# Machined Part Sales Price Build-up Based on the Contribution Margin Concept

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*One of the main competitive moves observed in the last two decades was the change in product pricing, evolving from a cost plus margin paradigm to a market-driven one. In the present days, the customer defines how much he or she is willing to pay for a given product or service. As a result, traditional cost accounting procedures and their related pricing formulas cannot accommodate that kind of change without significant turnaround in practices and concepts. Taking that into consideration, this paper proposes a procedure tool based on the contribution margin concept as well as on cutting process economic analysis to be applied to small and medium size (SMS) machining service companies. To improve the reader's comprehension, a numerical simulation is also presented. All the figures have been calculated taking into account the Brazilian currency (Reais). At this moment (2009), the exchange rate is approximately R$2.40 to US$1.00. The numerical simulation presented herein was developed mainly to allow the reader to follow the proposed procedure and not to consider the numeric results as actual data.*
***Keywords**: cutting process, contribution margin, sales price*

## Introduction

The economic environment has drastically changed all over the world in the last 15 years. In the particular case of Brazil, the economic stability that followed hyperinflation and the opening of Brazilian economy to the international markets have required local companies to rapidly adapt to a market-driven price paradigm. This situation can also be observed in many other countries, reason why the concepts presented herein could be applied to a wide variety of countries where price-driven buying decision-making is present.

However, it is a fact that most of the small and medium size (SMS) companies manage their businesses concerned only with cash flow. Very few consider the economic results shown by the Income Statement and Cost Accounting as tools to support daily business decision-making (Lucato & Vieira Junior, 2006). As a result, SMS companies tend to follow market prices with no concern regarding the related profitability. The eventual inadequacy of the accepted market prices is only noted when the cash flow begins to show deterioration signs. The SMS company managers can hardly identify the true cause of their problems (Lucato, 2005).

In order to support SMS companies in their efforts to better build-up their product prices and evaluate the profitability of market imposed values, this paper proposes a procedure tool based on the contribution margin concept to be applied to machining service companies. The proposed procedure enables price determination based only on variable costs, completely eliminating the need of fixed cost allocation to products. Besides, it considers adjustment to machining variables as a way to evaluate the impact of different machining conditions on product prices and delivery dates. In addition, a SMS company will have conditions to face a client by analyzing the relationship between cost and price, searching for possibilities to close a deal, accepting or not a prospective machining service. Last, but not least, the procedure is designed for ease of use taking into consideration the prevailing technical background of machining service companies. As a result, financial and accounting procedures are reduced to a bare minimum.

## Nomenclature

$CM$ = *contribution margin*
$COM$ = *sales commission, %*
$Cs$ = *cutting speed, m/min*
$Cs_{mc}$ = *minimum cost cutting speed, m/min*
$Cs_{mcL}$ = *minimum cost cutting speed limit, m/min*
$Cs_{mxp}$ = *maximum production cutting speed, m/min*
$C1$ = *independent cost on cutting speed, R$*
$C2$ = *operation cost, R$*
$C3$ = *tool cost, R$*
$d$ = *part or tool diameter, mm*
$EBIT$ = *operational income, R$*
$f$ = *feed, mm/rot*
$j$ = *capital cost, %*
$K$ = *Taylor´s tool life constant*
$Lc$ = *labor cost, R$/hour*
$lf$ = *feed length, mm*
$Ma$ = *machine age, years*
$Mac$ = *machine cost, R$/hour*
$Maac$ = *machine acquisition cost, R$*
$MEI$ = *maximum efficiency interval*
$Ml$ = *expected machine life, years*
$Mmc$ = *machine annual maintenance costs, R$/year*
$NS$ = *net sales, R$*
$OTH$ = *other taxes, %*
$Sc$ = *annual floor space cost, R$/ $m^2$.year*
$SMS$ = *small and medium size*
$So$ = *floor space occupied, $m^2$*
$tat$ = *tool edge changing and positioning adjustment time, min*
$Tec$ = *tool edge cost, R$/edge*
$ti$ = *independent time on cutting speed, min*
$Tmc$ = *total machining cost per part, R$*
$TPr$ = *target price, R$*
$tt$ = *total manufacturing time per part, min*
$Twh$ = *total number of working hours per year, hour*
$VbC$ = *variable cost, R$*
$x$ = *Taylor´s tool life expoent*
$Z$ = *bacth size*

