CAPACITY UTILIZATION FOR PRODUCT MIX USING OPERATION BASED TIME STANDARD EVALUATION

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Abstract

In this paper, a systematic and quantitative view is presented for the application of time study in woodworking furniture industry. The study is done in panel conversion plant on five CNC machines for various operations. For the calculation of cycle time, machining time calculator is developed and the operation research technique of mathematical programming is used for the capacity calculation of product mix. This makes manager to make faster decision in outsourcing problem and to improve the financial performance of the company.

Keywords *- Capacity utilization, cycle time, linear programming, manufacturing, time study.*

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1. INTRODUCTION

In the world of competitive business every enterprise wants to earn maximum profit with minimum inputs. Continuous improvement in the product is required for the survival of the industry in the global competition. Setting the time standard for different product is vital success of any enterprise. Time study gives the cycle time of the products on various machines which help in the capacity utilization calculations. From the manufacturing perspective, cycle time is one of the most important variables in manufacturing organizations. In this study, the woodworking organization encounters the very often situation of surplus demand than its capacity to manufacture. Because the company want to grab all the market demand in order to prevent other major competitors from penetrating the market and at the same time maintains the company reputation for on time delivery of products. The study is done in woodworking (modular furniture) industry based in central India.

1.1 Capacity Planning

Capacity planning is the determination of capacity and adjustment of capacity to changing demand. Capacity decision has direct influence on resource productivity and customer satisfaction. Excess capacity results in low productivity. Due to under-utilization of resource while inadequate capacity results in poor customer service through delayed delivery goods. Capacity planning is basically matching the resource to demand. In case of stable demand, capacity planning becomes simple. But fluctuation in demand creates problems of acquisition of resources to match the demand. Creation of capacity involves substantial investment. For manufacturing firm, creation of capacity means investment in resources like labor, machines and equipment etc. while for service organization, it means creation of more space, furniture, other accessories and equipments.

2. CASE STUDY

Central India based company having panel conversion plant (PCP) which manufactures five different types of product on five CNC rover machines at different prices. The company's present production process have job order production of various products which having product wise routing in which various operation are done with respect to product specification. The product wise routing is time consuming because one product gets lot of time due to various components and it is very difficult to take the timings. The system of the company has standard norms for standard products. If the products gets changes, then ultimately the norms also changes and thus the cycle time of the product also changes. Therefore there is loss in efficiency, utilization of man and machine.

In this study all the information related to raw material cost, hourly rate, selling price, demand, operation time, etc were collected. We have choose the five product given them name as A = prelamstorage@702, B = prelamstorage@1275, C = cabinet@1200, D = credenza@1350, E = pedestal on five CNC rover machine namely rover-20, rover B3, rover30, rover35, morby.

Table 1: Time study sheet of the company' product

ELE. NO.	ELEMENT DESCRIPTION	RATING	N. TIME (SEC.)	NO OF READINGS	AVG. TIME (SEC)	OCC.	NORM.TIME (SEC.)
1	Load panel on CNC & reverse	100	125.0	10.0	12.5	1:1	12.5
2	Reset against stopper, insure clamping ,operate start button	100	108.0	10.0	10.8	1:1	10.8
3	Auto cycle LH	100	88.0	1.0	88.0	1:1	88.0
4	Clean dust by air	100	87.0	9.0	9.7	1:1	9.7
5	Operate clamping switch, reverse panel & unload the panel	100	112.0	9.0	12.4	1:1	12.4
6	Load panel on CNC & reverse	100	90.0	7.0	12.9	1:1	12.9
7	Reset against stopper, insure clamping ,operate start button	100	94.0	7.0	13.4	1:1	13.4
8	Auto cycle RH	100	88.0	1.0	88.0	1:1	88.0
9	Clean dust by air	100	80.0	8.0	10.0	1:1	10.0
10	Operate clamping switch, reverse panel & unload panel	100	78.0	8.0	9.8	1:1	9.8

STD time = Normal time + (Normal time x allowance) =
176+176 X (0.13) = 198.9

As the time study sheet shows the auto cycle readings(cycle time) of CNC machine for particular product, this cycle time readings has to be noted from time to time for particular product. It is very difficult to note the cycle time again and again. To avoid this we have develop small software MACHINING TIME CALCULATOR in ms excel sheet for calculation of operation (element) wise timing. The element wise time reading is taken for various sizes of drill, face drill, KD/counter, grooving, hafle hole, routing and sizing, hinge etc. The time is taken for various element machines wise. The data like feed rate, speed of machine is entered in the software.

