Case Study

Even Robots Need a House: The Robotic Milking System Facility Investment Decision Case Study

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Abstract
In a classic labor vs. capital trade-off, some dairies are opting to install automatic milking systems (AMS). AMS has the potential to increase efficiencies but comes at a cost. Although the AMS units themselves are costly, the facility that houses them can often be a more significant expense. This case presents a fictional family dairy, typical for the western United States, that is now considering adoption of AMS. The case analyzes the economics of installing AMS under three facility investment scenarios; minimal retrofit to an existing facility, building a new open-sided barn, and building a new fully enclosed barn. This case study provides an opportunity to apply capital budgeting to a modern agriculture investment and addresses broader questions related to technology investment and adoption on farm.

1 Introduction

As Billy and Kelly Clark left the branch of the local farm credit agency, they reflected on the conversation they had with their loan officer, Dave. They had come to the branch to sign loan documents for the renewal of their annual operating loan. While the renewal was completed without any major concerns, the Clarks could not help but feel somewhat discouraged as they drove back home to their 144-cow dairy. The dairy is a small, family dairy typical of one in the intermountain region of the western United States and has been in the family for multiple generations. The dairy represents the Clarks' entire way of life. However, the current dairy landscape has given the Clarks reason enough to doubt the long-term viability of their operation without making substantial changes. The Clarks stand at a turning point in their operation and are ready to make the necessary changes to continue to compete in the dairy industry. They are considering the implementation of automatic milking systems (AMS). It would undoubtedly be a costly investment, and the Clarks want to make sure they maximize the potential payoff of such an investment. The automatic milking units themselves are costly, and the facility to house the units could be even more costly. Through their own research, the Clarks had learned that there are advantages and disadvantages to the various types of facilities to house the automatic milkers. As the Clarks consider making the change to AMS, they wonder which type of facility would be the best for their operation. Which would be the most efficient? Which would have the potential to best maximize their return on investment? Answering these questions would ultimately help them make their facility investment decision when converting to AMS.

The following case study for a family-operated dairy analyzes the economics of installing AMS under three facility investment scenarios; minimal retrofit to an existing facility, building a new open-sided barn, and building a new fully enclosed barn. This case study provides an opportunity to apply capital budgeting to a modern agriculture investment decision, while addressing questions related to technology investment and adoption on farm.

1.1 History of AMS

AMS, or robotic milkers, were first developed and introduced in Europe to address labor shortages in the early 1990s. By 2000, AMS technology had made its way to the United States (W.K. Kellog Biological Station, W.K. Kellogg Farm 2019). Since that time, AMS has steadily grown in popularity and has benefited from continued technological improvements (De Koning 2010). When a cow enters an AMS unit, the teats are located using a laser and then cleaned and prepared for milking. The AMS milks all four teats simultaneously and collects useful data on each cow and milk production. The cow is enticed to come back to the AMS by the unit providing a feed grain mixture to enjoy while milking. These systems have been shown to often increase milk productivity as well as gather useful data that can be used to monitor the herd and milk productivity more fully (Rossing et al. 1997).

1.2 Current Dairy Landscape

For some time now, the U.S. dairy industry has been declining in the number of operations as well as total number of milk cows, while simultaneously the number of cows per operation has been increasing. Additionally, the industry has seen tremendous growth in average production per cow. In 2005, 9 million U.S. dairy cows produced an average of 19,550 pounds per cow. In 2018, 9.4 million U.S. dairy cows produced an average of 23,149 pounds per cow (U.S. Department of Agriculture 2019). This increase in production is in contrast to decades-long decreases in per-capita demand. In 1975, the average American drank roughly 30 gallons of milk annually, while present per-capita annual consumption has fallen to about 18 gallons (U.S. Department of Agriculture 2018). Falling per capita consumption together with increased production results in excess supply and low milk prices, which in turn results in tight profit margins. From 2017 to 2018, the number of licensed dairy farms in the United States decreased by 6.8 percent (Dickrell 2019). Dairies surviving in the industry are getting larger on average to help combat low profit margins.