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**Subscripts**

*mc* relative to minimum cost cutting speed
*mcL* relative to minimum cost cutting speed limit
*mxp* relative to maximum production cutting speed

## Theoretical Background

The proposed procedure is based on two different sets of theoretical concepts: contribution margin and cutting process conditions. Therefore, the literature review will be carried out accordingly.

### Contribution Margin

The traditional cost accounting approach assumes three basic costing systems: absorption cost, activity-based cost and variable cost (Atkinson et al., 2001).

The absorption cost considers direct costs (material and direct labor) allocated to products, based on actual consumption of those resources. In addition, a significant part of the manufacturing overhead is allocated to products based on different cost allocation criteria (Jones, 1991).

Activity based cost assumes a similar approach regarding direct costs, but allocates total company overhead to products by determining the cost of each activity performed and the amount of each activity required to generate a product (Khoury and Ancelevicz, 1999).

In variable costing, costs are divided into fixed (no variance with production volume) and variable costs. Product costs incorporate only the variable portion which in most cases corresponds to the direct costs (Martins, 2003).

Fixed rate cost is a practical rule to determine costs as a fixed percentage of the product selling price. This method is used only in very small businesses where simplistic production and management techniques are present. Usually, there is no relationship among rates used and the real costs incurred, because very frequently cost rates are simply passed on from generation to generation, no matter what product costs actually are (Vasconcelos, 1996).

From the ease-of-use standpoint, the variable cost would probably be the best alternative for a SMS company, mainly because this approach completely eliminates the allocation of fixed costs and overhead to product costs (Cooper and Kaplan, 1999). As a result, the procedure proposed by this paper assumes that machined product cost will adopt the variable cost concept.

Lucato (2005) suggests that when using variable costing, the related Income Statement should be presented, as illustrated in Fig. 1.

As can be seen in Fig. 1, the contribution margin is the difference between net sales and total variable costs. Conceptually, the contribution margin is the amount of money that the company has available to cover all its fixed costs and to generate the desired profit.

| | **(values in R$ 1,000.00)** | **R$** | **%NS** |
|---|---|---|---|
| 1 | Gross sales | 5,000.00 | |
| 2 | Sale taxes | (1,390.00) | |
| 3 = 1-2 | **Net sales (*NS*)** | **3,710.00** | **100.0%** |
| | Variable costs | | |
| 4 | Direct material | (1,814.00) | |
| 5 | Direct labor | (183.00) | |
| 6 | Other variable costs | (44.00) | |
| 7 = 4+5+6 | **Total** | **(2,041.00)** | **55.0%** |
| 8 = 3-7 | **Contribution margin** | **1,669.00** | **45.0%** |
| 9 | Fixed costs | (1,217.00) | |
| 10 = 8-9 | Operating income (*EBIT*) | 452.00 | |
| 11 | Financial expenses | (85.00) | |
| 12 | Income tax | (67.00) | |
| 13 = 10-11-12 | **Net income** | **300.00** | **8.1%** |

**Figure1. Typical six-month Income Statement for a manufacturing company using a variable cost approach. Source: Lucato (2005). US$ ≈ R$2.40.**

### Price Build-Up Using the Contribution Margin Concept

The contemporary economic environment reveals that in most industries the prices of goods and services are market driven. Even so, there are situations where product cost should be used to determine an initial price level. That is the case of cutting process service companies.

Machining firms usually receive an engineering drawing along with a request for quotation for that particular part. In most cases, no target prices are informed by the prospective client[2]. Based on the drawing information, the company should prepare an initial offer taking into consideration its technical background and cost system.

