

The Cost Effectiveness of Implementing Monitoring Technologies in Livestock Management

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1 ABSTRACT

Technology is becoming more present in the current agribusiness industry. Although it is not the field's end product, the need for a well-rounded information systems environment comes with the urge for more productivity. The automation of certain routine tasks is necessary to keep pace with the lively modern market trends. This study aims to build a solid example of an implementation of one monitoring technology, focused on livestock management, that would promote this niche's need to follow some of those market trends. Brazil, a global agricultural power and ruler, faces two significant challenges in this field: cattle theft and bovine tuberculosis. The results show that under the ongoing advancement in information systems, many agribusiness entrepreneurs, farmers, do not necessarily need to be experts in the information technology field. By trusting in experts to provide what the business needs, these two main issues can be solved, the cost is reduced, and productivity is increased.

2 INTRODUCTION

The definition of technology is “the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment” [47]. The Agricultural Revolution was the first major iteration period to this subject, and it is dated 10 thousand years ago. “Mankind's transition from prehistorical hunting and gathering to permanent settlements was heavily dependent on tools for improving agriculture, animal raising, and crops. Certainly, the average person would not currently be able to identify technology's inception as a product of a causality relationship to agriculture” [48]. This is due to the fact that technology's image is not easily attached to the agriculture field. Throughout time, its endeavors became more committed to education, computer science, and infrastructure. Agriculture was almost forgotten by technological ventures.

Though, currently, the situation is different. Livestock management has been attracting much attention from IT (Information Technology), in the so-called PFL (Precision Livestock Farming) global wave. This trend produced “many projects that track bovine respiratory diseases, which is considered the greatest hindering factor in the industry” [48]. The agricultural sector is highly important because it is a major player in the global levels of food access. Therefore, technological incentives are imperative for this field. As is the case for many leading producers, Brasil's agribusiness industry is far from optimal levels. There, besides respiratory diseases, another considerable problem that hinders the country's beef productivity is cattle theft, which can be solved by “artificial intelligence and Internet of Things applications. [They] can create a major revolution in the cattle farming sector through the possibility of automation and transformation of data into information, in real-time – thanks to mobile connectivity, in various sectors of the production chain” [41]. Mankind's growth and improvement are directly dependent on changing the way food is produced.

3 LITERATURE REVIEW

3.1 IoT and PLF

The Internet of Things, which has been empowering the world since the late 90s', currently plays a key role in livestock management (LsM). Akhigbe, Munir, Akinade, Akanbi, and Oyedele [43], as well as Iwasaki, Morita, and Nagata [44], all agree and defend the idea that IoT has been attracting much attention and has been developing a significant role in LsM. The writers affirm that data is the main contributor in this field. As it happens in many others, decisions must be backed by information. When managers, regardless of the business area, make conclusions without solid information, they are performing under instincts, they are guessing. Although LsM naturally sustains more rudimentary practices, the field should take a more metrics-based approach. Those writers agree on the fact that by collecting the largest amount of data possible, more efficiency can be reached. To perform it, monitoring technologies bring its data collection tools as the currently ultimate solution.

In his book, Akhigbe introduces the idea of the fourth wave of human life [43], which is called by Schwab the fourth industrial revolution [45]. This term refers to a fundamental change in the way people live, work, and connect to one another. In this era, "things" of IoT communicate autonomously turning into IoTT (Internet of Things Technologies), which is the enabler of PLF (Precision Livestock Farming). Akhigbe defines PLF as the agricultural management that embraces IoT use in its practices [43]. While Iwasaki makes a more specific definition about PLF, saying that is the connection of biological and environmental data obtained by sensors via the cloud from remote farms [44]. He declares, though, that much of the information collected has not been effectively utilized due to difficulties sensors have been facing on these almost inhospitable locations. Then, Iwasaki introduces the term MEMS which stands for microelectromechanical systems technology, affirming that it enabled the manufacturing of smaller sensors that require low power to function [44]. These sensors technology is the one used by the companies analyzed in this Senior Project research paper.

Banhazi, Lehr, Black, Crabtree, Schofield, Tscharke, and Berckmans from the University of Southern Queensland support the idea that the agricultural field must change its management practices, and that there is an abundance of information available, but producers rely on their interests and beliefs instead of data [11]. This drives incorrect decisions and less productivity, which is supported by another paper from Berckmans [14]. The latter defines PLF as a real-time warning when something goes different from the planning and says that reliable solutions are only possible in this field if IoT is applied.

Berckmans also makes an important point when he affirms that PLF is vital not only because of its economic implications but also due to the increase in beef demand. He says that stopping or reducing meat consumption is an almost impossible task since convincing people to change their habits or forbidding them to eat meat is unattainable [14]. Banhazi says that PLF is able to solve this problem because it can offer farmers considerable time savings by supplying only data pertinent to their daily needs. It achieves that by sending the data collected by sensors to a centralized site, where is processed [11]. The farmers, then, are able to focus on more important tasks. All these points are further elucidated and explained in this Senior Project research paper.

The PLF field is somewhat recent and still faces many challenges, as is addressed in Banhazi's paper. He and the coauthors elicit that the technology deployed is in a limited amount

and far from reaching enough levels for greater and more precise evidence to convince many producers in adopting them [11]. The writers from the Australian university guarantees that if few steps are taken, this scenario may change. These are a clearer communication of the benefits to customers, identification of principal beneficiaries, and provision of more appropriate training. Their argument is strong since that understanding the target audience and how to steer their attention to the potential rewards the products offer is a pillar in any business. Therefore, if these actions are taken, IoT will be more effective in aiding such a vital business area that sustains the world's social fabric.

3.2 Product Solutions Available

An important source for the development of this paper was the research conducted by Stygar, Gómez, Berteselli, Costa, Canali, Niemi, Llonch, and Pastell, from the Frontiers in Veterinary Science [42]. It is open access and science platform from the Swiss Federal Institute of Technology Lausanne. These writers developed a systematic review on commercially available and validated sensors for cattle. They found 129 commercially available product solutions and further analyzed 50 of them. Of these products, 64% of them were collars that each animal wears. They identified 25 products that track the animal's health, and only eight offered the location tracking feature. This Senior Project research paper analyses two products that have similar designs and are focused on health and location due to the question it aims to answer.

A critical point the Swiss paper makes is that the effectiveness of the application of these products is at stake since most of them were not validated through research and trials. Only 14% of the products analyzed passed through a kind of validation, which indicates that producers must rely on other factors when selecting a product, as feedback from other users and the company's reputation. The writers from the Frontier in Veterinary Science affirm that the reasons for the irrelevant number on validation trials are insufficient reporting, low scientific interest, high cost and labor intensity of data collection, and reluctance to publish negative results. However, this Senior Project research paper will assume what companies communicate about their solutions as true and reliable since the goal is different, it aims to identify if the application is cost-effective [42]. Moreover, the third section of the Senior Project analyzes the companies' reputation and customer service relations, which are strong indicators of the reliability of their products.

