Real-time profit monitoring and activity-based cost management

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The paper presents activity-based costing as a management methodology for consistent on-line profit monitoring in a process plant. The details of a profit monitoring approach are outlined together with typical cost management examples, and the activity-based costing concept is presented as a tool in this context. Examples from the paper industry are presented, as well as an application of the model to track cost and quality variances in an integrated pulp and paper mill. The benefits from using real-time profit monitoring result from detailed cost and profit control, higher production, and reduced cost. These methods provide a management foundation for continuous improvement of quality and cost.

Cost, quality, and customer service are three main drivers for competitive success in process manufacturing. They are directly related to business profitability and the need for organizational commitment to a continuous improvement process. While cost-effective production has been the objective for a long time, today's focus is on high quality. In the near future, enhanced customer communications will be of utmost importance. The changes in our environment will have an impact on how we control our processes, how we view our business and customers, and the information we need to support our decisions. A flexible and structured management strategy includes a view of the process and business as a whole, providing guidance to all parts of the organization in a process for continuous improvement of quality and cost.

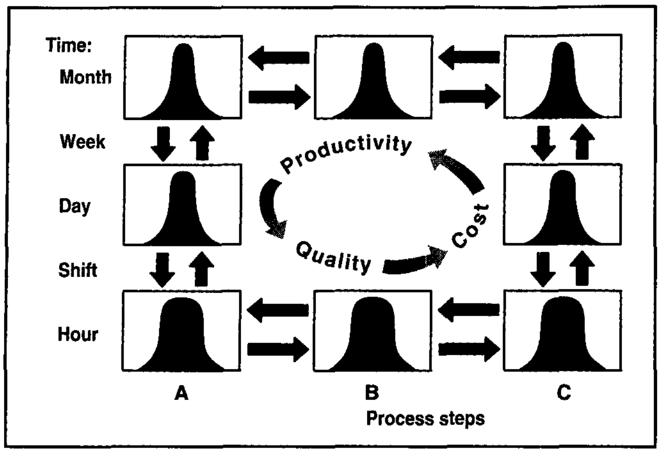
Why are some plants more profitable than others, and how have these manufacturers implemented solutions to these challenges? In this article, we will try to answer these questions by presenting the integrated relationships between quality, production, and cost and how they impact overall profitability. Furthermore, the activity-based costing concept will be used as a methodology to provide reliable product cost and support real-time decision making. According to Johnson and Kaplan *(1)*, today's management accounting information driven by the procedures and cycle of the organization's financial reporting system is too late, too aggregated, and too distorted to be relevant for managers' planning and control decisions. The following presentation is based on proven theory. It will show cases and examples from the paper industry and provide an application overview.

Profit monitoring

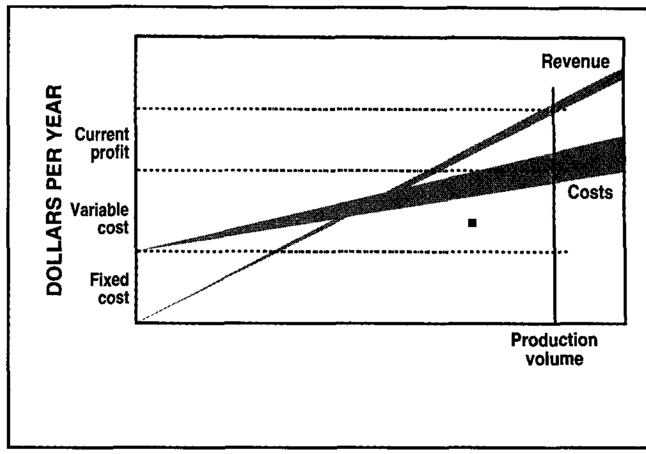
Many process industries operate in a market where the product price is given by the market. Given the total revenue, the profit becomes a function of how we use the raw materials, energy and chemicals, process information and existing knowledge to produce a high-quality product for our customers. The observed variations in profit are a direct function of the daily variances in quality, product mix, and usage of input resources as the product moves through the process and value is added. By the end of the process line, the profit can be calculated as the difference between sales price and product cost. However, profit was not generated at the last process step, but is the sum of the contributions made in all process steps. From such a view, the importance of detailed cost, quality, and production control at every single process step becomes obvious where each step is responsible for the cost generated and value added at that step.