2.1 Advantages

- There is no need to take the cycle time (Autocycle) again and again
- The operations having same cycle time are defined
- The output will get as the total machining time on each rover machine
- If new product comes, then it is useful to find out the new product lead time
- This helps in improving the efficiency of machine
- To know the capacity and resource calculation
- Meeting the delivery commitments of the customers

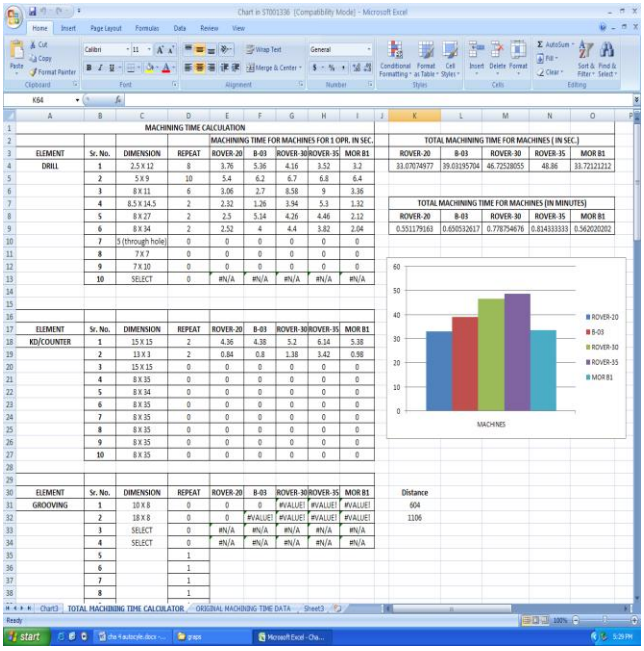

Fig 1 Image of Machining Time Calculator software

3. ANALYSIS & CALCULATION OF TIME

3.1 Calculation of Machining Time:

The machining time for the five products is calculated on the Machining Time Calculator with the help of drawing sheet on various CNC ROVER machines. The five machines will give the different machining time for above products. The machining time is calculated for different components of the respective products. The components wise machining time is

obtain and output time will get in seconds. The machining time calculator gives the graph which shows the lead time of product on various machines. For example the graph for product A is shown in figure.

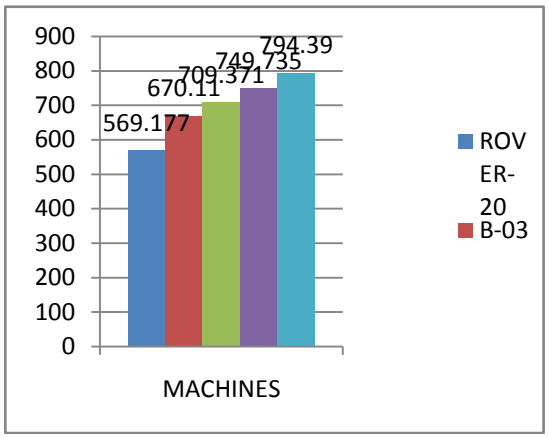

Fig 2 Machining Time in Sec for **Product A**

3.2 Calculation of Weekly Capacity

The weekly capacity of work centre is shown in table 2.

There are 5 machines, they run daily for 2 shifts (each of 8 hour shift) and 6 working days in a week i.e. (16x6x60 =5760 min). The setup time to be booked with small setup = 5min/setup and big setup = 10 min/setup. Therefore (45x5+0x10 = 225). The data of setup time is taken from company. Weekly capacity is calculated as (total weekly time – time lost due to setups). ie (5760-225) = 5535 min = 332100 sec.

Table 2: shows weekly capacity of various machines

Machine	Weekly time	Small setup	Big setup	Total	Weekly capacity (min)	Weekly capacity (sec)
R20 (M1)	5760	45	0	225	5535	332100
B3 (M2)	5760	15.75	3	108.75	5651.25	339075
R30 (M3)	5760	15.12	24.5	318.12	5441.88	326512.8
R35 (M4)	5760	57.62	6.125	349.35	5410.65	324639
MORBY(M5)	5760	27.125	0	135.625	5624.38	337462.8

Table 3: shows the cycle time and capacity utilization

Machine	Time/product at various work centers, in sec					Weekly capacity of machine
	A	B	C	D	E	
R20	569.17	525.76	522.93	682.69	347.21	332100
B3	670.11	641.51	620.91	768.05	400.09	339075
R30	709.37	650.52	620.18	795.27	400.36	326512.8
R35	749.74	639.01	610.39	798.58	390.28	324639
Morby	794.39	733.68	826.65	1074.2	396.1	337462.8

4. FOMULATION OF MATHEMATICAL PROBLEM (LP)

Let the company with m resources (1,2,…m) and n product (1,2,….n).

