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CASE STUDY

Automated Milking Systems: A challenge and opportunity for Midwest Dairy Farmers

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The Pioneer Farm

Today, Friday, June 21, 2024, is an important date for the Schmidt family. *Grandpa Joe*, 80 years old, has decided to retire after dedicating 60 years of hard work to ***Pioneer***, his dairy farm. Located near Madison, WI, the Pioneer farm is a cherished family legacy that has been the primary source of income for three Schmit generations. The enterprise has adapted to the dairy industry's changes and challenges throughout the decades. As Joe passes the reins to his only son, Jack, he reflects proudly on the farm's journey. With optimism, he believes the farm is well-positioned to thrive in the evolving landscape of dairy farming. Currently, the dairy operation milks 180 cows twice a day in a 20-year-old free-stall barn and parlor. Pioneer also has 1,033 acres of land devoted to cash crops, 430 of which are owned by Pioneer Farms and another 603 are rented.

Jack–who is currently 55 years old–plans to keep the operations as usual, milking the cows twice a day with the help of his wife, and occasionally hiring two or three temporary workers to help in the barn and the field. However, Joe warns him that it is currently difficult to find farm workers, expressing his frustration with recent experiences: "*We used also to get help from Martin's twins, but they are about to finish high school and want to apply to Harvard, so they are focusing all their time on studying, and our last worker, Ernesto, used to show up late almost every day; and sometimes he would not even show up! However, he knew we could not fire him because nobody else wanted the job.*"

To address the issue of labor, Jennifer, a 25-year-old animal science graduate and Jack's only daughter, proposes an alternative: modernizing the old barn by installing ***automated milking systems*** (**AMS**). Jennifer visited a couple of farms using this technology while taking a *Dairy Economics* class. "*AMS are robotic boxes that can milk cows on their own; it's super cool! The cows just walk to the machines and get milked. This could solve our issue with the workers.*"

Joe shares the vision with her granddaughter: "*Oh, right! Our neighbor Mike has just installed a couple of robots on his farm, and he really likes them. But I wanted to leave that decision to Jack, as I am about to retire.*" However, Jack expresses concerns about the financial implications of such an investment: "*I have seen the robots on Mike's farm. Yes, he was happy about it, but he also told me that each robot cost him about 200 grand! Not to mention the cost of installation and barn redesign. It is just too much money!*"

"*But imagine how much money you would save from hiring workers, and also, you can milk the cows as many times as they want!*" – Jennifer responds.

This debate–between Jack and Jennifer–continues for hours, both providing valid arguments. Joe then interjects, *"It is great to see how passionate both of you are when it comes to our farm; there is no doubt that our legacy is in good hands. I have an idea that could help with this discussion. What about hiring a consultant? Before deciding to install AMS, our neighbor Michael did the same. In fact, I have a card that Mike gave me in case I needed them."*

"Isn't that costly?" – interrupts Jack.

"No, because these are professionals working at a university; they provide their service for free to dairy farmers in Wisconsin and California."–responds Joe, while looking at his pockets – "*hey, I just found it! It is called Louis' Lab, an economic group with headquarters at UC Davis. Let's call them to hear their perspective on this issue."*

"Sounds good; in that way, we have an impartial third party"–responds Jack, to which Jennifer agrees.

"Okay, it's settled then. I will call them on Monday morning." concludes Grandpa Joe.

Louis Lab

Louis Lab is a multidisciplinary and multistate group which aims to improve the resilience of the U.S. dairy farm industry (official website: https://drlouis.us/louis-lab/). This effort is led by Dr. Luis Peña-Lévano, at the University of California, Davis. The lab also has partnerships with many universities and institutions. The lab partners are currently working on multiple projects related to dairy automation, labor issues, sustainable practices and farmers' perception of dairy policy programs.

On Monday June 24, 2024, Dr. Luis received a call from Joe requesting the lab services in order to assess the feasibility of adopting AMS on his farm. Your team is part of Louis Lab, and eagerly volunteers to conduct an economic and financial analysis for the Pioneer dairy farm. This consultancy requires a thorough analysis and will be presented on July 29, 2024 to the family.