The picture described above is illustrated in the lower part of Fig. 1, where the *X*-axis indicates the process line from raw materials to final products. At this level, quality and process data are sampled, and the operators make their decisions regarding control and improvement of the process. The *Y*-axis indicates data aggregation to higher time levels like day and month. Cost management systems usually operate at these aggregated levels and allocate cost downward to the detailed level, with data distortion as a result *(1)*. Furthermore, there is not a consistent link between aggregated and detailed data, complicating detailed analysis. A better way to do cost and profit control is to calculate cost data bottom-up analogous to quality and process data aggregation and

1. Plantwide integrated production, cost, and quality control



2. Cost-revenue diagram



providing improved data consistency. This is indicated by the vertical arrows (upward), and illustrates the possibility of zooming in on detailed data from an aggregated level (downward). The horizontal arrows show that cost is added as the product moves from step to step, by calculating a unit product cost for each step. This unit cost will be used when the product enters the next step as an input resource.

Each process step will introduce some variance based on the input resources and process performance. During data aggregation, this variation will be reduced (*Y*-direction). However, in the *X*-direction one may have variance propagation, and the total variance in the final product's cost and quality can be explained from the variation in the single process steps. This emphasizes the need for focusing on single process steps, still keeping a consistent overview of the overall plant performance and profitability.

Another way of illustrating total profit is using the cost-revenue diagram shown in **Fig. 2** *(2)*. The slope of the cost curve is a result of the aggregated product cost from the single process steps. The true picture is more complex showing a slope variance due to daily variations in the process and by running a variety of products. The variance may increase with increased production, increasing the variation in profit estimates at higher production volume. Profit monitoring means analyzing the cost, production, and quality details; learning from the process history; and taking actions to increase the profitability. This is a continuous improvement process, and it is based on consistent cost and profit calculation through the process line and further from unit level to higher aggregates.

Cost and profit management

Cost and profit management includes several applications in the plantwide operation, and some examples will be presented below. Real-time profit monitoring can be defined as integrated acquisition, processing and reporting of actual process, cost, and production data providing information on profitability of processes and products in approximate real time. Since the calculations are carried out bottom-up, product (grade) and order cost and profit can be calculated.

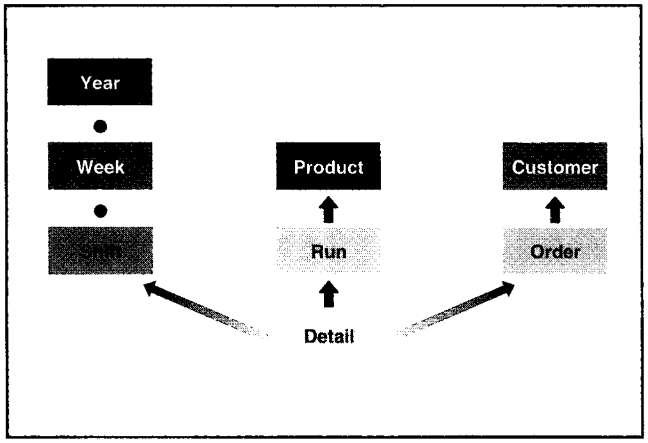
In addition to calculating total cost per process step, plantwide cost of single components of resources can be estimated. Hence, energy and raw material costs, which usually are regarded as two separate cost management issues, will be resolved as described above.

Cost management does not only handle actual cost, but may include cost variance calculations. Actual cost is based on real prices and unit costs multiplied with actual usage of resources. Usage and price variances can be calculated based on a difference from the standard usage ratios and prices. The standards could either be the yearly budget or a long-term goal. Often the standard is defined from the previous year's data, and the variance analysis provides a kind of benchmarking. More precisely a usage variance is the difference between standard usage and actual usage of a specific input resource. The price variance is the difference between standard price and actual price of a specific input resource. Hence, a negative cost variance means loss of money compared to the standard.

