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Managing the Sawmill with Product Costs – A Simulation Study

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Abstract:

This paper analyzes the effects of using product costs derived from an LP-model for managing the salesmen's efforts at a sawmill company. The salesmen are not controlled by sales quota, as is usual, but assessed by the accounting profit they generate. The analysis is realized by computer simulation experiments under various assumptions on sales response and the mill's flexibility in purchasing timber. The cost figures are recalculated in each period. The results indicate that the success of the approach decreases with the length of the recalculation period, and increases strongly with the mill's flexibility in purchasing timber.

Keywords: joint cost, product costing, linear programming, sawmilling, lumber costing, sales management.

1. Introduction

Several Swedish sawmill companies have recently developed product-costing systems for lumber products, possibly to meet the needs of new organizational set-ups and new market conditions. The market organizations have been changed from decentralized ones where a salesman was responsible for the sales of a single sawmill, to centralized organizations where the salesmen are responsible for specific markets or customers with products taken from several mills. An advantage of these new organizations may be better opportunities to coordinate marketing and production in the group. It may also facilitate specialization of salesmen in markets and customers, which may be of increased importance as markets change towards larger customers with increasingly specific needs.

The marginal cost of lumber is complicated due to the joint costs character of the production, where several products simultaneously are sawn from one log.

Several of the recently developed systems for cost calculation are founded on arbitrary allocation methods and may be expected to give deceptive product costs. Johansson and Rosling (2002) describe some of the methods and test them on a small sawmill case, which shows large discrepancy between calculated and theoretical defensible costs. Similarly, Balachandran and Ramakrishnan (1981) derived some cost allocation rules by game theory. Their rules are equitable, but not relevant for decision-making.

Manes and Cheng (1988, p. 123) discuss joint production in variable proportions, which is similar to sawmill production. The sawmill may typically obtain a desired mix of products by varying the amount of logs sawn according to a specific pattern. This flexibility may be limited, though, by insufficient flexibility in timber procurement and in the sawing process. The present paper derives the marginal costs of lumber products by an LP model of sawmill production that includes restricted flexibility in timber supply. The purpose of the paper is to analyze the economic effects of using the product costs to manage the salesmen's efforts.

Following Balachandran et al. (1997) the analysis relies on simulation.

Section 2 describes the long run planning problem. The characteristics of product costs in sawmills are discussed in section 3 and a theoretical defendable method for allocating the costs is outlined in section 4. Section 5 describes how demand is assumed to respond to sales efforts, and sales efforts to accounting profits. The simulations are described in section 6. Section 7 presents the results and section 8 concludes.

2. The Planning Problem

The objective of the company is to maximize long-run profit. Theoretically, the optimal production and sale may be found through maximizing a mathematical model that describes the long-run cost and revenue functions of the manufacturing and sales processes. When the optimal solution is found, all activities should be directed in a way that fulfils the plan. However, there is a considerable disadvantage of this approach.

One of the most obvious difficulties in practice is presumably to estimate the effects of the sales efforts, and thereby formulate accurate cost- and revenue functions of the sales (Cheng and Manes, 1992). This is possibly even more marked when the share of non-standardized business deals without known market prices increases, which tends to be the case for several sawmill companies.

An alternative approach would be to divide the planning problem into two parts: one production problem and one marketing problem. The production-planning problem should minimize the costs of production. The marketing problem should strive after maximizing the profit of the sales work. The salesmen have to estimate the revenues and costs of their sales efforts, and by that maximize the marketing profit. Decentralizing these decisions to the salesmen would be an important advantage compared to the non-divided optimization approach. However, to find the optimal solution for the whole company in this decentralized approach, the salesmen have to know the marginal costs of production. Given the current sales, D_k of product k, these cost are calculated through the dual of the following LP problem:

LP: $\quad 0\ \mathrm{IQ}_{\geq 0}\ \Sigma_i C_i X_i$ (1)

such that $\Sigma_i a_{ki} X_i\ ^{3}\ D_k$, for each product, k. *(2)*

Here C_i is the variable costs of sawing pattern i, X_i the amount of sawing pattern i and a_{ki} the yield of product k in sawing pattern i.

