Making Decisions with Data

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Summary
Making a decision is about choosing among potential actions. To assist our decision making, we often gather data to quantify the expected outcome from each potential action, and to estimate the probability of each outcome. Mistakes are sometimes made in the process of making a decision, including the selection of the wrong set of decision criteria. An investment decision is used to illustrate this. Many decisions have outcomes that extend well into the future. Correct decision analysis requires the proper factorization of the timing of the different outcomes as well as the life of the investment when appropriate. The optimum pre-pubertal rate of gain is used as an example of proper accounting of time. Lastly, the uncertainty regarding the outcome of each potential action has a substantial effect on decision making. Variance of outcomes must be considered and the tolerance for risk varies among decision makers. A simple example using bST is presented to illustrate the use of a cost-of-being-wrong analysis.

Abbreviation key: ADG = average daily gain, **EA** = equivalent annuity, **NPV** = net present value, **PP-ADG** = pre-pubertal average daily gain.

Introduction
Making a decision is about choosing between different available actions (or acts), including the action of "doing nothing". A decision problem exists when the consequences from each possible action differ. In instances when the consequences are well known, the problem is labeled as "decision under certainty". If, for example, I stand on the edge of a 500 ft cliff and consider two courses of action: a) I step forward, or b) I remain still, the consequences of each action are pretty well known. If I choose a) I die; if I choose b) I live. Unfortunately, this kind of decision-making problem is infrequent in real life. At the very least, they are infrequent in agriculture because we seldom know exactly the consequences of our management decision. If you think about it, a manager (human being) would not be required if the consequences of each possible action were known. A computer would then be a far more efficient (and cheaper) decision-maker. It is the uncertainty (also called risk) that challenges decision-makers and creates the need for data acquisition and analysis to assist in the decision-making process.

Making decision under uncertainty is very different from making decision under certainty of outcomes. This paper will present and illustrate basic concepts of quantitative decision-making. More specifically, I will address 1) the issue of choosing the correct decision criteria, and 2) the correct factoring of the effect of time, and 3) accounting for the uncertainty of outcome.

Using the Correct Set of Decision Criteria
A few years ago, I was approached by two brothers who were considering building heifer facilities for their expanding farm. About 330 cows were being milked in a new facility basically designed for 500 cows (this was a closed herd expanding from within). The heifer facilities consisted of run-down buildings unsuitable for cows (and arguably for heifers too). Heifer pens had to be cleaned manually

and the poor ventilation was believed to cause numerous problems starting at a young age. At 6 months of age, heifers were moved to a large loose pen in a remodeled tie-stall barn. The management believed that this barn was also a major cause of respiratory disease. At breeding age, animals were moved to an outside lot where conditions were often atrocious after periods of rain. The management recognized that the feeding and management of the replacement herd was less than ideal. The cost of building new facilities was estimated at $120,000. A nutrition consultant had estimated the consequences of building new heifer facilities as follows:

a) Increased average growth rate of heifers, going from 1.4 to 1.9 lbs/d,

b) No change in daily feed costs, resulting in net savings in feed costs of $120 per heifer, or $18,000/yr for a herd of 300 heifers,

c) Reduction in labor costs, going from $0.25/heifer per day, to $0.15/heifer per day. This would result in a net saving in labor cost of $99/heifer. The combined savings in feed and labor costs were estimated at $219 per heifer, or $32,850 per year,

d) Mortality rate would drop from 15% to 5%; this would result in 25 additional heifers per year, or a net increase of $10,000/year,

e) New heifer facilities would create room for a fresh cow group. This fresh cow group would result in 400 additional pounds of milk per cow, per year. At $13/cwt and accounting for $15 in additional feed costs per lactation to support this additional milk, this fresh cow group change would result in $18,500 in additional net income for the herd of 500 cows.

Thus, the sum of all savings and additional income was estimated at $79,350, resulting in a 66% annual rate of return on the $120,000 investment. With a return like this, why in the world were the two brothers hesitating?

Let us examine the farm financial situation at the time. Table 1 shows a summary of the year end balance sheet. Liabilities (debts) represent about 47.4% of assets. The farm has a severe imbalance between intermediate farm assets and intermediate farm liabilities. Table 2 reports an income statement with rounded financial figures for the prior year. The net farm income of $25,000 has to support the living expenses of two families. Clearly, profitability is an issue for this farm. Using figures from Table 1 and 2, a financial analysis was done (Table 3). This analysis showed that:

1. Liquidity is an issue, not because of a lack of cash to meet current liabilities, but because of grossly inadequate cash reserves (working capital too low).

2. This farm has pretty much borrowed its last dollar for now (debt to asset ratio – repayment capacity).

3. Profitability is grossly inadequate. The low profitability is the result of a) low operating profit margins, and b) insufficient asset turnover.