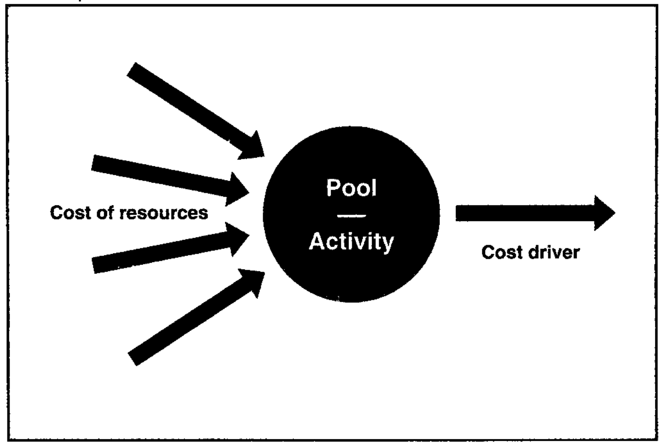
The cost and profit variances can be calculated for every single cost component of each process step. The variance in unit cost of the product out of a process step can be fully explained by the price and usage variances in that step. Furthermore, as this unit cost enters the next process step, the unit cost variance will be regarded as a price variance for the next process step. When all process steps are linked together, we can fully explain the cost variances for the final products from the detailed price and usage variances earlier in the process. Typically, a usage variance is caused internally in the process step, while a price variance is explained by a change in price from the supplier or unit cost from the previous process step. By having access to detailed process and quality data, cause and effect analysis can be performed to explain cost variances. For this reason cost, quality, and process data should be closely integrated as shown above in Fig. 1.

Cost management also includes keeping track of cost elements other than direct cost. Usually these are handled as indirect cost or overhead. They often represent a considerable portion of the total cost, and specifying them as overhead may distort the picture of product cost. The cost elements represent activities in the plant, and the following section describes an alternative way to keep track

3. Cost aggregation to various levels

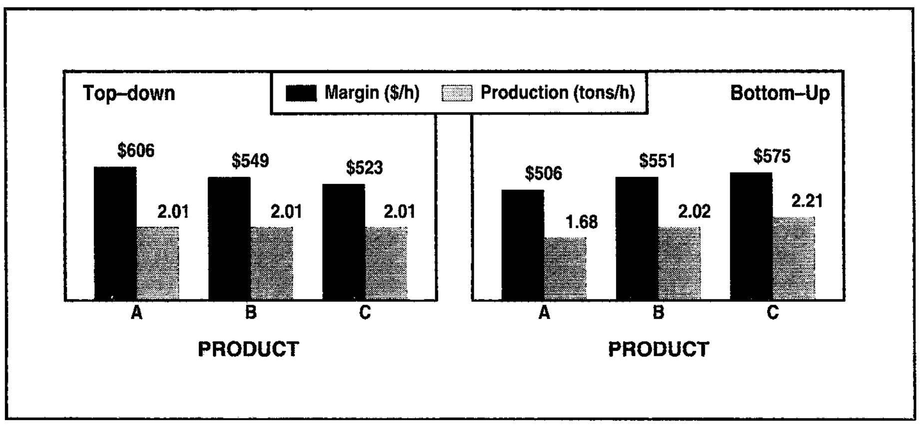


4. Cost pools and cost drivers



of these cost elements, in perfect congruency with the process diagram shown in **Fig. 1**.

5. Effect of data aggregation on profit margin



Activity-based costing

All company activities exist to support the production and delivery of the product to the customers, and the cost of these activities should be considered product cost. Activity-based costing (ABC) is a concept where consumption of resources is linked to production and service activities in the organization *(3)*. ABC handles all cost elements consistently within this concept whether it is cost of adding raw materials or cost of quality inspections. The various activities are organized in a hierarchy as one goes from unit (batch) level activities (energy, raw materials) through run/grade level activities (inspection, machine setups) to product and plant level activities *(4)*. The concept clearly requires bottom-up calculations, and the challenge is to identify the various levels and activities in the business process.

