THESIS

THE VALUE OF PREVENTATIVE CARE VERSUS TREATMENT FOR SMALL ANIMAL VETERINARY MEDICINE CLIENTS

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ABSTRACT

THE VALUE OF PREVENTATIVE CARE VERSUS TREATMENT FOR SMALL ANIMAL VETERINARY MEDICINE CLIENTS

The veterinary profession has witnessed a decline in the number of clients that are visiting veterinary clinics for annual preventative care exams. Studies have indicated that clients do not see the value of regular preventative care or annual examinations but clients would be willing to take their pets to their veterinarian more often and follow the recommended preventative care measures if they knew it would prevent problems and expensive treatments in the future. This paper investigates if regular preventative care in companion animal veterinary medicine is cost effective to the small animal veterinary medicine client.

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CHAPTER 1: INTRODUCTION AND BACKGROUND INFORMATION

In 2007, the American Veterinary Medical Association reported that annual dog and cat visits had been on the decline when comparing visits from 2001 to 2006 (AVMA 2007). The American Animal Hospital Association corroborated the finding that there was a decrease in visits to small animal veterinary clinics, with their biennial surveys from 2001 to 2011, and indicated that the decrease in visits may be accelerating over the years (American Animal Hospital Association 2001-2011).

In order to confirm the decrease in number of patient visits, identify the factors responsible and identify actions companion animal practitioners could take, Bayer funded a study on veterinary care usage in small companion animal medicine (Volk et al. 2011a).

In this study both veterinarians and small companion animal veterinary medicine clients were interviewed or surveyed to determine their views on veterinary care usage, specifically visiting the veterinarian for annual wellness exams. In order to accomplish this, fifty-eight small animal veterinary practice owners from across the United States were interviewed in person or by phone about the trends these practice owners were noticing in their clinics from 2006 to 2010, as well as the reasons they believed these trends were occurring (Volk et al. 2011a).

Veterinarians reported that they had noticed a decline in the number of visitors to their clinics. Thirty five percent of veterinarians surveyed reported that they witnessed a decrease in visits between one percent and ten percent, and sixteen percent of veterinarians surveyed witnessed a decrease in visits above ten percent. While many veterinarians saw a decline, thirty-four percent of veterinarians did notice an increase in their number of visits. These veterinarians also reported that wellness exams were the most important service their clinic offered and that they had a repeat client base (Volk et al. 2011a).

In order to combat this decade long decrease in veterinary practice visits, specifically the decline in annual wellness exams, the American Veterinary Medical Association and the American Animal Hospital Association established Partners for Healthy Pets in 2011 in order "to ensure that pets receive the preventive healthcare they deserve through regular visits to a veterinarian." Partners for Healthy Pets (PHP) created a two-stage process in order to achieve their goal. The first stage of this process was to create awareness within veterinary practices and veterinary colleges about the value and necessity of annual exams as the vital delivery method for individualized preventative healthcare. PHPs goal in this stage was to emphasize wellness exams as the key method for providing recommended wellness measures. This stage of the process has yielded positive direction, with a majority of veterinarians, veterinary technicians and veterinary practice managers indicating that their clinics were increasing emphasis on preventative healthcare. More than eighty percent of veterinary college deans and seventy percent of faculty stated that there has also been an increase in the focus of preventative care in veterinary college curriculums (Partners for Healthy Pets 2017).

The second stage of the PHP process is the widespread acceptance by pet owners of the value and need for preventative care measures and annual welfare exams. Unfortunately, the second phase of the PHP process has not been as successful and the majority of clients are not convinced that their time and money is well spent by regularly seeing their veterinarian (Partners for Healthy Pets 2017).

After interviewing practice owners, researchers of the Bayer Veterinary Care Usage Study (2011) collected information on the views of pet owners in regards to how they valued annual wellness exams and visiting their veterinarian. Eight focus groups were created in order to conduct qualitative interviews for pet owners on their views on veterinary care usage. Efforts were made in order to recruit dog and cat owners that represented a wide diversity with regards to age, income, socioeconomic levels and ethnicity. Following these focus groups, researchers then surveyed two thousand one hundred and eighty-eight pet owners on their views of veterinary care usage. Responses were representative of all regions and demographic groups (Volk et al. 2011).

When clients were surveyed about their views on taking their pets to the veterinarian, many clients reported that they did not see the value of taking their pet to the veterinarian when it was not presenting signs of illness. Thirty three percent of clients reported that they would only take their pet to the veterinarian if it was sick, and twenty four percent agreed with the statement that routine checkups were unnecessary for their pet. Only thirty-one percent of clients agreed that without checkups, their pet is more likely to get sick (Volk et al. 2011b).

Based on the studies done by Bayer (2011a), more than half of pet owners surveyed would be willing to take their pet to their veterinarian more often if they knew it could prevent problems and expensive treatments later. Fifty-six percent of dog owners and fifty-nine percent of cat owners indicated this type of thinking. Fifty-three percent of dog owners and fifty-nine percent of cat owners indicated they would bring their pet to the veterinarian more often if they felt it would allow their pet to live longer or have a better quality of life. Finally, forty-nine percent of dog owners and forty-four percent of cat owners indicated that if they really believed their pet needed examinations more often, they would comply with their veterinarians' recommendation of attending their yearly wellness exam (Volk et al. 2011).

Forty-three percent of veterinarians surveyed indicated that they had difficulty in recommending wellness exams and wellness procedures due to concern that their clients would only see them as “trying to make money”. This information in conjunction with clients willingness to comply with attending annual wellness exams and wellness measures if they knew it would prevent expensive treatments in the future and if they believed their pet needed more examinations, are the motivations for this paper.

The objective of this paper is to determine if regular preventative care in companion animal veterinary medicine is cost effective for the consumer, specifically comparing the value of preventing illness to treating illness, and to provide veterinarians the tools to communicate the value of preventative medicine. Based on reviewing the previously published literature on the value of preventative care, this study hypothesizes that when compared to the cost and risk of treating an illness, following preventative care measures recommended by a veterinarian will be cost effective for the small companion animal veterinary medicine client.

Clients are willing to comply with recommended wellness measures if they are fully aware of the value it presents to them and their pet. Clients need to be better informed of the value of wellness and veterinarians need better communication resources for veterinary practices to convey important information about preventive care and clinically relevant diseases. This paper used the results to create an example tool in order for veterinarians to communicate to clients what the best strategy is for their financial situation and for the healthcare of their pets.

In order to accomplish this objective, two methods were used to determine the value of prevention measures compared to the risk and cost of treating the subsequent illness. The first method used decision trees to compare prevention with the costs and risks of treating conditions that American Animal Hospital Association and Partners for Healthy Pets recommend preventing. When surveyed, clients indicated that they would follow wellness measures if they genuinely believed it would reduce future problems and costs in the future (Volk et al. 2011). These decision trees indicate the most cost effective option for clients based on cost and probability of contracting an illness for prevention and treatment.

The second method used five years of invoice data provided by a small companion animal veterinary clinic in order to determine the factors that influence the total spent on treatment for a pet over five years. Wellness measures, varying veterinary procedures, as well as pet specific factors were studied as variables that influence the total spent on treatment for a pet. Clients indicated that they would be inclined to bring their pet for wellness exams and follow preventative wellness measures if they were knew it would reduce treatment costs in the future (Volk et al. 2011). This information was used to determine if wellness measures lead to a decrease in treatment spending, have no effect or lead to an increase in treatment spending.

The information collected from these two models was then used to create educational materials for veterinarians. These educational materials can be used to help veterinarians relay the importance of prevention for pet health and the financial benefit to the client, without fear of accusations. This information will also give clients confidence that investing in their pets health is both necessary and will prevent problems and expensive treatments in the future.

CHAPTER 2: LITERAURE REVIEW

While there have not been any comprehensive studies on the cost effectiveness of prevention and treatment of the illnesses in this study, there have been other studies done on common illnesses that showed prevention being the most cost effective option for animal owners and the healthiest option for the animals.

