Technical Paper

Economics of Feeding: Total Cost Approach to ROI

When in the market for a feeding system, making a prudent return-on-investment decision involves looking beneath the surface for hidden costs and opportunities

Feeding systems perform the important function of dosing ingredients into a food, plastics, pharmaceutical or other product in exactly the correct proportion—an extremely critical function for one small piece of the manufacturing line. An efficient and accurate feeding system, whether gravimetric or volumetric, can pay for itself quickly by producing material cost savings and keeping the process line up and running reliably, producing end product within specifications.

Too often the savings that an efficient feeding system can produce over time are not considered at the time of purchase, and only the 'up front' capital cost of the equipment is reviewed initially. While it may be easy to obtain information on the acquisition cost of a new feeder line, it is more difficult to evaluate the hidden costs and potential savings of ongoing operation.

This article is intended to help processors see that acquisition cost is, in fact, only a small part of the total picture, and that they can build their own Total Cost Approach by uncovering the hidden costs, developing the unexploited efficiencies and considering the intangible factors in feeding.

The 'Total Cost' Approach

Like any process equipment, a feeding system costs something to acquire, performs a function, and costs something to support and sustain its ability to function as desired. Together, these three factors constitute total cost.

Acquisition Costs – The total of purchase price, installation and initial training costs.

Functional Efficiency - This factor reflects how well a given feeding system performs its basic function of controlling material rate as required by the application. Here, the potential exists for significant savings in material costs made possible by performance differences among different feeding systems. Likewise, functional efficiency also includes consideration of potential savings in waste and reject rates enabled by those same performance differences.

Support Costs - Beyond estimated service and maintenance costs, this piece also includes costs associated with feeder cleaning and system re-configuration as materials change, a potentially significant consideration in applications producing customized products involving shorter runs and frequent material changeovers.

Acquisition Costs: Rash or Rational?

Acquisition cost is the most easily computed component of total cost. Once you've carefully defined your application requirements you obtain a quotation from each potential supplier. Add in potential shipping costs along with estimated installation and training costs needed to become operational and you have summed up acquisition cost.

The key in the Total Cost Approach is not to stop the evaluation based on acquisition cost alone. Buying on price alone often results in a different decision from one produced by a complete Total Cost Approach analysis. To understand why, consider a simplified hypothetical case designed to illustrate the relative importance of acquisition cost, functional efficiency, and support costs in the Total Cost Approach. You're invited to perform the same exercise using costs and application scenarios relevant to your process.

An Example

ABC Company processes 1,000 lb/hr of red, blue and green product operating three 8-hour shifts per day. The plant operates 340 days per year. Regular material changeovers for the red, blue and green runs reduce available process uptime by 15%. Material cost averages $2 per lb, they incur a 1% reject rate, and they sell their product for $3.50 per lb. They just bought a replacement feeding system with a total acquisition cost of $100,000 and expect a 10-year service life. Now let's answer some basic questions:

Q. What is the hourly material cost?

A. Material Cost = $2/lb X 0.85 hrs/hr X 1,000 lb/hr = $1,700/hr

Q. Ignoring required labor, what is the hourly cost of lost production due to changeovers?

A. Cost of Lost Production = 0.15 hr/hr X 1,000 lb/hr X ($3.50/lb - $2/lb) = $225/hr

Q. What is the waste/reject cost?

A. Hourly Waste/Reject Cost = 0.01 X 0.85 hr/hr X 1,000 lb/hr X $2/lb = $17/hr

Q. What is the hourly burden of acquisition cost?

A. Hourly Burden = $100,000 / 10 yrs / 340 days/yr / 24 hrs/day = $1.23/hr

So, what can be learned from the ABC Company? Figure 1's pie chart shows just how small a slice is occupied by acquisition cost. In the example acquisition cost represents only 0.06% of total hourly cost, almost 14 times less than the already small waste/reject cost, 183 times less than the cost of lost production from changeovers, and 1,382 times less than the cost of materials. Note that *total* acquisition cost, not the *difference* in acquisition cost between potential suppliers was considered. If only supplier *differences* in acquisition cost were considered, it would hardly even show up on the chart.