While Fig. 1 indicates a vertically bottom-up calculation through the various time levels, a complete picture of bottom-up data aggregation complying with the ABC concept is shown in **Fig. 3**. The lowest level is the detailed unit (batch) level from which data can be aggregated to any higher time levels and new cost elements added at that level (e.g., cost of building). A set of consecutive units (batches) of the same product is called a run and provides aggregated cost from the unit level in addition to run specific cost (e.g., cost of a grade change). An order is a set of nonconsecutive units (batches) and stores aggregated order cost in addition to order specific cost and profit. Figure 1 shows how cost is aggregated horizontally in the process as value is added to the product. This is according to the ABC concept and will provide consistent and correct cost aggregation and traceability.

ABC may account for semifixed cost elements: cost which neither varies with units of production nor is fixed. The principle for activating such cost elements is to define a cost pool and a cost driver *(5, 6)*. A cost pool is a sum of cost elements of similar type, and the cost drive is the variable used to distribute the aggregated cost in the pool (see **Fig. 4**). Older theory described one or two cost pools using man hours or units of production as cost drivers. Today this may give an erroneous cost structure among products and several cost pools may be needed. The challenge is to define cost pools and cost drivers which characterize the cost elements within the pool. Furthermore, a decision must be made to which activity level the cost should be allocated. The model of pools and drivers must describe the overall structure of the business process, but does by definition not describe the expenditure of every dollar and cent.

Cases and examples from the industry

The difference between using bottom-up and top-down cost calculation in the profit analysis can be presented through the example shown in **Fig. 5**. The plant is a fine paper mill making several products, and we are focusing on three of these products: *A, B and C*. The mill allocated the same production rate to each product, and product *A* was ranked to have the highest profit margin and product *C* the lowest. When the mill studied the production rates in detail, they varied from product *A* through *C*. By using this bottom-up calculated production rate, the ranking of the products profitability was reversed, and product *C* was rated more profitable than product *A*.

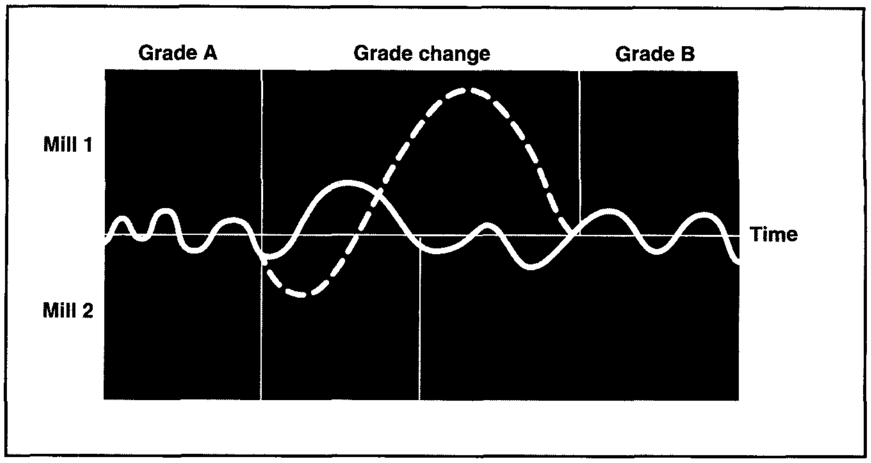
An example of integrated effects of quality, production, and cost is presented in **Fig. 6**. The figure shows variation in a quality property when changing from one grade to another. Grade change time is defined as the time it takes from running stable conditions for one grade to stable conditions for the next grade. Two different mills are presented both working in the same market segment, having the same equipment, and using the same raw materials.

