$v9=(v2, v3, v4) \quad (4)$$

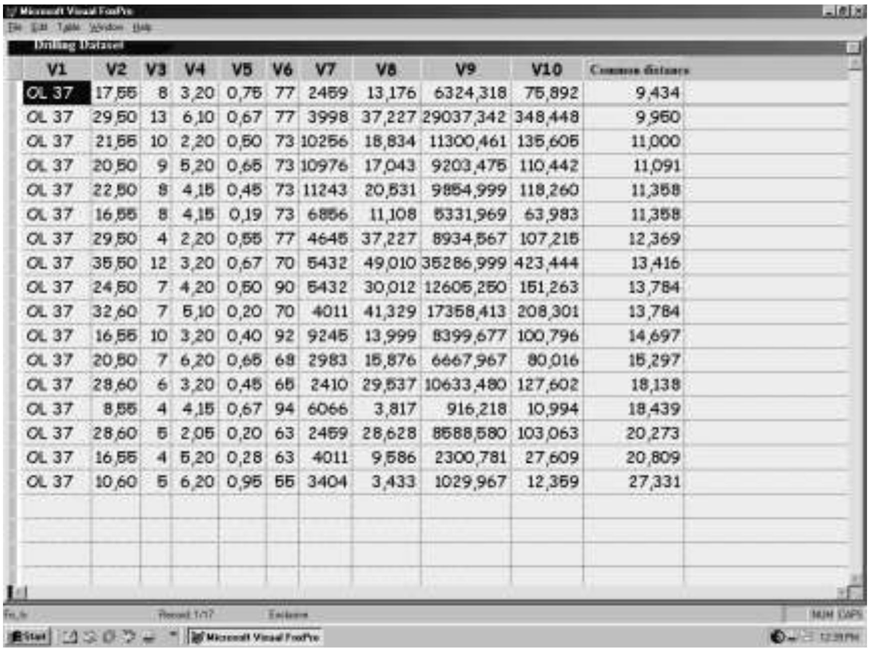
Results that EP is depending on v2, v3, v4, v5:

$$EP = \frac{Price - cost}{Asset \times timp}(v2,v3,v4,v5). \quad (5)$$

For the state clustering those lines for which the common distance will be minimal (Fig. 4) will be chosen from the database.

Table 3. Sequence from table with drilling operation variables

Item Nr.	Material type	Hole diameter [mm]	Nr. of holes	Drilling speed [mm/s]	Drilling feed[mm/s]	Nr. of pieces	Drilling time [s]	Energy consumption [KW/h]	Operation cost [Euro]	Waste quantity [Kg]
-	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10
6	OL 37	17.55	8	3.2	0.75	77	2459	13.17	158.10	75.89
14	OL 37	28.6	6	3.2	0.45	65	2410	29.53	265.8	127.60
31	OL 37	32.6	7	5.1	0.2	70	4011	41.32	433.9	208.30
38	OL 37	22.5	8	4.15	0.45	73	11243	20.53	246.3	118.26
47	OL 37	20.5	7	6.2	0.65	68	2983	15.87	166.6	80.01
60	OL 37	22.55	9	6.25	0.42	132	2459	37.29	503.9	241.64
73	OL 37	29.5	13	6.1	0.67	77	3998	37.22	725.9	348.44
83	OL 37	21.55	10	2.2	0.5	73	10256	18.83	282.5	135.60
92	OL 37	18.6	13	5.05	0.9	43	8201	8.26	161.1	77.35