The associated dual that calculates the product costs, Π_k for product k, is then

DLP: $\mathrm{Max}_{P^{3}0} \Sigma_k \Pi_k D_k$ *(3)*

such that $\Sigma_k a_{ki} \Pi_k \leq C_i$ for each sawing pattern, i. *(4)*

The interaction between the production-planning problem and the marketing-planning problem is illustrated in figure 1. The salesmen communicate their sales results to the sawmill, which returns the current marginal costs.

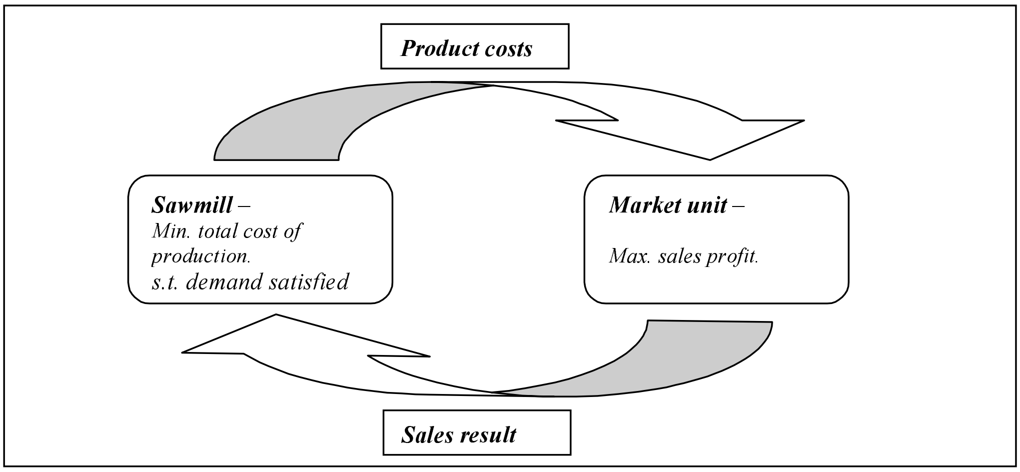

Figure 1. The optimization problem is divided in two parts - production and marketing. They are coupled with product costs and sales result.

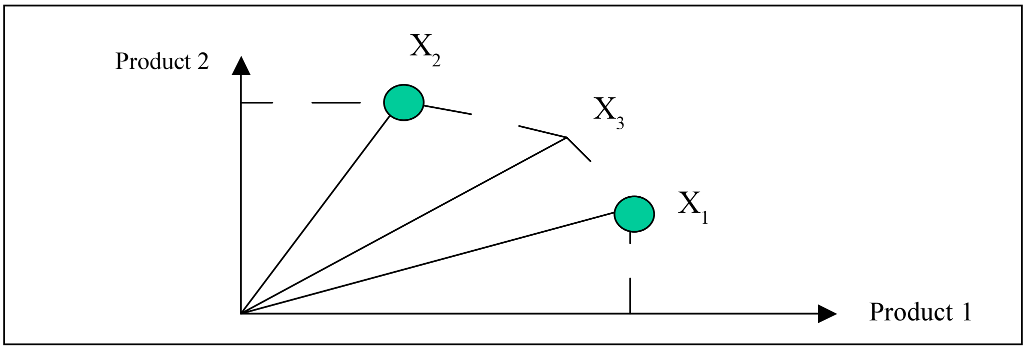

Figure 2. Iso-cost curve for lumber production. X_1, X_2 and X_3, respectively, correspond to a specific sawing pattern.

However, the joint cost character of the sawmilling process may raise doubts about using the product costs to manage the sales efforts. Even if the costs are calculated with a theoretical defensible method, the costs typically change with the sales.

3. The Product Costs

In contrast to the assembling industry, where product costs can be considered to be separable and constant in the long run, lumber cost are typically inseparable. This implies that the iso-cost lines are not linear but built up by linear segments, and consequently, the marginal costs are not constant. Since the marginal cost of a product may change as sales change, the planning had probably better be organized as an iterative process, with the marginal costs frequently recalculated.