In short, decisions on this farm must be targeted toward: 1) Improving short-term cash flow, 2) increasing operating margins by reducing operating expenses, and 3) increasing the turnover of assets by either decreasing the assets while maintaining gross farm revenues, or by increasing gross farm revenues. Immediately, the idea of building higher facilities seems counter-intuitive to these three objectives. As opposed to using a series of partial budgets, we prepared a complete pro forma analysis for the heifer facilities project (Table 4). Clearly, building heifer facilities does not improve short-term cash flow: the working capital hardly changes and the net cash farm income does not improve until the third year after the construction. The project would do little on the operating cost of milk sold until the third year. The turnover of assets changes hardly at all and the small improvement does not occur until the third year after the construction. In short, building heifer facilities on this farm at this time would be a bad decision.

We can summarize what we learned from this case study:

1. *If it sounds too good to be true, it is probably so*. There are very few miracles in this business and returns on assets of 66% are unlikely.

2. You have to *use the correct data*. In this case, the herd is made up of 330 milking cows, not 500 as used by the consulting nutritionist.

3. *Profit is not equal to cash*. In fact, additional profits often result in reduced short-term cash.

4. Additional profits are generally a good thing, but *profitability is not the sole criterion*. In this case study, liquidity (cash flow) should be the overriding criterion. If it doesn't cash flow the first year, it should be dead on arrival.

5. *Avoid* what I call *the Perrette's syndrome* (from a French children's story). In a project, not everything will go right. Actually, it is very unlikely that everything will go as planned even with the best and tightest management. The nutritionist had piled up a series of outcomes (reduced heifer mortality, increased heifer rate of gain, reduced feed costs, reduction in labor costs, increased production by lactating cows) each of them possible, but not very likely, and globally nearly impossible. Use conservative projections in your decision making.

6. *Use the right tool in your decision making*. The nutritionist had used a series of partial budgets. Personally, I do not like very much partial budgets because I have seen them abused too frequently. It is too easy to forget items that should be factored in the partial budgets. More importantly, partial budgets give incorrect information when capital items are factored as expenses whereas they truly are depreciable investments. In addition, partial budgets do not properly factor the effect of time, an important factor as we shall see in the next section of this paper.

7. *Use the right set of criteria*. Profitability is important but in many instances other criteria such as cash flow must be considered or may even be the overriding criterion.

8. *You must factor in your tolerance* (and that of your lender) *for risk*. Table 4 was prepared using a milk price of $15.20/cwt. What do you think would happen to this farm if it was to build heifer facilities and milk prices were to drop under $13.00/cwt? Accounting for risk in decision making will be covered in the third section of this paper.

Factoring the Effect of Time

If I were to give you $1,000, would you prefer to get it now or in 10 years from now?

If you were facing the decision of choosing between two different investments each with the same initial $1,000 investment, but one with a net present value of $1,500 and the other with a net present value of $2,000, which one would you choose?

The answers to both of these questions require the proper factorization of time. Intuitively, we all understand that time has a value. In answering the first question above, most sane people would prefer receiving the money right now. That's because we know that we could take the $1,000, invest it, and get a whole lot more than $1,000 in 10 years. But how much more? Put differently, how much less would I have to offer you right now for you to be indifferent of the two options? This, in essence, is the concept behind the Net Present Value (**NPV**). At an annual discount rate of 8%, $1,000 in ten years from now is the exact equivalent of $463.19 today[1]. At a lower discount rate of 5%, the same $1,000 in ten years form now is worth $613.91 today. Thus, when making a decision, the timing of the outcome can be as important as the outcome itself.

There are various equivalents to the NPV for accounting the effect of time (e.g., the net future value). However, there is one method repeatedly used in farm publications, the "payback time" that gives distorted and erroneous answers. According to this procedure, if you buy this super duper gizmo, "it pays for itself in four years"! The problem with this approach is that although time is being included (payback is x years), the value of time is not factored in. In Table 6, I prepared three examples to illustrate the NPV concept and the fallacy of the "payback time" method. In all three examples, we make an initial investment of $1,000. In the first example, the investment returns $999 in the first year, nothing in year 2, 3, and 4, and $1 in year 5. The second $1,000 investment returns $1 the first year, nothing in year 2, 3, and 4, and $999 in year five. The third $1,000 investment returns $200 in each of the five years. In all three cases, the sum of the five annual returns is $1,000, exactly what was invested. So, in all three instances "the investment pays for itself in 5 years". However, when time is properly accounted for, the NPV varies from -$45 to -$206 using a 5% discount rate, and from -$69 to -$266 with an 8% discount rate. Clearly, the three investments do not have equal value, and in all three instances, it would take more than 5 years for the investment to "pay for itself". In fact, the constant $200/year return would not reach a NPV of zero until 6.8 years after the investment, a figure which is 36% larger than the 5 year payback.

