# RENTABILITY OF NC MACHINES AND INPUT/OUTPUT ANALYSIS*

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## Summary

Through analyzing a NC machine, this article shows the influence of inputs and outputs on efficient operation. Starting from the technical-economical parameters, normal and capacity dependent cost standards are introduced, and the so-called planned passive costs are defined as a difference between standard and normal capacity utilization. The different inputs of different capacities are also illustrated. The influences of working point movements as a result of changing intensity, capacity utilization and input are analyzed, as well. In the end, the weak points of the system are defined, where intervention is needed.

NC and CNC machines are of great value, consequently all the firms having such machines strive for making the best use of them. Utilization is generally measured by the ratio of the theoretical and the executed (real) working hours/month.

The definition of the monthly theoretical—planned—working hours is a basic and constant problem. Namely, value is influenced by a lot of non-measurable factors (shift utilization, working order, maintenance periods etc.).

It seems always advantageous to define three shifts for the NC machines. The only question is: how are these three shifts utilized from output's point of view, i.e. what kind of product is produced, and how economically (how large is its coverage). This kind of economical calculation generally lacks company information.

Costs expressing inputs can be better estimated. When all information is available, the cost/hour values can analitically be defined. This machine time costs are, however, to be treated carefully, since they contain only the direct operating costs, but not the indirect (general) costs resulting from all the other machines' operation.

In spite of this apparent inaccuracy, machine time costs bear quite good information on the "capacity value" of the machine.

* This paper was prepared on the book of *L. Ladó:* Cost-benefit analysis. (In Hungarian). Közgazdasági és Jogi Könyvkiadó. Budapest. 1981.

Standard costing is based on integrated use of all the above informations. To measure effectiveness this method originates in capacity. If the amount of capacity is known, then the optimal, i.e. standard costs related to possible utilization can be defined. From standard costs, the cost/working hour values and the planned and real non-standard costs (related to different levels of utilization) are to be defined.

Comparing the standard, planned and real times and their costs one gets the so-called passive costs.

The first group of passive costs comes deliberately into being, when the utilization level is—due to certain causes—lower than standard value. Also in this case arises loss, but it can be regarded as planned loss (planned passive cost). All the deviations from the planned capacity utilization strongly influence the operational rentability. This influence can be exactly defined.

Such a way, company management has more information than the single machine time cost, namely input/output ratios and their consequences on rentability.

Next an input/output analysis will be shown for a CNC machine widespread in Hungary (lathe, type EV 630).

*Standard cost calculation for CNC lathe type EV 630-10*

*Data used in calculation*

| | |
|---|---|
| — Activated value of the machine | 6.236.000 Forints |
| — Amortization period | 7 years |
| — Groundface of the machine | 30 $m^2$ |
| — Value of workshop area | 4.184 Forints/$m^2$ |
| — Amortization ratio | 1.3%/year |
| — Electrical power consumption | 42 kW |
| — Power consumption factor | 0,97 |
| — Electrical power unit cost days | 1.57 Forints/kW hour |
| — Working days/year | 255 days |
| — Number of shifts | 3 |
| — Shift utilization factor | |
| — planned ($s_{up}$) | 0.82 (82%) |
| — optimal ($s_{uo}$) | 0.86 (86%) |
| — Hourly wage of a skilled worker | 28 Forints/hour |
| — Taxes and public insurance | 40% |
| — Tooling costs | 210.000 Forints/year |
| — Maintenance costs | 785.000 Forints/year |
| — Costs of technical preparation | 30.000 Forints/year |

*Calculating machine-hour costs*

— Useful (net) working time (for 3 shifts)
  a) optimal net working time
    $T_{no} = 255 \cdot 0.86 \cdot 8 \cdot 3 = 5269$ hours/year
  b) expected net working time
    $T_{ne} = 255 \cdot 0.82 \cdot 8 \cdot 3 = 5018.4$ hours/year
— useful (net) working time (for one shift)
  $255 \cdot 0.82 \cdot 8 = 1673$ hours/year
  (In the above calculations 8 hours/day is assumed.)