The mill with the shortest grade change time has been working systematically with process information for 15 years, is the most profitable in the market segment, and has learned how to make a near perfect grade change. The other mill has not been working accordingly, and the extended grade change period is a direct loss of profit due to quality failure. There are several unit processes in a paper mill, and—by systematic analysis of detailed information—the production can be increased, quality improved, and cost reduced.

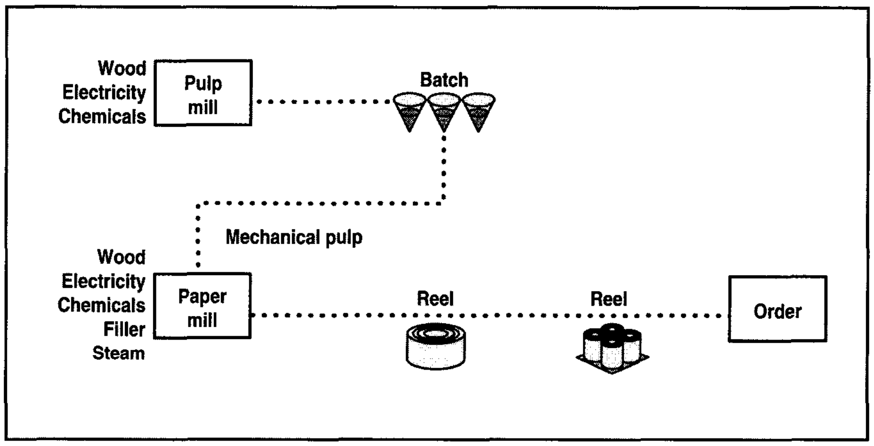
In another paper mill, a process quality control system was installed to improve quality control. The system was implemented for several paper machines and in the pulp preparation area. The project had strong management commitment, and more than 300 people were trained in using the system. The operators work in teams following standard operating procedures. The total effect of this implementation was improved quality, increased productivity, and reduced customer complaints. Again quality and profitability are closely related as explained in Fig. 1. Furthermore, the positive effect of systematic work and paying attention to details can never be overestimated.

Installation of cost systems on the shop floor may support empowerment of the work force. At Tiger Creek mill *(7)*, the process operators took ownership in a cost system, and product cost continuously improved over a period of time before incidentally the improvement stopped. Up to this point, the operators had specified and maintained the system and used it as a decision support system, while supervisors only used the reports from the system. Gradually the supervisors started using this information to give operators advice and orders for what to look out for in the process. The operators lost their primary ownership of the system, and cost improvement stopped. A real-time profit monitoring system has its strongest potential when it is used all the way from the shop floor to upper management, supported by training and management commitment.