One of these studies was done on the costs of mastitis and mastitis prevention in dairy herds. Fifty dairy herds were monitored over a one-year span in order to determine an estimation of the cost of mastitis by cow per year. In order to determine these values, each herd was visited on a monthly basis by a veterinarian in order to collect and sample milk for somatic cell counts prior to treatment, evaluate the cows and conduct interviews with the herd owners. The study indicated that the cost for preventing mastitis was $14.50 per cow, while the cost to the producers for cows infected by mastitis was $37.91 (Miller, PC and SE 1993).

Another study that looked that the value of preventing mastitis in dairy cows was performed by Yalcina el al (1999), and looked at the cost of mastitis in terms of milk loss and fines paid from contaminated milk. The study used multiple-regression analysis of field data to quantify the impacts of various mastitis-control procedures on bulk-tank somatic-cell count. Estimates of milk-yield depression and the probability of herds paying a penalty due to the presence of subclinical mastitis were calculated. The study determined that the minimum total cost of mastitis disease within herds that followed the preventative measures was £65.50 per cow per year (due to £41.40 revenue losses plus £24.10 mastitis-control expenditure). While, the average cost of subclinical mastitis for all high somatic cell count farms was £100 per cow per year. The study indicated that £34.50 could be saved by the application of mastitis-control procedures.

A more recent study done in 2003 by SP et al. determined the value of mastitis prevention by comparing milk produced between heifers that were treated with prepartum intramammary antibiotic infusion of heifer mammary glands at seven or fourteen days before expected parturition, compared to those that were not. Heifers in both groups were tested for presence of mastitis and the amount of milk produced, as well as the somatic cell count scores were recorded and compared between the treated and untreated heifers. The prepartum antibiotic-treated heifers produced significantly more milk than control heifers and had significantly lower somatic cell count scores than untreated control heifers. Prepartum antibiotic-treated heifers produced 531 kg more milk than heifers in the untreated control group. Multiplying this increase by a milk price of $0. 407/kg yielded a $216.24 per-heifer increase in gross revenue. The cost of treatment, including the cost of testing for antibiotic residues, was estimated at $15.60 for a net revenue of $200.64 per heifer. Researchers determined that prepartum antibiotic treatment to reduce the rate of mastitis in heifers during lactation was highly effective and economically beneficial.

These prevention studies show the value of prevention measures in animals when only looking at out of pocket costs. These studies take into account the out of pocket cost for preventing an illness as well as treating it. These studies do not take into account the emotional costs of watching an animal suffer through a disease, the cost associated with finding time to visit a veterinarian, the time and effort required to administer treatment, or the risks factors faced by humans (mastitis is not transferable to humans). When comparing the costs in production animals versus companion animals, it is not a direct comparison but does allow for the basis of the hypothesis of this study when comparing direct out of pocket costs.

Although there is minimal literature on pets, prevention analysis in humans has shown the value of preventative care. The global implementation of vaccines has been a marvel for modern medicine. Vaccination has resulted in the elimination of wild poliovirus from the Western Hemisphere. Over one hundred and ninety countries are polio-free and the disease now exists in only about twenty countries, all in the regions of Southeast Asia and Sub-Saharan Africa (CDC 2001). Measles is a major childhood killer in developing countries, accounting for about nine hundred thousand deaths a year that can be avoided through widespread vaccination. Since the implementation of vaccination policies, the American region has reported the lowest incidence rate of one point six cases per one hundred thousand people, in 1998—a seventy-five percent decline from 1997 (CDC 1999). Cases of measles have been on the rise recently, as a new wave of “anti-vaxxers” (individuals who believe vaccines are dangerous and should not be given) are pushing unsupported information of the “dangers” of vaccination. These claims have led to the highest number of outbreaks since 2000 (CDC 2017).

A number of different research institutions have researched the value of a variety of preventative measures. Birhane et al (2016) looked at the willingness to pay for dog rabies vaccine in pet owners in the Philippines and determined that eighty six perceny of respondents were willing to pay for the cost of the vaccine and that knowledge factors influenced the willingness to pay for pet owners. A study done by Lee et al. (2011) looked at the potential economic value of a hookworm vaccine, specifically on school age children and women of childbearing age. Using a Markov decision analytic, they were able to determine that the vaccine was cost saving and had potential health benefits to both populations. Ehreth (2003) compared the cost of preventing diseases such as Polio, Pertussis, Neonatal Tetanus and Yellow Fever, to the cost of treating these diseases. She also included the number of years of life that would have been lost, had vaccination not been implemented. She determined that the benefits to society in vaccinating the population outweighed the costs to society in vaccinating. These studies determine the value of prevention using a variety of different methods, and the outcomes were used as the basis for the hypothesis that preventative measures would be the most effective strategy for the client.

CHAPTER 3: DECISION TREES

Decision trees are quantitative diagrams with nodes and branches representing different possible decision paths and chance events (Palisade 2016). In order to create a decision tree, both the probability of an event occurring (risk) and its numerical consequence (cost) are needed. Precision tree, a tool created by Palisade, is used in order to create the decision trees in this research study. Precision tree uses Microsoft Excel to identify and calculate the value of all possible alternatives for each illness path (Palisade 2016). These decision trees then provide the best option for a client based on risk (probability of contracting disease) and cost. This evidence can then be presented to clients in order for them to see the value of prevention measures in reducing the risk of problems and expensive treatments in the future.

The American Animal Hospital Association (AAHA) and Partners for Healthy Pets both provide the recommended wellness measures for small companion animals in the United States (American Animal Hospital Association 2013). Some of the major illnesses that these organizations recommend taking preventative measures against are flea infestation, Canine parvovirus , leptospirosis, heartworm, kennel cough, and Lyme disease. These illnesses are commonly treated in veterinary clinics and are not required by law to be prevented for. Veterinarians provide clients with the options to either prevent these illnesses or risk infection and subsequent treatment.

In North America, the most commonly encountered flea species on dogs and cats is *Ctenocephalides felis*. Fleas are zoonotic parasites that thrive in warm and humid environments. Zoonotic parasites can be transferred from one organism to an organism of a different species. In this case, fleas contracted by pet dogs or cats can then be transmitted to their human owners

(Blagburn and Dryden 2009). *C. felis* can serve as a vector of cat-scratch disease and feline rickettsiae and can infect humans that contract fleas from their pets (CDC 2017). Fleas can be contracted by pets wherever there is a viable flea infestation. Signs of flea problems range from mild redness to severe scratching that can lead to open sores and skin infections (American Veterinary Medical Association 2016). The current methods for preventing flea infestation include topical (imidacloprid, dinotefuran, fipronil, metaflumizone, selamectin) and oral (spinosad, nitenpyram) adulticides (Blagburn and Dryden 2009).The treatment for fleas is very similar to the prevention for fleas. When a client comes into the clinic with a pet infested with fleas, a veterinarian will recommend a flea preventative. Once administered, the fleas will begin to die and the infestation will be treated. A steroid may also be recommended in order to help reduce a pet's level of itching. For pets with flea allergies and severe infestations, antibiotics are recommended if the itching has produced a secondary rash and infection. In order to help completely remove fleas from the pet's environment, a client should also take care to vacuum all areas where the pet has been, and products can be purchased in order to help remove fleas from the home environment. The severity of environmental cleanup will vary based on the level of flea infestation. An infestation severe enough may even require fumigation from a knowledgeable professional. Without proper environmental cleanup and continual flea prevention, re-infestation of the pet and home from residual fleas will occur (Blagburn and Dryden 2009).