The answer to the second answer is not as obvious. Let's say that I have two potential investments, both with an NPV of $1,000. In this first instance, the NPV of $1,000 is achieved in five years. In the second, the NPV is cumulated over 10 years. Which one would you choose? The five-year investment, of course, because after five years you can reinvest the money. Investments are recurring processes. A neat way to solve the problem of choosing between two recurring investment alternatives with different lengths (called "lives" in the financial jargon) is to express the returns (calculated as NPV) as an annuity equivalent. The annuity equivalent is an estimate of the periodic net payment one would receive each year of an investment's life. The annuity equivalent is expressed as an annuity factor (AF) calculated as follows:

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[1] The equation used to calculate the NPV is not given here because it is a standard financial function in all major spreadsheet softwares (e.g., Microsoft Excel).

$$AF = \frac{1}{\frac{(1+i)^m - 1}{i}} \qquad [1]$$

where m = average life of an investment (years)
i = annual interest rate (e.g., 0.05)

The equivalent annuity (**EA**) is then simply calculated as:

$$EA = NPV \times AF \qquad [2]$$

This technique is easily applied to the simple investment decision problem of the two investments, each with a NPV of $1,000, but with different lives (5 and 10). The equivalent annuity (EA) using an interest rate of 5% is calculated as $1,000 x 0.181 = $181 for the first case (5 y life) and $1,000 x 0.080 = $80 for the second case (10 y life). That is, the first investment produces returns expressed in today's dollars that are equivalent to $181 per year, compared to $80 per year for the second investment. At equal risk, the first investment is clearly a better one.

We will now apply the equivalent annuity technique in a decision problem regarding the rate of gain in growing heifers. It has been known for some time that the prepubertal rate of gain affects first lactation performance. Figure 1 summarizes results from three studies that examined the effect of prepubertal rate of gain on first lactation milk yield. Each additional unit of average daily gain (**ADG**, expressed her in g/d) before puberty results in a reduction of 2.09 kg of milk production in first lactation. Expressed differently, an increase of 0.1 lb/d in ADG before puberty results in a 210 lb reduction in first lactation milk yield. Based on these results, many have recommended limiting prepubertal ADG to a figure not to exceed 1.5 lbs/d. But is this the best economic decision?

Figure 2 presents how we can address this question looking at scenarios ranging from 1.54 to 2.65 lbs/d (700 to 1200 g/d) of pre-pubertal ADG up to 800 lbs (363 kg – breeding age) followed by a uniform ADG of 1.9 lbs/d (860 g/d) until freshening at 1350 lbs (612 kg). Results of our analysis are presented in Table 5. First lactation yields were discounted by 210 lbs for each 0.1 lb/d increment in ADG. Thus, we expect average first lactation milk yield to decrease by 917 lbs if we increase ADG from 1.54 to 1.98 lbs/d. Our calculations assume no production losses in second and third lactations. The expected (average) life expectancy is three lactations in all cases. The total cost (undiscounted) to raise the animal to 1350 lbs decreases with pre-pubertal ADG (**PP-ADG**) due to the dilution of maintenance feed costs and fixed costs (e.g., housing). The age at first freshening drops by 163 days (nearly ½ a year) by increasing the PP-ADG from 1.54 to 2.65 lbs/d. Lifetime revenues are increased by lowering the PP-ADG (consequence of greater first lactation yield) but so are lifetime costs due to the greater costs of raising the animal and the greater feed costs in first lactation. The undiscounted lifetime net income is maximized at a PP-ADG of 1.70 lbs/d. When we apply an 8% annual discount rate, the NPV of lifetime net income is maximized at a PP-ADG of 2.15 lbs/d. Over the range of PP-ADG that we looked at, the life of our investment varies between 4.5 and 4.95 years. When we account for the difference in investment life (equivalent annuity), the optimum PP-ADG becomes 2.5 lbs/d. Just as importantly, the estimated equivalent annuity is very flat between 1.9 and 2.6 lbs/d (less than $10/y per heifer difference over this entire range).

So what do we conclude from this exercise?

1. The economic optimum prepubertal rate of gain is nowhere close to 1.5 lbs/d.

2. Accounting for the effect of time on the value of money and investment life increases the optimum pre-pubertal ADG from 1.7 to 2.5 lb/d.

3. The effect of prepubertal ADG on profitability appears to be very flat over the range of 1.9 to 2.5 lbs/ of PP-ADG. Considering that most of the experimental measurements were done with PP-ADG at less than 2.2 lbs/d, a rational decision would be to target a PP-ADG of 2.0 to 2.1 lbs/d and to call it a day.

In short, when considering different actions requiring different investments, one must:

1. *Bring all future flows of money into today's dollars*, and

2. *Account for the different lifespan of the investments required by the different actions*.