Given the obvious relative costs illustrated here, at the time of purchase, cost-conscious feeder buyers will focus their attention not just on the acquisition cost burden, which represents only the smallest fraction of the total hourly cost of the feeder line, but will seriously evaluate different feeding systems by focusing on the savings to be realized by:

- Cutting the reject rate with more consistent feeding
- Reducing changeover time with flexible and cleanable feeding equipment
- Shaving material costs to the bone with high performance feeders that can improve both momentary and long-term accuracy

From this lesson two important guiding principles emerge to help focus your efforts to achieve your own Total Cost Approach:

The first is that even small operating efficiencies are compounded over time and can pay big dividends. It's the nature of the processing activity. A few dollars per hour saved in material cost efficiencies steadily mount over time to far overshadow any one-time cost. Several minutes saved in material changeovers can contribute significantly to increased long term line efficiency. Or even a marginal improvement in momentary accuracy can permanently

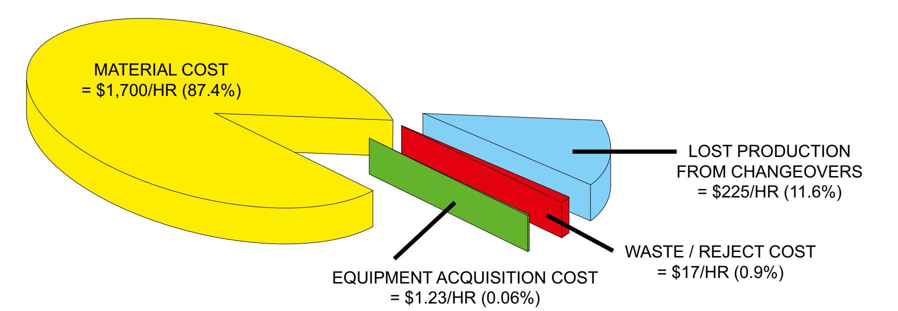

Fig. 1 - ABC Company's Hourly Cost Elements

reduce feeding-related reject rates.

The second guiding principle is the opposite of the first: unrealized opportunities carry real costs. In the competitive arena of processing, plant managers need to seize every possible opportunity to reduce costs.

Functional Efficiency: Setting the Savings Strategy

How can feeding actually cut material costs? It all starts with the application itself. Feeding applications run the gamut from simple single-ingredient volumetric setups to sophisticated multi-ingredient gravimetric blending systems, each with its own defined purpose or function. Part of that defined function is a set of quality standards, carefully composed to assure consistent end-product properties. Properties like taste, nutritive value or shelf life for a food item... color, hardness or surface properties for a plastic pellet... or efficacy, solubility, or stability if it's a pharmaceutical.

Some of those quality standards govern the feeding function. Standards for some simple applications might only specify a target rate or basic proportion for each ingredient. But for more critical applications, upper and lower statistical tolerances may also be placed on each material to control variability and assure desired end-product attributes.

Here's the key to setting your savings strategy: By analyzing and exploiting the opportunities afforded by strategically operating within an application's quality standards, feeding-related material costs can be minimized. To understand exactly how this can be accomplished, first briefly consider the definition of feeder accuracy.

Feeder performance is measured by determining the standard deviation of weighed samples taken from the feeder's discharge. A consistent, highly uniform discharge results in a small standard deviation with a narrow distribution of sample weights, while a less consistent discharge produces a higher standard deviation and a broader distribution of sample weights.

Typically, feeder performance is cited at two standard deviations or 2 Sigma. Thus, a feeder with a measured ±0.3% standard deviation will be said to have a repeatability of ±0.6% at 2 Sigma.

Now, consider a typical feeding application where multiple ingredients are being blended. One ingredient will be the most expensive. If that component can be minimized *while still conforming to the blend's quality requirements*, total material cost will fall.

To see how, refer to the illustration in the upper portion of Figure 3. If a low precision feeder is employed, it must operate at a rate well enough above the ingredient's minimum allowable proportion to avoid violation of the limit threshold. However, a feeder capable of higher accuracy will be able to operate nearer to the minimum threshold, permitting a continuing savings in material cost proportionate to the difference in performance levels.