4. Calculating the Cost of the Boards

The cost of a sawing pattern includes all costs accumulated up to the sawing, including the timber cost and minus net revenues from by-products, i.e., sideboards, cellulose chips, bark and saw dust. Costs after the sawing point, e.g. drying-, grading- and packaging costs reduce the market prices.

Some of the characteristics of the LP model are:

· Only the marginal costs of centre boards (main products) are calculated.

· The sales volumes of all centre boards are fixed to their present level.

· Market prices for all by-products are fixed.

· Restricted timber supply – saw classes are available in fixed or semi-fixed proportions.

Technically, this is realized by adding the following constraints to *LP,*

$$(1/r)\, q_t \Sigma_i X_i \leq \Sigma_i \varepsilon_{it} X_i \leq r\, q_t \Sigma_i X_i \text{ for each log type, t,} \qquad (5)$$

where e_{it} equals 1 or 0 depending on whether pattern *i* requires log type *t* or not, q_t denotes the proportion of log type *t* in today's timber supply, and r and 1/ r denote the max possible changes of q_t. The dual formulation, *DLP,* changes correspondingly.

· The marginal costs of centre boards are restricted by upper and lower bounds (max/ min prices).

Technically, this is realized by adding to *DLP* the constraints

$$P_k^{min} \leq \Pi_k \leq P_k^{max} \textit{ for each product k,} \qquad (6)$$

with corresponding changes in the primal formulation, *LP*.

The upper bound (max price) on the marginal cost may be interpreted as the marginal cost for the mill of buying the board externally. The lower bound (min price) may be interpreted as the net marginal revenue of selling surplus quantities (typically to non-regular customers). See Johansson (2002) for a detailed formulation of the LP model and interpretation of the product costs of the dual formulation.

5. Modelling the Sales Response

Through purposeful sales work, the demand of each product can be increased or decreased from one sales period to another. In each period, the salesmen are assumed to strive to change the sales volume of each product to maximize the accounting profit, i.e., the total revenues minus product costs minus selling costs. The market organization's problem may be stated as:

$$\text{Max}_{T^3 0}\ \Delta\text{Profit(T)} = \Sigma_k((P_k - \Pi_k)\, \Delta D_k) - \Sigma_k\, (L\, T_k), \qquad (7)$$

Where P_k denotes the market price minus costs after sawing, DD_k the sales change, T_k the sales time (h) and *L* the sales cost (SEK/h). Subscript *k* denotes the product.

The Sales Response

Since the salesmen have to work with more demanding customers the more they sell, the sales increase effect is assumed to diminish when the sales volume increase. When the salesmen want to decrease sales, they are similarly required to work harder the greater the decrease. These assumptions implicitly mean that the salesmen in advance can estimate how difficult it will be to change the sales to a specific customer and so, allocate their sales time in an optimal way (cf. Beswick, 1977).

Additional notations:
a_k = sales increase of a sales hour when the current sales volume is 0 m^3, product , *k*
b_k = change in sales effect due to volume, b_k ³ 0 for all *k*,
h_k = sales decrease per sales hour when the current sales volume is 0 m^3, product *k*,
PROF = set of profitable products, i.e., *k* for which $\boldsymbol{P_k}$ ³ Π_k
UNPROF = set of unprofitable products, i.e., *k* for which $\boldsymbol{P_k} < \Pi_k$.

A schematic view of the sales response presents in fig. 3.