Because We Live in an Uncertain World

When a person is uncertain about the consequences of his decision, he faces risky choice. In the past, people studying how decisions are made differentiated the cases of decisions when the probability of different outcomes could be ascertained (decision under risk) from those decisions when probability of outcomes was unknown (decision under uncertainty). In this paper, I adopted the modern position that the degree of knowledge regarding the probability of outcomes is a continuum. Thus, I will use the term decision under uncertainty to characterize decision making when outcomes are uncertain regardless of the degree of knowledge regarding the probability of each outcome.

Decision-making under uncertainty is difficult to rationalize but procedures exist to allow the process to be systematized. This set of procedures is known as decision analysis. The discipline studying decision under uncertainty is known as decision theory.

Uncertainty changes the optimal decision. For example, we are quite certain that every one of us will die. There is much uncertainty, however, whether you will die next year. If we could know this for sure then there would be two distinct optimal courses of action. If you knew with certainty that you were to die next year, then you should be buying as much life insurance as you can. If you knew for sure that you were not going to die next year, then you shouldn't buy any life insurance at all. Because of the uncertainty regarding the timing of one's death, most of us decide that it is best to carry some life insurance, not as much as if we knew we were going to die, but more than if we knew that we weren't. Of course, this simplistic example assumes that life insurance companies are unaware of the timing of our death. In reality, insurance companies play the counter-game, betting that you will live. When indications point to the contrary, they just refuse to insure you. Which is why it is hard for a person on death row to buy life insurance!

Uncertainty implies variance of outcome and this variance must be considered in decision-making. Here is a very simple example to illustrate this:

Case 1. I put two piles of money in front of you: pile A contains $100; pile B has $101 (there is no trick here). Which one would you choose? The answer, of course, is pile B (at least for most of us) because we known the outcome with certainty and we prefer more money to less.

Case 2. Pile A still has $100. This time, pile B has $202, but if you choose this pile, you will have to first flip a coin (a fair coin). If you flip a head, you walk away with the $202. If you get a tail, you get nothing. Which option would you choose? The expectation from pile B is $101 (i.e., (202 x 0.5) + (0 x 0.5)). That is, if were to repeat this process over and over, on <u>an average</u> you would walk away with $101. But some people are uncomfortable with the prospect of walking away empty handed half the time.

Case 3. Pile A still has $100. This time, option B is different. You flip the coin and if you get a head, you receive $302. If, however, you get a tail then you have to pay $100. Which option do you choose? The expectancy (i.e., on an average) is still $101 for option B (302 x 0.5 – 100 x 0.5) but a good proportion of people feel very uncomfortable with the prospect of forking out $100 half the time.

Case 4. Many will argue that in Case 3, the potential loss of $100 is really no big deal. In Case 4, pile A still has $100. Option B is different. You flip a coin. If you get a tail, you must give me everything you own: farm, cows, land, boats, cars, airplanes, etc, (everything except your teenage kids)! So if you get a tail, you walk away completely ruined. If you get a head, however, I will double everything that you own and I will throw $202 on top of it. Which option do you choose? Notice that the expectation of option B is still a net gain of $101, one more dollar than option A. So, if all you were considering for making decisions were <u>averages</u>, than you should choose option B. Most, if not all of us, however would take option A.

Going from Case 1 to Case 4, the expected gains (the averages) of option A and option B did not change, but the variance of the outcome for case B increased from zero in Case 1 to a very large variance in Case 4. There is a point where the variance exceeds our threshold of comfort, our tolerance for risk. This threshold varies across individuals. With advancing age, people tend to become more risk avert whereas younger people are more tolerant to risk. My teenage son would probably choose case 4 because (1) he owns very little, and (2) he has a whole lifetime (which looks rather short when he is driving my car) to recoup his losses if he were to get a tail.

Decision-making in dairy farming is a process very similar to the four cases that we just covered except that there are many more piles and that we are not so sure about the probability of each outcome; we are no longer flipping a simple coin. Consequently, as we contemplate the different decision options we try to peek under the coin tossing machine before we make a decision: we seek data, information to tell us whether the coin will land on a head or tail.

Assume that you are a farmer in the Midwest. It is mid-May and your alfalfa crop is at the optimal stage of maturity for harvest. You will store the crop as haylage, so you need one full day of good weather. If you harvest and it rains, much of the crop value is lost. If you harvest and it doesn't rain, you have perfect silage in your silo. What should you do? Do you cut the alfalfa or not? In a moment of brilliance, you think about getting additional data: you will seek a weather forecast for the day. You have four options where to get your forecast from:

a. your two-year old son,
b. your teenage daughter (she knows everything…),
c. the weather bimbette on the TV weather station, or
d. the National Weather Service.

Do you have the same confidence in each of the forecaster? Most certainly not, so our decision-making process must account for the quality of the data, the quality of the information used to assist in decision-making.

