

Process cost analysis with TESSPA

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ABSTRACT

A detailed cost model that has been developed within the research project TESSPA has been further developed to suit small businesses with short series. The article addresses the theories behind the model and its structure. Including description of methods to collect manufacturing data and prepare it to be used in a cost model. Then describes the adaptation of the model to a smaller company with functional workshop layout. In addition, deals with a short analysis of the company's production and the conclusions drawn from it.

Keywords: TESSPA, Process cost, Systematic Production Analysis, Manufacturing Economic Simulation.

1. INTRODUCTION

It has recently been common practice to outsource the manufacture and assembly to low-wage countries to reduce costs and thus stay competitive. After analyzing how well this has worked, many people have begun to question whether it really pays to move the production. Therefore it can be questioned if the production had been moved if more detailed models to base decisions on had been available.

Earlier analysis within a Swedish research project called TESSPA has focused on calculating part costs, whereas this project will focus on calculating the process cost. A model will be developed in collaboration with a small company in Småland, Sweden and then tested in their production.

2. THEORY

Some of the parameters needed to calculate the part cost is the production rate, scrap rate, down time rate, setup time and production time.

The scrap rate q_Q is the proportion of scraped details from one batch.

$$q_Q = \frac{N_Q}{N} \quad \text{Equation 1}$$

where N_Q is the number of scraped details and N is the number of manufactured details.

The down time q_S defines how much the process is down.

$$q_S = \frac{t_S}{t_P} \quad \text{Equation 2}$$

where t_S is average stop time for one part and t_P is the production time for one part, including average stop time.

Production rate q_P may occur when the production have to lower the production rate to be able to maintain a given quality.

$$q_P = \frac{t_{0V} - t_0}{t_{0V}} \quad \text{Equation 3}$$

where t_{0V} is real cycle time.

Time for a batch through a processing step with regards to time losses can be calculated as:

$$T_p = T_{su} + N \cdot t_p = \frac{T_{su0}}{1 - q_{Ssu}} + \frac{N_0 \cdot t_0}{(1 - q_Q)(1 - q_S)(1 - q_P)} \quad \text{Equation 4}$$

where t_P is the real production time for one part, T_{su0} is the nominal setup time and q_{Ssu} is the down time rate.

The above mentioned parameters are then assembled in an equation that calculates the part cost in one planning point.

The cost model is based on the following cost parameters:

- **Material cost** for one part, k_B in kr/part
- **Equipment cost during run time**, k_{CP} in kr/hour
- **Equipment cost at down time**, k_{CS} in kr/hour
- **Employees cost**, k_D in kr/hour.

The model becomes as follows:

$$k = \frac{k_B}{N_0} \left[\frac{N_0}{1 - q_Q} \right]_b + \frac{k_{CP}}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)} \right]_{c1} + \frac{k_{CS}}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)} \cdot \frac{q_S}{1 - q_S} + T_{su} \right]_{c2} + \frac{k_D}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)(1 - q_S)} + T_{su} \right]_d$$

Equation 5

Cost term b describes the material cost of one part.

Cost term c1 describes equipment cost at production.

Cost term c2 describes equipment cost at down time.

Cost term d describes the employees cost at production and down time.

There can in some cases occur reduced occupation and that over capacity can in some ways be considered as down time. Therefore should the down time that occur be added to the cost term c2 and d in equation 5. Used capacity can be defined as:

$$U_{RB} = \frac{T_{Plan} - T_{SFK}}{T_{Plan}} = 1 - \frac{T_{SFK}}{T_{Plan}}$$

Equation 6

and where :

$$T_{SFK} = \frac{1 - U_{RB}}{U_{RB}} T_{Plan} = \sum_{i=1}^{n_b} T_{SFKb_i}$$

Equation 7

where T_{plan} is all planned time and T_{SFK} is down time that consists of free capacity.

Equation 5 is then changed as follows:

$$k = \frac{k_B}{N_0} \left[\frac{N_0}{1 - q_Q} \right]_b + \frac{k_{CP}}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)} \right]_{c1} + \frac{k_{CS}}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)} \cdot \frac{q_S}{1 - q_S} + T_{su} + \frac{1 - U_{RB}}{U_{RB}} T_P \right]_{c2} + \frac{k_D}{60N_0} \left[\frac{t_0 N_0}{(1 - q_Q)(1 - q_P)(1 - q_S)} + T_{su} + \frac{1 - U_{RB}}{U_{RB}} T_P \right]_d$$

Equation 8

To describe the result in one planning point four result parameters can be used, Quality parameters, Down time parameters, Production rate parameters and Environment & recycle parameters.