From the scientific perspective, the Frontiers in Veterinary Science paper highly emphasizes that the products available cannot guarantee the delivery of the promised results because there are just not enough trials. In the contrast, the writers declare that regarding health monitoring, several traits measured by these technologies have a potential application for delivering a reasonable health assessment. These traits are the animal's body temperature, lameness, water consumption, rumination, feed intake, and non-active behavior. They further explain that changes in the behavior of animals can be processed to obtain early-warning signals for health problems, potentially enabling to prevent them, and being useful for operational decisions [42]. They conclude that even if a technology is not able to provide highly accurate health data on the individual level, it could still be useful to estimate the herd-level prevalence of health problems. Reaffirming the soundness of conducting this Senior Project research paper because the products analyzed do not present trials. Moreover, the Swiss paper focuses on how PFL technologies can improve animals' welfare. Whereas this Senior Project research paper focuses on the economic implications of applying certain PFL technologies.

4 OVERVIEW OF THE ORGANIZATION'S CHALLENGES

Being the world's largest exporter of beef [50] makes Brazil a global agricultural power and ruler; it is often categorized as the feeder of the planet. A considerable amount of what people serve on their tables comes from a Brazilian state called Mato Grosso, which is the largest producer of livestock in the country. In 2020 the state held 32.7 million head of cattle [1]. This provides insight into Brazil's agricultural global influence. The state of Mato Grosso is home to Rio Branco farm, which is located in the north part of the state. It is 40 miles away from Sinop, a Brazilian Midwest thriving city, which has been experiencing an economic boom in the past decade, due to the agricultural sector. Rio Branco is a farm of grand scale that assessed the cost-effectiveness of introducing monitoring technology to its herd of cattle, so it could resolve two major problems, cattle theft, and bovine tuberculosis.

Rio Branco farm was established in 1997. It is a family business and a sole proprietorship. Rogerio Safra is the founder and owner, who purchased land from 17 neighboring farmers in order to constitute his farm. Mr. Safra has worked in the banking industry and has owned, and managed technology and home appliances stores before entering the agricultural world. At the end of the '90s decade, he understood the potential of this field and saw a great investment opportunity in the region of Sinop. At that time, much deforestation and land cleaning were needed, so the land could become more productive. The entire process of forming the farm was very challenging due to restricted access to the region and common health issues caused by malaria, which afflicted many workers. Establishing a farm of great proportions, as it is Rio Branco, demands decades of work endeavors.

The farm currently has an area of around 25 thousand hectares of productive area. Many families live there since 45 full-time employees are working for Rio Branco. Other 25 independent contractors eventually establish temporary residence on the farm, which offers small apartments that are called "beehives" that have the only purpose of providing shelter for the short-term workers. In the command post of the business, there is a cafeteria that offers three meals per day for all workers, though this service is not offered for their family members. The farm also has a primary school, which runs from kindergarten through 6th grade. The school was incorporated into the business in an agreement with the local state government, so the children who live there did not need to commute daily to Sinop. A van ride is provided by Mato Grosso's government for the older children to attend elementary and high school. The farm's environment is very busy with the great daily movement of people. The business is often characterized as a small village or as "a town of its own" by Sinop inhabitants. The organization is much respected, and Mr. Safra holds a great reputation in the local community.

Rio Branco's production consists of cattle raising and soybean plantations. The herd of cattle is composed of around 11 thousand heads. Only 10% are cows. Usually, the cattle are sold when they reach three years old, or 36 weeks. Therefore, the management has the goal of holding the animals for only around one year since they are purchased until sold to the slaughterhouses. It is perceived that this business strategy is the one that provides the largest profits in cattle raising. Purchasing calves demands more time and money investment and buying ones that are older than two years also results in more costs. When the cattle are ready, they are sold to three different slaughterhouses, Marfrig, Minerva, and JBS. Negotiations happen on either a weekly or biweekly basis depending on the time of the year. Given this industry's perfectly competitive market characteristics, Mr. Safra and his team are usually the ones who are requested and contacted by the slaughterhouses. Beef production does not require marketing efforts or to be promoted. Cattle

come to Rio Branco farm already sold to the plants. It is a product that demand is greater than its supply.

Rio Branco's slaughterhouses clients are global firms. Their production is exported to many different countries. China is currently the main consumer of Brazilian beef [51]. Therefore, the market trends and price fluctuations are all based on the American Dollar. The COVID-19 pandemic has disrupted a great portion of the world's supply chain, and one of its consequences was increased China's dependence on the Brazilian beef supply, which caused a surge in beef pricing. Moreover, the Brazilian currency, the Real, suffered a 30% devaluation in the same period. These factors positively influenced Rio Branco's revenue. In 2020, the total farm's revenue has reached over five million dollars, of which 87.2% came from cattle. The business works with 30 mechanical parts and general inputs suppliers and with 70 cattle vendors, the latter are distributed all over the state of Mato Grosso. These vendors reach out to Mr. Safra's team constantly given Rio Branco's great demand and its outstanding reputation of a good payer.

The company stands for honesty and transparency and it complies with all environmental regulations from the Brazilian government. Its culture can be described as very welcoming and inclusive. Rio Branco follows a vertical management structure. At the top of the pyramid, there is the owner and founder, Mr. Rogerio Safra, who is responsible for maximizing business value, setting long-term goals, and overseeing and assisting the lower-level managers with their functions. Following the scheme, the next is the Chief Manager, who is Mr. Safra's son, Antonio Safra, who oversees the business operations. He is responsible for sales negotiations and forecasting, mechanical parts and general inputs purchasing management, and legal compliance and litigation management. In general, he is the one who most runs the business. Employees report to him first, before contacting his father.

Next, there is the Livestock Manager, who is responsible for everything related to the cattle, from purchasing the animals and cattle run allocation, until they are sent to the slaughterhouses. Every employee that works with cattle reports to him. Following the scheme, there is the Crop Manager, who oversees the soybean plantations. Along with them, there is the Human Resources manager. She is in charge of workforce recruitment, performance management, employee development, and also assists the Office Manager in compensation and benefits. Rio Branco's office is located in the city of Sinop and is controlled by the Office Manager, who is responsible for the financial management, accounting, payroll, data analysis, and reporting. He also assists with any issue that arises regarding hardware and software; he is responsible to increase overall efficiency by enabling the maximum number of processes to be automated. Moreover, he researches new systems trends and the need in updating the current systems. Rio Branco's leadership structure can be seen in Figure 1.