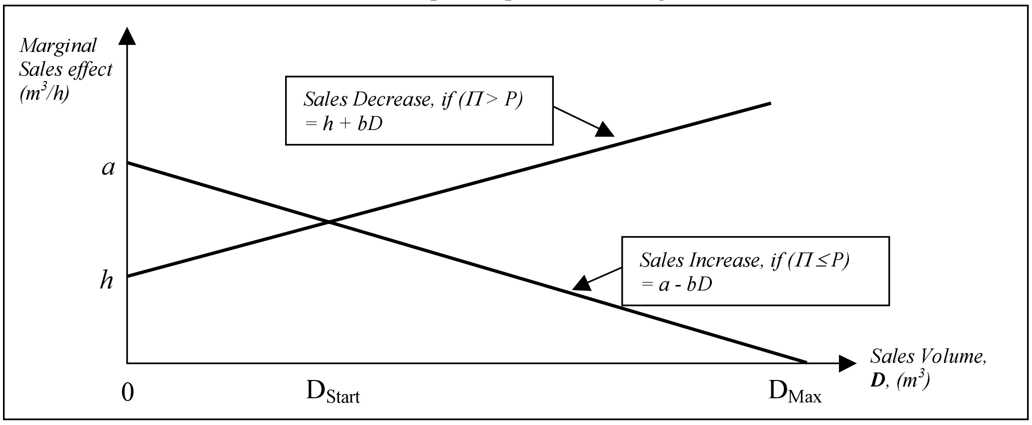

Figure 3. Schematic view of the sales model. In the tested cases, the marginal effect for sales increase and decrease are equal at today's sales volumes. D_{Start} denotes today's sales of the product. Note that sales volume cannot exceed D_{Max}

Volume change – increase (*k* Î *PROF*) is stated as:

$$\Delta D_k = \{a_k - b_k\,[D_k + (D_k + \Delta D_k)]/2\}\,T_k \quad \text{or}$$
$$\Delta D_k = (a_k - b_k\,D_k)/(1/T_k + b_k/2). \tag{8}$$

Minimizing (8) now gives:

$$T_k^* = \{(2/b_k)[\{(P_k - \Pi_k)\,[a_k - b_k\,D]/L\}^{½} - 1]\} \tag{9}$$

Substituting T_k^* into (8) gives:

$$\Delta D_k = (a_k - b_k\,D_k)/(b_k/\{2[\{(P_k - \Pi_k)\,[a_k - b_k D_k]/L\}^{½} - 1]\} + b_k/2), \tag{10}$$

which expresses the expected sales increase from one period to the following.

Volume change – decrease (*k* ∈ *UNPROF*)

Analogous to profitable products, the expected sales decrease for unprofitable products may be derived as:

$$\Delta D_k = (h_k + b_k D_k)/(b_k/\{2[\{\Pi_k P_k)[h_k + b_k D_k]/L\}^{1/2} - 1]\}+b_k/2) \qquad (11)$$

6. The Simulation Model

The calculations are based on a Swedish pine sawmill, which belongs to a large sawmill group. The mill, which has a yearly sales budget of about 160 000 m^3 and 152 main products (combinations of width, thickness and quality), makes and sells products mainly to the furniture and joinery industries. Production capacities, costs and product prices were collected from the company's present costing system. These data were further processed in Microsoft Excel, Microsoft Access and in a program developed in Microsoft Visual Basic. LINGO from LINDO software Inc. was used to implement the LP model.

When the coefficients in the sales model were determined, the average sales changes per hour were compared with actual average change per sales hour in the company. However, the observable sales work concerns mainly preservation of the current sales budget and not sales work that actually change the budget, which is the aim to mimic in the present study. Therefore, the modelled sales changes were set considerably lower. It was assumed that the company could increase the sales of a product three times the volume of the present budget, i.e. D_{Max} in fig. 3 was set to $3D_{Start}$. Furthermore, the marginal sales effect (both increase and decrease) in today's budget was calculated as 0.5 % of the product's volume. These facts together with the linearity assumption determine the coefficients *a, b* and *h*. For each product, the coefficients *a* and *b* were solved with the two related equations:

$$\begin{cases} 0.005D_{Start} = a - bD_{Start} & (12) \\ 0 = a - 3bD_{Start}, & (13) \end{cases}$$

Equation (12) corresponds to the marginal sales increase at D_{Start} and (13) at D_{Max}.
Coefficient *h* was then solved by (14):

$$0.005D_{Start} = h + bD_{Start}, \qquad (14)$$

which corresponds to the marginal sales decrease at D_{Start}.

Thus, $b = 0.0025$ for all products. Coefficients *a* and *h* differ among products dependent on their present sales. The variable sales cost, *L*, was set to 1000 SEK/h.
To imitate the tardiness in sales response, the maximum sales change in each period was restricted by:

$$\Delta D_k \leq z\, D_k, \qquad (15)$$

where *z* was set to 10% and 30% to imitate different length of the period between the recalculations of the product costs. An adjustment of the coefficients in the sales model would have given a similar effect, but then it would have been necessary to adjust the coefficients for each product to obtain realistic responses. The constraint (15) was considered a reasonable simplification to avoid excessive computational efforts.