Totally dependent on the application and the variables involved, savings may at first appear modest on a per pound or per hour basis, but when totalled over time can become quite significant. Such performance-related economies can form a major element in building your own Total Cost Approach, and can be used to evaluate the 'gravimetric or volumetric' decision, or to quantify and compare savings potentials associated with performance differences amongst competing feeders.

Extending the above approach to the entire blend affords the potential for additional savings. Once the most expensive ingredient has been minimized, the process can be repeated with the next-most-expensive ingredient and so on until, at some point, a maximum limit boundary associated with one of the less expensive ingredients will be encountered indicating that the blend's total material cost is minimized.

As shown in the lower portion of Figure 3, the use of a precision feeder even on less expensive blend components allows these cheaper materials to be fed closer to their *maximum* limits, permitting further minimization of total blend cost.

Note that while feeder performance is typically expressed at a 2 Sigma level, the application's quality standards may be based on a different statistical confidence level. Account must be taken of differences in Sigma levels when computing savings potentials.

The cost minimization strategy can be formalized into the following series six easy to follow steps:

STEP 1: Assemble Input Data

Computing the cost minimized solution for any blend or recipe requires minimum and maximum tolerances and total recipe rate, as well as unit cost and feeder repeatability performance for each ingredient. (For batch operations use weigh scale accuracy instead of feeder repeatability.)

STEP 2: Rank All Ingredients by Unit Cost

Ingredients are assigned an ordinal ranking based on decreasing unit cost (e.g., $/lb) with '1' being the most expensive ingredient, '2' being the next most expensive, and so on.

STEP 3: Calculate Operating Proportion Limits

Based on feeder performance and ingredient tolerances, calculate the minimum and maximum allowable operating proportions for each ingredient, defining the range of setpoints over which each ingredient feeder may operate.

$$S = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}$$

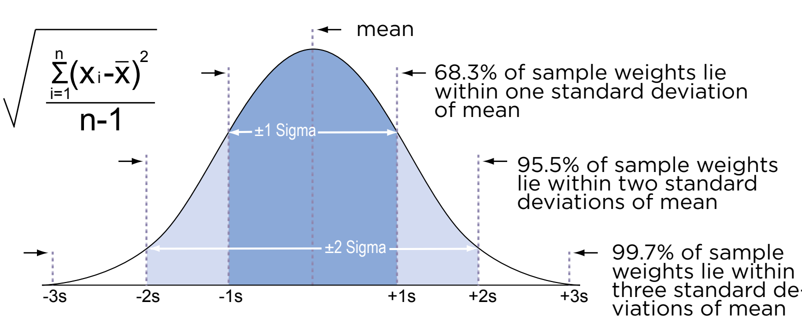

Fig. 2: The consistency of feeder discharge is expressed statistically as standard deviation.

STEP 4: Temporarily Maximize All Operating Proportions

Then, as a starting point, temporarily assign all operating proportions to the maximum values calculated in Step 3, resulting in a total recipe percentage greater than 100%.

STEP 5: Minimize Operating Proportions by Cost Rank

Beginning with the most expensive ingredient (Rank 1), replace its maximum operating proportion with its minimum operating proportion. If total recipe percentage remains above 100%, repeat the process using the next most expensive ingredient (Rank 2) and so on until total recipe percentage falls below 100%.

STEP 6: Restore Residual Deficit

The ingredient that causes total recipe percentage to fall below 100% cannot be minimized. To restore total recipe percentage to the required 100%, the deficit is simply added to that ingredient's minimum operating proportion. (A cost-minimized recipe will always contain, at most, one ingredient that remains neither minimized nor maximized, but lies somewhere within its allowable operating range.) The recipe is now cost-minimized.

Application Example: A Matter of Taste

To illustrate the cost minimization procedure, consider the following example. Application input data is shown in Table 1. While shopping for a feeding system for a new process line, a food plant engineering team is trying to decide whether to invest in gravimetric feeders or go with volumetric feeders that cost less but would offer lower accuracy and fewer line efficiencies. The team is tempted to save money on the capital expenditure by choosing volumetric feeders, based on input from research that the human sense of taste can only distinguish a 5-10 % variation in ingredient composition.