Using the variable cost approach, it is fairly easy for the machining company to establish the direct costs involved (material, direct labor, machine and tooling costs, related to independent cutting speed times). Based on this information, the initial price to be offered could be established through the Eq. (1).

$$TPr = \frac{VbC}{(1 - \%\,CM) \cdot (1 - \%\,Taxes)} \qquad (1)$$

Assuming that the income statement shown in Fig. 1 refers to the machining company under discussion, the rationale behind the aforesaid calculation is as follows: the average prices accepted by the market have enabled the company to generate a 45% contribution margin to sales. Considering the present level of production volume, this rate generates enough money to cover all the fixed costs, financial expenses and income tax and still produces an 8% net income over sales. Assuming that the machining company is pleased with its current profitability level, it could, in principle, continue to price its goods using a 45% contribution margin rate. If so, when dividing the variable costs by the (1 – % *CM*) factor, the net sales price will be obtained. Then, dividing net

[2] The automotive industry is an exception. (Salerno et al., 2003).

sales price by (1 – % Taxes) the gross sales, price will be determined. The eventual need to improve profitability could be achieved through proper contribution margin rate adjustment (Hirshleifer and Hirshleifer, 1998; Lucato, 2005).

If for any reason the price obtained according to the described methodology is considered too high when compared to current market prices, a reverse analysis could be performed. Starting with the market price and deducting all taxes and direct costs required manufacturing the part; a new contribution margin could be determined. Management judgment will define if the market price and its related contribution margin could be reasonably accepted or if the total quoted amount should be decreased (Monroe, 2000; Lucato, 2005).

In very small companies where the fixed rate cost system is used, selling prices could be determined by applying a fixed rate on the costs incurred. This is not the case of the method proposed herein. The contribution margin used is the percentage that the company is actually obtaining as a result of its actual financial performance in the marketplace. This is totally different from using fixed rates established by historical values, with no relationship with actual financial results obtained.

**Economic Analyses in Machining Process**

Based on the aforementioned concepts, the price build-up for machining service companies will basically depend on the machining cost calculation for the operations required to produce a given part.

Diniz et al. (2001) indicate that the total time to be considered in a machining operation should be calculated as follows in Eq. (2).

Diniz et al. (2001) also showed that the total machining cost per part, assuming only direct costs, consists of three elements: the independent cost on *Cs*, (part material cost plus labor and machine cost during the non productive time) (*C1*), the operation cost (including labor and machine costs) (*C2*) and the tooling cost (tool itself plus the cost incurred to change and adjust the tool edge) (*C3*).

$$t_t = t_i + \frac{\pi \cdot d \cdot l_f}{1000 \cdot f \cdot Cs} + \left[\frac{\pi \cdot d \cdot l_f \cdot C_s^{x-1}}{1000 \cdot f \cdot K}\right] \cdot t_{ft} \tag{2}$$

Total machining cost per part expressed in terms of the machining variables is the sum, as showed in Eq. (3).

$$T_{mc} = C1 + C2 + C3 \tag{3}$$

or, the cost per part as a function of cutting process parameters could be written as shown in Eq. (4), where each part is respectively related to *C1*, *C2* and *C3* from Eq. (3).

$$T_{mc} = C1 + \frac{\pi \cdot d \cdot l_f}{1000 \cdot f \cdot C_s} \cdot \left(L_c + M_{ac}\right) + \left\{\left[\frac{\pi \cdot d \cdot l_f \cdot C_s^{x-1}}{1000 \cdot f \cdot K}\right] \cdot \left[T_{ec} + \frac{t_{at}}{60}\left(L_c + M_{ac}\right)\right]\right\} \tag{4}$$

The machine cost per hour is calculated by Eq. (5), as follows:

$$M_{ac} = \frac{1}{T_{wh}}\left[\left(M_{aac} - M_{aac} \cdot \frac{M_a}{Ml}\right) \cdot j + \frac{M_a}{Ml} + M_{mc} + S_o \cdot S_c \cdot j\right] \tag{5}$$