The max and min values of the products costs, (6), were calculated as 1.5 and 0.5 times the net market prices, respectively. The timber flexibility, r in (5), was set to 1.1 and 2.0. The two cases are referred to as 10% and 100% timber flexibility, respectively. The simulations started by calculating the marginal costs of the products assuming today's sales budget. In the next step the marginal cost were used to direct the marketing efforts, which in turn gave a new sales result that was used in the next iteration. The iterations were repeated 20 times.

7. Results

Sales Changes

When the product change, *z*, were restricted to 10%, which means that the costs are recalculated in short intervals or that the sales change slowly, resulted in a somewhat increasing profit of the sawmill (fig. 4). The profit is calculated as the revenues of all products minus the total (real) costs of manufacturing and sales.

The case with z = 30% tests a longer period between cost recalculations. Fig. 4 shows that the total net profits of the sawmill then had a negative trend. The salesmen changed the sales too much in each period for the calculated product costs to remain valid.

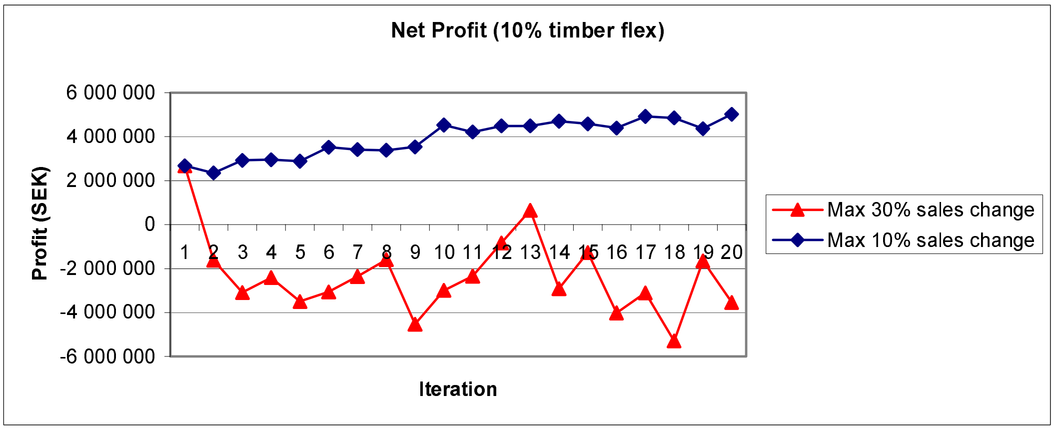

Figure 4. Net profit assuming max 10% and 30% sales changes per product and iteration. 10% timber flexibility.

In the 30% case the actual total sales change was, in average, about 20% per iteration. In the 10% case, the total sales change was about 5% per iteration.

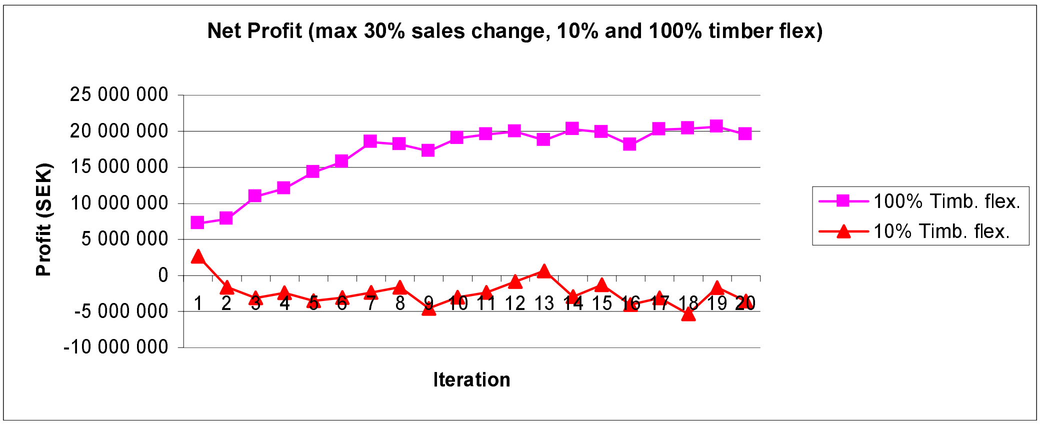

Figure 5. Net profit assuming max sales change restricted to 30%. Timber flexibility 100% and 10%, respectively.