This haylage-making example can be used to make an additional point. One option is always to delay the decision: wait until tomorrow. This way, you know for sure that the crop will not get rained on after being cut today. But by tomorrow, the crop will have aged by one day and its nutritional value will be reduced. Thus, there is an inherent cost in delaying the decision. There is always an opportunity cost in delaying a decision. Sometimes it is best to absorb this cost and wait for better information (data); other times the cost of the delay exceeds it value.

A Classic Tool: the Cost-of-Being-Wrong Analysis

We will use a simple example (actually an over-simplified example) to illustrate how to perform a cost-of-being-wrong analysis. We have a herd of cows and we must decide whether to use bST or not. Table 7 shows the partial budget that we will use to make our decision. If we were certain of prices and outcomes, the optimal decision would always be to use bST. Thus, under certainty, every coherent and rational dairy producer would be using bST. So why is it that only a portion of all U.S. herds use bST (we conveniently ignore the recent supply problem as a contributing cause)? Either we believe that the U.S. population of dairy farmers is made up predominantly of morons, or else uncertainty alters the decision making at least in some instances.

A cost-of-being-wrong analysis consists of setting a matrix of decision options (columns) and possible outcomes (rows). For each combination of decision and outcome, we calculate the change in net revenues (Table 8). In our example, there are two possible decisions: either we use bST or we don't. The two possible outcomes are: bST works and we get a response of 12 lbs/cow per day, or bST does not work, in which case we get no additional milk, but we incur the expense of bST plus the labor cost. Of course, if we decide not to use bST, our net income does not change regardless of whether bST would have worked or not. We can then calculate the expected change in net revenues for different frequencies of success. Using this approach, it becomes clear that a decision-maker must expect bST to work more than 40% of the time for the decision to use bST to be the optimal one.

Results presented in Table 8 were calculated using averages. They did not incorporate the uncertainty of prices and magnitude of response. Table 9 shows the same cost-of-being-wrong analysis, this time using conservative (pessimistic) values for the price of milk ($12/cwt), feed prices ($0.09/lb of DM), and magnitude of net response (6 lbs of milk/d). A risk-avert decision-maker would have to anticipate a probability of success of 99% or greater for the optimal decision to be to use bST.

The effect of uncertainty in this decision-making problem is substantial. Without uncertainty, every dairy farm should use bST. When elements of uncertainty were introduced, the technology must have a rate of success that exceeds 40% if it is to be used. When uncertainty and risk aversion are considered, the rate of success must exceed 99% for risk-avert decision-makers to adopt the technology.

Final Words

Procedures in decision analysis serve as aids and do not replace the intangible quality of good decision makers. Twenty years of work in this industry have shown me that excellent decision makers are those who:

1. Know when to make a decision,
2. Known when there is sufficient information,
3. Know that a good decision does not guarantee good outcomes,
4. Make decisions with higher frequencies of favorable outcomes than bad managers, and
5. Can separate trivial decision making questions from the important ones.

Table 1. Year-end balance sheet for Blue Bird farm.

	$
Assets	
Current farm assets	152,000
Intermediate farm assets	1,335,000
Long-term farm assets	2,168,000
Total farm assets	3,655,000
Liabilities	
Current farm liabilities	123,000
Intermediate farm liabilities	207,000
Long-term farm liabilities	1,402,000
Total farm liabilities	1,732,000
Farm net worth	
Owner equity	1,923,000

Table 2. Income statement for Blue Bird Farm for the year preceding the decision to build facilities.

	$	$/cwt
Accrual receipts		
Milk sales	1,396,000	15.20
Livestock	81,000	0.88
Crops and other receipts	10,000	0.11
Total accrual receipts	1,487,000	16.19
Accrual expenses		
Feed and crops	572,000	6.23
Hired labor	136,000	1.49
Livestock	180,000	1.96
Machinery	122,000	1.33
Real estate	83,000	0.90
Other	204,000	2.22
Total operating expenses	1,297,000	14.13
Expansion livestock	5,000	0.05
Depreciation	160,000	1.74
TOTAL ACCRUAL EXPENSES	1,462,000	15.92
Net farm income without appreciation	25,000	0.27

Table 3. Farm financial indicators used in the financial analysis of the farm business.