The Eq. (2), considering the total machining time as a function of the cutting speed [*tt* = f(*Cs*)], shows a minimum point where the first derivative equals zero. Treating the aforesaid equation, it is possible to determine the cutting speed that minimizes machining time or maximizes production output. This speed is called the cutting speed of maximum production ($Cs_{mxp}$) and it can be calculated by Eq. (6).

$$Cs_{mxp} = \sqrt[x]{\frac{K}{(x-1) \cdot t_{at}}} \tag{6}$$

Similarly, considering the Equation 4 above and expressing the total machining cost as a function of the cutting speed [*Tmc* = f(*Cs*)] it is possible to determine a point where the cutting speed minimizes the total machining cost. This is the minimum cost cutting speed ($Cs_{mc}$), which can be determined as follows:

$$Cs_{mc} = \left\{\frac{K \cdot \left(L_c + M_{ac}\right)}{60 \cdot (x-1) \cdot \left[T_{ec} + \left(\frac{L_c + M_{ac}}{60}\right) \cdot t_{at}\right]}\right\}^{\frac{1}{x}} \tag{7}$$

The cutting speed of maximum production ($Cs_{mxp}$) is not very helpful because the high flexibility of the current machine tools makes cutting edge changing and adjusting a variable tending to zero. As a result, $Cs_{mxp}$ assumes very high values, which usually exceed the maximum cutting speed available in the machine (see Eq. (6)). On the other hand, very small tool change and position adjustment times ($t_{at}$) considered in Eq. (7) turn the minimum cost cutting speed ($Cs_{mc}$) to:

$$Cs_{mcL} = \left\{\frac{K \cdot \left(L_c + M_{ac}\right)}{60 \cdot (x-1) \cdot T_{ec}}\right\}^{\frac{1}{x}} \tag{8}$$

Consequently, $Cs_{mcL}$ speed represents the maximum $Cs_{mc}$ when cutting edge change and position adjustment times approach zero. In this case, such speed is called the minimum cost cutting speed limit.

On the other hand, it is possible to show that the graphic representation of machining time and machining cost as a function of the cutting speed can define a region in the graph called “the maximum efficiency interval (*MEI*)”, as shown in Fig. 2.

Figure 2 shows that the minimum cost cutting speed limit is always within the *MEI*, which is very useful to verify which will be the best cutting speed to be selected, considering the constraints imposed by technical and economic conditions related to a particular environmental scenario.

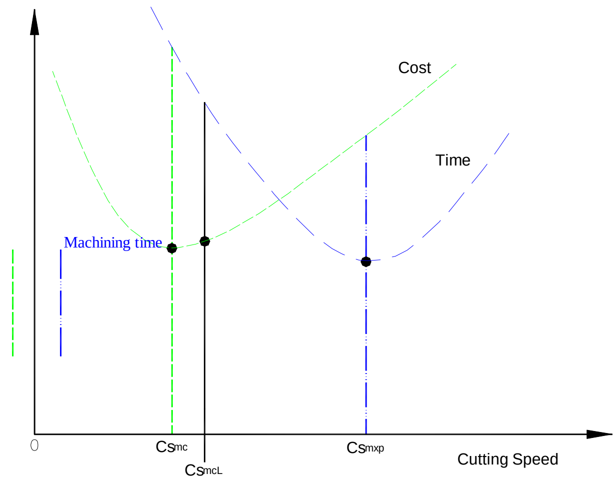


**Figure 2. The maximum efficiency interval – MEI.**

## The Proposed Procedure

The procedure to build-up machined part sales price proposed by this paper starts by defining all the parameters involved in the machining operation, as shown in Table 1.