*Amortization* (of the machine)

— activated value: 6 326 000 Forints
— amortization period: 7 years
— amortization costs:

$$\frac{6\,326\,000}{7} = 903.71 \text{ Forints/year}$$

— amortization key:

$$\frac{903.71}{6\,326\,000} = 14.3\%/\text{year}$$

— amortization cost/one machine hour:

$$\frac{903.71}{5018.4} = 180.08 \text{ Forints/hour}$$

*Amortization* (of building and area)

— amortization of the building:
  $4184 \text{ Forints/m}^2 \cdot 30 \text{ m}^2 = 125\,532$ Forints
— amortization of the area:

$$\frac{125\,532 \cdot 1.3}{100} = 1631.92 \text{ Forints/year}$$

— amortization cost/one machine hour:

$$\frac{1631.92}{5018.4} = 0.33 \text{ Forints/hour}$$

*Manpower costs*

— hourly wage: 28 Forints/hour
— yearly wage: $5018.4 \cdot 28 = 140\,515.2$ Forints/year
— taxes and public insurance:
$0.4 \cdot 28$ Forints/hour $= 11.2$ Forints/hour
— yearly taxes and public insurance:
$140\,515.2 \cdot 0.4 = 56\,206.08$

Summarizing the manpower costs:

| | Forints/hour | Forints/year |
|---|---|---|
| Wage | 28 | 140 515.2 |
| Taxes + insurance | 11,2 | 56 206.08 |
| Total | 39.2 | 196 721.28 |

*Energy costs*

— power consumption: 42 kW
— power consumption factor: 0.97
— unit cost of power: 1.57 Forints/kW hour
— yearly power consumption:
$42 \cdot 0.97 \cdot 5018.4 = 204\,449.62$ kW hours/year
— energy costs:
$204\,449.61 \cdot 1.57 = 320\,985.9$ Forints/year
— energy costs/hour: 63.96 Forints/hour

*Tooling costs:*

210 000 Forints/year
41.85 Forints/hour

*Maintenance costs:*

785 000 Forints/year
156.42 Forints/hour

*Costs of technical preparation:*

30 000 Forints/year
5.98 Forints/hour

*Machine-hour costs in total*

| | |
|---|---|
| Amortization (machine + workshop area) | 180.41 Forints/hour |
| Wages + taxes and insurance | 39.2 Forints/hour |
| Energy | 63.96 Forints/hour |
| Tooling | 41.85 Forints/hour |
| Maintenance | 156.42 Forints/hour |
| Technical preparation | 5.98 Forints/hour |
| | 487.82 Forints/hour |

## Calculating utilization difference

*Planned cost of planned production*

$C_{pp} = c_{pp} \cdot u_{pp} = 487.8 \cdot 5018.4 = 2\,448\,000$ Forints/year
Planned cost of planned production on standard level:
$C_{pp\,st} = c_{st} \cdot u_{pp} = 475.6 \cdot 5018.4 = 2\,386\,700$ Forints/year

*Planned passive cost:*

$C_{pp} - C_{pp\,st} = 2448 - 2386.7 = 61\,300$ Forints/year (Fig. 1.)

*Control, based on standard cost/hour:*

| | |
|---|---|
| planned per unit cost of | $c_{pp} = 487.8$ Forints/hour |
| per unit standard cost | $c_{st} = 475.6$ Forints hour |
| difference: | 12.2 Forints/hour |