Labor shortages are also currently affecting the dairy industry. The U.S. labor economy is strong, with wages and employment in many categories reaching record highs. As the unemployment rate falls, wages are pushed to higher levels to compete for laborers. The growth in wages puts increased pressure on the already tight dairy profit margins. The U.S. dairy industry relies heavily on immigrant labor. According to a national dairy labor survey conducted by the National Milk Producers Federation, immigrant labor accounted for 51.2 percent of the U.S. dairy labor pool in 2013 (Adcock, Anderson, and Rosson 2015). Tightening regulations surrounding immigrant labor only further intensifies the pressure on the already difficult dairy labor situation. Additionally, even if immigrant laborers were readily available, it is becoming increasingly difficult for dairy farmers to compete with other industries for these laborers' services. As wage rates increase in other industries, such as manufacturing, construction, transportation, and mining, it becomes more difficult to find immigrants willing to work within agriculture. Similar to the United States, birth rates in Mexico are falling, and populations are moving toward urban areas. This results in fewer people with agricultural backgrounds who would be interested in U.S. farm work.

1.3 Problems for the Clark Dairy

These trends are all too evident in the Clarks' community. They have already seen numerous other small dairies driven from the industry because of the decreased demand, tight profit margins, and labor scarcity. Lately their own profit margins have been thin, but thankfully, their herd has been healthy and production has been high. Up until this point, the Clarks have not had much of a labor problem, as they have managed to keep the dairy running by both working full-time themselves, as well as with the aid of their three children. However, with their youngest daughter Julie recently graduating high school and joining the military, the availability of qualified labor is now in the forefront of the Clarks' minds. The Clarks are in their mid-fifties, and both of them feel they are healthy and should be able to continue working for many years. However, it would take more than the two of them to continue operating the dairy. In the past, they had always relied upon their three children to help with day-to-day operations and had always thought that one day one of the children would take over full time. Recently, they have come to the realization that passing the dairy to the children is an unrealistic succession plan. Their eldest son, Michael, received his degree at the local state university in agribusiness several years ago and is now currently working for a large seed distributor in the supply chain department. He loves his job and loves the stability of his career. Though he always enjoyed working on the family dairy, he has no intentions of leaving his career. Their middle daughter, Stacy, also enjoyed working on the dairy and loves agriculture. However, after recently marrying a potato farmer from southern Idaho, she is now unable to continue working on the dairy.

Without the help from their children, the Clarks know it will be nearly impossible to keep the dairy running without additional hired labor. Farm labor in the local community is hard to come by, expensive, and unreliable. Often farms end up competing for labor, and workers leave for greener pastures. Aside from the unavailability of laborers, the Clarks are also beginning to long for more flexibility in their lives. For as long as they have been married, they have been tied to the dairy. Running the dairy is a full-time business with no weekends or holidays off. The work is relentless, and there is no time for relaxation or vacation. With the kids grown and out of the house, the Clarks are now longing for some added flexibility to have time to make quick visits to see their children and continue to be a part of their lives.

Given the current situation, the Clarks are beginning to consider the drastic change to AMS. They are at a crossroads, and something has to give. A couple of the regional dairies have recently installed AMS. The robotic milking systems are attractive to the Clarks because of their potential to produce increases in efficiency such as increased pounds of milk per cow, pounds of feed to pounds of milk conversion, and pounds of milk per hour of labor. Of more importance to the Clarks, however, is that AMS is a classic capital for labor tradeoff. For some dairies, AMS has proven to be a successful way to innovate and manage the labor shortage problem within the industry. Almost like folklore, stories have been circulating between the local dairymen about how a family that installed AMS on their dairy recently took a quick two-day trip to attend a relative's wedding in Oregon, while leaving the dairy solely in the hands of one capable hired hand. A story such as this is enough to make any conventional dairyman envious, and the Clarks are no exception. Almost immediately upon hearing this story, the Clarks began researching AMS and exploring the possibility of installing robots on their farm. It was not long before they were completely sold. They were ready for change and felt like it was now or never, as they were making the transition to having no children available to work on the farm.

After signing the operating loan renewal documents, the robots quickly became the center of the conversation with Dave. They had explained their reasoning and benefits to implementing AMS and asked Dave what his thoughts were and if it would be something that farm credit could help finance for them. Dave indicated that he would be glad to help in getting the financing ready for their request but had some questions for them. He let the Clarks know farm credit had recently helped one of the other local dairies finance AMS and said he was well aware of the potential increases in efficiency and flexibility these systems can provide. However, he also mentioned these benefits come at a cost, specifically, the cost of the AMS units, facilities to house them, and annual maintenance and repairs. For their 144-cow dairy, Dave knew two robots would be necessary to keep up with the milking. Each robot alone would cost approximately $190,000. Dave explained that the cost of the robots is, to a large degree, fixed and out of their control.