Wisconsin Dairy Industry

Wisconsin is a dairy state, home of the largest number of dairy operations in the nation (Peña-Lévano et al., 2023). As of September 2022, there were 6,275 license herds registered in the state, with a production of 31.7 billion pounds of milk [**Fig. 1**]. Wisconsin dairies generate an annual revenue of $45.6 billion–equivalent to 14% of the U.S. milk output (Dairy Farmers of Wisconsin 2022), making it the second largest dairy producer–only surpassed by California.

The Wisconsin dairy landscape is unique, comprised of primarily small- and medium-scale dairy farms. Most of these operations are family-owned (Peña-Lévano et al., 2023), with multiple generations managing these farms. Nevertheless, in recent decades, the state is facing structural changes. Approximately 43 dairy herds close operations or have sold to a larger farm. While the production has steadily grown over time–even during the pandemic, and the number of dairy cows have remained relatively constant, the number of operations have decreased from 11,761 farms (in 2012) to only 6,275 farms (in 2022) [**Fig. 1**]. As of April 2024, recent numbers show there are only 5,595 license herds in the state, with 92% of them producing Grade A milk (DTCAP, 2024).

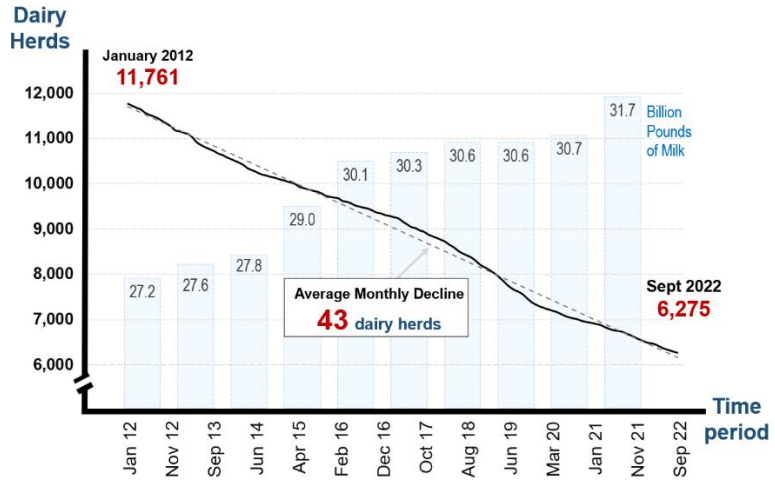

Fig. 1 Wisconsin Milk Production and Number of Licensed Herds

Source: Peña-Lévano, Burney and Beaudry. 2023. Automatic Milking Systems: An Exploratory Study of Wisconsin Dairy Farms. Journal of ASFMRA.

Dairy owners are currently facing adverse challenges, grappling with consistent declines in net returns, low milk prices, supply chain bottlenecks, labor shortage and wage pressure–issues intensified after the COVID-19 pandemic (Luckstead, Nayga Jr, and Snell 2021; Njuki, 2022; Peña-Lévano et al., 2020). Rising inflation has also led to higher feed cost, freight, fertilizer, and fuel, further exacerbating production costs (Liebrand 2022).

Wisconsin dairy farms are mostly family owned, relying heavily on family members to accomplish the daily activities of the farm (Peña-Lévano et al., 2023). Depending on the operation size, licensed herds also hire external agricultural workers. Overall, labor represents 20-30% of the total milk production cost (Tranel 2017). However, retaining farmworkers has become a major challenge for dairy enterprises, which further reduces efficiency in production. In 2008, the labor turnover ratio was 11.9% (Rosson, 2012)–higher than in other comparable industries.

Automated Milking Systems

Automated Milking Systems (AMS) are milking robots, able to milk between between 60 to 70 cows per day. Overall, AMS technology enables cows to be autonomously milked about three times daily. In order to correctly identify each animal and get consistent data, each cow has a collar (or transponder) uniquely identifying it within the system. This identification enables the AMS to track individual cow data, such as milking frequency and milk yield. When a cow needs to be milked, it can freely enter the milking station, often attracted by feed incentives or automated cleaners like brushes.

