Outline

Case study 1 “Mechoff”

Design of manufacturing systems – Job Shop

- Introduction
- Input data
- Top management’s questions

MECHOFF – ***Top Management's questions***

- Is it possible to meet demand without buying any new machines (just varying the **number of shifts**)?
- Or is it necessary to buy **new machines** (**how many**)?
- **Space** is not a constraint because an eventual new expansion of the manufacturing plant was taken into account in the design of layout.

MECHOFF – **Draft solution**

<u>Objective</u>
To find the best alternative which allows the company to process all products of family SP in house at the lowest costs.

Assumptions:

- ✓ The production cycle of family SP includes **3 operations**: milling (M1), drilling (M2) and face grinding (M5).
- ✓ **Drilling capacity** is considered to be **available** (no further investigation is needed)

MECHOFF – **Draft solution**

Procedure

The following steps can be followed to find the best solution:

1. Evaluating the **required capacity** to satisfy the demand in M1 and M5.
2. Verifying the **available capacity** in both M1 and M5 departments with the current configuration and, hence, the amount of **missing capacity**.
3. Identifying **potential alternatives** to provide the missing capacity:
   - ✓ using overtime
   - ✓ adding one shift
   - ✓ buying new machines
   - ✓ a mix of the above mentioned alternatives.

MECHOFF – **1. Required capacity**

It can be evaluated with the following formula (*please make sure that all time elements are expressed with the same unit of measure*)

$$NH_i = \sum_{j=1}^{N} \left(\frac{T_{ij} \cdot Q_j}{3600 \cdot \left(1 - SR_{ij}\right)} + \frac{STT_{ij}}{60} \cdot NL_j \right) \cdot \frac{1}{A_i} \cdot \frac{1}{HC_i} \cdot \frac{1}{TR_i}$$

Where:

- i = index of the machine-type
- j = index of the product-type
- N= number of different product-types
- Tij = unit working time [seconds/piece]
- Qj = quantity of product-type j that has to be produced [pieces/year]
- SRij = scrap rate ($0 \leq SRij < 1$)
- STTij = setup time [minutes/setup]
- NLj = number of lots of product-type j [lots/year]
- Ai = availability ($0 < Ai \leq 1$)
- HCi = human coefficient ($0 < HCi \leq 1$)
- TRi = trial rate ($0 < TRi \leq 1$)

MECHOFF – **Required capacity – Deptm M1**

Item	Yearly demand (units/year)	Working time (hours/unit)	Required hours (hrs/y)) TLij * Qj	N. of lots per year	Setup time (hours/setup)	Setup hours (hrs/y) TPMij * Nlj
PZ1	500	0.55	275	10	3	30
PZ2	500	0.25	125	12	1.5	18
PZ3	500	0.4	200	18	2	36
PZ4	500	0.4	200	9	2	18
DI1	2500	0.2	500	40	2	80
DI2	3400	0.2	680	40	1.5	60
DI3	6250	0.3	1875	30	1.5	45
DI4	5000	0	0	25	/	
DI5	500	0.2	100	15	1	15
RO1	8000	0	0	30	/	
RO2	500	0	0	5	/	
RO3	6500	0	0	20	/	
RO4	500	0	0	10	/	
RO5	10000	0	0	50	/	
SP1	5000	0.5	2500	25	1.5	37.5
SP2	7000	0.45	3150	35	1	35
SP3	2600	0.3	780	13	1.2	15.6
SP4 (new item!)	2000	0.6	1200	20	2	40
		total	11585		total	430
		scrap rate 4%	11585/0,96 = 12068			

MECHOFF – **Required capacity – Deptm M5**

Item	Annual demand (units/year)	Working time (hours/unit)	Required hours (hours/year) TLij * Qj	N. of lots per year	Setup time (hours/setup)	Setup hours (hours/year) TPMij * Nlj
PZ1	500	0	0	10	/	
PZ2	500	0	0	12	/	
PZ3	500	0	0	18	/	
PZ4	500	0	0	9	/	
DI1	2500	0.5	1250	40	1	40
DI2	3400	1	3400	40	0.5	20
DI3	6250	0.7	4375	30	1	30
DI4	5000	0.2	1000	25	0.5	12.5
DI5	500	0	0	15	/	/
RO1	8000	0.5	4000	30	2.5	75
RO2	500	0.95	475	5	3	15
RO3	6500	0.98	6370	20	2.5	50
RO4	500	1.05	525	10	3	30
RO5	10000	0.65	6500	50	4	200
SP1	5000	1.2	6000	25	2	50
SP2	7000	0.8	5600	35	1.5	52.5
SP3	2600	0.9	2340	13	1	13
SP4 (new item!)	2000	1.5	3000	20	2	40
		total	44835		total	628
			44835/0,96 = 46703			