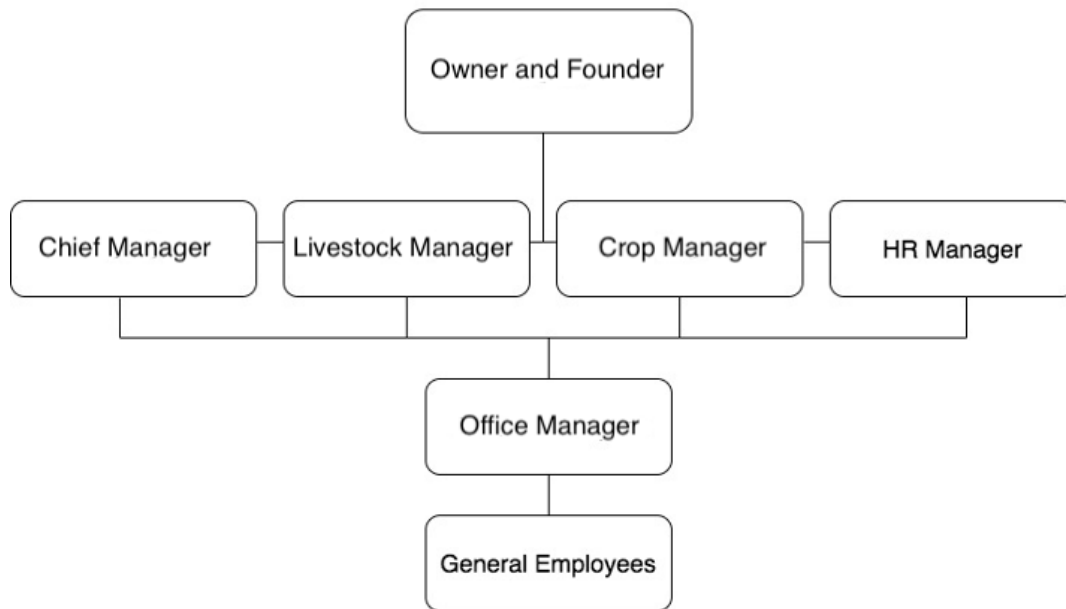


Figure 1: Rio Branco’s Leadership Structure. Created by the Author, Gustavo Teixeira.

The farm has been facing two major problems, cattle theft, and bovine tuberculosis. Cattle theft is a very serious worldwide problem. The crime occurs mostly in undeveloped nations in Sub-Saharan Africa and Latin America but also englobes wealthy countries like the United States. It is often depicted in Hollywood movies that portray anti-heroes being cattle rustlers, which hinders the industry by sustaining “myths and falsehoods spread by activists from organizations with nice-sounding names and hidden agendas” [2]. This falsely creates a Robinhood image for criminals that are attracted by the huge gains that are similar to bank robberies. They can profit millions of dollars by stealing cattle. In Brazil, there are large police operations that try to tackle these crimes. Recently in the country, a “criminal organization stole about 12,000 head of cattle [in the estate of Rio Grande do Sul, in the south] and then resold them as far as the northern state of Tocantins, 2,600 kilometers away” [3]. The rustlers sold the cattle for a much lower price but were still able to generate around \$6 million.

The crimes have become more sophisticated. They used to happen at a more local level but have turned into an interstate problem. The Brazilian livestock control laws mandate that each animal must be under a GTA, Animal Transport Guide/Document. Given that, “stolen animals are often sold to slaughterhouses or thieves kill the cattle themselves before selling their meat to grocery stores. Some also steal the animals, move them, slaughter them and then sell their meat directly to consumers” [4]. Cattle theft has become more common in Rio Branco Farm’s region, the Midwest, with a greater focus in the neighboring state of Goiás. The high record prices of beef have attracted more criminals into this practice. Tracking stolen animals is a challenging task, which boosts the lawbreaker’s belief that it is easy money. This context challenges police investigations. Moreover, the gang groups take advantage of the vastness of the Midwest countryside and monitor difficulties to continue committing these crimes.

The Chief Assistant of the DERCR, the State Police Office for the Repression to Rural Crimes of Goiás, Murilo Gonçalves Almeida affirmed: “Cattle is more difficult to track, especially if it's for slaughtering. Cattle are goods that have a high level of rotation. Farmers buy, sell, raise, sell again, and cattle with two or three identification marks are common. This is favorable to criminals. It's much easier, for example than stealing a vehicle” [4]. Given the farm's grand proportion, this scenario is no different from Rio Branco, which reverberates into an overwhelming situation. In 2018, 274 heads have gone missing, followed by 94 in 2019, and 314 in 2020, which accounts for an average of 2% annual loss of the herd. The business management has reported to the police every occurrence, but nothing has ever been found.

Many factors could be in place; however, cattle theft is certainly a major player in the disappearance of these animals. Mr. Safra's team has been implementing some strategies in trying to prevent it. For instance, they applied a policy of continuous biweekly maintenance and checking of fences that protects the land's borders, as well as stronger protection and stricter access requirements to the propriety. Another crucial tactic has been of sustaining a friendly relationship with the neighbors, which brings many other positive assets for the business. However, none has shown meaningful satisfying results. The recent major crime in the south of the country has led to a “bill proposing the use of a comprehensive livestock tracking system; [this] was being debated by the city council of Dom Pedrito, [RS]. The law will introduce a database of cattle brands and signs that authorities targeting cattle theft could consult via a cellphone application to check for irregularities” [3]. This news has instigated the Office Manager to investigate and study the possibility of implementing monitoring technologies in Rio Branco.

The current second major critical problem impacting the business is modest bovine tuberculosis (TB) outbreaks. Similar to cattle theft, this is considered a global issue. It is a serious health threat since it “is the most infectious [tuberculosis], capable of infecting most mammals” [5]. The disease is caused by bacteria; it is a “major infectious disease [that causes] a general state of illness, pneumonia, weight loss, and eventual death” [6]. The overall status of outbreaks is considered in control. Even though cattle herds do not usually suffer from it, the complexity stands on the fact that many wildlife animals carry the illness, making the cattle susceptible to contract it from the natural fauna that lives on the farms. Slight outbreaks may become a real hazard because “cattle are considered to be the major reservoir [for the disease] and are the main source of infection for humans” [6]. Rarely people are infected by being in close contact with the animal; however, if contaminated meat is consumed, the person can show symptoms that are similar to regular tuberculosis as fever, night sweats, weight loss, [...] disease in the lungs, and gastrointestinal disease. [Moreover], If untreated, a person can die of the disease” [7].