Indicators	Blue Bird Farm	Target Benchmarks[1]
Liquidity		
1 – Current ratio	1.24	>1.25
2 – Working capital ($)	29,000	125,000
3 – Cash flow coverage ratio	1.67	>1.25
Solvency		
4 – Debt/asset ratio (%)	47	<40
Profitability		
5 – Return on farm assets (%)	1.6	>6
6 – Return on equity (%)	-4.2	>6
7 – Operating profit margin ratio (%)	4.0	>15
Repayment capacity		
8 – Term debt coverage ratio	0.9	>1.3
9 – Capital replacement and term debt repayment margin	-25,000	>70,000
10 – Debt/income ratio	69.3	<10
Financial efficiency		
11 – Asset turnover ratio (%)	40.5	>50
12 – Operating expense ratio (%)	78.3	<65
13 – Depreciation expense ratio (%)	10.8	<12
14 – Interest expense ratio (%)	9.3	<12
15 – Net farm income ratio (%)	1.7	>20
16 – Labor productivity ratio (%)	6.3	n/a
17 – Machinery and equipment productivity ratio (%)	2.9	n/a

Table 4. Pro forma analysis of the investment in heifer facilities.[1]

Criteria	Base	Year 1	Year 2	Year 3	Year 4
Average number of heifers	380	390	403	384	409
Milk sold (cwt/y)	91,841	93,083	94,117	102,391	105,080
Operating cost of milk sold ($/cost)	14.23	14.15	14.04	13.54	13.39
Farm capital per cow ($)	8032	8058	7998	7408	7275
Milk sold per worker (lbs/year)	941,963	954,692	965,300	1,042,675	1,062,485
Labor cost ($/cows/per y)	428	422	418	388	385
Liquidity					
Working capital ($)	29,000	28,000	23,000	14,000	38,000
Net cash farm income ($/y)	137,000	147,000	158,500	223,500	245,000
Solvency					
Debt-to-asset ratio	48.6	47.8	44.5	41.2	37.8
Profitability					
Net farm income ($/y)	25,000	23,000	34,500	100,000	121,000
Return on farm assets (%)	1.4	1.3	1.3	2.7	3.0
Return on equity (%)	-4.0	-4.1	-3.2	-0.2	0.7
Operating profit margin ratio (%)	4.0	3.2	3.2	6.2	6.7
Repayment capacity					
Term debt coverage ratio	0.85	0.89	0.90	1.06	1.26
Capitol replacement and term debt replacement margin	-35,402	-25,619	-23,414	14,332	52,231
Debt/income ratio	69.3	75.3	47.0	15.1	11.5
Financial efficiency					
Asset turnover ratio	40.5	40.4	40.7	43.9	44.7
Operating expenses ratio	77.6	77.2	77.4	75.7	75.6
Depreciation expense ratio	11.1	11.8	11.6	10.7	10.4
Interest expense ratio	9.6	9.4	8.7	7.4	6.7
Net farm income ratio	1.7	1.6	2.3	6.2	7.3
Labor productivity ratio	6.1	6.2	6.2	6.6	6.7
Rate of return on added investment	-	-2.4	-0.7	31.5	32.9

[1]Milk price set at $15.20/cwt as in the base year.

Table 5. Economic analysis of the pre-pubertal rate of gain decision.

	Pre-Pubertal Rate of Gain (lbs/d)					
	1.54	1.76	1.98	2.20	2.43	2.65
Body wt. at 92d (lbs)	200	200	200	200	200	200
Total costs: birth to 92 d ($)	152	152	152	152	152	152
Age at 800 lbs (mo)	15.8	14.2	12.9	11.9	11.1	10.5
Age at first freshening (mo)	25.3	23.7	22.4	21.4	20.6	20.0
First lactation yield (lbs)	19,914	19,456	18,997	18,536	18,078	17,617
Second lactation yield (lbs)	22,542	22,542	22,542	22,542	22,542	22,542
Third lactation yield (lb)	23,600	23,600	23,600	23,600	23,600	23,600
Total cost of 1st freshening ($)	1202	1152	1114	1083	1059	1041
Lifetime revenues ($)	8451	8392	8334	8275	8216	8157
Lifetime total costs ($)	7304	7242	7190	7147	7110	7079
Lifetime net income ($)	1797	1800	1794	1778	1756	1728
Lifetime NPV of net income ($)	1139	1164	1174	1169	1167	1151
Investment life (y)	4.95	4.81	4.71	4.63	4.56	4.50
Equivalent annuity ($)	288	301	309	312	316	315

[1]Based on daily feed costs of $0.95, $1.00, $1.05, $1.11, $1.17, $1.24 for each prepubertal ADG and non-feed costs of $0.45/d between 200 and 800 lbs; daily total costs of $1.75 from 800 lbs to calving; feed costs for maintenance during lactation of $1.10/d; and feed costs per lbs of milk of $0.028; fixed costs during lactation of $3.00/d; mean value of calf at birth is $50; salvage value at culling is $500.
[2]Calculated using an annual discount rate of 8%.

Table 6. Three cases to illustrate the concept of net present value (NPV) on a $1,000 investment with different flows (annual payments) over five years.