**Table. 1. Involved Parameters (US$ ≈ R$2,40).**

| Material | | | Operation | |
|---|---|---|---|---|
| Material specification | SAE 1045 | | Cutting speed (m/min) | 200.00 |
| Specific gravity (g/cm$^3$) | 7.80 | | Feed (mm/rot) | 0.134 |
| Diameter of work (mm)$^{(*)}$ | 25.40 | | Feed length (mm) | 90.00 |
| Length of work (mm) | 100.00 | | Part diameter (mm) | 22.00 |
| Material cost (R$/kg) | 4.50 | | Lot size (parts) | 500 |
| Machine | | | Tooling | |
| Description | Lathe A4 | | Description | XPTO |
| Working hours per month (h) | 336 | | Constant K | 5.02x$10^{10}$ |
| Operation efficiency (%) | 85.0 | | Constant x | 4.16 |
| Acquisition value (R$ 1,000.00) | 250 | | Tool changing time (min) | 1.00 |
| Equipment age (years) | 5 | | Tool cost per edge (R$) | 5.50 |
| Expected life (years) | 12 | | Labor | |
| Capital cost (% per year) | 22.0 | | Wage and benefits (R$/hour) | 23.50 |
| Maintenance cost per month (R$) | 1,700.00 | | | |

Based on that information, a set of interconnected spread sheets will allow calculation of the total independent cost (*C1*), the operation cost (*C2*) and the tool cost (*C3*), as follows:

The total independent cost on *Cs*, (*C1*), shown as item 6 in Table 2, is the sum of items 4 and 5 in the same table.

**Table. 2. Involved parameters (US$ ≈ R$2,40).**

| Material cost – *C1* | | |
|---|---|---|
| 1 | Workpiece material | SAE 1045 |
| 2 | Part weight (kg/part) | 0.395 |
| 3 | Material cost (R$/kg) (before taxes) | 4.55 |
| 4 = 2x3 | Material cost (R$/kg) | 1.76 |
| 5 | Independent cost on Vc (estimation based on 8% of cutting time) (R$/part) | 0.019 |
| 6 = 4+5 | **Total independent cost on *Cs* (R$/part) – *C1*** | **1.779** |

The operation cost (*C2*) is the result of the machine cost plus the labor cost. The machine cost expressed in R$ per operating hour is calculated by Eq. (4). The machine cost per part will be obtained by multiplying the cost per operating hour by the cutting time divided by 60 to adjust the measurement units. The labor cost can be determined by multiplying the hourly wage rate divided by 60 by the cutting time expressed in minutes. All these calculations are shown in Table 3.

**Table. 3. Operational cost calculation (C2) (US$ ≈ R$2,40).**

| | | |
|---|---|---|
| 1 | Identification | Lathe A4 |
| 2 | Working hours per month (h) | 336 |
| 3 | Operation efficiency | 85.0% |
| 4 = 2x3/100 | Effective working hours (h) | 285.6 |
| 5 = calculated by Eq. (5) | Machine cost (R$/operation hour) | 21.39 |
| 6 | Hourly wage rate (R$/hour) | 23.50 |
| 7 | Cutting speed (m/mm) | 200.00 |
| 8 | Feed (mm/rot) | 0.134 |
| 9 | Feed length (mm) | 90.00 |
| 10 | Part diameter (mm) | 22.00 |
| 11 = (πx10x9)/(1000x8x7) | Cutting time (min) | 0.232 |
| 12 = 5/60x11 | **Machine cost (R$/part)** | **0.083** |
| 13 = 6/lot size (parts) | **Labor cost (R$/part)** | **0.047** |
| 14 = 12+13 | **Operation Cost – C2 (R$/part)** | **0.130** |

Finally the tool cost (*C3*) is obtained through calculation of the last factor of Eq. (4), as can be seen in Table 4.