MECHOFF – **Required capacity**

Department M1

$$\mathbf{NH_{M1}} = \sum_{j=1\ldots J} \{ TLij * Qj/(1\text{-}SRj) + TPMij * Nlj \} * 1/Ai * 1/HCi * 1/TRi =$$
$$= (12068 + 430) * 1/0.95 * 1/0.94 * 1 = \mathbf{13996\ hours/year}$$

Department M5

$$\mathbf{NH_{M5}} = \sum_{j=1\ldots J} \{ TLij * Qj/(1\text{-}SRj) + TPMij * Nlj \} * 1/Ai * 1/HCi * 1/TRi =$$
$$= (46703 + 628) * 1/0.95 * 1/0.94 * 1 = \mathbf{53002\ hours/year}$$

MECHOFF – **2. Available vs. missing capacity**

$$\mathbf{AH_i(s) = WH_i(s) \cdot SE}$$

where:
$WH_i(s)$ =yearly working time available (depending on the number of shifts/day)
SE = scheduling efficiency ($0 < SE \leq 1$), in this case it is equal to 0.8

AH_{M1} = 2 machines * (7.5 hours/shift * 2 shifts * 220 days/year) * 0.8
= **5280 hours/year**

Missing capacity in M1 = 13996 – 5280 = **8716 hours/year**

AH_{M5} = 12 machines * (7.5 hours/shift * 2 shifts * 220 days/year) * 0.8
= **31680 hours/year**

Missing capacity in M5: 53002 – 31680 = **21322 hours/year**

MECHOFF - **3. Evaluation of alternatives**

Assumptions about the number of operators/machines:

- ✓ in the current configuration there are **29 machines**
- ✓ **30 operators** working on **two shifts**

- ➢ therefore, it is possible to assume that **15 operators** work on the shop floor each shift
- ➢ on average, **one operator supervises 2 machines**.

MECHOFF – **3a Overtime only**

Assumptions:

- ✓ Overtime can be used for not more than **2 hours/day** during the week
- ✓ Overtime can be applied on **8 hours basis on Saturday**.

Therefore, max overtime (OT) for one machine in one year is:

OT = 2 hours/day * 220 days/year + (220/5) Saturday/year * 8 hours/Saturday = 792 hours/year

OT $_{M1}$ = 2 machines * 792 hours/year * 0.8 = **1267 hours/year**

OT $_{M5}$ = 12 machines * 792 hours/year * 0.8 = **7603 hours/year**

Conclusion: the use of overtime is not enough to meet the demand of missing capacity. Therefore, overtime can be used only in combination with other alternatives.

MECHOFF – **3b Adding 3rd shift**

Assumptions:

✓ Number of machines stays the same

Adding the **third shift** the following capacity (hours) is available:

AH_{M1} = 2 machines * (7.5 hours/shift* 220 days/year) * 0.8
= **2640 hours/year**

AH_{M5} = 12 machines * (7.5 hours/shift* 220 days/year) * 0.8
= **15840 hours/year**

Note: in case of **third shift,** it is possible to use overtime only on Saturday:

OT_{M1} = 2 machines * (220/5) Sat./year * 8 hours/Sat. * 0.8 = **563 hrs/y**

OT_{M5} = 12 machines * (220/5) Sat./year * 8 hours/Sat. * 0.8 = **3379 hrs/y**

Conclusion: the addition of the third shift is not sufficient to satisfy the entire demand.

MECHOFF – **3c Adding 3rd shift + new mach.**

Assumptions:

- ✓ Missing hours **M1** = 8716 hrs/y
- ✓ AH_{M1} (third shift) = 2640 hrs/y
- ✓ Additional capacity which is needed (△) = 6076 hrs/y

- ➢ **Additional capacity/machine** = 7.5 hours/ shifts * 3 shifts/day * 220 days/year * 0.8 = **3960 hours/year**

- ➢ The number of **new machines** is = 6076/3960 = **1.53**

Conclusion: two new machines are needed.

The average **level of saturation** in the **M1** department would be:

Required hours/Available hours = 13996/((2+2 machines) * 3960)) = **0.88**

MECHOFF – **3c Adding 3rd shift + new mach.**

Assumptions:

- ✓ Missing hours **M5** = 21322 hrs/y
- ✓ AH_{M5} (third shift) = 15840 hrs/y
- ✓ Additional capacity which is needed (△) = 5482 hrs/y

- ➢ **Additional capacity/machine** = 7.5 hours/ shifts * 3 shifts/day * 220 days/year * 0.8 = **3960 hours/year**

- ➢ The number of **new machines** is = 5482/3960 = **1.38**

Conclusion: two new machines are needed.