Canine parvovirus is caused by *Parvo enteritis*, which is a virus that is able to survive in the heat, cold, humidity and dry weather for multiple days after being shed in feces and urine. It is contracted through contact with infected dog's excrement's or through any area or person that has been exposed to the shed virus. (American Veterinary Medical Association 2016).Canine parvovirus spreads rapidly among dogs via the fecal-oral route (direct transmission) or through oronasal exposure to fomites contaminated by feces (indirect transmission) (Goddard and Leisewitz 2010). An effective way of preventing Canine parvovirus infection is to vaccinate and to keep pets away from any area or people that have been in contact with an infected pet. The most indicative signs of Canine parvovirus are vomiting, bloody diarrhea, body temperature extremes and abdominal pain (American Veterinary Medical Association 2016). Canine parvovirus is diagnosed through clinical symptoms and a positive parvovirus test. Because Canine parvoviral enteritis is a viral infection, there are no agent-specific treatments, and instead management of this condition remains as supportive care. Pets that die from Canine parvovirus do so due to the secondary symptoms from Canine parvovirus. Hospitalization is necessary for the best management of Canine parvovirus, for this study, hospitalization will be set at ten days. Fluid therapy for the ten days will also be included to treat dehydration, reestablish effective circulating blood volume, as well as correct electrolyte and acid-base. Amount of fluids received will vary based on the size of the dog. Catheters used to provide the fluids will be changed every seventy-two hours as per veterinary regulations. A complete blood count test and packed cell volume test will be administered twice a day in order to monitor patient progress. Although some clients elect to have their pets receive a blood transfusion, financial constraints will be assumed and blood transfusions will not be included for this study. Antiemetic drugs and antibiotics will also be prescribed to reduce vomiting and protect against secondary infections. Metoclopramide and a polyflex/batril combination will be administered three times a day in order to properly manage treatment (Goddard and Leisewitz 2010).

Heartworm disease is a condition caused by an infestation of *Dirofilaria immitis* (heartworms) in the heart, lungs and blood vessels. Heartworms originated in Asia and were brought to the Americas in dogs by early explorers. Mature female heartworms in infected dogs produce microfilaria that travel through the infected dogs' bloodstream. These microfilariae are then ingested when a mosquito feeds off the infected dog. They then are transmitted to another dog when that mosquito feeds off it. In order to prevent the infestation of the larvae, heartworm preventatives are recommended (American Heartworm Society 2016). These preventatives kill newly acquired heartworm larvae but do not affect mature worms. This is why a heartworm test is necessary before dogs can be prescribed the prevention medications (Merck 2016). Signs of heartworm disease include a mild cough, lethargy, fatigue after physical activity, decrease in appetite, and noticeable weight loss. Heartworm is diagnosed through a SNAP Canine Heartworm test to predict antigen load and give some indication to the level of infection. A thoracic radiography can also be used as a method for determining disease severity and for assessing changes after treatment, but may not be done due to financial concerns by the clients. A SNAP test is then normally followed by a chemistry panel, complete blood count and a urinalysis. At this time, monthly macrolide (heartworm) preventive is prescribed to prevent further infection, reduce circulating microfilariae, and kill larval stages not yet susceptible to adulticide therapy. Administration of adulticide therapy can be postponed to the end of the transmission season, to allow larvae to fully mature. Adulticide therapy is then accomplished through the organoarsenic compound melarsomine dihydrochloride (Immiticide). Melarsomine dihydrochloride is the only adulticidal drug approved by the FDA for heartworm treatment. The AHS recommends the three-dose protocol, one deep intramuscular injection into the belly of the epaxial lumbar muscles followed at least one month later by two intramuscular injections of the same dose twenty four hours apart. Melarsomine kills the large adults that are not targeted by the maclide preventative. While cage rest is vital to the recovery process, and cage rest is most easily assured at a veterinary clinic, financial constraints will be assumed, and hospitalization will be limited to only days when procedures were done (Bowman and Atkins 2009).

Kennel Cough occurs due to an inflammation of the upper airways due to the bacteria *Bordetella bronchiseptic*. In order to prevent kennel cough, vaccination is recommended. This vaccine is strongly emphasized in dogs that spend time with dogs that do not live in the same household, as the illness is extremely contagious. Most boarding and grooming facilities require the vaccine, due to the high risk of an outbreak. (Merck 2016). Experimental studies and field reports indicate that the most common clinical sign of kennel cough infection in dogs is a dry, hacking, paroxysmal cough. Coughing tends to become more extreme with excitement and exercise and veterinarians will elicit coughing through palpations of the laryngeal or tracheal regions, in order to confirm diagnosis. When symptoms of kennel cough infection persist and involve more severe, systemic signs, a number of antimicrobials can be used to prevent further spread and systemic invasion (Bemis 1992). While antibiotic selection should be based on bacterial sensitivity results, few owners elect for this test. When that is the case, tetracycline, doxycycline, or quinolones are appropriate choices. For this study, doxycycline will be prescribed twice a day for ten days. Coughing in dogs may be managed by restricting exercise and avoiding excitement as well as prescribing an antitussive medication. For this study, coughing tabs will be prescribed every four hours for five days, as many clients bring their pets in due to irritation from their dogs consistent coughing and subsequent vomiting (Datz 2003).

Lyme disease is a zoonotic disease that is caused by the bacterium *Borrelia burgdorferi*. Lyme is transmitted through tick bites, and is primarily transmitted through the deer tick. Lyme disease can be prevented with regular tick-prevention products and by vaccination against Lyme disease (AVMA 2017). Pets that have been infected with Lyme disease may not show symptoms for two to five months after the initial infection. When signs do appear, they include fever, loss of appetite, recurrent lameness, joint swelling and decreased activity. When diagnosing Lyme disease in a dog, there is no individual test result that documents clinical illness from *B. burgdorferi* infection. A positive diagnosis of Lyme disease should include evidence of exposure to *B. burgdorferi*, clinical signs consistent with Lyme disease, a positive serologic test for antibodies against the agent, and consideration of other possibilities. For this study, we will assume a positive 4DX test for tick-borne diseases and that clinical symptoms were found. Due to the presence of different strains of *B. burgdorferi* in the field and because it is difficult to diagnose Lyme disease in the field or induce clinical disease in experimentally infected dogs, the optimal drugs and duration of therapy are unknown. The most commonly recommend treatment is doxycycline at ten mg/kg PO q24h for a minimum of one month. This study will follow the recommendations of a consulted veterinarian of the appropriate dose of doxycycline twice a day for six weeks (Littman, et al. 2006).

Leptospirosis is a zoonotic bacterial disease caused by infection with *Leptospira* bacteria, with a worldwide distribution, and is an emerging infectious disease in humans and in dogs. These bacteria are found in soil and water, and most pets become infected through exposure from water shared by wildlife (Skyes, et al. 2011). Some dogs display mild or no signs of disease, whereas others develop severe illness or death, often as a result of renal injury. Signs of leptospirosis may include fever, shivering, muscle tenderness, dehydration, vomiting, diarrhea, loss of appetite, lethargy, and jaundice. In general, veterinarians suspect leptospirosis in dogs with signs of renal or hepatic failure, uveitis, pulmonary hemorrhage, acute febrile illness, or abortion (Skyes, et al. 2011). Leptospirosis can be prevented through a vaccine that protects dogs for at least twelve months and treatment includes antibiotics and supportive care (American

Veterinary Medical Association 2016). Similar to the case of Lyme, optimal treatment for leptospirosis is unknown. While there is no definitive test for leptospirosis, diagnosis is based a combination of present symptoms and acute antibody titers found using the microscopic agglutination test (MAT). A complete blood count and urinalysis may also be completed to determine the health of the pet. Penicillins or doxycycline traditionally have been the antimicrobials of choice for treatment of humans and dogs with leptospirosis. For this study doxycycline, five mg/ kg PO for two weeks will be used as the main treatment. In addition to antibiotics, subcutaneous fluids may also be recommended in order to reduce secondary symptoms of infection (Skyes, et al. 2011).