The cost of the facility to house the robots, however, he explained is much more variable and requires important decisions on their part that could have different consequences for their operation moving forward. He asked about what type of facility investment they had planned and how they had come to that decision. The Clarks were aware that different types of facilities offered different pros and cons for an AMS dairy, but to this point had not given the facility much thought beyond thinking they would simply retrofit their existing facilities to accommodate the robots. They indicated this to Dave and explained that they thought this would be the most economical way to switch to AMS. Dave cautioned them against making this hasty assumption. He explained that the greatest efficiency gains from AMS could be expected with a fully enclosed barn, designed with cow comfort in mind. The fully enclosed barn allows the cows to be more relaxed, free from the effects of weather, and the buildings can be designed for cows to free flow to the AMS. Efficiency gains without this level of investment in a new facility are still possible but to a lesser degree. Thus, before concluding their conversation, Dave challenged the Clarks to explore more fully the question of what level of facility investment they intended to go with. Dave indicated they could expect the terms and interest rates for the AMS and facility loans to be approximately 7 years at 5.5 percent and 15 years at 6.5 percent, respectively, each requiring a 20 percent down payment. They set up an appointment to meet again in a week at which time Dave indicated they could talk over the terms of the loans more specifically once the Clarks had made a decision on what type of facility investment they felt was best.

2 Analyzing the Investment

That evening the Clarks sat around their kitchen table and began to wonder how to answer the facility investment question presented by Dave. They knew that just because retrofitting their existing facility may represent the cheapest option it might not have the best long-term pay off potential. They knew they needed to find a way to evaluate the facility investment decision economically. They called their oldest son Michael and asked him how he would approach this problem. He told his parents he would be right over. Upon arrival, he joined them at the table and pulled out his laptop. He explained that he had taken an agribusiness class during his time at the university that covered these types of questions. He pulled up an Excel worksheet titled “Capital Budgeting Template.” He told them about how they had built this template in class and what type of analysis it could handle. He dug through some old folders in his computer and found his class notes on capital budgeting. Feeling like his agribusiness professor, he began to explain the concept of capital budgeting.

> “We need to identify the key variables or what will be changing on the farm if we invest in these robots,” Michael said.

Kelly pulled out a legal pad and began to build a list under the heading “Key Variables.” The first key variable would be the initial cost of the project. In this case, it would be the cost of two robots and facility investment. They all agreed they would look at three initial facility cost scenarios. The first being retrofitting the current barn, the second being building a new open-sided barn, and the third being building a new fully enclosed barn. From their conversation with Dave, they knew they could expect the greatest efficiency gains with the third scenario, the lowest with the first, and the second scenario falling somewhere in between. The second key variable would be changes to production and costs due to the robots. The Clarks had previously contacted their county extension agent as they were exploring AMS, and they now recalled that he had forwarded them some research on the costs and benefits of AMS. The research provided them a range of productivity gains, cost savings, and herd health changes. This information would help them estimate the annual change to cash flow upon installing AMS under each of the three facility investment scenarios. The third key variable would be the length of the investment. They decided to rely on the information provided by the AMS manufacturer. The company claims each AMS has a useful life of 15 years. The fourth key variable would be the salvage value of the investment. This was more difficult because a strong market for used AMS did not exist, as most that had been installed in the area were still in production. Again, they chose to rely on the advice of the AMS manufacturer and use a salvage value of $40,000 per AMS. They used a simple straight-line depreciation method for annual depreciation cost over the 15-year useful life of the AMS as well as the facility, with the facility having a salvage value of 15 percent of the initial cost. The final variable would be the discount rate or opportunity cost of investing in the project. The Clarks were confused about this concept, so Michael once again pulled out his class notes and explained the purpose of the discount rate.

> “The discount rate is used to account for the time value of money, the risk of the investment, and the cost of funds used to finance the firm. I remember my professor explaining that the funds used to finance a firm could come from either debt or equity or both. The key is to figure out what the

cost of our debt and equity are and then we can get to our discount rate. If I remember correctly, he called this the weighted average cost of capital," Michael explained.

He then explained to his parents the weighted average cost of capital (WACC) method to come up with a discount rate.