The issue is perceived by many as a problem of the past; however, 44% of all countries have presented occurrences in recent years [8]. In Brazil, the Ministry of Agriculture and Livestock, 20 years ago, initiated the National Program for Control and Eradication of Bovine Brucellosis and Tuberculosis (PNCEBT). The program offered TB-free certifications for farms. It is discretionary to the farm management to be accredited, which may be achieved by “regular testing-and-culling of cattle and subsequent restriction on animal movements” [9]. The certification leads to advantages to the business as some valorization to the final product and the waive of mandatory examination of the heard before trading happens with the slaughterhouses. “However, the number of certified properties in Brazil is negligible, with only 798 certified farms, out of a total of about two and a half million cattle farms” [9]. Elucidating the failure of the program, which is due to one main reason: The costs of being awarded the certification surpass the financial benefits.

In Rio Branco farm, the disease scenario is not unprecedented. As it happens with farms of grand scale, some minor outbreaks affect a handful of animals out of thousands that rotate annually in the business. It is considered a somewhat common health issue where there is a land highly densely populated by animals. The business strategy chosen by Rio Branco management, of raising only grass-fed cattle, favors the organization when it comes to health issues. When feedlot cattle raising is the strategy in place, health problems occur much more frequently. So, why rare and minor TB outbreaks are considered a major problem for Rio Branco? All beef trade in Mato Grosso is controlled by INDEA (Institute of Agricultural Defense of the State of Mato Grosso). In order to be able to sell cattle to slaughterhouses, farm management must be registered in the institute, which facilitates the GTAs, the Animal Transport Guide/Document that holds information of every single head. Slaughterhouses perform many screenings on the animals when they arrive. If any sign of diseases is found, they immediately report to INDEA, which promptly suspends the farm's registration, blocking the organization of any further trade. Therefore, the farm management becomes unable to issue and request any GTA.

Even though the outbreaks are minor and insignificant when compared to the total number of heads being sold, they come with tremendous disruption to the whole business process. The proceeding of unblocking the registration is arduous and considerably lengthy. INDEA veterinarians must visit the land to check the heard, so later they can issue a reauthorization document for allowing further trade under that registration. The process can take up to a month, which significantly harms the production of a business that sells weekly and biweekly. Rio Branco faced one situation like this in 2018, followed by two in 2019, and one in 2020, equaling an average of 1.3 annual occurrences, decreasing 0.5% of total annual revenue. However, besides the financial implications, selling a possible harmful product goes against Rio Branco's values and principles. Many strategies have been applied by management. The farm does not have any full-time veterinarians, but contracts professionals every two months to perform health screenings when the animals must pass through the panels for vaccinations and weighing.

Additionally, Rio Branco holds four different registrations in INDEA. This approach was chosen due to legal reasons, and it came to be quite helpful when handling this type of situation. Juridically, Rio Branco is composed of four different farms, so no environmental issue or litigation could hinder the production of the entire business. This is a common course of action among large Brazilian farms. Therefore, when there are TB appearances, animals are transferred from an INDEA registration to another, which is a process legally permitted. However, this approach impacts the business' accounting and taxes proceedings. It also generates more work for different sectors staff, ranging from the ones who must handle the INDEA visit, to the corporate office, resulting in higher labor costs. More importantly, it does not solve the problem at its root cause, it only remediates the issue. When researching monitoring technologies applied to livestock, motivated by the potential solution for tracking the cattle missing, the Office Manager discovered the myriad of advantages these technologies also bring to the health status of the herd. Among the many options available, the Office Manager narrowed his analysis into two alternatives.

5 COMPANIES; PRODUCTS; PURPOSES; SOLUTIONS

5.1 SmarTernack

Beef is a highly desired food product that has been experiencing a steady growth in demand in the past decades. In 2019, the demand was around 70 million tons and it is “projected to increase to 74 million by 2023” [10]. In some regions of the world, it is considered a luxury, while in others, a basic necessity. To achieve its full production potential, efficiency must be a priority in the global commodities industry. The relatively recent technological trend of PLF (precision livestock farming) has much to offer in increasing this sector’s productivity. PLF can “manage individual animals by continuous real-time monitoring of health, welfare, production/reproduction, and environmental impact. The word “continuous” means that PLF technology is measuring and analyzing every second, 24h a day, and 7 days a week.” [14] If appropriately administered, PLF “could improve or at least objectively document animal welfare on farms, facilitate product segmentation and better marketing of livestock products, reduce illegal trading of livestock products, and improve the economic stability of rural areas” [11], besides all positive environmental implications it may bring.

In Indonesia, for instance, beef supply is less than 60% of its demand. Though, the country is one of the largest producers of beef in the world. Currently, its government aims to turn the nation in the upcoming 10 years self-sufficient in beef, which encourages and stimulates research in PLF. It is there that SmarTernack was born, which markets itself as the “smartest PLF solution to revolutionize the cattle-farming industry” [12]. By using a system based on IoT, it promises to help farmers to reach higher levels of efficiency by tracking cattle health, their movement, and general activities. SmarTernack is one of the investment segments of Dycodex, a 5-year-old tech startup, that “has the vision to solve problems effectively with technology, innovation, early-adopting spirit, and tight software-hardware integration, which [is applied] in each disruptive product that [they] develop to enhance the lives of mankind” [13]. This tech venture offers two variants in its products, called “Tracking” and “Health & Productivity.” Depending on their needs, farmers can choose to use either one or both combined. An overview of the product’s capabilities and functionalities is depicted in Figure 2. SmarTernack was the first option analyzed by Rio Branco’s Office Manager.