However, several team members conduct a careful analysis of ingredient costs, needed line changeovers, cleaning requirements and typical reject rates. Then several team members propose that while the quality standards would let them get by with a volumetric system, the initially more expensive gravimetric feeder system could actually cost less in the long run.

After obtaining feeder performance data and performing the ingredient cost minimization technique presented above, the team summarized the results as shown in Table 2.

The team initially planned to spend $412.70 per hour to produce 1,000 lb of product using volumetric feeders set to operate at each ingredient's target rate. However, by employing more precise gravimetric feeders, they calculated they could cut ingredient cost 7% to $383.68, an hourly savings of $29.02.

Operating approximately 8,000 hours per year, the team calculated an annual savings in material cost efficiency of about $232,000 and a payback period of less than three months.

In many pharmaceutical or chemical applications, expensive ingredients could cost more than ten times as much, bringing the Return On Investment (ROI) even faster. While this particular case might be hypothetical, it does reflect a reality many processors have discovered: high-performance feeders can cut costs even in relatively low-precision applications!

By applying this cost minimization strategy to your own application using your own costs, rates and recipes, you can see for yourself not just whether gravimetric is the way to go, but also to compare differing performance capabilities among supplier offerings and to actually quantify the cost efficiencies attached to each alternative.

This recipe review strategy of minimizing the expensive ingredients and maximizing the less expensive ingredients can result in cost savings even with a volumetric feeder line achieving 2-10 % accuracy. The range of acceptable changes would not be as great, so savings would not be as great either.

Coperion K-Tron offers a powerful but easy-to-use tool for calculating potential ingredient cost savings and evaluating options: The FeedSmart Recipe Optimizer is available free of charge from Coperion K-Tron and can be downloaded at **www.coperion.com/feedsmart.**

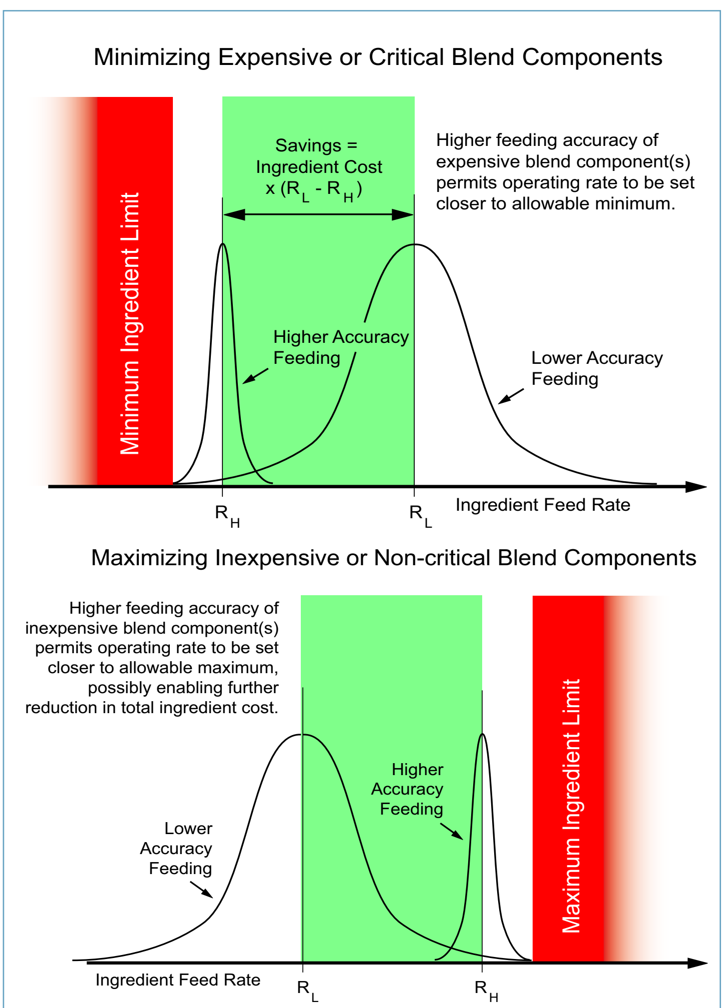

Fig. 3 - Minimizing Material Cost in Blending Applications

Reject the Reject

Reject or waste product is always painful and something to avoid. As for the feeding portion of the process and its mission