WACC simply uses the cost of debt, cost of equity, and the proportions of each to estimate the discount rate. The cost of debt is simply the contractual rate of interest on loans. This rate could come from the annual operating loan, or if the farm has multiple loans, it could come from the average interest rate across all loans. The cost of equity is more difficult to estimate. In theory, the cost of equity represents the opportunity cost of having equity capital invested in the farming operation. The cost of equity can be estimated by looking at historical returns on equity (ROE). Caution should be exercised in choosing the time period to estimate cost of equity because it is dependent on the profitability of the firm. For that reason, an average ROE is preferred over a single time period measurement. The final piece in estimating WACC is to use the balance sheet to calculate the capital structure of the firm. The capital structure is the mix of debt and equity. The percentage of debt and equity provide the weights used to estimate WACC. For example, if a firm had 60 percent debt, 40 percent equity, 5 percent cost of debt, and 6 percent cost of equity, WACC could be calculated as:

$$WACC = w_d K_d + w_e Ke$$

$$WACC = (.60 * .05) + (.40 * .06) = 0.054$$

"Now that we have all the key variables," explained Michael, "we can put them into my Excel spreadsheet and estimate the net present value (NPV) of the investment."

"Wait a minute," said Billy. "What is this NPV?"

Michael explained, "NPV is simply the difference between the present value of future cash flows of the investment and the cost of the investment. If that difference is positive, then the investment is profitable. If that difference is negative, then it is not a profitable investment. When comparing NPV calculations between investments, the higher the NPV the better the investment."

Billy nodded in agreement, and then a concerned look came over his face. "What about the debt payments? We have talked about the outflow, inflows, and profitability. That is all good and well, but if we can't make the payments, what good is all this stuff. Dave will want to know if we can make the payments on the new loan."

Michael agreed and sat there for a moment. Then he scrolled down in his Excel template and saw the section titled "Financial Feasibility." He recalled his professor discussing the difference between NPV and financial feasibility.

Michael explained to his parents, "Financial feasibility uses the cash flows from the NPV portion and then subtracts the debt payments to analyze whether the project is financially feasible. Financially feasible simply means that the investment generates enough cash flow to make the debt payments. If there is not enough cash flow to make the debt payments, then the investment would not be financially feasible."

The Clarks smiled and agreed that they were ready to analyze the investment.

The Clarks first made the necessary assumptions for changes in cost and efficiency gains based off the research the extension agent had provided. Then they organized all the key assumptions and variables into two tables. In the first table, they listed all the project analysis assumptions that all three scenarios would have in common, such as the size of the dairy herd, number of AMS units required, the labor rate, etc. This information is found in table 1. The second table contained a summary of key variables that could vary between the scenarios such as the cost of the facility, anticipated labor hour reduction, milk production change, etc. This information is summarized in table 2.

Most of the key variables contained in table 2 are intuitively understood, such as “milk production increase.” This is just the increased milk production under each scenario expected as a result of switching to AMS. However, some of the variables may be less intuitively understood and warrant further explanation.

Software Value per Cow/Year: increases to income can be expected due to the increased precision management abilities afforded by the AMS computer system. The herd management software included with AMS has the ability to track and record rumination data, milk conductivity, and cow activity, and the computer can send out timely reports to managers to alert them of any significant changes or potential problems. The software also heightens mastitis and heat detection ability.

Reduced Feed Savings: it is typical on many western dairies to feed the cattle along feed bunks that are not enclosed and that are fully exposed to the weather. This results in wasted feed from rain, snow, sunshine, and birds. Covering the feeding area in an open-sided barn reduces much of this feed waste while feed waste is eliminated in fully enclosed barns.

Table 1. Project Assumptions

Assumption	Value
AMS Salvage Value	$40,000
Number of AMS	2
Cost per AMS	$190,000
Number of Cows	144
AMS Useful Life	15
Labor Rate per Hour	$15
Insurance Rate per $1,000 Value	0.5%
Tax Rate	0.15
Milk Price per cwt.	$17.91[a]
Loan to Value Ratio	0.8
Facility Loan Term (years)	15
Facility Loan Rate	6.5%
AMS Loan Term (years)	7
AMS Loan Rate	5.5%

[a] 10-year average milk price (Livestock Market Information Center 2019)