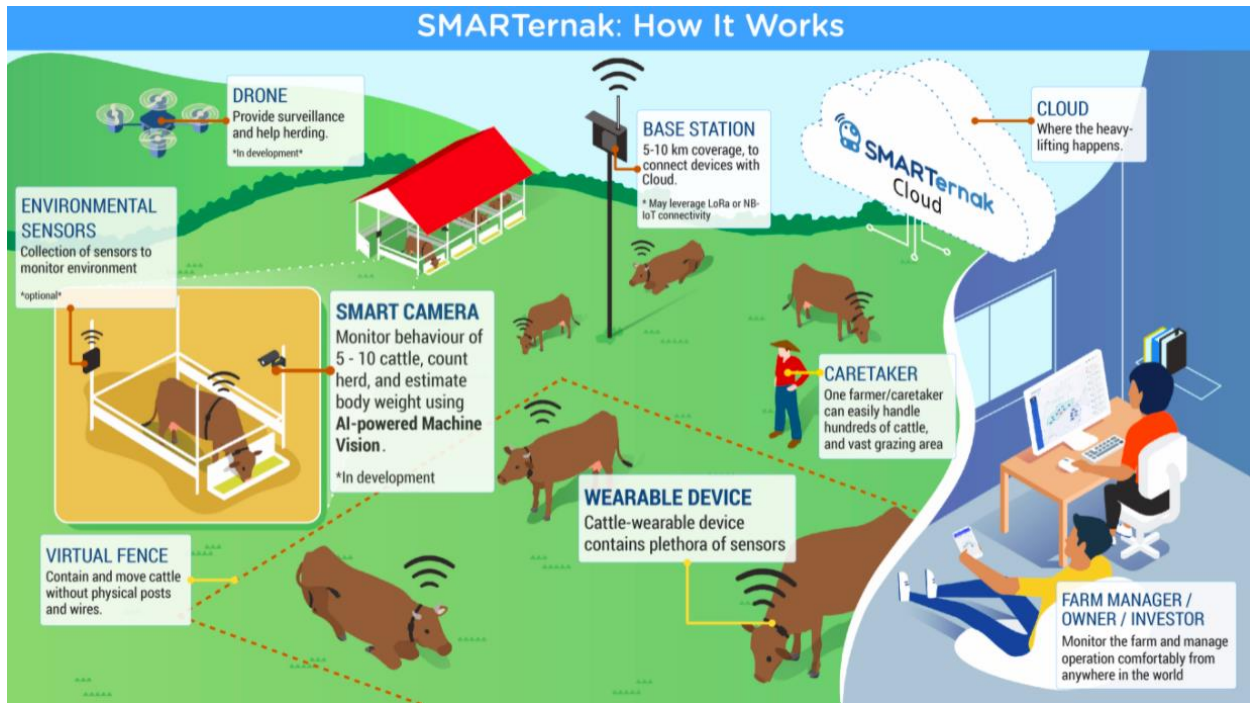


Figure 2: SmarTernack Overview via Dycodex. (<https://dycodex.com/smarternak/>).

The features are various, and the ones available for both variants are listed below:

- Activity prediction and action recommendation
- Wide-area coverage
- Compact and unobtrusive design
- Smart energy management
- Web and app platforms
- Anti-theft system

This first feature eases the burden of physically having to check on the animals. Artificial intelligence, over time, better understands the behavior of the herd by monitoring them, which leads to recommendations provided to the farmers of what they must do with their livestock. The second feature means that the technology used was tailored precisely for cattle management. It is radio-based and covers a range area of up to five kilometers. The company promises to make provisions for farms of any size “no matter how big or small the scale” [12]. Regarding design, the product size is 79x79x19 mm. SmarTernack markets it as convenient, resilient, and unnoticeable, which all contribute to the lack of interference to the animals’ daily life.

Moreover, the product does not require much energy, and the little it does it is refilled with solar energy and by the animal’s body heat. Users have access to all information collected by the devices through a user-friendly dashboard available on the web and mobile. The information is updated in real-time. Additionally, the gadget requires prior commands before being removed. If by any chance this does not happen, it sends an automatic notification saying it was removed without authorization or perhaps stolen, also providing the last location where it was still attached to the animal.

All features offered in each variant can be seen in Figure 3. There is a one-time cost, in American Dollars in 2021, of implementing SmarTernack of \$105 per animal for the “Tracking”

or “Health & Productivity” variants. If the Ultimate package is chosen, the one-time cost increases to \$182 per animal. There is the additional cost of \$6 per month per animal [52] for the subscription that provides “access to web dashboard and mobile apps, all future updates, on-site training and assistance, and Device warranty and support” [15]. The costs were found in a company’s document explaining the product’s features, and they were converted from the Indonesian Rupiah to the US Dollar based on the exchange rate of October 2021. Another important point during the Office Manager’s research was the lack of customer service promptness in responding to questions made. Smarternack never replied to the inquiries.

<i>SmarTernack Variants' Features</i>		
Tracking	Health & Productivity	Ultimate
Cattle position tracking	Activity insight	Cattle position tracking
Virtual geofencing	Behavior insight	Virtual geofencing
Herd counting	Health insight	Herd counting
Grazing insights	Surrounding environment monitoring	Grazing insights
Activity insight	Weight gain insight (beta)	Activity insight
Behavior insight	Device removal alert	Behavior insight
Device removal alert	Rich web-based dashboard	Health insight
Rich web-based dashboard	Android & iOS app	Surrounding environment monitoring
Android & iOS app		Weight gain insight (beta)
		Device removal alert
		Rich web-based dashboard
		Android & iOS app
		Energy harvesting from solar
		Additional battery lifetime
		Backup battery

Figure 3: SmarTernack Variant’s Features. Created by the Author, Gustavo Teixeira.

5.2 Chipsafer

Motivated by a mouth disease outbreak that disrupted the beef supply of her country, Victoria Alonsoperez, an electronics and telecommunications engineer launched her company Chipsafer in 2017. She is from Uruguay, a country, like Brazil, that heavily depends on the farming industry. At the time of the outbreak, many animals had to be sacrificed so the disease could be contained. She saw the potential that monitoring technologies had on helping the core industry of her home country. If the cattle of that time were monitored, the disaster would be prevented. Chipsafer is a platform that can track and early detect anomalies in cattle behavior completely remotely and autonomously [16].

Similar to SmarTernack, Chipsafer offers a self-recharging collar that each head of cattle wears, which continuously transmits data about the animal’s location and its health. All data is sent to Chipsafer’s servers, where it is processed, and a detailed analysis is provided to the farmer.

The features offered are various. (1) The animals' owner is able to know where their animals are, and if any anomaly in the heard behavior is detected. (2) The sick animals are spotted early by the automated disease tracking software. (3) The devices have a long-term battery that can last over 10 years. Moreover, (4) If any animal goes beyond the specified area of the farm, its management is notified. (5) If the device is removed, the farmer is also notified through the (6) web and app-based platforms available that hold all the information. Finally, the farmers receive actionable information so the farms' production can be improved [29]. There is a one-time cost of \$10 per device and a \$1 annual charge per head for access to the dashboard [46].

Chipsafer made a partnership with Semtech. The latter describes itself as “a leading global supplier of high-performance analog and mixed-signal semiconductors and advanced algorithms for infrastructure, high-end consumer and industrial equipment” [17]. Semtech is a founding member of the LoRa Alliance. LoRa is “a low power wide area networking (LPWAN) standard based on Semtech’s LoRa devices, leveraging the unlicensed radio spectrum in the Industrial band” [17]. This technology’s functionalities are depicted in Figure 4. The company advocates for this technology because it offers a lower bandwidth but with a longer connection range. Moreover, Semtech affirms that LoRa “offers an efficient, flexible and economical solution to real-world problems in rural and indoor use cases, where Cellular, Wi-Fi and Bluetooth Low Energy (BLE) networks are ineffective” [18], which was very promising for Rio Branco’s scenario.