V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	Common distance
OL 37	17,55	8	3,20	0,75	77	2459	13,176	6324,318	75,892	9,434
OL 37	29,50	13	6,10	0,67	77	3998	37,227	29037,342	348,448	9,960
OL 37	21,55	10	2,20	0,50	73	10256	18,834	11300,461	135,605	11,000
OL 37	20,50	9	5,20	0,65	73	10976	17,043	9203,475	110,442	11,091
OL 37	22,50	8	4,15	0,45	73	11243	20,531	9854,999	118,260	11,358
OL 37	16,55	8	4,15	0,19	73	6856	11,108	5331,969	63,983	11,358
OL 37	29,50	4	2,20	0,55	77	4645	37,227	8934,567	107,215	12,369
OL 37	35,50	12	3,20	0,67	70	5432	49,010	35286,999	423,444	13,416
OL 37	24,50	7	4,20	0,50	90	5432	30,012	12605,250	151,263	13,784
OL 37	32,60	7	5,10	0,20	70	4011	41,329	17358,413	208,301	13,784
OL 37	16,55	10	3,20	0,40	92	9245	13,999	8399,677	100,796	14,697
OL 37	20,50	7	6,20	0,65	68	2983	15,876	6667,967	80,016	15,297
OL 37	28,60	6	3,20	0,45	65	2410	29,537	10633,480	127,602	18,138
OL 37	8,55	4	4,15	0,67	94	6066	3,817	916,218	10,994	18,439
OL 37	28,60	5	2,05	0,20	63	2459	28,628	8588,580	103,063	20,273
OL 37	16,55	4	5,20	0,28	63	4011	9,586	2300,781	27,609	20,809
OL 37	10,60	5	6,20	0,95	55	3404	3,433	1029,967	12,359	27,331

Fig. 4. Table ordered by the lowest common distances

Consider that customer's requirements are: v1=OL 37; v2=21; v3=6; v6=82. At the operational level, the variables clustering is based on facility "best model" provided by the technique of neuronal networks applied on experimental data set. After using the software, our variables, time and cost: v7 and v9, necessary to calculate the EP for drilling operation are dependent on the following variables:

$$v7=(v2, v4, v5) \quad (3)$$

A set of data will be selected, data that are close to customer's demands and thus, the mathematical model will be linear, resulting mathematical models for time and cost during drilling operation:

$$\begin{aligned} v7 &= a_0 + a_1 v2 + a_2 v4 + a_3 v5 \\ v9 &= b_0 + b_1 v2 + b_2 v3 + b_3 v4 \end{aligned} \quad (6)$$

Having the first four states, k=4, according to algorithm k-NN (Near Neighbour) will be obtained a system mathematic for cost and time. Solving the systems solutions will be obtained for determining the coefficient of the mathematical model. Linear models obtained for the cost and time are local models because they are valid only near the state are queried.
They are also ephemeral because after interrogation they are abandoned.
The method is very efficient because a mathematical model is built for each input series.
Moreover, after practical checking the solution resulted during negotiations with customer, this model will be added in the table with initial experimental data, enriching the database by one new experience. Taking the drilling speed, *v*, as a control parameter for the entire process, on the bases of data from table 4, we represented the EP variation graphically depending on *v* (Fig. 5).

Table 4. EP values for different drilling speed

Drilling speed [rev/min]	Earning Power [%/hour]
100	0.15414
180	0.193682
227	0.207301
273	0.206644
318	0.182055
364	0.120791
410	0.009412

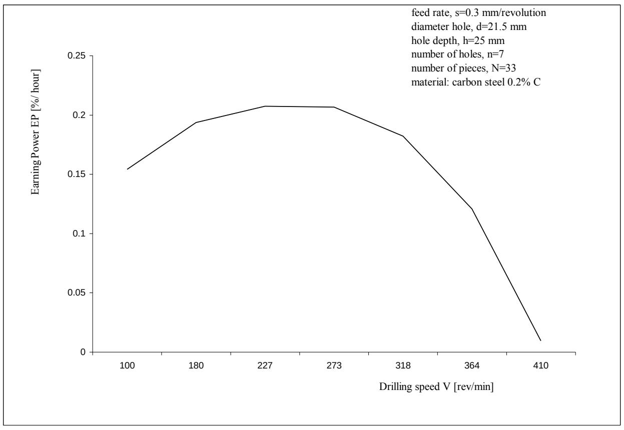


Fig. 5. The variation of the Earning Power depending on drilling speed

It can be noted that when turning and welding operations as well as for the drilling operation, EP has a maximum value for a certain speed value, i.e. for optimal speed.
In case of drilling operation, optimal speed is *v=227 rev/min*. For job 2 containing welding and drilling operations, EP is calculated according to the following formula:

$$EP_{i2} = \frac{(P_{i21} + P_{i22}) - (c_{i21} + c_{i22})}{A_{i21} \cdot t_{i21} + A_{i22} \cdot t_{i22}} \left[\frac{Euro}{Euro \cdot min} \right] \quad (7)$$

where: P_{i21}, c_{i21}, A_{i21}, t_{i21}, P_{i22}, c_{i22}, A_{i22}, t_{i22}, are provided in tables 5 and 6.
By numerical simulations, for the cases of 11 drilling speed values (Table 6) and 13 rate of welding values (Table 5) EP for job 2 got 143 values.

Table 5. Data for welding EP evaluation

Rate of welding [mm/s]	Welding cost, c_{i21}[Euro]	Welding time, t_{i21} [s]	Welding price, P_{i21} [Euro]	Welding Asset, A_{i21} [Euro]
1.2	207.025	257978	150	1875
2.2	143.075	255409	150	1875
3.2	111.95	252761	150	1875
4.2	100.35	250036	150	1875
5.2	99.275	247236	150	1875
6.2	103.975	244363	150	1875
7.2	111.95	241418	150	1875
8.2	121.875	238405	150	1875
9.2	133.125	235325	150	1875
10.2	145.25	232182	150	1875
11.2	158.025	228979	150	1875
12.2	171.35	225718	150	1875
13.2	185.05	222404	150	1875

Table 6. Data for drilling EP evaluation

Drilling speed [rev/min]	Drilling cost, c_{i22} [Euro]	Drilling time, t_{i22} [s]	Drilling price, P_{i22} [Euro]	Drilling Asset, A_{i22} [Euro]
110	6.575	6703	13.75	2500
200	6.725	5223	13.75	2500
250	7.125	4602	13.75	2500
300	7.875	4094	13.75	2500
350	9.1	3678	13.75	2500
400	10.95	3338	13.75	2500
450	13.55	3060	13.75	2500
500	16.975	2833	13.75	2500
550	21.175	2648	13.75	2500
600	25.775	2497	13.75	2500
625	28.125	2432	13.75	2500

Maximum value for EP was obtained for a optimal drilling speed, *v=200* rev/min and optimal rate of welding *v=5.2* mm/s. Maximum value for EP is $1.12 \cdot 10^{-7}$ [euro/euro/min].

3. Conclusion

The calculation for job EP is an effective tool for making decisions about accepting or outsourcing the job. The company will keep only those jobs that bring favorable EP and the other ones are given to other manufacturing companies for execution. The manager can easily make a selection of more favorable jobs for its company. Some relevant studies can be found in [4] and [5].

References

[1] L. Daschievici, D. Ghelase, "Control based on in-cycle learning of manufacturing system", in International Journal of scientific Research and Innovative Technology, vol.6, no.5, 2019.

[2] E. Shehab and H. Abdalla: *An Intelligent Knowledge-Based System for Product Cost Modelling*, Int J Adv Manuf Technol 19:49–65, 2002.

[3] Ghelase D, Daschievici L., "Adaptive Control of the manufacturing system" in International Journal of scientific Research and Innovative Technology, vol.6, no.5, 2019.

[4] M. H. Roushdy, "Recycling of Cullet, Waste Clay Bricks and Wastes Resulted from Wheat and Sugarcane Cultivations in the Manufacture of Fired Clay Bricks", WSEAS Transactions on Environment and Development, vol. 17, pp. 192-200, 2021

[5] Olusegun Osho, Alexander Ehimare Omankhanlen, Mojisola Fasanmi, Victoria Akinjare, "Liquidity and the Performance of the Nigerian Manufacturing Firms: An Economic Value-added Approach", WSEAS Transactions on Environment and Development, vol. 17, pp. 47-55, 2021