6. Reduction of grade change time



7. Cost and process model

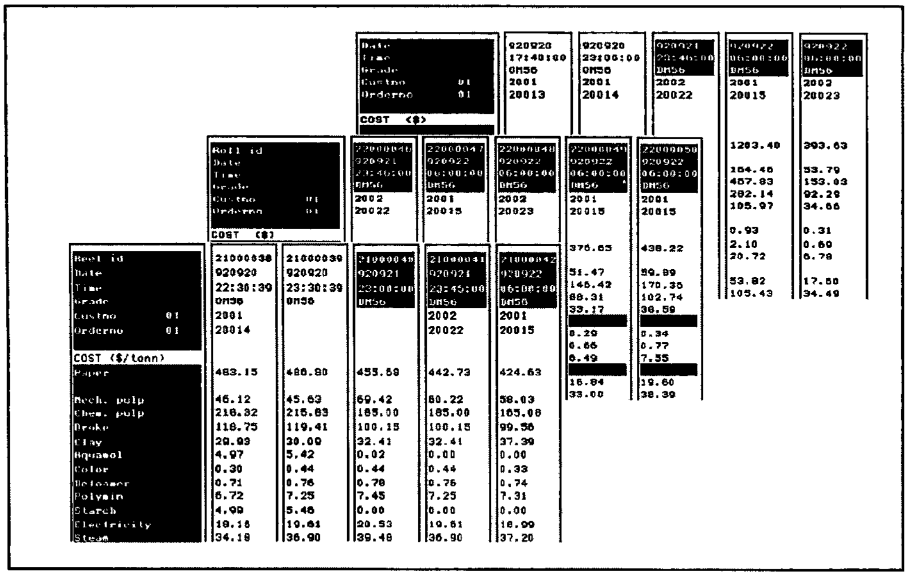


Successful implementation of an on-line profit monitoring system

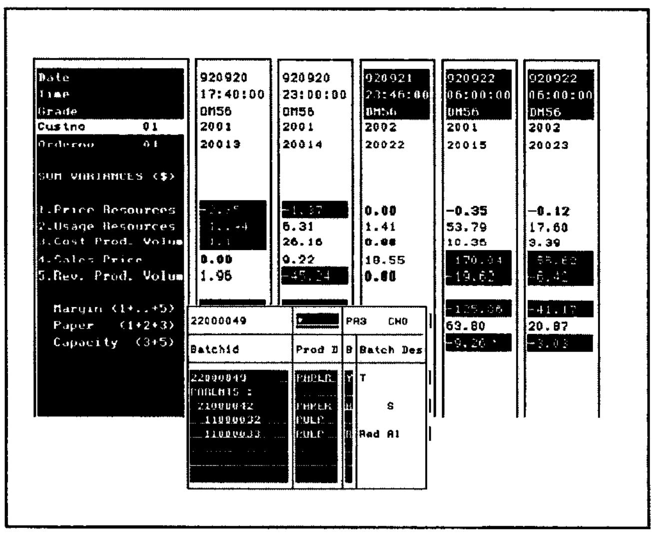
A summary of the previous paragraphs can be made by stating key requirements for successful implementation of an on-line cost and profit monitoring system:

1. Need for management commitment, training, and paying attention to details by defining procedures and responsibilities
2. Easy to use, flexible, and configurable system to support changes in production, organization, and procedures
3. Establish a consistent framework for the methodology to be used including how to reconcile process measurements and link accounting and manufacturing data.
4. The system should perform consistent data aggregation bottom-up from detailed data level to higher aggregates including run and order levels.
5. Ability to trace cost from raw materials to final products

8. Paper cost at order, roll and reel level



9. Profit variance analysis



6. Ability to store cost, quality, and production data in the same data structure for presentation in the same context on reports, forms and graphics.

Overview of applications

A system under installation in a paper mill supporting some of the listed requirements for reporting and analyzing cost, production, and quality will be presented in the following section. The cost model is explained by the process model in **Fig.** 7.

The drawing shows an integrated mechanical pulp and paper mill. The paper mill turns out reels which are cut into rolls, and the rolls can be randomly grouped to fill various orders. The pulp mill is an independent process step, and unit production cost can be calculated as a sum of all the input raw materials and resources. The unit cost for pulp is input to the paper mill as a running average. By linking reel turnup times and pulp production times, an approximate correct unit cost for pulp will be used in the paper mill. The cost of paper reels are calculated at reel turnup time as a sum of all the input raw materials and resources. The rolls are related to specific reels and inherit the unit cost from the parent reel for calculation of roll cost. By grouping rolls into an order, the order cost and profit are calculated. Price, usage, and capacity variances are calculated in the same structure. Descriptions of equations used can be found in *(8)*. All calculations are consistently linked, and actual cost and cost variances can be tracked from the order level back to unit operations in the previous process steps. The configured model is based on a generic concept which supports the structure presented in Fig. 1.

Paper cost at the order and customer level, for paper rolls and paper reels, is presented in **Fig. 8** in a real-time spreadsheet. When new data enter from the process (e.g., a reel turnup), cost calculations are performed and the spreadsheet is updated automatically. The rows in the spreadsheet are the various cost components like raw materials (fibers), energy, and chemicals, and the columns have different meanings on the three displays. The columns represent orders, rolls and reels, respectively, and the customer and order numbers are displayed on all forms. The process steps (e.g., paper machine and winder) are linked together through genealogy providing consistent cost calculations as value is added to the product. At the order level, the total revenue for the order can be presented, and a profit margin can be calculated.