	Cases		
Time (year)	1	2	3
	flow of $		
0 (initial)	-1000	-1000	-1000
1	999	1	200
2	0	0	200
3	0	0	200
4	0	0	200
5	1	999	200
Sum of all returns ($)	1000	1000	1000
NPV ($) @ 5%/y	-45.51	-206.00	-127.72
NPV ($) @ 8%/y	-68.81	-295.53	-186.54
Years to pay back	5	5	5

Table 7. Partial budget for cost-of-being-wrong analysis of bST decision problem.

	Mean change ($/cow per d)
Milk revenues: 12 lbs x $0.13	1.56
bST	(0.45)
Feed: 4.8 x $0.07	(0.37)
Labor	(0.05)
Total	0.69

Table 8. Cost-of-being-wrong analysis for the bST decision problem (changes in net revenues per cow, per day).

	Decisions		
Outcomes	use bST	do not use bST	
bST works	$0.69	$0.00	
bST does not work	-0.50	$0.00	

	Expected change in net revenues		
Probability of Success (%)	use bST	do not use bST	Optimal Decision
30	-$0.14	$0.00	do not use
40	-$0.02	$0.00	indifferent
50	$0.10	$0.00	use bST
60	$0.21	$0.00	use bST
70	$0.33	$0.00	use bST

Table 9. Cost-of-being-wrong analysis for the bST decision problem: risk avert decision maker (changes in net revenues per cow, per day).

	Decisions		
Outcomes	use bST	do not use bST	
bST works	$0.02	$0.00	
bST does not work	-0.50	$0.00	

	Expected change in net revenues		
Probability of Success (%)	use bST	do not use bST	Optimal Decision
50	-$0.24	$0.00	do not use
60	-$0.19	$0.00	do not use
70	-$0.14	$0.00	do not use
80	-$0.08	$0.00	do not use
90	-$0.03	$0.00	do not use
95	-$0.01	$0.00	do not use
99	$0.01	$0.00	use bST