Ing	Recipe Target (%)	Recipe Target (lb/hr)	Ingr. Cost ($/lb)	Ingredient Tolerance (%) Min	Max
A	50.00	500.00	$0.22	47.00	53.50
B	30.00	300.00	$0.50	27.00	33.00
C	10.00	100.00	$0.33	9.00	12.00
D	5.00	50.00	$1.20	4.00	6.00
E	4.00	40.00	$0.61	3.00	5.00
F	1.00	10.00	$3.53	0.70	1.20
Total	100.00	1,000.00			

Table 1 - Application Example Input Data

to control and combine materials, there are basically two causes of waste: Human interface error and equipment malfunction.

As long as people are in the mix there will be human error, but more often than not human interface error is at least partially caused by an overly complicated control interface, or a simple lack of adequate training. So the first step in minimizing waste is to carefully consider the control system's ease of use, and then be sure the people who will be working with the feeding system are adequately trained.

Equipment malfunction can either halt the process altogether or, worse yet, cause the production of off-spec product if the malfunction is partial or transient. The problem may be evident (e.g., feeder #3 doesn't work, or ingredient 'B' is out of tolerance), but the cause may be elusive. Unlike simpler pieces of process equipment, a gravimetric feeder is as much instrument as equipment. It must receive, contain, weigh, move, control and discharge material with precision. A problem in its ability to perform any of these functions can reduce performance or interrupt operation.

While it's impossible to predict the unpredictable, it's important to recognize that equipment malfunction and the waste costs it incurs can be minimized through the selection of quality equipment along with a program of regular preventive maintenance. In estimating your Total Cost Approach you may choose to ignore this cost category altogether if you're only comparing alternatives. But if you choose to build an absolute estimate of total costs, you may want to consult with potential suppliers first and then apply a best guess estimate for each alternative.

Support Costs: Estimating Off-line Factors

Costs keep right on accumulating even when the process is down, either for scheduled or unscheduled maintenance, or for equipment or material changeovers between production runs.

Service and Maintenance - The single best way to limit service and maintenance costs is to develop your own in-house capability through an initial investment in maintenance training. That way troubleshooting and maintenance expertise will always be on-site to handle any emergencies and minimize unplanned downtime.

Of course, backing you up are the feeder supplier and the sales representative. As part of your Total Cost Approach, consider the supplier's service capabilities and costs closely. Can you reach the factory 24/7? Do they have a service hotline to help solve your problem over the phone? How experienced are the factory service personnel? How quickly can a serviceperson arrive at your door when you need someone there? What costs are involved? Aside from the 'hard' costs you can nail down, decision factors in issues of service and maintenance are largely subjective. That's why it's so important to investigate, ask questions and gather the facts.

Cleaning - All feeders need to be cleaned anywhere from 'once in a while' to several times a day, depending on the application. So, the major determining factor in this cost area is the cleaning frequency. You may not be able to do much about the frequency of required cleaning, but by careful choice 'up front' you can minimize cleaning time, and thus contribute to your Total Cost Approach.

As mentioned earlier, even small operating efficiencies are compounded over time and can pay big dividends. If your application involves frequent material changeovers, any small efficiency you can gain in the cleaning operation will be multiplied through time and return the favor to you in the form of reduced ongoing costs

How can you improve cleaning efficiency? First, whenever possible locate the feeder with cleaning and maintenance access in mind. A hard-to-reach feeder is less likely to receive the cleaning and maintenance attention it deserves. Your people need to get to the feeder and have enough 'elbow' room to work on it.