Fig. 2 Automatic Milking Systems – DeLaval Prototype

Source: Designed by the authors.

Once inside the dairy station, the AMS identifies the cow and initiates the milking process. Automated brushes clean and disinfect the cow's teats to maintain hygiene before milking (i.e., called *preparation*). Next, robotic milking arms or teat cups are attached to the cow's udders. Top-notch sensors within the system monitor milk flow and detect several data, including any abnormalities, such as signs of mastitis [**Fig. 2**]. The AMS also collects milk yield and quality data–including somatic cell counts and cow health parameters. This data is typically stored and accessible through a computer or mobile device. Also, some AMS units may apply post-milking

teat disinfectant after milking to prevent infections. The cow is then free to leave the milking station.

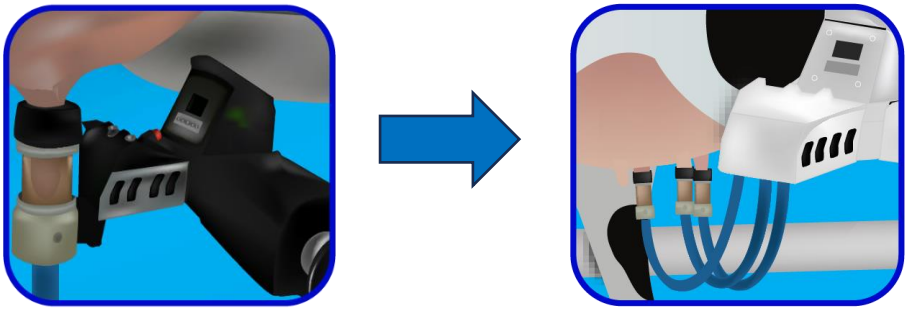

Fig. 3 Preparation (left) and milking (right) using AMS

Source: Designed by the authors.

A brief overview of the adoption of robotic milking systems

AMS emerged during the latter half of the 20th century. The conceptual framework of automation was started in the early 1950s, but it was not until the 1970s–amidst rising labor costs in developed nations–that practical initiatives for automated milking gained traction. During the 1970-1990 period, various European institutions undertook endeavors focused on teat position determination and developing apparatus for the automatic attachment of milking clusters (Rossing & Hogewerf, 1997; Sharipov et al., 2021). The Gascoigne Melotte's experimental milking robot debuted in 1986 at the De Waiboerhoeve research farm in Lelystad, Netherlands (Sharipov et al., 2021).

However, it was not until 1992 that the practical adoption of AMS occurred, marked by the inaugural adoption of four milking robots, named the *Astronaut*, by Lely Industries (Sharipov et al., 2021). By 1998, approximately 100 Astronaut systems were operational on Dutch farms, with similar expansions in northern Europe, Italy, and Japan (John et al., 2016; Sharipov et al., 2021). By 2010, AMS accounted for substantial milking equipment in several European countries, particularly in Denmark and the Netherlands. Subsequent years witnessed a significant surge in global AMS deployment, with installations surpassing 35,000 units by 2017 (Sharipov et al., 2021).

Few studies have examined North American dairies in conjunction with European farms. An exploratory case study (Schewe & Stuart (2015)) on 15 *Danish*, 5 *Dutch* and 15 *U.S. Midwest* farms found that differences in herd management, herd health, and milk quality are important factors when producers assess the advantages of AMS; they sustain that the implementation of AMS can lead to significant benefits. Tse et al. (2018) found that *Canadian* producers using AMS credit this technology with increased profitability, enhanced quality of life, and improved cows' health. Interestingly, Heikkilä et al. (2012)'s study on *Finish* diaries concludes that animal welfare and producer profits are more important factors influencing AMS adoption than market and sociodemographic conditions. However, Jacobs & Siegford (2012) argues that there are contradictory results regarding AMS benefits, attributing management practices and facility design as major sources of variation. Few studies, such as Steeneveld et al. (2012), found insignificant differences in labor costs, net output, or technical efficiency. Research on animal health also provided mixed results when analyzing somatic cell count in *U.S.* and *European* milking systems (Helgren & Reinemann, 2006; Hovinen et al., 2009). Thus, it is not entirely clear whether this technology's net benefits outweigh implementation and maintenance costs.