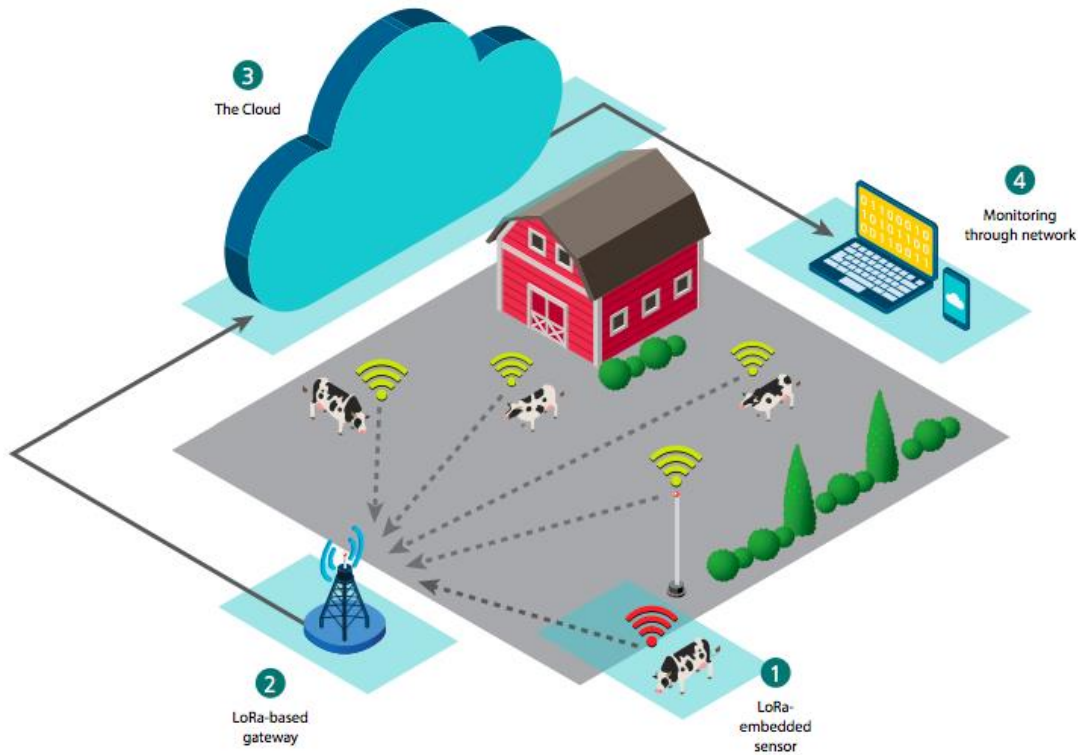


Figure 4: LoRa Technology’s Functionality via Semtech.

(<https://www.semtech.com/company/press/semtech-lora-technology-and-chipsafer-connects-cattle-ranching-to-the-cloud>).

Both SmarTernack and Chipsafer offer fairly similar products. The same features are present in both gadgets. However, there are two major differences when comparing these two options of PLF

products. The first one is the technology utilized for transmitting data, the network. SmarTernack provides two options for its clients regarding the network, the NB-IoT, and LoRa. While Chipsafer takes a more standardized approach, using only LoRa, this paper will make considerations about SmarTernack's product as it only uses NB-IoT. By doing so, a better comparison can be made, a clearer conclusion can be reached, and a more comprehensible elucidation can be composed about the differences in both products and their technologies.

The second major difference, which is critical, is in pricing. Considering Rio Branco's business case, the farm possesses 11 thousand heads. The Office Manager found that by adopting to SmarTernack's Ultimate package solution, the business would incur a cost in the first year of \$2,002,000 plus the \$66,000 monthly subscription fee that allows access to the dashboard that contains all the information. This results in an investment of \$2,794,000 in the first year considering that the application would be used just for the current herd, not accounting for the new comings. Chipsafer's option would present a one-time cost of \$110,000 plus an \$11,000 annual subscription fee, resulting in an investment of \$121,000 in the first year. The price difference is tremendous, Smarternack is almost 24 times more expensive than Chipsafer.

6 NETWORK AND DATABASE STRUCTURES

6.1 Network

Developed by Huawei and Ericsson, the Narrowband IoT or NB IoT is a "communication standard designed to [enable] IoT devices [to] operate via carrier networks either within an existing GSM carrier wave in an unused guard band between LTE channels or independently" [19]. This technology, which is the one utilized by SmarTernack's product, uses only 200 kilohertz and is able to work with a great number of endpoint devices. It is also "designed to work with constrained devices which refers to IoT gizmos that have serious limitations in processing power, network connectivity, or battery life" [19]. This elicits why it is an appropriate choice of network technology to apply for PLF gadgets that operate in remote areas. Other examples of devices that use the same network architecture are the many sensors applied in crop farms and the ones used in areas that have extreme weather. It is a great option for situations in which there is no need for large rates of data transfer, which means it operates with lower bandwidth. Basically, it is possible to apply NB IoT in any area that has coverage of the mobile network.

An excellent characteristic of NB IoT is that it does not require gateways and the sensors can directly communicate with primary servers [20]. It was standardized by 3GPP, which "unites telecommunications standard development organizations known as Organizational Partners and provides their members with a stable environment to produce Reports and Specifications" [21]. 3gpp "covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications" [21].

NB IoT uses cheap nodes that have long-lasting batteries able to work for over 10 years. Its use is also appropriate for challenging cases of devices with high density, and with the ones that are underground or deep indoors, which demonstrates how flexible this technology is. The deployment of this tech service opens doors for new pathways in IoT. Even though it is a technology that offers many assets for the IoT arena, unfeasible would be the application to Rio Branco's scenario. Most of the farm's area does not sustain any mobile coverage, aggregating

another shortcoming for SmarTernack's product in Rio Branco's decision-making process in choosing the correct technology.

Given the ongoing digital transformation, all markets have been experiencing, fast and reliable access to data is critical for positive business performance, and this is no different for Rio Branco. Specifically, when attempting to address, with technology, the two major issues the company was facing. In this scenario in which cellular is not available, LoRa is an option that can be applied. LoRaWan (low-power wide-area network) promises a simpler way to monitor and connect businesses' assets. Using LoRaWan connected sensors, any company can easily obtain the insights they need to automate processes and improve efficiency [22]. It "was specifically developed for large-scale IoT communication such as the need to cover vast distances and massively scale at low deployment and operating costs" [22].