Table 2. Key Variables for the Three Facility Investment Scenarios

Variable	Scenario 1	Scenario 2	Scenario 3
Facility Cost	$70,000	$470,000	$920,000
Milk Production Increase (lbs./Cow/Day)	4.35	7.61	11.60
Repair Cost per AMS/Year	$7,000	$7,000	$7,000
Labor Reduction (Hrs./Day)	6.25	7.65	8.4
Software Value per Cow/Year	$40	$40	$40
Net Change in Utilities Per Cow/Year	$5.75	$5.75	$5.75
Increased Feed Costs	$7,129	$9,533	$13,594
Reduced Feed Savings (Eff./Waste)	$2,858	$10,426	$22,366
Facility Salvage Value	15%	15%	15%
Facility Useful Life	30	30	30

Increased Feed Costs: To produce more milk requires more feed. Notice that the increased feed costs associated with AMS can be somewhat offset by the "reduced feed savings." Net Change in Utilities per Cow/Year: while admittedly small, there is also often a noticeable increase in utilities needed to run an AMS dairy as compared with more conventional practices.

3 Results and Sensitivity Analysis

After summarizing the key variables, they all turned their attention to Michael's laptop as he quickly began inputting the assumptions for the key variables for each scenario into three copies of the "Capital Budgeting Template." It was not long before he had filled in the template with the necessary information to calculate the NPV for each of the three scenarios. They then input the debt payment information based on the terms they had discussed with Dave for both the equipment and facility loan and again calculated the NPV for the financial feasibility sections.
Michael organized the resulting calculations for all three scenarios and placed them in a single table for ease of comparison. The results for all three scenarios are summarized in Table 3.

> As the Clarks looked over the results, Kelly said, "Based on our discussions about NPV, it appears scenario 3 would be the best option because it has the highest NPV for the project analysis." Michael quickly countered, "That would be correct if we were only worried about project profitability and did not consider financial feasibility. We should focus our attention on the financial feasibility results because we are most concerned with the viability of the project when debt payments are considered."

The NPV calculations under the financial feasibility section clearly favored scenario 1; the minimal retrofit of existing facilities.

> Billy asked, "What is the IRR?"

> Michael responded, "IRR stands for internal rate of return. It simply represents the discount rate that would make the NPV calculation equal zero."

He further explained that the IRR could be thought of as the maximum discount rate that an investment will support. Any discount rate above the IRR would cause and investment's NPV to be negative and indicate that the investment would not be feasible.

> Following Michael's explanation Billy said, "In that case, it appears that based on IRR, again scenario 1 appears to be the direction we should take."

Michael agreed but also pointed out that all three investment scenarios had positive NPV and IRR for the financial feasibility analysis.

Table 3. NPV and Internal Rate of Return (IRR): Project and Financial Feasibility for the 3 Investment Scenarios

Level of Analysis	Measure	Scenario 1	Scenario 2	Scenario 3
Project Analysis	NPV	$160,326.78	$228,201.56	$307,177.96
	IRR	9.5%	8.5%	8.1%
Financial Feasibility	NPV	$100,781.47	$82,870.68	$64,945.74
	IRR	10.7%	8.3%	6.9%

> "All three investments appear to be doable," he said, "but it's important for us to remember that these results all assume no variance in the assumptions we input."

He explained how this could sometimes make a big difference in capital budget analysis because without allowing for variance, they essentially eliminate risk from the analysis. Michael explained that in his college course the professor emphasized the importance of considering the riskiness of an investment by considering the individual riskiness of the input assumptions.

> "For example," Michael said, "We have assumed milk production will increase in the third scenario by 11.6 pounds of milk per day. But how much do we expect this assumption could vary."

They all agreed that this was a good point and that they would need to consider the riskiness of all the assumptions of the analysis before making a decision. If the assumption of 11.6 pounds of milk per day was increased by 10 percent to approximately 12.76 pounds of milk per day in the third scenario, perhaps it would look like the more attractive option. Following this logic, Michael demonstrated how they could perform a "sensitivity analysis" of sorts by changing key input assumptions either upward or downward by a set percentage to help them get a better feel for the riskiness of each investment scenario. The Clarks agreed variables such as milk price, labor rate, salvage value, milk production increase, increased feed costs, feed savings, and the initial cost of the facility were all important variables to consider when evaluating risk. As the Clarks discussed the riskiness associated with these key variables, they began making changes to their Excel spreadsheet to evaluate the effects of variance in these key variables.

After spending many hours into the night evaluating the impacts of risk in their analysis, they eventually all felt like they had come to a consensus of what investment they should choose. All that was left was to present their results to Dave the following week and secure the financing needed to undertake their chosen investment. Only time will tell if they chose wisely!

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