The average **level of saturation** in the **M5** department would be:
Required hours/Available hours = 53002/((12+2 machines) * 3960) = **0.95**

MECHOFF – **3c Economic assessment**

Assumptions M1:

- ✓ **Total cost** = investment cost M1+ operator cost M1
- ✓ In the new configuration there are 4 machines and 2 operators/shift are needed at M1
- ✓ Assuming that nr 1 operator per shift already works at M1, 2 new operators for the third shift and 2 operators for the other 2 shifts (or 1 operator/shift) have to be hired.

Therefore:

- ➢ **Investment cost M1** = 2 * (150000 *0.05) = **15000 Euro/year**
- ➢ **Labour cost M1** **=** 1 * 13.5 €/hour * 7.5 hours/shift * 220 days/year
  + 1 * 14.5 €/hour * 7.5 hours/shift * 220 days/year
  + 2 * 15.5 €/hour * 7.5 hours/shift * 220 days/year
  = **97350 €/year**

MECHOFF – **3c Economic assessment**

Assumptions M5:

- ✓ **Total cost** = investment cost M5+ operator cost M5
- ✓ In the new configuration there are 14 machines and 7 operators/shift are needed.
- ✓ Assuming 6 operators per shift already works in the department M5, 2 new operators (or 1 operator/shift) for the first 2 shifts and 7 for the third shift have to be hired.

Therefore:

- ➢ **Investment cost M5** = 2 * (250000 *0.05) = **25000 Euro/year**
- ➢ **Labour cost M5** **=** 1 * 13.5 €/hour * 7.5 hours/shift * 220 days/year
  + 1 * 14.5 €/hour * 7.5 hours/shift * 220 days/year
  + 7 * 15.5 €/hour * 7.5 hours/shift * 220 days/year
  = **225225 €/year**

Total cost M1+M5 = 15000 + 97350 + 25000 + 225225 = 362575 €/year

MECHOFF – **3d Adding new machines (2 shifts)**

Assumptions:

- ✓ Missing hours **M1** = 8716 hrs/y

- ➢ **Additional capacity/machine** = 7.5 hours/shifts * 2 shifts/day * 220 days/year * 0.8 = **2640 hours/year**
- ➢ The number of **new machines** is = 8716/2640 = **3.3** i.e. nr **4**

- ➢ Missing hours **M5** = 21322 hrs/y

- ➢ **Additional capacity/machine** = 7.5 hours/shifts * 2 shifts/day * 220 days/year * 0.8 = **2640 hours/year**
- ➢ The number of **new machines** is = 21322/2640 = **8.1** i.e. nr **9**

MECHOFF – **3d Economic assessment**

Assumptions:

- ✓ **Total cost** = investment cost M1+ operator cost M1+ investment cost M5 + operator cost M5
- ✓ **Operators M1**: 6 machines and 3 operators/shift are needed. If 1 op./shift already works in M1, 4 new operators (or 2 op/shift) have to be hired.
- ✓ **Operators M5**: 21 machines and 11 op./shift are needed. If 6 op/shift already works in M5, 10 new operators (or 5 op/shift) have to be hired.

Therefore:

- ➢ **Investment cost M1** = 4 * (150000 *0.05) = **30000 Euro/year**
- ➢ **Investment cost M5** = 9 * (250000 *0.05) =**112500 Euro/year**
- ➢ **Labour cost M1** **=** 2 * 13.5 €/hour * 7.5 hours/shift * 220 days/year
  + 2 * 14.5 €/hour * 7.5 hours/shift* 220 days/year
  = **92400 €/year**
- ➢ **Labour cost M5** **=** 5 * 13.5 €/hour * 7.5 hours/shift * 220 days/year
  + 5 * 14.5 €/hour * 7.5 hours/shift* 220 days/year
  = **231000 €/year**

Total cost M1+M5 = 30000 + 112500 + 92400 +231000 = 465900 €/year

MECHOFF – **3e New Machines + overtime**

Assumptions:
✓ Required capacity in M1 = 13996 hours/year
✓ Required capacity in M5 = 53002 hours/year

One machine working in overtime works for 3273,6 hours/year
(220days/year*2 shift/day* 7,5 hours/shift +792 overtime hours/year) * 0,8

Number of required machines M1: 13996/3273,6 = 5 machines
Since there are already 2 machines, the number of **new machines** will be 3