Leptospirosis is a zoonotic disease that can be spread from pets to their owners. Humans can become infected through contact with urine (or other body fluids, except saliva) from infected animal or though contact with water, soil, or food contaminated with the urine of infected animals. The symptoms of leptospirosis in humans do not differ significantly from those in pets. Symptoms of leptospirosis in humans include high fever, muscle aches, jaundice and abdominal pain. Without treatment, leptospirosis can lead to kidney damage, meningitis, liver failure, respiratory distress, and even death (CDC 2017). A study done in Italy by Ciceroni et al. (2000) determined that 18.2% of reported Lepto cases were due to direct contact from an animal or animal urine. Between 1947 and 1994, the most recent years for which data was available, 2,958 cases of leptospirosis were reported in humans in the United States (CDC, 1996). Just as recently as February 2017, BCC news (2017) reported three diagnosed cases of leptospirosis in New York City, with two of the cases being treatable and the other case being lethal to the patient.

3.1: Decision Tree Methods and Data

In order to determine the costs for prevention and treatment for each illness, a combination of veterinary expertise, clinical studies and the American Animal Hospital Association Fee Reference book (2016) were used. A veterinarian was consulted on the treatment plans recommended for each disease, and this information was supported through use of clinical studies. The preventative measures and treatments were then priced out using the AAHA Fee reference book.

3.1.1: Probabilities

In order to determine the probabilities of a pet contracting each of the specific diseases, data from Banfield hospitals on disease prevalence was used. Banfield is a veterinary service company with over nine hundred veterinary medical clinics across the United States and Puerto Rico; with the majority of clinics located within a Petsmart retail store (Banfield 2016a). Banfield researchers have access to their clinics medical records and use this information in order to determine the number of cases of each disease seen in their hospitals. The information from these records is then provided to the public through portals on their website and their major publication "State of Pet Health Report". The Banfield portal provides the prevalence values for each disease for the country as a whole and by state. Unfortunately, Banfield does not provide readily available statistics on Leptospirosis . In order to determine the prevalence of Leptospirosis , research using the Veterinary Medical Database was used to acquire this information (Ward et. al 2002). The Veterinary Medical Database is a collection of medical information on patients and visits from twenty-two North American Veterinary College teaching hospitals. The number of diagnosed Leptospirosis cases for each veterinary teaching hospital was provided by the database. This information was then compiled into an average probability for the entire country.

Each illness in this study has varying prevalence values throughout the United States due to the biology of each specific disease. For example, Lyme disease is a tick borne illness, with the species of tick that most commonly spreads the disease concentrated in North Eastern States. As such, the probability of contracting Lyme while in a state such as New York is much higher than a state with low tick populations. Fleas (the causative organism for flea infestations) thrive in warm and humid environments, and so the prevalence of fleas is higher in South Eastern states than North Eastern states. Due to these differences in prevalence values, each illness in the study, with the exception of Leptospirosis, was broken up into three categories. The third of states with the lowest risk of infection were placed into the "Low Risk" category, the third of states with the highest risk of infection were placed into the "High Risk" category, and the remaining states were placed into the "Medium Risk" category. The prevalence values for each of the states in each category were then averaged together to give low risk probability of contracting a specific illness, medium risk and high risk. This is the case for each illness, minus Leptospirosis, which uses the country average probability for each state, due to lack of state level information. The breakups of risks by state are summarized in Table 1 and the probabilities of contracting an illness while not on prevention are summarized in Table 2

Each preventative measure for the subsequent illness has a separate tree for each of the varying risk categories. Each illness has three separate trees per prevention method for small dogs and three trees for large dogs due to varying costs of treatment based on size. Illnesses for cats have only three trees, as there is minimal variation in cost due to cat size.

In order to determine the probability of a pet contracting each of the specific diseases, while on disease prevention, multiple case studies on the efficacy of these preventative measures were used. The efficacy values were subtracted from one hundred, and the subsequent values were then multiplied by the probability of contracting the disease without vaccination, in order to determine the probability of contracting an illness after being treated with prevention measures. The probabilities of contracting an illness with prevention are summarized in Table 3.

The Seresto Collar and Frontline Plus are two commonly prescribed flea preventatives that are used in this study as preventative measures for flea infestation. The Seresto collar is polymer matrix collar, with the active ingredients of imidacloprid and fluethrin, that pets wear in order to prevent fleas and ticks for up to eight months (Bayer 2016). In a study done by Stanneck et al. (2012), two groups of cats and dogs (treated group and control group) were infected with fleas and monthly flea counts were conducted for a span of eight months. Efficacy was calculated as reduction of infestation rate within the same treatment group and statistically compared between the two treatment groups. Preventive efficacy against fleas in cats/dogs treated with the Seresto collar was between ninety seven point four percent/ninety four point one and one hundred percent/ one hundred percent respectively. This paper uses the overall mean of ninety-eight point three percent/ninety six point seven percent for the efficacy of the Seresto collar (Stanneck et al. 2012).

Frontline plus is a topical solution, with the active ingredients of fipronil and methoprene, which is applied to a pet every thirty days (Frontline 2017). In order to determine the efficacy of Frontline against adult fleas and preventing egg production in dogs, a study was conducted on sixty-one flea-infested dogs. Sixty-one flea infested dogs were given Frontline topical solution and then flea counts were conducted on all dogs at weeks two, four, eight, and twelve following initial treatment. Efficacy was calculated as the mean percent reduction in tick or flea count at each time point compared with the mean pretreatment initiation count for each treatment group. These values were then averaged together to give an efficacy value of ninety-seven point eight five percent (Rohdich et al. 2013). This leads to the efficacy of Frontline Plus in this study to being ninety-seven point eight five percent.

The efficacy for Frontline in cats was determined using a study conducted on one hundred and eighty flea-infested cats in seven different European countries. Each animal was treated at days zero, thirty, sixty at their respective veterinary clinics. For each animal, at least three flea counts were performed on days zero, thirty, sixty and/or ninety in order to evaluate the prevalence of flea infestation and the efficacy of control. At day ninety, eighty-nine point four one percent of cats were cured of their flea infestation (Beugnet and Franc 2010). Using this value, the efficacy of Frontline on cats is eighty-nine point four one percent.

The preventative measure for Canine parvovirus is a vaccine administered once a year by a veterinary professional. In order to determine the efficacy of the Canine parvovirus vaccine, eighty-nine puppies of varying breeds were vaccinated with the Canine parvovirus vaccine, while twenty-three puppies were left as the unvaccinated control group. Both groups were then tested for levels of parvovirus antibodies. Dogs that had significant levels of parvovirus antibiotics were determined to be effectively protected against Canine parvovirus. Eighty percent of the puppies in the study were found to have reached the necessary levels of resistance post vaccination (De Crammer et al. 2011). This leads to the efficacy of the Canine parvovirus vaccine to be eighty percent.

The preventative measure for leptospirosis is a vaccine administered once a year by a veterinary professional. In order to determine the efficacy of the leptospirosis vaccine, effectiveness of vaccination was determined as a measurement of the renal carrier state. When infected with leptospirosis, dogs develop renal damage due to the side effects of the disease. This study compared 34 beagles of various ages vaccinated with the leptospirosis vaccine, to 36 unvaccinated control beagles. These dogs were then challenged with leptospirosis and were measured for the renal carrier state. Two of the thirty-four vaccinated beagles were found to be in the renal carrier state, with thirty-two of the beagles found not to be in the renal carrier state (Minke et al. 2009). This leads to the efficacy of the leptospirosis vaccine to be ninety-four percent.

According to the American Heartworm Society (AHS), the lack of efficacy in heartworm preventatives is due to compliance issues and failure to properly administer the correct doses as labeled on the packaging. The AHS claims that infections of heartworm while pets are on heartworm medication, is due to missed or delayed doses, especially in cases of high endemic areas. When there is an infection, despite full compliance of heartworm preventatives, the AHS claims that it is due to biological factors, such as failure of absorption of active ingredient, variation in host metabolism and variation in host immune response to parasites (American Heartworm Society 2017).