Capacity utilization of planned production:
$u_{pp} = 5018.4$ hours/year

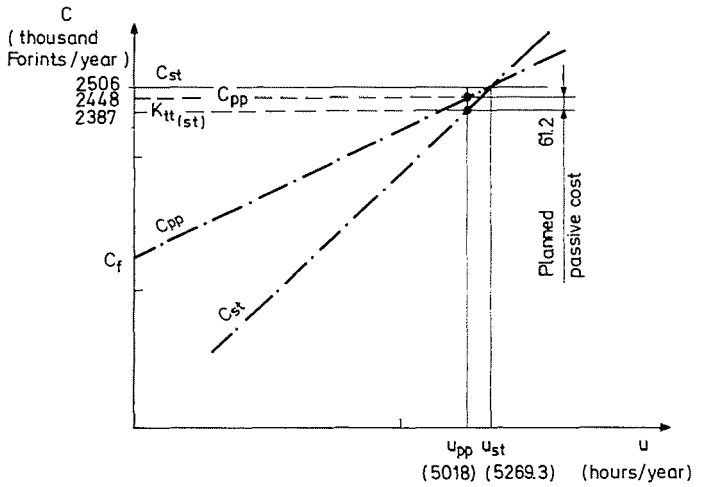


*Fig. 1.* Diagram of planned passive costs

**Defining standard and utilization dependent cost norms**

| Capacity utilization (%) | | | 85% | | | 90% | | | 95% | | | 100% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours/year | | | 4516.5 | | | 4767.5 | | | 5018.4 | | | 5269.3 | | |
| Cost factor | machine-hour; Forints/year | | $K_p$ | $K_f$ | $K_t$ | $K_p$ | $K_f$ | $K_t$ | $K_p$ | $K_f$ | $K_t$ | $K_p$ | $K_f$ | $K_t$ |
| Amortization | 180.41 | 0 | | 905370 | 905370 | | 905370 | 905370 | | 905370 | 905370 | | 905370 | 905370 |
| Wages + taxes and insurance | 39.2 | 1 | 177047 | | 177047 | 186886 | | 186886 | 196721 | | 196721 | 206556 | | 206556 |
| Energy cost | 63.96 | 1 | 288884 | | 288884 | 304938 | | 304938 | 320986 | | 320986 | 337034 | | 337034 |
| Tooling cost | 41.85 | 0.8 | 151198 | 42000 | 195198 | 159601 | 42000 | 201601 | 168000 | 42000 | 210000 | 176399 | 42000 | 218339 |
| Maintenance cost | 156.42 | 0.6 | 423894 | 314000 | 737894 | 447452 | 314000 | 761452 | 471000 | 314000 | 785000 | 494548 | 314000 | 808548 |
| Cost of technical preparation | 5.98 | 0 | | 30000 | 30000 | | 30000 | 30000 | | 30000 | 30000 | | 30000 | 30000 |
| Total | 487.82 | | 1041023 | 1291370 | 2332393 | 1098887 | 1291370 | 2390247 | 1156707 | 1291370 | 2448077 | 1214537 | 1291370 | 2505907 |
| Machine-hour cost | Forints/hour | | 230.5 | | 516.4 | 230.5 | | 501.4 | 230.5 | | 487.8 | 230.5 | | 475.6 |

"Standard" utilization: 100%
$K_p$ = proportional cost
$K_f$ = fixed cost
$K_t$ = total cost

**Summary and interpretation of results***

| Capacity utilization machine-hour/year | Type of costs | Cost value and calculation | |
|---|---|---|---|
| | | Thousand Forints/year | Forints/hour |
| $u_{st} = 5269.3$ | standard cost | $C_{st} = 2505.9$ | $c_{st} = \frac{C_{st}}{u_{st}} = \frac{2\,505\,907}{5269.3} = 475.6$ |
| (100%) | ($C_{st}$; $c_{st}$) | $C_{pst} = 1214.5$ | $c_{pst} = \frac{C_{pst}}{u_{st}} = \frac{1\,214\,537}{5269.3} = 230.5$ |
| $u_{pp} = 5018.4$ | planned cost of | $C_{pp} = C_{ppp} + C_f = 2448.0$ | |
| (95%) | planned production | $C_{ppp} = 1156.7$ | $c_{pp} = \frac{C_{pp}}{u_{pp}} = \frac{2\,448\,077}{5018.4} = 487.8$ |
| | ($C_{pp}$; $c_{pp}$) | $C_f = 1291.37$ | |
| | | $C_{pp} = c_{ppp} \cdot u_{pp} + C_f$ | $c_{ppp} = \frac{C_{ppp}}{u_{pp}} = \frac{1\,156\,707}{5018.4} = 230.5$ |
| | | $C_{ppp} = c_{pst} \cdot u_{pp}$ | |
| $u = 4767.5$ | actual cost of | $C = C_p + C_f = 2390.2$ | $c = \frac{C}{u} = \frac{2\,390\,247}{4767.5} = 501.4$ |
| (90%) | production (C; c) | $C_p = 1098.9$ | |
| | | $C_f = 1291.37$ | $c_p = \frac{C_p}{u} = \frac{1\,098\,877}{4767.5} = 230.5$ |

* in our example: "standard" utilization = 100%
planned utilization = 95%
measured, actual utilization = 90%

*Passive cost:*

$$5018 \text{ hour/year} \cdot 12.2 \text{ Forints/year} = 61\,300 \text{ Forints/year}$$

*Costs of the actual production*

Actual (measured) capacity utilization: 90%.
Related working hours/year: 4767.5.