Cost variances (e.g., usage and price) are calculated on-line for single cost components in every process step. These variances are aggregated to order level, and **Fig. 9** presents a condensed summary. The variance components 1–5 are aggregated bottom-up based on data from the roll and reel level. A negative cost variance is negative for the business, and yellow and red colors are used to indicate a warning or alarming variance respectively.

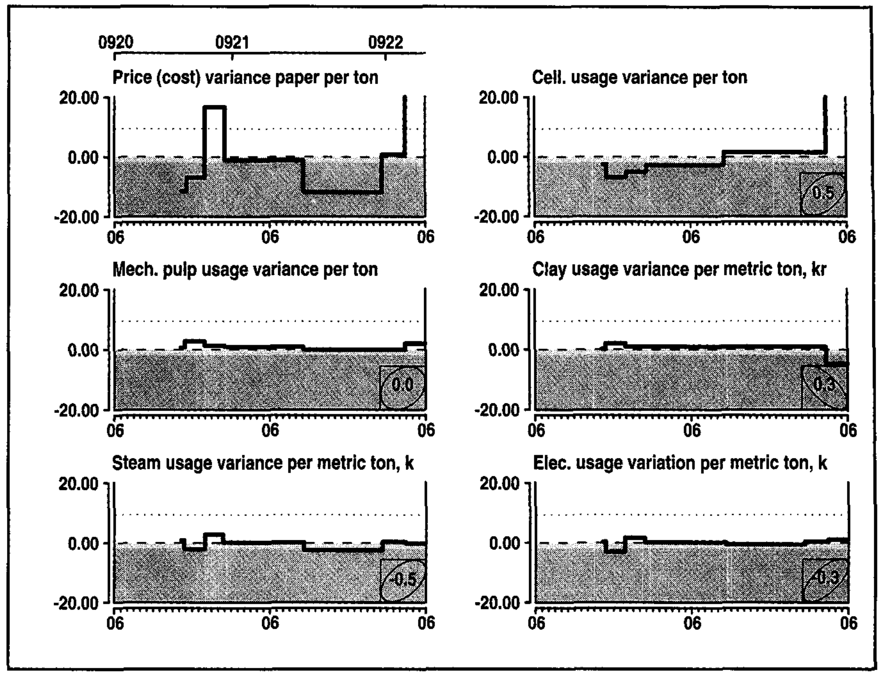
Line 1 shows the overall price variance in input resources, and line 2 is the sum of all usage variances at the order level. The effect of a sales price variance is presented in line 4. Lines 3 and 5 are related to capacity variations. A higher production capacity than target means using more resources (line 3), but selling this added volume will give a contribution in revenue (line 5). The overall capacity variance is the sum of line 3 and 5. The sum of lines 1–3 is the variance in production cost, and sum 1–5 is the variance in contribution margin. Each order can be studied in detail by analyzing these cost variance components (e.g., negative production cost or sales price variance). The pop up display in Fig. 9 presents this full cost traceability from an order to the units (batches) in previous process steps.

Cost variances can be analyzed in a graphic display as shown in **Fig. 10**. All graphs have the same *X*-axis (time) and scale on the *Y*-axis, and the color-highlighted background indicates warning and alarm limits. The graph on the top left is the cost variance to be analyzed: variance in production cost per unit. The other five graphs show various cost variance components and their contribution to the overall cost variance. Several of these forms can be linked together presenting variances for all the cost elements. Each graph has in the lower right corner a number representing elasticity to the overall production cost variance, and an oval indicates high or low, positive or negative correlation to the graph top left. The elasticity, correlation, and the visual picture from the graphs give a good overview of the relationship between the cost variances.