Despite the claims of the AHS and the FDA that heartworm preventatives are one hundred percent effective, this study will use efficacy values of recent studies done in laboratory settings. Due to an increase in reports of failure of effectiveness of heartworm preventatives a study by Byron et al. was conducted on the efficacy of four common heartworm preventatives, Revolution, Heartgard, Sentinel and Advantix II. The values determined in the Bryon study were used for the decision trees in this paper, in order to determine an accurate probability of a dog contracting heartworm despite being treated with prevention medications. five groups of eight lab reared dogs were exposed to fifty third-stage heartworm larvae. Four of these groups were treated with the varying types of preventative medication prior to exposure, and the 5th group was used as a control. These dogs were then euthanized and necropsied for recovery of heartworms. Efficacy was calculated by determining the difference between the mean number of heartworms in treated dogs, from the mean number of heartworms in the control group (Efficacy= mean number of heartworms in control dogs- mean number of heartworms in treated dogs / mean number of heart worms in control dogs X 100) (Byron, Arther and Bowles 2016). The efficacy of Revolution, Heartgard, Sentinel and Advantix II were calculated to be twenty eight point eight percent, twenty nine percent, fifty two point two percent and one hundred percent respectively.

In order to determine the efficacy of the recombinant, nonadjuvanted *Borrelia burgdorferi* Lyme vaccine, seventy-nine mixed breed dogs of at least one year in age and with complete histories of immunizations and medical histories from Lyme endemic areas, were divided into two groups. Sixty dogs were put into the vaccinated group and nineteen dogs were put in the not vaccinated group. Vaccinated group dogs were dogs that had each been given 2 doses of the OspA Lyme vaccine before 6 months of age and were given boosters each year according to the manufacturer's instructions. Dogs in the not vaccinated group were dogs that had not ever received the OspA Lyme vaccine. Canine SNAP 3Dx test was used for the detection of *B. burgdorferi* infection. Vaccine efficacy was calculated as preventable fraction by comparing infection rates in unvaccinated and vaccinated dogs. The vaccinated group had a preventable fraction of sixty point three percent. Based on this, the efficacy of the Lyme vaccine is sixty point three percent (Levy et al. 2005).

There are multiple methods in preventing for kennel cough infection in dogs. This paper uses the efficacy of the live avirulent *Bordetella bronchiseptica* vaccine. In a study conducted by Hess et al. (2011), fifty beagles were randomly assigned to treatment groups and control groups. During the process of the study, multiple beagles were removed from the study for various reasons. The puppies were each vaccinated at eight weeks of age, then challenged with *Bordetella spp* five weeks post vaccination. A puppy was considered positive for tracheobronchitis when observed coughing on any two days. Only one of the fourteen puppies in the treatment group was positive for tracheobronchitis. This leads the efficacy of the bordetella vaccine to be ninety two point eight two percent (Hess, et al. 2011).

3.1.2: Costs

In order to determine the costs associated with preventing these diseases, the American Animal Hospital Association fee reference book (2016) was used. The American Animal Hospital Association (AAHA) is the only organization to accredit companion veterinary hospitals (American Animal Hospital Association 2017). In order to become an AAHA accredited veterinary clinic, clinics must meet their over nine hundred accreditation standards. Twelve to fifteen percent of veterinary clinics in the United States and Puerto Rico are currently AAHA accredited veterinary clinics (American Animal Hospital Association 2017). AAHA surveys each of its accredited hospitals once a year to determine the average and median prices for veterinary services and procedures. They also collect information on the average and median percent mark ups for medications and vaccines. This book provides the average price for the prevention options for each illness used in this study (American Animal Hospital Association 2016). The expected costs of prevention was broken up into two groups, cost to prevent an illness in small dogs (1lbs-25lbs) and the cost to prevent an illness in large dogs (26lbs-100lbs).

This method was used due to the fact that prevention products vary in cost based on dog size. The mean prices for each preventative measure are provided in Table 4.

In order to determine the costs for treating these diseases after a pet has been exposed and contracts the disease, veterinary professionals were consulted on the treatment plan. Veterinarians provided information on the treatment options and the procedures and drugs necessary to complete them. Because the effects of these illnesses vary based on situation and there is no one method to treat, these procedures were then cross-referenced with clinical studies on these illnesses to assure treatment plans were in line with the what is recommended by the veterinary community. Once the information on these procedures and medications were provided, the AAHA veterinary reference fee book (2016) was used to determine the mean costs of each of each treatment. The average treatment cost for each procedure and product was summed together to give the total average expected cost of treating an illness. Similarly to determining the costs of prevention methods, the average expected treatment costs are broken up into small and large dog treatment costs. Dosages of medications vary based on pet size and so to give the most accurate representation of treatment costs, small and large dogs are priced separately. Treatment plans were stated in the previous section and the costs for each treatment is summarized in Table 5.

In order to create the pathway for choosing to purchase flea prevention, the probability of contracting fleas while on the preventative measures of either the Seresto Collar or Frontline, and the cost of these preventative measures for six months were used. Six months was chosen due to clients commonly purchasing flea prevention for only the six months of the year that are warm weathered. For the pathways that represents foregoing prevention, the costs of treatment were used, as well as the probability of flea infestation while not on prevention as determined by Banfield studies (2016a).

The heartworm decision trees used the probabilities provided by the Banfield research and the costs determined using AAHA reference fee book. The purchase heartworm prevention pathway used the costs of each specific heartworm preventative, and the probability of contracting heartworm while on said prevention. The preventative measures researched are Heartgard, Revolution, Sentinel, and Advantix II. The “does not purchase heartworm preventative” pathway used the cost to treat heartworm as provided by the American Heartworm Association and the probability of contracting heartworm while not on prevention.

The pathway for purchasing leptospirosis prevention used the cost of the leptospirosis vaccine, as determined by the AAHA reference fee book (2016), with a probability of contracting the disease while vaccinated. The “does not purchase leptospirosis vaccine pathway” used the probability of contracting leptospirosis and the costs of treatment, as determined from veterinary knowledge and the AAHA reference fee book (2016). The probability of contracting leptospirosis was the same for each state and so there were only be two decision trees for leptospirosis , one for small dogs and one for large dogs.

The Lyme disease tree has a treatment pathway that used the probability of contracting the disease as provided by Banfield and the costs, determined through the AAHA reference fee book. There has been some debate in the veterinary community about the validity of the Lyme disease test in properly assessing if a dog has contracted Lyme, but this study will assume that all the diagnosed Lyme cases were diagnosed correctly and the probabilities are accurate. The Lyme prevention pathway used the cost of the Lyme vaccine and the probability of contracting Lyme while on prevention.

The Canine parvovirus decision trees used the cost of vaccinating for Canine parvovirus and the probability of contracting Canine parvovirus while vaccinated in order to create the pathway for purchasing prevention. Canine parvovirus is a condition where survival is not guaranteed even if treatment is performed. There is a ninety-five percent success rate for treatment when clients bring their pets in as soon as symptoms are presented. In order to account for this, the probability of a dog having to be euthanized (five percent) and the cost of euthanasia ($94.49 for small dogs and $103 for large dogs) were included in the cost of treatment.

The kennel cough trees use the cost of treating and managing kennel cough and the probabilities of contracting the illness. Despite the fact that kennel cough does not need to be treated at the veterinary office, most clients choose to have their pets treated, due to the frustration from their pets consistent coughing, gagging and subsequent vomiting. Due to this fact, treatment costs were used and a "no cost" treatment pathway was not included. The kennel cough preventative pathway used the cost of the bordetella vaccine and the probability of contracting kennel cough while vaccinated with this vaccine.