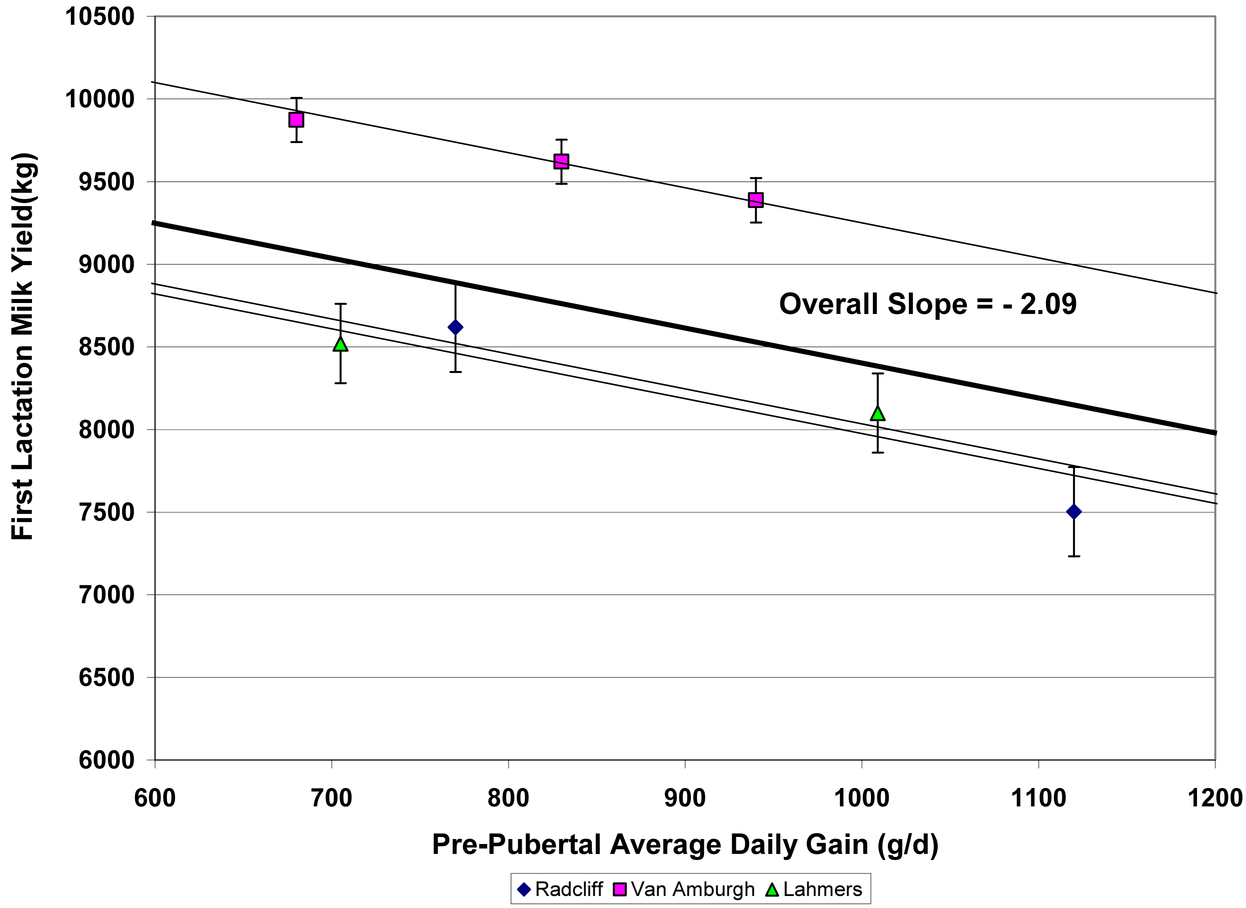

Figure 1. Response of first lactation milk yield to change in pre-pubertal average daily gain.

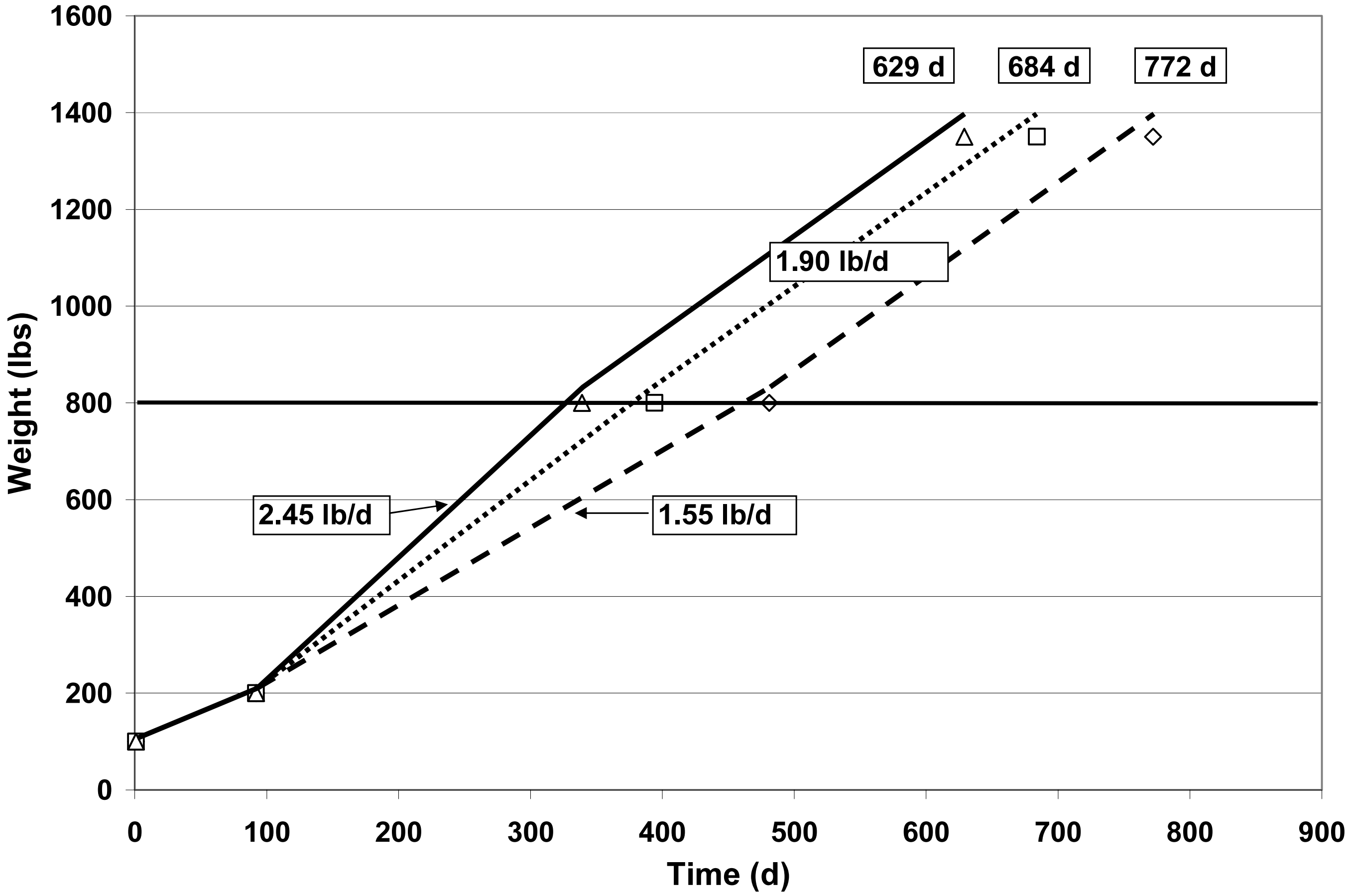

Figure 2. Illustration of pre-pubertal rate of gain strategies and their effect on age at first freshening.