There also needs to be some factor groups to be able to describe the influence on the production.

- A. Tools
- B. Work material
- C. Process
- D. Employees and organization
- E. Wear and maintenance
- F. Special factors
- G. Peripherals
- H. Unidentified factors

By combining the result parameters and the factors a matrix is formed (production performance matrix, PPM).

This is used to identify problems in the production, and a concept figure can be studied below.[1]

Factor groups A-G och H	Result parameters				Σ factors
	Quality parameters. Q	Down time parameters. S	Production rate parameters. P	Environment & recycle parameters MK	
A. Tools					
B. Work material					
C. Process					
D. Employees & org.					
E. Wear & maintenance					
F. Special factors					
G. Peripherals					
H. Unidentified factors					
Σ					
Result parameters					

Figure 1. Production performance matrix.

3. PROCESS COST MODEL

Equation 8 is developed for series where there is a possibility to get statistically reliable information. While in smaller companies with small series that is not always possible, and therefore it is easier to gather data at machine level instead.

The machine cost per hour is built up by among others tool cost, electricity cost, maintenance cost and space cost: In some cases the tool cost can be very high if you compare it with the other costs in the hourly machine cost. If that is the case it can be interesting to be able to examine the tool cost separately. The tool cost is then calculated as follows:

$$K_A = \frac{k_A}{60} \left[\frac{t_f N_0}{(1 - q_Q)(1 - q_P)} \right]$$

Equation 9

where k_A is the tool cost per hour and t_f is the time for operative processing.

The equation for the process cost then becomes as follows:

$$\begin{aligned}
k &= \frac{k_A}{60} \left[\frac{t_f N_0}{(1-q_Q)(1-q_P)} \right]_a + k_B \left[\frac{N_0 \cdot q_Q}{1-q_Q} \right]_b \\
&+ \frac{k_{CP}}{60} \left[\frac{t_0 N_0}{(1-q_Q)(1-q_P)} \right]_{c1} \\
&+ \frac{k_{CS}}{60} \left[\frac{t_0 N_0}{(1-q_Q)(1-q_P)} \cdot \frac{q_S}{1-q_S} + T_{su} + \frac{1-U_{RB}}{U_{RB}} T_P \right]_{c2} \\
&+ \frac{k_D}{60} \left[\frac{t_0 N_0}{(1-q_Q)(1-q_P)(1-q_S)} + T_{su} + \frac{1-U_{RB}}{U_{RB}} T_P \right]_d
\end{aligned}$$

Equation 10

To then be able to get the process cost the batch cost is divided with the time it took to manufacture the batch, including down time. The process cost will then be calculated as follows:

$$K_P = \frac{k}{T_P} \quad \text{Equation 11}$$

To be able to clarify the effect the different parameters have on the process cost the equation is divided in several different posts, scrap cost, down time cost, set up time cost, production rate cost and value adding cost.

Scrap cost K_Q :

$$K_Q = \frac{\sum_{i=0}^n \left[\frac{K_A}{60} \left(\frac{t_{fi} \cdot N_{0i} \cdot q_Q}{1-q_Q} \right) + K_B \left(\frac{N_{0i} \cdot q_Q}{1-q_Q} \right) + \frac{K_{CP}}{60} \left(\frac{t_{0i} \cdot N_{0i} \cdot q_Q}{1-q_Q} \right) + \frac{K_D}{60} \left(\frac{t_{0i} \cdot N_{0i} \cdot q_Q}{1-q_Q} \right) \right] \cdot 60}{\sum_{i=0}^n \left[T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right]}$$

Equation 12

Down time cost K_S :

$$K_S = \frac{\sum_{i=0}^n \left[\frac{K_{CS}}{60} \left(\frac{t_{0i} \cdot N_{0i} \cdot q_S}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right) + \frac{K_D}{60} \left(\frac{t_{0i} \cdot N_{0i} \cdot q_S}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right) \right] \cdot 60}{\sum_{i=0}^n \left[T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right]}$$

Equation 13

Set up time cost K_{Tsu} :

$$K_{Tsu} = \frac{\sum_{i=0}^n \left[\frac{K_{CS} + K_D}{60} \cdot T_{sui} \right] \cdot 60}{\sum_{i=0}^n \left[T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right]}$$

Equation 14

Production rate cost K_U :

$$K_U = \frac{\sum_{i=0}^n \left[\frac{K_{CS}}{60} \left(\frac{1-U_{RB}}{U_{RB}} \cdot \left(T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right) \right) \right] \cdot 60}{\sum_{i=0}^n \left[T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right]}$$