In summary, while AMS adoption in the United States is still in its infancy, with limited economic literature (Barkema et al., 2015), European countries and New Zealand have made significant

progress in integrating this technology into their dairy operations, and understanding the downsides surrounding its adoption. The experiences of these nations provide valuable case studies and lessons we intend to use on our research project to shed light on both benefits and challenges associated with automated milking systems.

Financial Profile of Pioneer

Pioneer Farm's current financial position is stable, but nothing to brag about. The farm owners have done an excellent job of keeping the farm afloat, especially during the volatility of milk prices in the 2012-2024 period. However, farm growth has stagnated and the farm has trailed behind the average dairy farm size in Wisconsin.

The farm currently has two enterprises: dairy and cash crops. The dairy enterprise includes 180 milking cows, all Holsteins, with about 80 replacement heifers. The herd is in good health and instances of mastitis and other diseases have been far and few. Milk produced per cow equals approximately 25,400 lbs per year. For cash crops, corn and soybeans are grown on 1,033 acres, 430 of which are owned by Pioneer Farms and another 603 are rented. Yields of both commodities have been modest, falling under the county average the past couple of years.

The balance sheet is quite typical of a small Wisconsin dairy farm [Table 1]. Assets are valued at about $3.7 million, with land (including tillable land) valued at $1.1 million, and buildings and improvements (barns and other structures) valued at about $0.8 million. Intermediate assets such as breeding livestock, machinery, equipment, and vehicles are valued at $1.3 million, and current assets equal $0.5 million. While current assets comfortably exceed current liabilities, a major proportion is attributed to unsold inventory of forage and cash crops. It is not certain how quickly this inventory can be unloaded or utilized in production. The Pioneer Farm ended the last fiscal year with only $5,330 in cash and about $105,000 in accounts receivable.

[*Insert* **Table 1 -** Pioneer's Balance Sheet]

The Pioneer Farm has relatively low debt. Short-term liabilities include a couple of operating loans and a credit card balance. These liabilities equal about $100,000. Long-term liabilities include several small low-interest loans that the owners have been consistently paying off over the last decade. The largest long-term liability is a real-estate loan with a balance of $331,900, interest rate of 6%, and 9 years left in the payment schedule. Total liabilities equal $788,500 and owners' net worth (at market value) equals about $2.9 million.

The Profit & Loss Statement [Table 2] shows major profitability challenges the farm has been facing over the past few years. The farm ended the last fiscal year with a net income of -$121,582, the year before that one with a net income of $35,792. The farm is on track to end the current fiscal year with a net income of $34,461. The 3-year average of net income is $17,160. Gross crop income has been about 33% of overall gross revenue, whereas milk sales are about 56% of gross revenue.

[*Insert* **Table 2 -** Pioneer's Profit & Loss Statement]

Operating expenses have hovered between 90%-98% of total revenues. Major operating expenses include purchased feed of $273,500, land rent of $150,800, and hired labor of $179,650. The owners have several hired hands that help manage the barn, do the milking, run the field equipment, etc. Total labor for the current year includes 12,000 hired labor hours with an estimated 2,000 unpaid hours from owners and family. The average hourly rate paid to hired hands is $14.97. Repair expenses are a relatively small percentage of total expenses, and the farm relies mostly on the owners and family members to conduct repairs and maintenance. Both Joe and Jack have basic mechanic and electrician skills, and Jennifer is quickly learning from her dad and grandpa.

Your role: Assess the feasibility of adopting AMS on the Pioneer farm

This consultancy requires a throughout analysis in order to answer the following questions:

- What are the opportunities and challenges of adopting robotic milking systems?
- What considerations and costs should be taken into account when adopting AMS? What assumptions need to be made when making these types of decisions?
- Is it financially profitable for the Pioneer farm to invest in AMS? If so, which type of robots would you recommend? If AMS is not recommended, would you advise the Pioneer farm to remodel the barn with another type of structure?
- What additional recommendations would you provide to the Pioneer farm to improve its financial resilience in the long-term?
- If AMS is financially profitable, do you think Pioneer would take your advice? Why or why not?

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