3.2: Decision Tree Results

Figures 1 through 62 show the results of each individual decision tree, Figure 1 is presented in this chapter as an example, while figures 2 through 62 are located in Appendix A. Table 6 summarizes the results of each of the decision trees for each of the preventative measures. Tables 7 and 8 summarize the expected costs of foregoing prevention and expected costs of prevention respectively for small dogs and cats. Tables 9 and 10 summarize the expected costs of foregoing prevention and expected costs of prevention respectively for large dogs. Tables 8 and 10 use the prevention options for fleas and heartworm with the lowest costs, as clients surveyed stated that they wanted to reduce their overall spending on their pet, and the decision trees indicated these options were the most cost effective of the relevant preventative measures. Tables 11 and 12 summarize the difference in expected cost of prevention from the expected cost of treatment.

Whether or not a preventative measure for each specific disease was the effective option for clients was determined by the risk of disease contraction and cost of prevention and treatments. For flea infestations, Frontline flea prevention was cost effective for both large and small dogs in high risk states. The expected cost for foregoing prevention was $71.14 and $61.80 respectively, while the expected cost of purchasing Frontline was $23.03 and $22.54 respectively. Seresto Collar flea prevention was also cost effective for large and small dogs in high risk states. The expected cost of foregoing prevention as previously stated is $71.14 and $61.80 respectively, while the expected cost of purchasing the Seresto Collar was $62.83 and $53.88 respectively. In cats, flea prevention was cost effective only in the case of Frontline flea prevention in high risk states. The expected cost of foregoing prevention was $22.26, while the expected cost of purchasing Frontline was $20.03. These results indicate that in areas of high risk of flea infestation, clients should purchase flea prevention for their pet if they wish to not pay more in order to treat their pet for a flea infestation. Veterinarians must relay to these clients that based on the risks and costs in the area they are living, foregoing prevention is likely to produce larger out of pocket treatment costs than if they purchase flea prevention. Veterinarians can provide two the cost effective options for flea prevention to clients and express to them the benefits of each. For example, Frontline has a lower expected prevention cost but has to be applied once every month, while Seresto has a higher expected prevention cost but only needs to be applied once every eight months. Both scenarios are cost effective but the non-cost based requirements may affect the purchase clients make.

For vaccines against illnesses, none of the vaccinations were the cost effective option except for the Canine parvovirus vaccine. For states with high risk of Canine parvovirus, vaccinating was the cost effective option, for both large and small dogs. The expected cost for foregoing prevention was $41.01 and $37.53 respectively, while the expected cost of purchasing the Canine parvovirus vaccine was $32.68 and $31.99 respectively. These results indicate that clients in high risk states should vaccinate their dogs for Canine parvovirus in order to not pay a higher fee should their pet become infected. Veterinarians can present to their clients that when looking only at out of pocket costs, purchasing Canine parvovirus prevention is cost effective and will save them money in the future. Veterinarians can relay to their clients that if they choose to forego the prevention while living in a high risk area, they have the expected out of pocket cost greater than their cost of prevention.

Advantix II heartworm prevention was the cost effective option for clients living in high risk states for heartworm for both large and small dogs. The expected cost of foregoing prevention was $41.34 and $40.15 respectively, while the expected cost of purchasing Advantix II was $20.54 and $18.46 respectively. None of the other heartworm preventatives at any risk level were considered the cost effective options for small or large dogs. These results indicate that when preventing for heartworm, clients should purchase Advantix II heartworm prevention in order to not have to pay more in the future, should their pet become infected with heartworm. Veterinarians should recommend prevention options, specifically Advantix II to clients and inform them that purchasing prevention for their pet has a roughly $20 net benefit than if they forego prevention and risk treatment. When looking solely at out of pocket costs, preventing for heartworm disease through the use of Advantix II is cost effective.

When looking at the methods of prevention that do not result in being cost effective, veterinarians must ask their clients what they are willing to pay to keep their pets safe. Tables 11 and 12 rank each preventative measure by the amount of the difference in expected cost of foregoing prevention to the expected cost of prevention. For values that are negative, this indicates an expected loss to clients that they should be asked if they would be willing to pay. Veterinarians must ask clients if they are willing to pay this value in order to keep their pet healthy reduce their risk of a more expensive treatment and prevent multiple follow up visits.

For each prevention measure, there is a break-even cost of treatment that will cause an owner to be indifferent to the choice of purchasing prevention or risking treatment. At this point, the expected costs for both options is equal. In order to determine at what point the expected cost of prevention becomes the same as the expected cost of treatment, equation 1 was used. This equation solves for the additional cost of treatment that would make prevention as desirable as risking treatment.

(1) Inconvenience cost= [Prevention Cost/ (Probability of contracting an illness + probability of contracting an illness while on prevention)]-Treatment costs

While each of these illnesses have tangible out of pocket costs, there are costs associated with treatment that do not have a strict monetary value. Treatment does not only include the price you pay at the veterinary office, treatment also includes the time and energy finding a veterinarian that has open appointments, watching your pet suffer through an illness that could have been prevented, finding someone in the family to take the animal to the clinic, following with the recommended treatments, and in some cases, the risk that humans in the household will also become ill. All of these non-monetary costs are accounted for in the break-even additional treatment cost, which in this study will be referred to as the inconvenience cost. Expected cost of treatment at the break-even point includes the out of pocket costs to the client, as well as a numerical representation of the time and energy costs associated with treatment. These are costs that veterinarians must relay to their clients in order for the client to have a full understanding of the full costs associated with foregoing prevention. Tables 13 and 14 summarize the break-even inconvenience cost for each prevention measure.

In the case of prevention measures that were cost effective, the break-even additional treatment costs are negative. In these cases, even if the cost of treatment was over estimated, prevention will be the cost effective option. For example, the cost of treating flea infestation compared to purchasing Frontline flea prevention can be over estimated by $47.00 and still be cost effective to the veterinary consumer. In the case of the Seresto collar, flea infestation treatment costs can be over estimated by $13.41 and it would still be the cost effective option. The treatment cost for parvovirus can be over estimated by $648.09 and in the case of Advantix II, treatment for heartworm can be over estimated by $390.37 and both options will still be cost effective for clients living in high risk states. In these cases, veterinarians can present to clients that not only are these options cost effective, they have a range of costs in which they continue to be cost effective. This range allows veterinarians to present their treatment costs and indicate to clients that it is above the threshold for making prevention the cost effective option.

In cases where prevention was not the cost effective option, the break-even price is positive. These values are presented to clients as additional inconvenience costs of treating a pet, should they contract the illness. In small dogs, the break-even amounts vary in magnitude based on prevention. In the case of the bordetella vaccine in high risk states, the break-even point is an additional $24.22. Veterinarians must ask their clients if avoiding losing sleep over their dogs consistent coughing, regularly cleaning up vomit, and medicating their dog for a week is worth an additional inconvenience cost $24.22. Veterinarians must ask clients that live in high risk areas that are reluctant about paying for the bordetella vaccine what their time and energy is worth, and if it is worth less than $24.22. In cases where clients value their time and energy above $24.22, the cost effective option because purchasing prevention.

In the case of treating flea infestation or purchasing Frontline flea prevention in small dogs and cats in medium risk states, the break-even additional cost are $107.14 and $274.98 respectively. This indicates that for small dogs, an additional cost of $107.14 will make purchasing Frontline as desirable as risking treatment. Veterinarians must convey to clients that non-monetary costs associated with flea infestation and ask their clients if they believe their time and energy is worth more than these values. Fleas are a zoonotic parasite that can migrate from the pet host to human hosts. These fleas can also carry contagious diseases, such as cat scratch fever, and infect children and adults in the household. Fleas are also able to continue living in carpets and bedding, and so in addition to the hassle of bringing a pet to the veterinarian and purchasing flea treatment, clients must also invest effort into making sure the house no longer has fleas or re-infestation will occur. Veterinarians must ask their clients if avoiding all these extra non-out of pocket risks and costs is worth $107.14 for small dogs and $274.98 in cats. Clients may choose to purchase Frontline despite it not being the cost effective option when looking at out of pocket costs, if it was properly communicated to them that there are other costs associated with treatment. If clients indicate that the safety of their family and their time and energy is worth more than $107.14/$274.98, then the expected cost of treatment increases and prevention becomes the cost effective option.