The further analysis may have two directions:

1 Actual costs of actual production are equal to planned costs of actual production, i.e. costs of actual production are acceptable (reasonable) even from the plan's point of view.

In this case:

$u = u_{ap} = 4767.5$ hours/year
$C = C_{ap} = 2\,390\,200$ Forints/year
$c = c_{ap} = 501.4$ Forints/hour
$C_p = C_{pap} = 1\,098\,900$ Forints/year
$c_p = c_{pap} = 230.5$ Forints/hour

where the index "ap" is for "actual" and "planned"

2 Actual costs of actual production are not equal to the planned costs of actual production, i.e. the inputs of the real production would be reasonable only in case of 5% lower utilization.

In this case:

| Type of cost | capacity utilization machine-hours/year | Cost | |
|---|---|---|---|
| | | thousand Forints/year | Forints/year |
| planned cost of actual production ($C_{ap}$; $c_{ap}$) | $u_{ap} = 4516.5$ | $C_{ap} = C_{pap} + C_{ft} =$ $= 1041 + 1291.37 = 2332.37$ ($C_{pap} = c_{pst} \cdot u_{at}$) | $c_{ap} = \frac{C_{ap}}{u_{ap}} = \frac{2\,332\,393}{4516.5} = 516.4$ $c_{pap} = \frac{C_{pap}}{u_{ap}} = \frac{1\,041\,023}{4516.5} = 230.5$ |

*Calculation of actual production costs transformed to plan level*

*Analysis according to 1 assumption*

$u = u_{ap} = 4767.5$ hours/year
$C = C_{ap} = 2\,390\,200$ Forints/year
$c = c_{ap} = 501.4$ Forints/hour

Costs of the actual production (transformed on the plan) on standard level:
$C_{ap(st)} = u \cdot c_{st} = 4767.5 \cdot 475.6 = 2\,267\,420$ Forints/year

*Capacity utilization difference:*

$C_{ap} - C_{ap(st)} = 2\,390\,000 - 2\,267\,400 = 122\,780$ Forints/year
(Fig. 2)

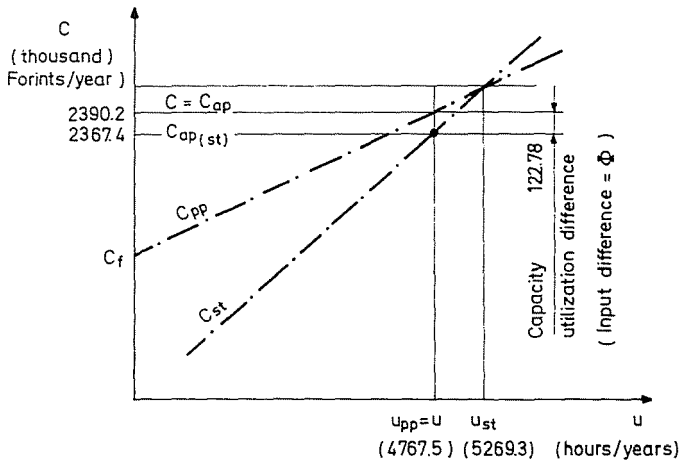


*Fig. 2.* Capacity utilization difference according to assumption 6.1

Control based on specific time expenditure:
$c_{ap} - c_{st} = 501.4 - 475.6 = 25.8$ Forints/hour
$25.8 \cdot u = 25.8 \cdot 4767.5 \approx 122\,780$ Forints/year

*Input difference:*

$C = C_{ap} = 2\,390\,200$ Forints/year
$C - C_{st} = 0$

*Analysis according to 2 assumption*

(It is assumed that actual expenditures would require cca. 5% less capacity utilization on plan level.)