Flexibility in Timber Supply

Figure 5 shows the profit trend with 100% and 10% timber flexibility. It is worth noting that 100% flexibility gave an increasing profit trend although the max sales change was restricted to 30% per iteration and product.

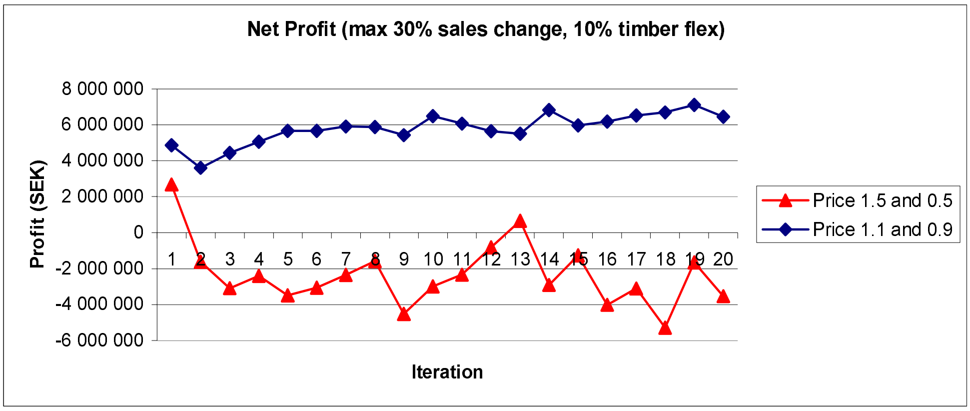

Figure 6. Profit of the sawmill. Max and min prices calculated as 1.5 and 0.5 times the market price, respectively, compared to max and min prices calculated as 1.1 and 0.9 times the market price, respectively. Timber flexibility 10% and max sales changes per product and iteration 30%.

Assuming max 10% or 30% sales changes and 100% timber flexibility, the average profit increased from about 50 SEK/m^3 to 100 SEK/m^3. With 10% timber flexibility, 10% sales change made the average profit to increase slightly, whereas it decreased with 30% sales change per period.

Max and Min prices

If the gaps between the max and min prices shrink, the estimates of the marginal cost would be less erratic and the period between recalculations of the costs may be extended. Figure 6 shows that if the max and min prices of each product is closer to the market price, where the max price is calculated as 1.1 times the market price and the min price 0.9 times the market price, the trend of the company's profit is positive, whereas it is negative when the max price is calculated as 1.5 times the market price and the min price as 0.5 times the market price.

Implied Sales Changes

Figure 7 shows the trends of the average sales change per period for some of the tested cases.

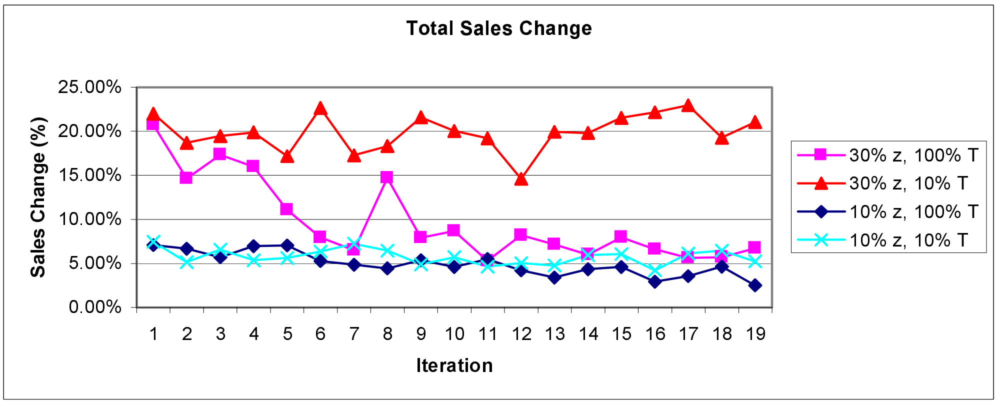

Figure 7. Average sales change per period (proportions of total sales). z denotes max sales change, and T denotes timber flexibility (=r-1).