**Table 4. Tool cost calculation (C3) (US$ ≈ R$2,40).**

| Total cost – *C3* | | |
|---|---|---|
| 1 | Specification | XPTO |
| 2 = calculated by Eq. (5) with data from Table 1 | Tool cost (R$/part) - *C3* | 0.095 |

As mentioned before, knowing the total machining costs will make it possible to build-up the part sales price by applying the concepts presented in the literature review, as shown in Table 5:

The example in Table 5 assumes that the machining company is trying to obtain a 50% contribution margin for its prices. Also it will be paying a 5% sales commission and another 3% on variable costs (delivery freight, for instance). In that case the net sales price can be obtained by dividing the total machining costs by the factor (1 – %*CM* – %*COM* – %*OTH*), as explained before. The final sales price (including sales taxes) will be determined according to the current fiscal practices existing in Brazil.

**Table 5. The sales price build-up (US$ ≈ R$2,40).**

| Sales price build-up | | |
|---|---|---|
| | | One part (R$) |
| Material cost | *C1* | 1.779 |
| Operation cost | *C2* | 0.149 |
| Tool cost | *C3* | 0.095 |
| Total cost | | 2.022 |
| Contribution margin | 50.0(%) | 2.407 |
| Sales commission | 5.0(%) | 0.241 |
| Others | 3.0(%) | 0.144 |
| Net sales price | | 4.814 |
| Taxes: ICMS/PIS/COFINS | 21.65(%) | 1.330 |
| Sales price | | 6.145 |
| Taxes: IPI | 5.0(%) | 0.307 |
| Total sales price | | 6.452 |

However, it is well known that market prices could be lower than those obtained by the suggested method of calculation. In that case, the client will most probably go back to the company and ask for some kind of negotiation where a target price could be offered. In order to evaluate the feasibility of the proposed price, a contribution margin analysis could be developed as shown in Table 6.

**Table 6. Contribution margin analyses (US$ ≈ R$2,40).**

| Contribution margin analysis | | |
|---|---|---|
| | | One part |
| Purchase price proposed by client | | 6.00 |
| Taxes: IPI | 5.0(%) | 0.30 |
| Sales price | | 5.70 |
| Taxes: ICMS/PIS/COFINS | 21.65(%) | 1.23 |
| Net sales price | | 4.47 |
| Sales commission | 4.6(%) | 0.20 |
| Others | 3.0(%) | 0.13 |
| Total machining cost | | 2.02 |
| Contribution margin | 53.7(%) | 2.10 |
| Lot size (parts/month) | | 500 |
| Total monthly contribution | | 1,050.00 |

As can be seen, the analysis starts by deducting the sales taxes from the proposed price. Sales commission (it is a common practice to reduce the percentage of sales commission when an additional price discount is given), other variable costs and the total machining cost are also deducted from the net sales price to generate the contribution margin per part. This amount multiplied by the monthly lot size will define the total contribution amount expressed in monetary terms that the company will get if it decides to accept the suggested price.

The decision rule to accept or reject the proposition will depend on the individual characteristics of the executive in charge of decision-making. Even so, the final position will rely on the company situation at the moment the decision is made: if the total contribution amount already obtained by the company is assumed to be enough to cover its fixed costs and to generate the desired profitability level, the suggested price will most probably be accepted. On the other hand, if the situation is quite different, common sense says that the price proposed by the client will be rejected.

## Conclusions

The present paper supports the following conclusions: a sales price build-up procedure based on the contribution margin concept is proposed which will offer a simple and practical way for machined part service suppliers to prepare and submit quotations to their clients.

The proposed method can also be considered a useful negotiation aid whenever a price discussion between supplier and customer takes place.

The proposed procedure considers the machining variables for sales price build-up, changes in cutting conditions could be made to generate more profitable results, compensating eventual discounts granted during price negotiations with clients.

The proposed procedure also takes into consideration only the variable costs of the cutting process. The resulting contribution margin will allow the machined part service provider to verify if and when its total fixed costs are covered by the contribution amount obtained in current jobs at the plant. It is an interesting piece of information, because the machined part service provider could even strategically agree to manufacture a low price part (meaning a very low contribution margin) as long as the remaining parts running in the plant generate enough contribution to cover all its fixed costs and provide the desired profit level.

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