In the case of large dogs, treating the disease compared to purchasing the Lyme vaccine and the bordetella vaccine in high risk states both have break-even additional costs of less than

$30. In the case of Lyme, an additional $24.27 would need to be added to the out of pocket cost in order to make both prevention and treatment equally desirable. Veterinarians must ask their clients what is it worth to them to avoid having to medicate their dogs for weeks, avoid having to watch their dog suffer from limb pain, and avoid the hassle of returning to the veterinarian for treatment. Veterinarians must ask their clients if their time and energy and pets quality of life is worth more to them than $24.27. If that is the case, than prevention becomes a desirable option to the client. For bordetella vaccine, an additional cost of $19.12 would make the two options equally desirable. Veterinarians must ask their clients if avoiding the time and energy bringing their pet to the clinic, watching them suffer and medicating them is worth more to them than $19.12. If it is, than the bordetella vaccine becomes the cost effective option.

In situations where prevention is indicated to be cost effective, veterinarians should present the results to their clients in order for their clients to feel confident in their investment in prevention. In cases where prevention measures are not cost effective when only looking at out of pocket costs, prevention may become equally as desirable and cost effective when the time and energy of treating an illness are given a monetary value and added to the out of pocket treatment costs. These are the additional costs included in treatment costs in order to reach the break-even point, referred to as the inconvenience cost. Veterinarians must present to a client the inconvenience cost, and ask if a clients time and energy are worth more than the inconvenience cost. If it is the case, than prevention will become the cost effective option and clients will choose to prevent. But this cost needs to be properly communicated to clients. Clients need to understand that not only are they avoiding out of pocket costs, they are also avoiding costs associated with the inconvenience of treating a pet. In cases where the break-even cost is in the thousands, prevention may not be worth it to the client, but in the cases where the inconvenience cost is below $100, clients may find that avoiding the non-out of pocket costs is worth more than the break-even treatment cost and so prevention becomes the cost effective option for them.

Table 1: Risk Level by State

	Fleas (Canine)	Fleas (Feline)	Parvovirus	Heartworm	Kennel Cough	Lyme
Alabama	Medium	Medium	Medium	Medium	Low	Medium
Arizona	Medium	Low	High	High	High	Low
Arkansas	Low	Low	Low	Medium	Low	Low
California	High	High	High	High	High	High
Colorado	High	High	High	High	High	High
Connecticut	Medium	Medium	Low	Medium	Medium	High
Delaware	Low	Low	Low	Low	Low	Medium
Florida	Medium	Low	High	Medium	High	Medium
Georgia	High	High	High	High	High	Medium
Idaho	Low	Low	Low	Low	Low	Low
Illinois	Medium	Medium	High	High	High	High
Indiana	Medium	Medium	Medium	Medium	Medium	Medium
Iowa	Low	Low	Low	Low	Low	Low
Kansas	Medium	Medium	Medium	Medium	Low	Low
Kentucky	Medium	Medium	Medium	Low	Medium	Medium
Louisiana	High	Medium	High	High	Medium	Low
Maryland	Medium	High	Medium	High	High	High
Massachusetts	Medium	Medium	Low	Medium	Medium	High
Michigan	Medium	Medium	Low	Medium	Medium	Medium
Minnesota	Low	Medium	Low	Medium	Medium	High
Mississippi	Medium	Medium	Medium	High	Low	Low
Missouri	High	High	High	High	Medium	Medium
Montana	Low	Low	Low	Low	Low	Low
Nebraska	Low	Low	Low	Low	Low	Low
Nevada	Low	Low	High	Low	Medium	Low
New Hampshire	Low	Medium	Low	Low	Low	High
New Jersey	Medium	Medium	Medium	Medium	High	High
New Mexico	Low	Low	Medium	Low	Low	Low
New York	Medium	High	Medium	Medium	Medium	High
North Carolina	High	High	High	High	High	High
Ohio	High	High	High	Medium	High	Medium
Oklahoma	High	Medium	High	High	Medium	Low
Oregon	High	High	Medium	Low	High	Medium
Pennsylvania	High	High	Medium	Medium	Medium	High
Rhode Island	Low	Low	Low	Low	Low	Medium
South Carolina	High	High	High	High	High	High
South Dakota	Low	Low	Low	Low	Low	Low
Tennessee	High	High	High	High	Medium	Medium
Texas	High	High	High	High	High	High
Utah	Low	Low	Medium	Low	Medium	Low
Virginia	High	High	Medium	High	High	High
Washington	High	High	Medium	Medium	High	Medium
Wisconsin	Low	Low	Low	Low	Low	Medium

Table 2: Probability of Contracting Illness as a Percentage'

	Low Risk	Medium Risk	High Risk
Fleas (Dog)	1.1700	11.8100	86.6447
Fleas (Cat)	0.3757	4.7600	31.2053
Parvovirus	0.0650	0.5143	2.6447
Heartworm	0.0600	0.5071	5.5567
Kennel Cough	0.8021	4.3107	22.0207
Lyme	0.1664	1.0707	11.2367
Leptospirosis	0.0370	0.0370	0.0370

Table 3: Probability of Contracting Illness While Following Preventative Measures as a Percentage

	Low Risk	Medium Risk	High Risk
Seresto Collar (Canine)	0.0386	0.3897	2.8593
Frontline (Canine)	0.0252	0.2539	1.8629
Parvovirus Vaccine	0.0130	0.1029	0.5289
Leptospirosis Vaccine	0.2220	0.2220	0.2220
Heartgard	0.0426	0.3601	3.9452
Sentinel	0.0287	0.2424	2.6561
Advantix II	0.0000	0.0000	0.0000
Revolution	0.0427	0.3611	3.9563
Bordetella Intranasal Vaccine	0.0321	0.1724	0.8808
Lyme Vaccine	0.0661	0.4251	4.4610
Seresto Collar (Feline)	0.0064	0.0809	0.5305
Frontline (Feline)	0.0398	0.5041	3.3046

Table 4: Cost of Preventative Measures

	Price-Small Dog	Price- Large Dog	Price- Cat
Seresto Collar (Dog)	51.84	60.48	-
Frontline (Dog)	21.53	22.01	-
Parvovirus Vaccine	24.48	24.48	-
Leptospirosis Vaccine	21.68	21.68	-
Heartgard	37.70	59.09	-
Sentinel	64.07	55.39	-
Advantix II	18.46	20.54	-
Revolution	21.18	21.89	-
Bordetella Vaccine	21.09	21.09	-
Lyme Vaccine	30.10	30.10	-
Seresto Collar (Cat)	-	-	51.84
Frontline (Cat)	-	-	18.23

Table 5: Cost of Treatment

	Price- Small Dog	Price- Large Dog	Price- Cat
Leptospirosis	269.60	276.74	-
Parvovirus	1419.45	1550.82	-
Kennel Cough	67.87	72.97	-
Heartworm	722.58	743.97	-
Lyme	146.04	167.48	-
Fleas	71.33	82.11	71.33