The negative trend in the case of max 30% sales change and 30% timber flexibility may be explained by the fact that the costs of the products are successively coming closer to the prices. The rapid change might be a sign of great efficiency in the allocations of sales efforts.

8. Concluding Discussion

The tested cases show that restricted flexibility in timber supply, which probably is a quite realistic assumption for many Swedish sawmills, and relatively high costs for selling surplus quantities and buying products in short supply, the product cost have to be recalculated in short intervals. When the sales changes were restricted to 0.1 times the current volumes, there was a positive trend in the long run profits. The average sales change was then about 5%, which corresponds to about 8000 m^3 at the present annual sales of 160 000 m^3. Today, about 70% (112 000 m^3 p.a.) of the sales concern renewed contracts and about 30%(48 000 m^3) are sold to new customers or concern sales changes to regular customers. This may imply that the sawmill has to recalculate the product costs about 48 000/8000 = 6 times per year, which perhaps is an impractical short interval.

However, when the flexibility in timber supply was assumed to increase to 100%, which probably is quite optimistic, the long run profit had a positive trend also when the sales changes were increased to max 0.3 times the current sales volumes, with an average sales change of about 20% in the first sales periods. This should imply recalculation of the product costs between once and twice a year (48/[0.20x160]), probably a quite practical interval.

When the costs of selling surplus volumes and buying products in short supply decreased, there was a positive trend in the long run profit also when the sales changes were restricted by max 0.3 times the current sales volumes. This is probably an effect of fewer or possibly smoother breakpoints in the iso-cost line (c.f. fig. 2), which may give fewer or smaller shifts of the product costs, and therefore more stable cost estimates.

From figure 2 it can be concluded that the marginal cost of a product with unchanged sales may alter when the volumes are changed for other products, which may strengthen the error in the marginal cost estimate, of course. This effect possibly reduces if a large part of the product volume is considered as by-products, which are sold in arbitrary amounts to fixed market prices. However, it is difficult to predict the actual effect of reducing the number of main products, but in general one would guess it should have a positive effect on the cost estimates. Figure 8, which should be compared to fig. 4, shows how the long run profit evaluates when the max sales changes are restricted to 30% of the current volumes and 89 of 150 centre products are by-products.

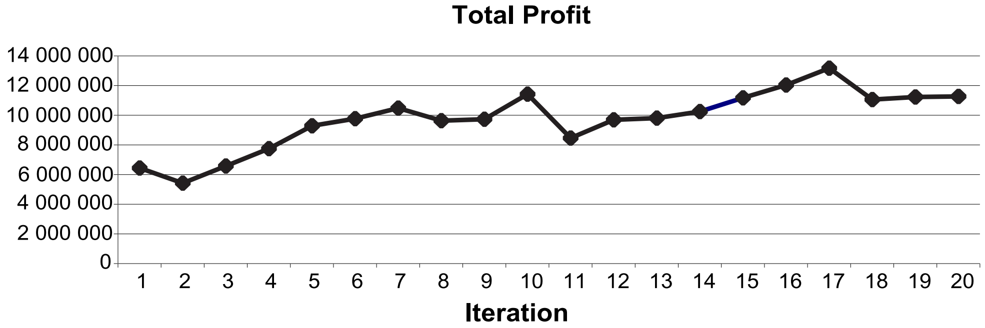

Figure 8. Total profits. Assuming 10% timber flexibility, max 30% sales change per product and iteration. 89 of 152 centre products were considered to be by- products, sold in arbitrary amounts to fixed market prices.

Thus, a sawmill with only a minor part of its production as main products may have easier to manage its sales force through product costs.