*Basic data:*

$u_{ap} = 4516.5$ machine-hours/year
$C_{ap} = 2\,332\,370$ Forints/year
$C_{pap} = 1\,041\,000$ Forints/year
$c_{ap} = 516.4$ Forints/hour
$c_{pap} = 230.5$ Forints/hour
$c_{st} = 475.6$ Forints/hour
Cost of actual production (transformed on the plan) on standard level:
$C_{ap(st)} = u_{ap} \cdot c_{st} = 4516.5 \cdot 475.6 = 2\,148\,040$ Forints/year

*Capacity utilization difference*:

$C_{ap} - C_{ap(st)} = 2\,332\,370 - 2\,148\,040 = 184\,330$ Forints/year

Control based on specific time expenditure:
$c_{ap} - c_{st} = 516.4 - 475.6 = 40.8$ Forints/hour
$40.8 \cdot u_{ap} = 40.8 \cdot 4516.5 \approx 184\,330$ Forints/year

*Input difference*

C (actual) = 2 390 200 Forints/year
$C_{ap}$ (planned) = 2 332 370 Forints/year
$C - C_{ap} = 2\,390\,200 - 2\,332\,370 = 57\,830$ Forints/year

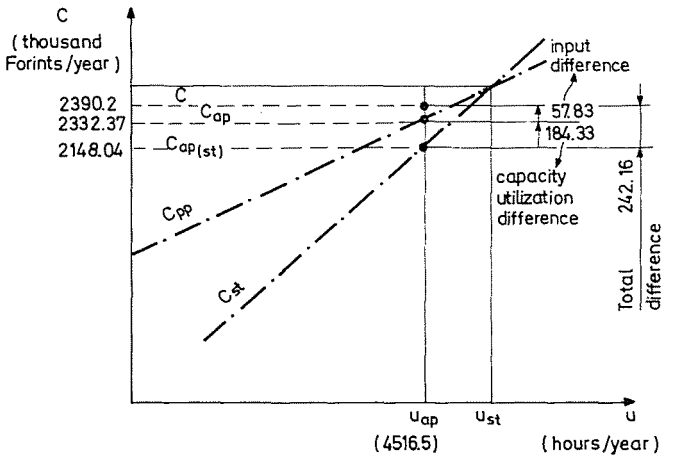


*Fig. 3.* Capacity utilization difference and input difference according to assumption 6.2

*Total difference* (Fig. 3)

| | |
|---|---|
| Capacity utilization difference: | 184 330 Forints/year |
| Expenditure difference: | 57 830 Forints/year |
| Total: | 242 160 Forints/year |

## Calculation with working point displacement

### *Intensity difference*

In case of 2 assumption, intensity difference can be calculated.
Actual production on standard level:
$C_{(st)} = u \cdot c_{st} = 4767.5 \cdot 475.6 = 2\,267\,420$ Forints/year
Standard costs of actual production, transformed on the plan:
$C_{ap(st)} = u_{ap} \cdot c_{st} = 4516.5 \cdot 475.6 = 2\,148\,040$ Forints/year

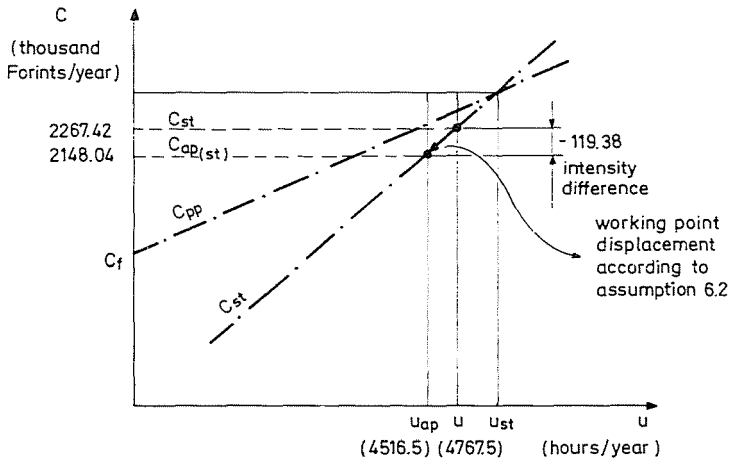


*Fig. 4.* Representation of intensity difference

*Intensity difference:* (Fig. 4)