These are all characteristics needed for Rio Branco's circumstances. Similar to NB IoT, it penetrates concrete and underground, operates in adverse weather, and breaks through the noise. Its battery lasts up to 15 years and it delivers firmware updates remotely. LoRa is a "radio modulation technique based on chirp spread spectrum technology (CSS)" [23]. Semtech, the company that Chipsafer partnered with, is one of the technology's major providers and that "keeps its lips sealed on exactly how the physical layer specification comes together" [23]. So, its intricacies are unknown. The technology can cover thousands of devices sending small packets of data with a single gateway that can reach up to 10 miles. Regarding its cyber security, LoRa holds an open and interoperable standard and its developers and enthusiasts affirm that security was built into its protocols since its inception. The technology has data origin and mutual end-point authentication, integrity and replay protection, and end-to-end encryption using the AES-128 standard [22]. It is considered the global de facto Ip1 standard.

6.2 Database Structures

Regarding database structures, both SmarTernack and Chipsafer do not hold the herds' information in their own servers. They outsource the service to a Cloud provider. The companies use CRM database, which is serviced free of cost. CRM (Customer Relationship Management) database "enables to manage and store all customer interactions into a shared company database" [24]. CRM is marketed as a "way of managing interactions with prospects, leads, and customers, as [all] move through the sale cycle. [It] organizes communications across all departments [...] CRM system uses SQL [which] enables to store large amounts of data and is quick to run searches, reports and database queries" [24]. RBDS (Relational Database Management System) is a row-oriented database and the basis for SQL.

In row-oriented databases, data is stored row by row, so "the first column of a row will be next to the last column of the previous row" [25]. For example, a table called Bulls has three attributes which are markNumber, age, and weight. The row-based database would store this data on a disk, filling up all information of all attributes of the first row, then for the second, and so forth. When a new record is added to the database, it would be appended to the end of the information already stored. This type of database format has some benefits. First, it can be written faster since it only needs to keep adding the rows to the end of the previous set of data. Moreover, the row-oriented database is beneficial when the user needs to retrieve entire rows. However, this type of database is not optimal when the user needs to do aggregation. For instance, assuming the average weight of the bulls need to be calculated, for the database to provide this information, it

would load all the data in the rows stored, including the markNumber and age of the bulls. This is extra work and costs time for the program and the user; it is not efficient.

Although row-oriented databases are not the most efficient, they are the most secure because they follow the database principle called ACID (Atomicity, Consistency, Isolation, Durability). It “refers to a standard set of properties that guarantee database transactions are processed reliably. ACID is especially concerned with how a database recovers from any failure that might occur while processing a transaction. [It] ensures that the data remains accurate and consistent despite any such failures” [26]. Atomicity guarantees that “either all of the transaction succeeds or none of it does. While Consistency guarantees that all data will be valid according to all defined rules, including constraints, cascades, and triggers. Isolation means that no transaction will be affected by any other transaction. Finally, Durability means that, once a transaction is committed, it will remain in the system” [26]. After becoming aware of how the sellers proceed regarding their databases, Rio Branco’s Office Manager knew this approach would suffice the company’s concern with their data security.

7 Due Diligence of Product Purchase / Implementation

Due diligence is defined as a “process of verifying, investigating, and auditing a potential deal or investment opportunity to corroborate facts, financial information, and other pertinent data” [27]. In Rio Branco’s situation, the Office Manager understood the critical importance of this process. He decided to complete it so he could make a more well-round and thorough presentation about the investment opportunity for Mr. Rogério Safra. The Office Manager established a few steps for his process that are depicted in Figure 5.

<u>Rio Branco's Due Diligence for Investing in Monitoring Technologies</u>
1 - Select two compelling products available on the market
2 - Learn the cost of implementation of the products
3 - Look at providers' reputation
4 - Determine if the implementation will be profitable

Figure 5: Due Diligence for Product Investment. Created by the Author, Gustavo Teixeira.

The result of the first and second steps was elucidated in the previous sections. Step 1 was performed solely based on a web search, looking for products with good reviews and feedback from current users. The products had to be focused on tracking location and monitoring health services. SmarTernack and Chipsafer were the two companies chosen to continue in the selection process. Step 2 was performed with step 1 simultaneously since the primary cost of implementation is one of the most important factors; it is a criterion that holds a high value in the selection process.

Between those companies, the analyzes' result indicated that Chipsafer's product would be more beneficial. Step 3 will be discussed in this section of the paper, and Step 4 in the last section.

Mostly, the sole reason for businesses to update their operations is because they are envisioning more profits, to add more business value. The principal incentive behind the Office Manager's research was to identify if adhering to monitoring technologies would solve Rio Branco's issues with cattle theft and bovine tuberculosis, so in the end, more profits are achieved. In the settlement process, it is of vital importance to understand the possible provider's dependability, notoriety, and trustworthiness. Commonly, companies spend a great deal with marketing efforts, so their products are branded as superb and capable to deliver prosperous results. However, this is not often the case. Thus, further research has to be executed on what different sources affirm about the product's efficacy.

It is easily notable that Chipsafer holds a great reputation. The company has been awarded recognition prizes continuously since it was inaugurated. Its image is highly attached to its founder, Victoria Alonsoperez. It is a common practice for enterprises to affiliate their label to an influencer since "there are powerful reasons for using a human face for marketing. A 2008 study showed that e-commerce websites that showed images with faces enhanced initial trust" [28]. However, this may become problematic. If the influencer, in this case, the CEO, misbehaves, the company suffers. Warren Buffet in Berkshire Hathaway's shareholder's letter of 2010 affirmed: "[companies] can afford to lose money – even a lot of money. But can't afford to lose reputation – even a shred of reputation" [28]. This demonstrates how Chipsafer's marketing efforts could be worrisome for Rio Branco. Considering the potentially long-lasting and significant deal, the farm's management was aiming to settle, it is critical that Chipsafer maintains its good reputation standing. On the other hand, the provider shows capable of preserving a respectful profile, which is indicated by a myriad of awards it has received.

The most remarkable recognitions are The Innovator of the Year of 2014, given by MIT Technology Review, winning the 2018 Cisco's Extreme Tech Challenge, and being laureated by Tech Interactive in 2021 [29]. The Massachusetts Institute of Technology is one of the most prestigious universities in the world. It was established in 1861 and is considered a global research leader in science and technology. The MIT Technology Review was founded by the university in 1899. It "is a world-renowned, independent media company whose insight [and] analysis explain the newest technologies and their commercial, social and political impacts" [30].

Moreover, Cisco is a distinguished "multinational technology conglomerate corporation [that] develops, manufactures and sells networking hardware, software, and other high-technology services and products" [31]. Tech Interactive is a science and technology center in Silicon Valley that defines itself as "a world leader in the creation of immersive STEAM education resources to develop the next generation of problem-solvers, globally" [32]. Therefore, the endorsements by these awarders represent reliability. By learning about the awards when completing the third step on the due diligence process, the Office Manager was reassured that Chipsafer would be an adequate business partner. Presenting the great reputation, the company holds, helped to persuade the higher-level management of Rio Branco to implement the idea.