Equation 15

Value adding cost K_{VA} :

$$K_{VA} = \frac{\sum_{i=0}^n \left[\frac{K_A}{60} (t_{fi} \cdot N_{0i}) + \frac{K_{CP} \cdot K_D}{60} (t_{0i} \cdot N_{0i}) \right] \cdot 60}{\sum_{i=0}^n \left[T_{sui} + \frac{t_{0i} \cdot N_{0i}}{(1-q_Q) \cdot (1-q_P) \cdot (1-q_S)} \right]}$$

Equation 16

4. PROCESS DESCRIPTION

For this analysis two machines have been chosen. One is a half automatic turning machine called Lilla Chevaliern and the other is a fully automatic milling machine called Rödgers.

5. COST ANALYSIS

Before gathering information from the production a production safety matrix is constructed. The different quality parameters are:

- Q1 Dimensional error, which means that if a part is scrapped because it has the wrong dimensions it should be placed here.
- Q2 Crack, which means that if a part is scrapped because of a crack or other material flaws it should be placed here.
- Q3 Wrong material, which means that if an operator has used the wrong material and it has to be scrapped it should be placed here.

There are also four down time parameters:

- S1 Planned down time, here should all planned down times be placed, except set up time.
- S2 Unplanned down time, all down time that is not planned should be placed here, except for unplanned employee absence.
- S3 Set up time, here is all set up time placed.
- S4 Occupation rate, here is all the time placed when the machine is free to use for other orders.

Production rate losses were not included since they are considered to be negligible. Environment and recycle parameters have not been included since environmental impacts are considered to be negligible.

The various costs, machine cost per hour during production, machine cost per hour during down time tool costs and personnel costs, has been based on total costs for the company's production and then allocated to each machine and hours.

After having spent a week in the production monitoring the machines two PPMs were compiled. When this data was compared to the one gathered from the MUR-system (a production monitoring system) it was obvious that the operators didn't key in the codes. This means that the information from the MUR-system is limited.

At an examination of scrap reports the scrap rate was calculated to about 1 %, but several observations of scraping made by the author has made it obvious that not all scraping is accounted for. This means that the scrap rate is higher than calculated, and is therefore estimated to 3 % in all calculations.

It is possible to show the distribution of the process cost by summing the different cost items from equation 12 – 16. Figure 2 shows that the downtime cost and scrap cost appears to be a major part of the overall process cost.

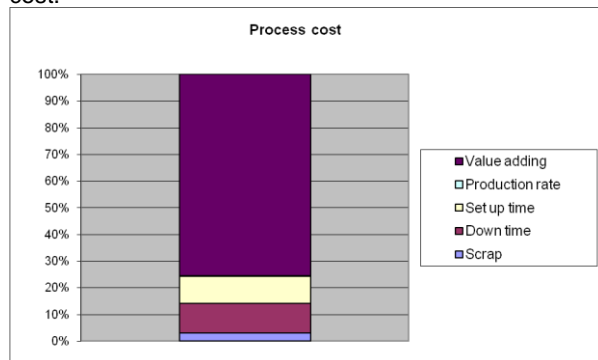


Figure 2. Process cost.

The compiled production performance matrix shows that the scrap rate is almost exclusively due to the human factor, why it is relatively easy to reduce.

Staff working with other machines is a major contributor to the downtime cost. This can be reduced if the work is planned better and if operators have better knowledge of the process and equipment.

Programming error is the biggest factor of scraping, which is largely due to the fact that operators sometimes have to write new programs, even if the component has been run previously. This can be avoided if all the programs are saved down in a uniform manner.

The human factor is a common denominator to the biggest cost here and it is because there are too few practices in the process.

6. CONCLUSIONS

One conclusion to be drawn from this work is that the methodology in TESSPA works well in theory, but not quite as well in practice for a company with small batch sizes and functional workshop layout. First and foremost, it is because it becomes difficult to develop a model to reflect reality sufficiently well in the company's case. This is largely due to that there is not enough specific routines for the operators.

Another conclusion to be drawn is that although it is difficult to develop a realistic model of production, it is still possible to develop a relatively realistic model. This means that it is not possible to calculate process costs or part costs as accurately as would have been desired, but it can still give a very good picture of production costs. Therefore, the methodology can be used to further develop the production process.

- [1] Ståhl, Jan-Eric (2007). *Industriella Tillverkningssystem – Länken mellan teknik och ekonomi*. Division of Production and Materials Engineering, Lund University, Sweden