Let the k_i is the capacity per week in sec for particular machine.

Let a_n is the processing time in sec to process a product say A
Raw material price = R_A
Market price = M_A
Market demand = D_A
Cycle time = a_1,b_1,c_1,d_1,e_1 Products = A,B,C,D,E
No. of products manufactured in company = Z_i
Outsource price = S_i

Due to capacity constraints company can manufactureZ_i.
$Z_i \leq D_i$

The LP objective function as follows

Z_{max} = (M_A-R_A) A+ (M_B-R_B) B + (M_C-R_C) C + (M_D-R_D) + (M_E-R_E) E

Subject to

M1 a_1A+b_1B+c_1C+d_1D+e_1E $\leq k_{i1}$

M2 a_2A+b_2B+c_2C+d_2D+e_2E $\leq k_{i2}$

M3 a_3A+b_3B+c_3C+d_3D+e_3E $\leq k_{i3}$

M4 a_4A+b_4B+c_4C+d_4D+e_4E $\leq k_{i4}$

M5 a_5A+b_5B+c_5C+d_5D+e_5E $\leq k_{i5}$

4.1 Formulation of a Problem by using Simplex Technique:

Z_{max} = (M_A-R_A) A+ (M_B-R_B) B + (M_C-R_C) C + (M_D-R_D) + (M_E-R_E) E

Maximize Z = 1166.67A + 1166.67B + 1666.67C + 1083.34D + 833.34E

subject to

569.17A + 525.76B + 522.93C + 682.688D + 347.208E <=332100
670.11A + 641.506B + 620.91C + 768.045D + 400.091E <= 339075

709.371A+650.517B+620.18C+795.271D+400.362E<=326512.8
749.735A
+639.005B+610.394C+798.577D+390.278E<=324639
794.39A + 733.678B + 826.645C + 1074.229D + 396.101E <= 337462.8

Market Constraints

A<= 80, B<= 100, C<= 100, D<= 70, E<= 400

The resulting optimum product mix is to manufacture 29, 100, 100, 0,400 of A, B, C, D, E respectively.

5. METHODOLOGY FOR LINEAR PROGRAMMING ANALYSIS

The market selling price of product A is 7000. The raw material cost for product A is 7000/1.2=5833.33=R_A . Considering the 20% profit. The (M_A-R_A) = 1166.67, from the table 5 the contractor price for all the products A,B,C,D,E, are 6200,6500,7500,6000,4800 respectively. The throughput per manufacturing unit of A can be calculated as (market price x (company profit% /100). The throughput per contracted unit is calculated as contractor price minus raw material cost i.e. (6200-5600=600). All the calculations are done in Indian currency.

Table 4: shows the machine hr rate and cost for product

Machine	R20	B3	R30	R35	MORBY
Cost/hr	364	520	520	401	548
Product	A	B	C	D	E
Machine time	569.177	641.506	620.18	798.577	396.101
Machine time hr	0.158105	0.178196	0.172272	0.221827	0.110028
Cost for product	57.55012	92.66198	89.58156	88.9526	60.29537

The total throughput manufactured in company is equal to the throughput per manufactured unit x units to manufacture. Units contracted outside = market demand – units to manufacture. The total throughput contract is calculated as (throughput per contracted unit x units contracted outside). i.e (600 x 51=30600).

The product throughput is the sum of total throughput manufactured in company and total throughput contract. Overall throughput is the summation of total product throughput for all the products. Similarly throughputs for other products are calculated.

From the table 4 the cost for product is calculated as cost/hr x machine time hr. The cost for product is also called as operating expenses (OE). Similarly OE for other products is calculated. The product OE in company mfg is the product of OE and units to manufacture. The summation of product OE in company mfg for all the products is calculated. The highlighted portion shows the input variables.