$C_{ap(st)} - C_{(st)} = 2\,148\,040 - 2\,267\,420 = -119\,380$ Forints/year
Control, based on specific time expenditure:
$(u_{ap} - u) \cdot c_{st} = 4516.5 - 4767.5 \cdot 475.6 = 251 \cdot 475.6 = 119\,380$ Forints/year

## Capacity utilization difference for the modified working point

*Capacity utilization difference:*

— Available capacity: $u_{ap} = 5269.3$ hours/year
— Used: $u = 4767.5$ hours/year
— Actual cost of actual production on standard level: 2 267 420 Forints/year

Planned costs of actual production modified for the actual capacity utilization:
$C_{up} = (C_{ppp} \cdot u) + C_f = (230.5 \cdot 4767.5) + 1\,291\,370 = 2\,390\,270$ Forints/year
Capacity utilization difference:
$C_{up} - C_{st} = 2\,390\,270 - 2\,267\,420 = 1\,228\,500$ Forints/year
Input difference:
$C - C_{up} = 2\,390\,200 - 2\,390\,270 = -70$ Forints/year (almost zero)

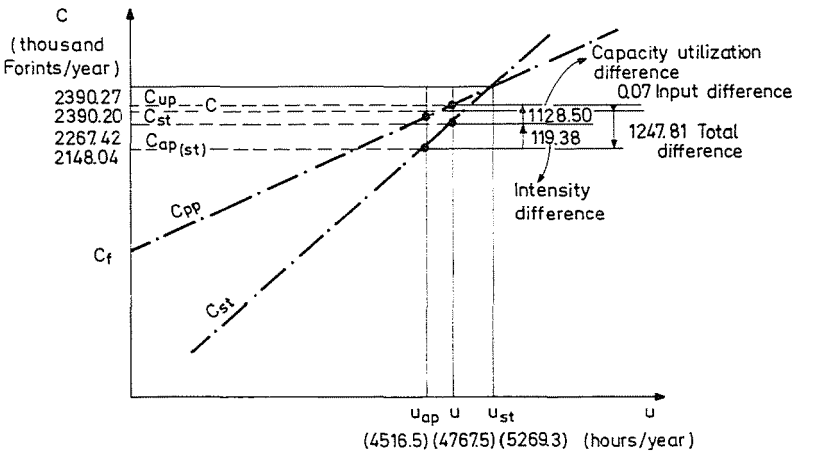


*Fig. 5.* Representation of the total difference based on working point displacement

*Total difference taking working point displacement into consideration:* (Fig. 5)

| | |
|---|---|
| — Intensity difference: | 119 380 Forints/year |
| — Capacity utilization difference: | 1 128 500 Forints/year |
| Total: | 1 247 880 Forints/year |
| — Input difference: | 70 Forints/year |
| | 1 247 810 Forints/year |

## Conclusion

a) When the standard (100%) capacity utilization of the CNC machine type EV 630 is planned for 95%, the resulting passive cost is 61 300 Forints/year on plan level.
b) A further 122 780 Forints/year capacity utilization difference is to be calculated when the measured actual capacity utilization is 90%, and inputs are reasonable according to plan ($C = C_{ap}$, $u = u_{ap}$).
c) Assuming that actual inputs would require by 5% less planned capacity utilization, an input difference also occurs. Its value—with capacity utilization difference of 184 330 Forints/year—is 57 830 Forints/year.
d) Accepting the assumption mentioned in c) there is an intensity difference, too, resulting from working point displacement. It is caused by the difference of standard costs of actual production's time requirement (u), and its actual reasonable time requirement ($u_{ap}$).
e) As a result of working point displacement, an additional capacity utilization and input difference is involved by the total difference (the values are 1 128 500 Forints/year and 70 Forints/year, respectively).

Our intentionally complex analysis aimed at calling the attention to the fact, that different levels of capacity utilization result in different costs which influence the machine's operational efficiency. These calculations are very useful aids in the management when valuable machines and equipments are at disposal.

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