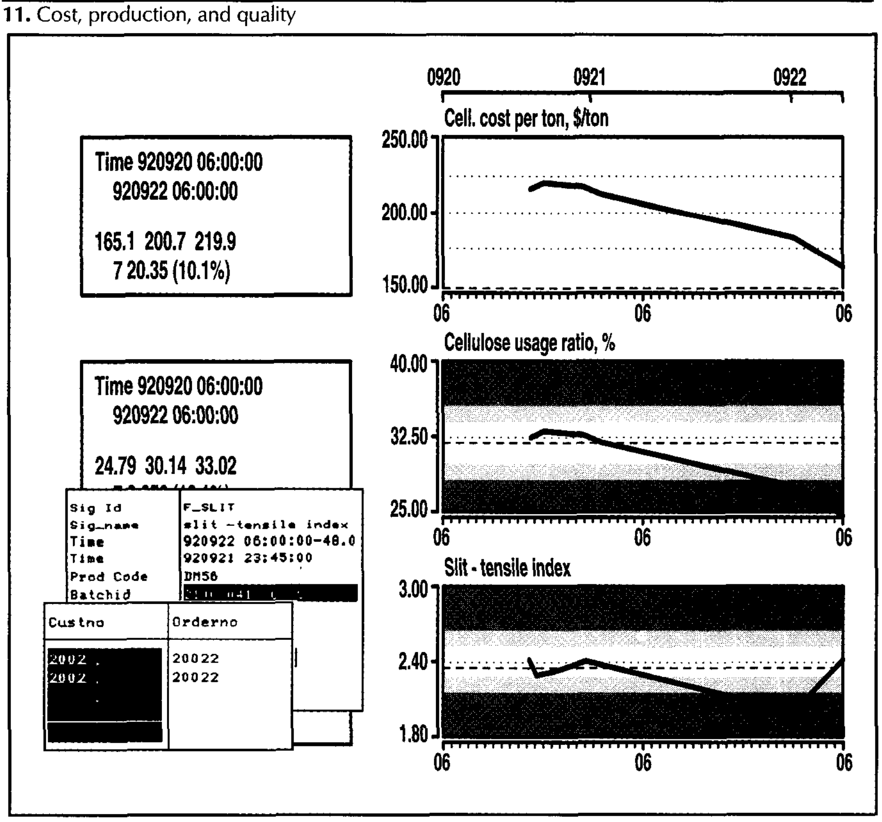
To be able to perform a consistent profit analysis according to the outline in Fig. 1, cost, quality, and production data must be handled in the same structure using the same presentation tools. **Figure 11** shows three graphs for cost, usage, and quality effects of using chemical pulp. The operator on the shop floor will follow closely the usage of chemical pulp because of its effect on paper cost. As usage of chemical pulp decreases, the cost is reduced proportionately. However, the tensile strength also decreases. Hence, we are making a low-cost, low-quality product, but the graph gives us an early warning to take action. The cost traceability can be used retrospectively to look forward in the process by pointing at the low tensile value, then displaying the customer that received paper from this reel.

A few application examples have been shown to demonstrate the profit model. However, all displays and calculations are controlled by the users and can be modified and extended to cover new elements in the model.

10. Cause and effect cost variance analysis



11. Cost, production, and quality



Conclusions and business benefits

Having access to detailed and concise process information will enable reduction in production, quality, and cost variability, and the process can be run closer to its targets. Providing early warning in the process by alarming on cost variances can solve process problems in an early stage. Hence, the plant will benefit from real-time profit monitoring by having higher production and reduced cost. The detailed and consistent cost calculations provide a sound understanding of the cost structure of the production process. Cost and quality objectives for all process departments can therefore be established, creating increased understanding and motivation for common goals.

On-line profit monitoring can be established in the process plant based on the activity-based costing concepts to analyze the cost effects from production and quality variability in the various process steps. Consistent cost and variance calculations can be performed along the process line from raw materials to final products as value is added to products. The methodology presented gives a foundation for most of the cost and quality management applications like product costing, cost variance analysis, and integrated quality and cost control.

Quality and production are already established in the continuous improvement cycle by observing process variations, making decisions, taking actions, and learning from the process. By using the activity-based costing concepts, the cost management issues are added to the continuous improvement cycle providing consistent and integrated processing of quality, production, and cost data. TJ

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