And then carefully assess the feeder's design and cleanability features in light of your specific cleaning requirements. What degree of teardown is required for cleaning? How easy is it to remove and replace the feed screws or weigh belt? Can the outside of the feeder be sprayed down? What about the use of cleaning agents? Will some material-contact components stain and possibly contaminate future process runs? How about crevices, seals and welds? Do they provide a place for material to accumulate? In fact, if you have the opportunity, you may want to actually tear down and re-assemble the feeder to the extent you'll need to for cleaning. Time the activity for each kind of feeder you're considering. Then compare.

Feeder Re-Configuration - Today many factories use flexible production lines that produce multiple variations of the same base product, requiring shorter process

	ORIGINAL RECIPE		COST MINIMIZED RECIPE		
Ing	Recipe Target (%)	Hourly Ing Cost	Gravimetric Accuracy	Recipe Target (%)	Hourly Ing Cost
A	50.00	$110.00	±0.25%	53.22	$117.09
B	30.00	$150.00	±0.3%	27.08	$135.41
C	10.00	$33.00	±0.5%	11.94	$39.40
D	5.00	$60.00	±0.7%	4.03	$48.36
E	4.00	$24.40	±0.6%	3.02	$18.41
F	1.00	$35.30	±1.2%	0.71	$25.01
Total	100.00	$412.70		100.00	$383.68

Table 2 - Application Example Original and Cost Minimized Recipes

runs and more frequent material changeover. Wherever possible, re-configuring one feeder to perform the function of two or more is far preferable to the added procurement cost and ongoing time consumed in continually switching out and maintaining multiple feeders.

To achieve savings here, processors need to review if a feeder offers not just fast cleaning but also easy changeover, by way of replaceable feeding elements, fast disconnects, multi-speed gear boxes to offer a wide feeding rate range or turndown capability, or switchable feeder/bin units for fast material changeover. Evaluate the reconfiguration and cleaning activity and estimate the actual time required to make the changeover. Remember, feeder re-configuration may often have to be performed during time-critical process changeovers where every minute consumed is a minute's lost production.

Building Your Own Total Cost Approach

Any experienced buyer knows that important decisions shouldn't be made on dollars and cents alone. Counting costs has its place, but accounting for the intangibles is crucial to an optimal Total Cost Approach. A true Total Cost Approach achieves a logical balance between the two.

The first step in including intangibles in your decision is to simply identify them. Jot down everything you can think of that doesn't have a direct cost attached to it but does have value in your decision. Then review and refine your list until you're satisfied. A sample list follows:

- Application assistance availability
- Systems engineering capability
- Equipment reliability
- Plantwide connectivity & controls integration
- Backward compatibility & retrofits
- Integrated equipment offering
- Relationship with supplier & agent
- Supplier reputation and standing in the industry
- Supplier laboratory testing capabilities
- Outside references

You now have the foundation to include intangibles in your decision. The next step is for you and others involved in the process to discuss and rate each supplier in each area. The specifics of the rating system aren't important, but the process of discussion, evaluation, opinion gathering and consensus building is.

When you've completed your ratings, you may further refine the effort by weighting each factor to reflect its relative importance. Then total up all the weighted ratings to arrive at a single score for each potential supplier.

Finally, with all countable costs counted and intangible factors factored, you're ready to make a decision. To include the intangibles consider them only after all the costs associated with acquisition, functional efficiencies and support are totalled for each potential supplier. Without doubt there will be a difference among the total cost figures associated with each supplier.

The question becomes *"Do the differences in the ratings of the intangibles suggest a change in the decision indicated on the basis of cost alone?"* If no, the 'cost alone' choice is endorsed. If yes, the 'cost plus intangible' decision is your Total Cost Approach.

Conclusion

Applied properly, the Total Cost Approach is a far-reaching decision tool that reflects all envisioned costs for each alternative you're considering, whether direct expenditures or in the form of achievable process savings. It requires gathering 'hard' numbers and estimating 'soft' ones. It demands careful analysis, attention to detail and a bit of 'thinking out of the box.'

No one ever said good decision-making is easy. But in the end, you'll have the confidence you made the best decision, and you'll have the evidence to prove it.

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