Table 5: shows the LP analysis result

Details	Product				
	A	**B**	**C**	**D**	**E**
Contractor Price	6200	6500	9500	6000	4800
Market price	7000	7000	10000	6500	5000
Company Profit %	20	20	20	20	20
Raw material cost/Unit	**5600**	**5600**	**8000**	**5200**	**4000**
Contractor profit	600	900	1500	800	800
Company Profit	1400	1400	2000	1300	1000
Market Demand	80	100	100	70	400
Units to manufacture	29	100	100	0	400
Throughput/ mf. Unit	1400	1400	2000	1300	1000
Total throughput mfg in company	40600	140000	200000	0	400000
Units contracted outside	51	0	0	70	0
Throughput/ contracted Unit	600	900	1500	800	800
Total throughput contract	30600	0	0	56000	0
Total product throughput	71200	140000	200000	56000	400000
Overall throughput (I)	867200				
Operating expenses OE	44011.46				
Net profit (I-OE)	823188.5				

	Product				
	A	**B**	**C**	**D**	**E**
OE	57.55012	92.66198	89.58156	88.9526	60.29537
Product OE in company mfg.	1668.953	9266.198	8958.156	0	24118.15
Total OE company mfg.	44011.46				

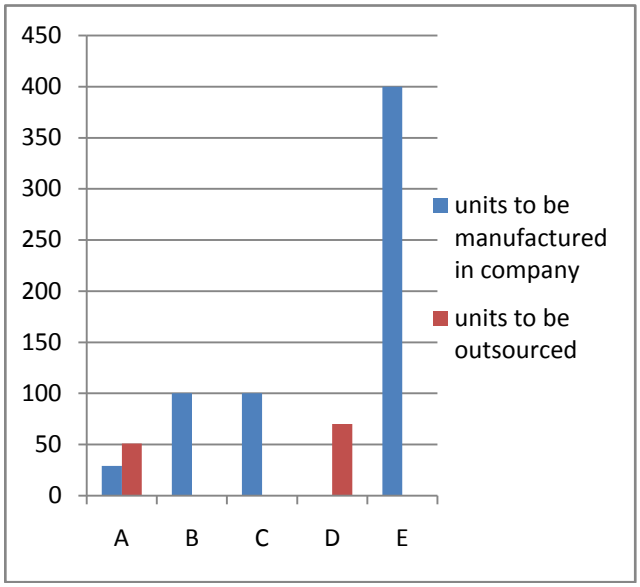

Fig 3: units to be manufactured and outsourced

6. RESULTS

- In LP analysis, net profit obtain is **Rs 823188.5**
- The resulting optimum product mix that is to manufacture **29, 100, 100, 0,400** of **A, B, C, D, E** respectively
- To outsource **51 of A** and **70 of D**
- Operating expenses is **Rs 44011.46**

7. CONCLUSION

The setting of time standards helps in the achievement of production targets of the company. Application of machining time calculator helps in calculation of auto cycle reading with the help of drawing sheet. When new product comes then we can decide the cycle time with help of machining time calculator. Due to this there is no need to study the timing of operation again and again. In capacity utilization for the product mix, the LP model is simple and helps the manager to make faster decision in outsourcing problem with maximum throughput. When demand exceeds the capacity, the suggested model guides the exact quantity to be manufactured as well as the quantity to be outsourced. The model is simple to use and requires only two variables to compute, one is contractor's profit and another is work time in resource. It is also requested to consider setup time during study as this having significant impact.

REFERENCES

[1]. Carl R Lindenmeyer 2001, How to design and conduct a computer integrated time study with active element performance rating(CITS APR).

[2]. Dr.C.K Jain,Bharat Chede, Aparna Soni,2007 Quantitative analysis of capacity constrained resources for theory of constraints in manufacturing. ICRTME (2007) IP26-IP34.

[3]. P S Chakraborty, G Majumdar, B Sarkar, 2006, Constraints resource management and production related decision-a case study. IE (I) Journal-PR Vol86, 2006, 48-53.

[4]. Edverd J. Williams and Cilia Ortiz, 1996, Steel production method improvement study, Advances in Industrial engineering applications and practice.324-329.

[5]. S.A.Oke, 2006, A case study application of time study model in an aluminum company. The pacific journal of science and technology volume (7) number (2). 153-162.

[6]. Iain S. MacLeod, 2003, Real world effectiveness of ergonomic methods. Applied Ergonomics 34 (2003) 465-477.

[7]. Jason J. Saleem, Brian M. Kleiner, Maury A. Nussbaum, 2003, Emperical evaluation of training and work analysis tool for participatory ergonomics, International Journal of industrial ergonomics, 31(2003)387-396.

[8]. Stefano Apolloni, Marcello Lando, Matteo Savino,1984, Advanced techniques of theory of constraints and activity based costing for scheduling of high technology production lines. North river press Inc 1984.

[9]. Industrial Engineering and Production Management by Martand Telsang.

[10]. Industrial Engineering and Management by O. P. Khanna.