8 THE COST-EFFECTIVENESS OF THE PRODUCT IMPLEMENTATION

The last step in the due diligence process was the result of the Office Manager's extensive research. Decisions on large investments in changing business processes must be prudent and precise. The two main issues Rio Branco faces regards quality management, which is a business topic broadly researched. "During the decade of the 20s' until the 50s', the world experienced the greatest

iteration of statistical models and methods for improving production. A central figure contributed tremendously to this surge in research in statistics and in the [quality management studies], William Edwards Deming” [49].

Even though quality management theories are widely popular in the manufacturing industry, they encounter great resistance in the commodities sector. This aversion to quality improvement is explained by the Five Points of Criticism to quality management. They are very much applicable to Rio Branco’s higher-level management decision-making process. It was a condition the Office Manager had to consider and understand if he intended to reach his goal of convincing Rogerio Safra in applying Chipsafer’s product solution.

The Five Points of Criticism are (1) Quality costs upfront investment. This is true; however, if appropriately applied, the improvement brings greater benefits in the end. (2) Change is bad. Exiting work’s comfort zone demands effort. (3) Territory. Employees tend to see a change in processes as disloyalty about their performance. It makes them insecure. (4) Problem-solving bias. “If ain’t broken, don’t fix it;” typical behavior of businesses that sustain a reactive mindset, which is insufficient to drive quality. (5) Culture. Companies holding an inwardly focused view are those that salary is on the top of the priority pyramid, and that considers employees as subordinates, which bears much bureaucracy, common characteristics of farms.

The Office Manager had to explain in detail to Rio Branco’s higher-level management that a pivotal point in Deming’s work was the “realization that [quality improvement] analysis is just as appropriate and vital to many non-manufacturing processes and systems: to administration, marketing, sales, service operations, training, and many others” [34]. Therefore, his research on how to improve quality levels in the farming field was only possible because of Deming’s findings. If considered Rio Branco’s grand proportions, it can be seen as a beef industry. Deming developed the idea of Total Quality Control, which is the “continual, relentless, perpetual search for improvement [...] in all aspects and all sections of an organization’s work and activities” [34]. Therefore, organizations, like Rio Branco must be centered on the idea of continual improvement if they are aiming to achieve great success. Rio Branco’s 2022 revenue comparison between a scenario with Chipsafer implementation compared to no implementation, is depicted in Figure 6. The organization would acquire \$6500 more in revenue in the first year of implementation.

2022	Rio Branco's Revenue No Implementation	Rio Branco's Revenue Chipsafer Implementation
Beef Revenue	\$4,474,200	\$4,474,200
Soybean Revenue	\$652,800	\$652,800
Cattle Theft Loss	(-\$102,000)	----
TB Loss	(-\$25,500)	----
Chipsafer Cost	----	(-\$121,000)
TOTAL	\$4,972,500	\$4,979,000

Figure 6: Rio Branco's 2022 possible Revenues. Created by the Author, Gustavo Teixeira.

9 CONCLUSION

The production of beef, a commodity consumed by 86 percent of the world population [36], is highly concentrated in a few countries. Brazil sustains an enormous number of sizeable farms that produce this product. Around two thousand and four hundred farms have more than 10 thousand hectares of land [35]. Two common issues these businesses face are cattle theft and bovine tuberculosis, which hinder productivity and cut a considerable profit amount of the flagship Brazilian product. Many strategies have been applied in trying to tackle those problems. However, a final solution was never reached. This research paper addresses a feasible resolution, making considerations about the principal factor in place, money. Since those problems directly affect final profits, the paper answers if the proposed solution would be cost-effective.

The Internet of Things has been introducing innovation and solutions globally for a variety of sectors for around 20 years. This is no different for the agricultural field. Monitoring technologies aiding this sector, called PLF (Precision Livestock Farming), brought sensors to track animals' location and health, with the intent of increasing farms productivity, offering a myriad of product solutions that promise to resolve this business case issue. Among all companies and their products, the research paper analyses and compare two solutions. The analysis stands on the overall picture of the provider, features, and specifications of the product, cost of implementation,

the due diligence process when implementing, and a conclusion about its economic applicability. The final intent of this paper is that its findings would be able to be tailored to similar business cases.

The two companies selected to be analyzed have many similarities. The first one, Smarternack, received incentives from the Indonesian government intending to increase beef productivity there and finally become self-sufficient in its internal market. The inception of the second company, Chipsafer, which is from Uruguay, was motivated by a spread of a disease that afflicted much of that country's cattle herd. Its founder had a background in engineering and saw a financial opportunity as well as a chance of helping her homeland. Both products have very similar features but greatly diverge in the network technology used and the price charged for implementation, the two decisive factors.

Another important point during the research was the difference in the customer service promptness in responding to questions made. Smarternack, the more expensive product solution, never replied to the inquiries; while Chipsafer answered all questions and made itself available for further research questioning. Smarternack is more than 24 times more expensive than Chipsafer. It can be concluded that Smarternack's product solution is not focused on farms that have the proportion of Rio Branco, which is not clearly stated on their website. On the contrary, their marketing efforts affirm that the product would be able and financially sound to be applied to farms of any size, which can bring doubts on their credibility. Then, the researcher concluded that the due diligence process would be performed regarding only the Chipsafer product solution.

The Office manager's research showed that the application of the product would be financially profitable by not only increasing the company's revenue and solving the two major issues Rio Branco faces but also by starting a revolution on the processes of the organization, disrupting the status quo of the business. In Rio Branco's first year of implementation, a revenue gain of \$6500 would be possible. This number is negligible compared to the business's total revenue. However, the implementation is reasonable considering the following years, which would not incur many costs, since the purchase of the majority of collars would be accomplished in the first year.

Moreover, using the implementation of this product is a justification and incentive for the business to focus on Total quality improvement, which is the relentless, perpetual improvement in Rio Branco's processes. Only by incepting a possibly considered slight change by implementing this product, a gradual and much more important change can be made in the entire business, focusing on its culture. This might be the greatest opportunity for Rio Branco to enter a new level of efficiency. If it understands and sees itself as a "manufacturer" of beef in which quality will continuously, perpetually be pursued and improved, it can arrive at a higher degree of productivity. In the end, it can become a motivator for similar farms with likely business cases. By introducing a change on Rio Branco's core business process, the Office Manager has the potential of launching a positive disruption to the production of the largest beef exporter in the world, Brazil.

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