Number of required machines M5: 53002/3273,6 = 17 machines
Since there are already 12 machines, the number of **new machines** will be 5

<u>Remark</u>: the procedure adopted in this case is a variant of the procedure previously used
The solution is found by:
1. *Evaluating the **required capacity** to satisfy the demand in M1 and M5;*
2. *Verifying the **available capacity with one machine working in overtime** in both M1 and M5 dept.s*

MECHOFF – **3e Economic Assessment**

Assumptions:

✓**Total cost =** investment cost M1+ operators cost M1 + investment cost M5+ operators cost M5 + overtime cost

✓ **Operators M1**: 5 machines and 3 operators/shift are needed. If 1 operator per shift already works in M1, 4 new operators (or 2 op./shift) have to be hired.

✓**Operators M5:** 17 machines and 9 operators/shift are needed. If 6 operators per shift already work in M5, 6 new operators (or 3 op./shift) have to be hired.

Therefore:

- **Investment cost M1:** 3* (150.000 *0,05) = 22.500 Euro/year
- **Investment cost M5:** 5* (250.000 *0,05) = 62.500 Euro/year
- **Labour cost M1:** 2* 13,5 €/h * 7,5 h/shift* 220 d/y + 2*14,5 €/h * 7,5 h/shift* 220 d/y = **92.400 €/year**
- **Labour cost M5:** 3* 13,5 €/h * 7,5 h/shift* 220 d/y + 3* 14,5 €/h * 7,5 h/shift* 220 d/y = **138.600 €/year**
- **Overtime cost:** 3 operators work in M1 and 9 operators work in M5 21€/hour * 792 hours/year * (3+9) = **199584 €/year**
- **Total cost = 22500 + 62500 + 92400 + 138600 + 199584 = *515584 €/year***

MECHOFF – **3f New Mach + overt + 3rd shift**

Assumptions:
✓ With the 3rd shift, the only possible overtime is Saturday.
✓ Required capacity in M1 = 13996 hours/year
✓ Required capacity in M5 = 53002 hours/year

A machines working 3 shifts during the week and 1 shift on Saturdays works for 4241,6 hours/year
(3 shifts/day*7,5 hours/shift*220 days/year + 352 overtime hours/year)*0,8.

Number of required machines M1: 13996/4241,6 = 4 machines
Since there are already 2 machines, the number of **new machines** will be 2

Number of required machines M5: 53002/4241,6 = 13 machines
Since there are already 12 machines, the number of **new machines** will be 1

MECHOFF – **3f Economic Assessment**

Assumptions:

✓**Total cost =** investment cost M1+ operators cost M1 + investment cost M5+ operators cost M5 + overtime cost

✓**Operators M1:** 4 machines and 2 op/shift are needed. If 1 op/shift already works in M1,1 op./shift and 2 new op. for the 3rd shift have to be hired.

✓**Operators M5:** 13 machines and 7 op/shift are needed. If 6 op/shift already work in M5,1 op./shift and 7 new op. for the 3rd shift have to be hired.

Investment cost M1:	2* (150.000 *0,05) = 15,000 Euro/year
Investment cost M5:	1* (250.000 *0,05) = 12,500 Euro/year
Labour cost M1:	**(**1 * 13,5 €/h + 1 * 14,5 €/h + 2 * 15,5 €/h) * 7,5 h/shift* 220 d/y = **97.350 €/year**
Labour cost M5:	**(**1 * 13,5 €/h + 1 * 14,5 €/h + 7 * 15,5 €/h) * 7,5 h/shift* 220 d/y = **225.225 €/year**
Overtime cost:	2 operators work in M1 and 7 operators work in M5 21€/h * (220/5) Sat/y * 8 h/Sat * (2+7) **= 66528 €/year**

Total cost = 15000 + 12500 + 97350 + 225225 + 66528 = *416603 €/year*

MECHOFF – **Concluding remarks**

Required Capacity M1: 13996 hours/year
M5: 53002 hours/year

Missing Capacity M1: 8716 hours/year
M5: 21322 hours/year

	Alternative	Cost (€/year)	No. of M1	No. of M5	Number of overtime hours	Number of third shift hours
A	Overtime	Not enough	2	12	8870	0
B	3° shift	Not enough	2	12	0	18480
C	**3° shift + new machines**	**362 575**	**4**	**14**	**0**	**29700**
D	New machines	465 900	6	21	0	0
E	New machines + overtime	515 584	5	17	195148	0
F	New machines + overtime + 3° shift	416 603	4	13	5610	28050

The most convenient is alternative c