Even when the max sales change was restricted to 10% per period, the marginal costs of several products changed considerably between iterations. This may obviously confuse the salesmen that will use the cost figures to allocate their efforts – just a small sales change may make a highly profitable product an unprofitable one and vice versa. Therefore, to obtain organizational confidence of the cost figures, it would be important that the users understand the specific costing situation and its consequences for the cost figures. The excerpt in figure 9 shows that some products have a relatively unchanged marginal cost, whereas other changes considerably between iterations.

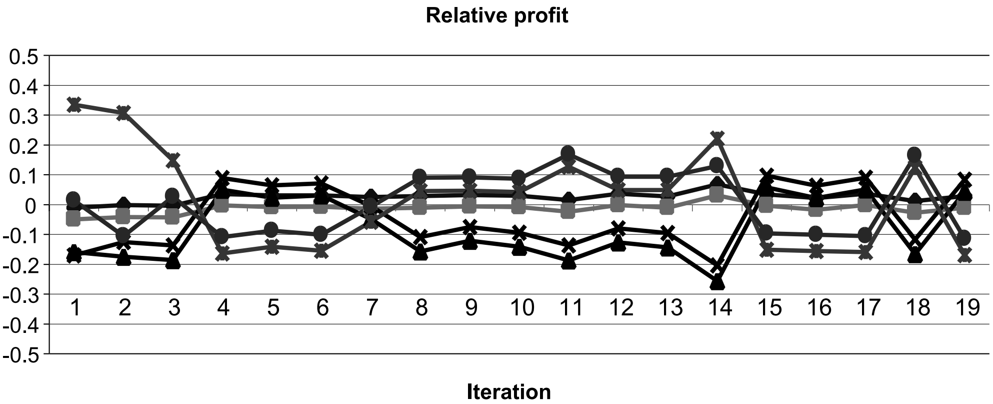

Figure 9. Relative profit measured as the profit divided by the net market price. Six qualities with dimension 38 by 175 mm. 100% timber flexibility, max 10% sales change per product and iteration. Max and min prices calculated as 1.5 and 0.5 times the net market prices, respectively.

The calculated marginal costs concern the long run cost of production. Thus, the implied sales efforts may break short-run capacity constraints, and create waiting lines of customer orders. However, these waiting-lines were not modelled in the simulated cases. An important motive for using long-run costs is that they may create incentives to change the capacities in the right direction.

Technically it would be quite easy to consider the short run costs through extending the cost allocation model with restricted max capacities of all possible bottlenecks. The problem, at least in practice, would rather be to decide the capacity restrictions since they typically depend on the present production situation and may change considerably when the share of different sawing patterns change. In addition, more constraints will presumably make the calculated product cost figures even more erratic.

In the simulations, the salesmen were strictly assumed to optimise their accounting profit. Further research may demonstrate how to design effective reward systems that motivates this salesman behaviour.

References

BALACHANDRAN, B. V., BALAKRISHNAN, R. AND SIVARAMAKRISHNAN, K. 1997. On the Efficiency of Cost-Based Decision Rules for Capacity Planning. The Accounting Review, Vol. 72, No 4, pp. 599-619.

BALACHANDRAN, B.V. AND RAMAKRISHNAN, R.T.S. 1981. Joint Cost Allocation: A Unified Approach. The Accounting Review LVI, pp. 85-96.

BESWICK, C. A. 1977. Allocating Selling Efforts via Dynamic Programming. Management Science, Vol 23, No. 7: 667-678.

CHENG, C. S. A., MANES, R.P. 1992. The Marginal Approach to Joint Cost Allocation: A Model for Practical Application. Journal of Accounting Research.

JOHANSSON, M., 2003. Allocating the Timber Cost to Sawn Products – A Case Study, Submitted to proceedings of ICFIM conference 2003.

JOHANSSON, M. and ROSLING, K. 2002. The Timber Cost of a Board. Scandinavian Forest Economics 39, pp. 229-239.

MANES, R.P. AND CHENG, C.S.A. 1988. The Marginal Cost Approach to Joint Cost Allocation: Theory and Application. Studies in Accounting Research #29. American Accounting Association, Fl.