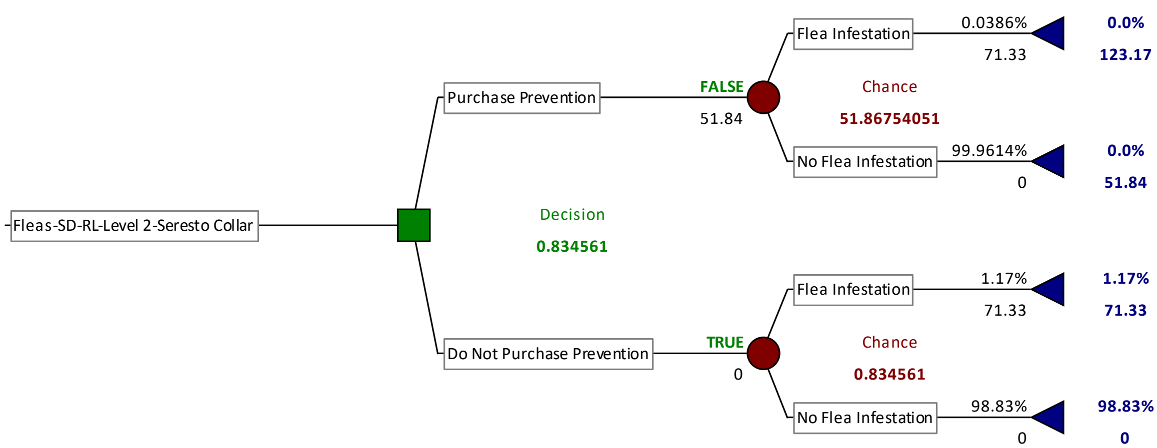

Figure 1: Decision Tree for Seresto Collar Flea Prevention in Low Risk State for Small Dog

Table 6: Summary of Outcomes of Decision Trees

Prevention Method (Animal treated)	**Prevention Cost Effective Option**	**Not Preventing Cost Effective Option**
Seresto Collar Flea Prevention (Large & Small Dog)	High Risk States	Low Risk States Medium Risk States
Frontline Flea Prevention (Large & Small Dog)	High Risk States	Low Risk States Medium Risk States
Seresto Collar Flea Prevention (Cat)		Low Risk States, Medium Risk States, High Risk States
Frontline Flea Prevention (Cat)	High Risk States	Low Risk States Medium Risk States
Lyme Vaccine-Lyme Disease Prevention (Large & Small Dog)		Low Risk States Medium Risk States High Risk States
Bordetella Vaccine-Kennel Cough Prevention (Large & Small Dog)		Low Risk States Medium Risk States High Risk States
Parvovirus Vaccine-Parvovirus Prevention (Large & Small Dog)	High Risk States	Low Risk States Medium Risk States
Sentinel Heartworm Prevention (Large & Small Dog)		Low Risk States Medium Risk States High Risk States
Advantix II Heartworm Prevention (Large & Small Dog)	High Risk States	Low Risk States Medium Risk States
Heartgard Heartworm Prevention (Large & Small Dog)		Low Risk States Medium Risk States High Risk States
Revolution Heartworm Prevention (Large & Small Dog)		Low Risk States Medium Risk States High Risk States
Leptospirosis Vaccine-Leptospirosis Prevention (Large & Small Dog		All states (uses country average)

Table 7: Summary of Expected Cost of Foregoing Prevention in Small Dogs and Cats

	Disease	Cost to Treat	Probability of Infection (Risk)	Cost of Foregoing Prevention (Cost x Risk)
Low Risk States	Fleas(Dog)	71.33	1.1700%	0.8345
	Fleas(Cat)	71.33	0.3757%	0.2680
	Parvovirus	1419.45	0.0650%	0.9226
	Heartworm	722.58	0.0600%	0.4335
	Kennel Cough	67.87	0.8021%	0.5444
	Lyme	146.04	0.1664%	0.2430
	Leptospirosis	269.60	0.0370%	0.0998
	Expected Cost of Foregoing Preventative care (Dogs)			3.0778
	Expected Cost of Foregoing Preventative care (Cat)			0.2680
Medium Risk States	Fleas(Dog)	71.33	11.8100%	8.4238
	Fleas(Cat)	71.33	4.7600%	3.3952
	Parvovirus	1419.45	0.5143%	7.3000
	Heartworm	722.58	0.5071%	3.6645
	Kennel Cough	67.87	4.3107%	2.9255
	Lyme	146.04	1.0707%	1.5636
	Leptospirosis	269.60	0.0370%	0.0998
	Expected Cost of Foregoing Preventative care (Dogs)			23.9772
	Expected Cost of Foregoing Preventative care (Cat)			3.3952
High Risk States	Fleas(Dog)	71.328	86.6447%	61.8019
	Fleas(Cat)	71.328	31.2053%	22.2581
	Parvovirus	1419.4534	2.6447%	37.5398
	Heartworm	722.5804	5.5567%	40.1514
	Kennel Cough	67.866	22.0207%	14.9445
	Lyme	146.0369	11.2367%	16.4097
	Leptospirosis	269.60	0.0370%	0.0998
	Expected Cost of Foregoing Preventative care (Dogs)			170.9471
	Expected Cost of Foregoing Preventative care (Cat)			22.2581

Table 8: Summary of Expected Cost of Prevention for Small Dogs and Cats

	Disease	Cost to Prevent	Probability of Contracting Disease	Cost of Disease Treatment	Cost of Prevention (Cost to Prevent+ [Risk x Cost to Treat])
Low Risk States	Frontline (Canine)	21.53	0.0252%	54.35	21.54
	Parvovirus Vaccine	24.48	0.0130%	1419.45	24.66
	Leptospirosis Vaccine	21.68	0.2220%	269.60	22.28
	Advantix II	18.46	0.0000%	722.58	18.46
	Kennel Cough	21.09	0.0321%	67.87	21.11
	Lyme Vaccine	30.1	0.0661%	146.04	30.20
	Frontline (Cat)	18.23	0.0398%	54.35	18.25
	Expected Cost of Preventative Care (Dog)		0.3584%		138.26
	Expected Cost of Preventative Care (Cat)		0.0398%		18.25
Medium Risk State	Frontline (Canine)	21.53	0.2539%	54.35	21.67
	Parvovirus Vaccine	24.48	0.1029%	1419.45	25.94
	Leptospirosis Vaccine	21.68	0.2220%	269.60	22.28
	Advantix II	18.46	0.0000%	722.58	18.46
	Kennel Cough	21.09	0.1724%	67.87	21.21
	Lyme Vaccine	30.1	0.4251%	146.04	30.72
	Frontline (Cat)	18.23	0.5041%	54.35	18.50
	Expected Cost of Preventative Care (Dog)		1.1763%		140.27
	Expected Cost of Preventative Care (Cat)		0.5041%		18.50
High Risk States	Frontline (Canine)	21.53	1.8629%	54.35	22.54
	Parvovirus Vaccine	24.48	0.5289%	1419.45	31.99
	Leptospirosis Vaccine	21.68	0.2220%	269.60	22.28
	Advantix II	18.46	0.0000%	722.58	18.46
	Kennel Cough	21.09	0.8808%	67.87	21.69
	Lyme Vaccine	30.1	4.4610%	146.04	36.61
	Frontline (Feline)	18.23	3.3046%	54.35	20.03
	Expected Cost of Preventative Care (Dog)		7.9556%		153.57
	Expected Cost of Preventative Care (Cat)		3.3046%		20.03

Table 9: Summary of Expected Cost of Foregoing Prevention in Large Dogs

	Disease	Cost to Treat	Probability of Infection (Risk)	Expected Cost of Foregoing Prevention (Cost x Risk)
Low Risk States	Fleas	82.11	1.1700%	0.9607
	Parvovirus	1550.82	0.0650%	1.0080
	Heartworm	743.97	0.0600%	0.4464
	Kennel Cough	72.97	0.8021%	0.5853
	Lyme	167.48	0.1664%	0.2787
	Leptospirosis	276.74	0.0370%	0.1024
	Expected Cost of Foregoing Preventative care			3.3815
Medium Risk States	Fleas	82.11	11.8100%	9.6977
	Parvovirus	1550.82	0.5143%	7.9756
	Heartworm	743.97	0.5071%	3.7730
	Kennel Cough	72.97	4.3107%	3.1456
	Lyme	167.48	1.0707%	1.7932
	Leptospirosis	276.74	0.0370%	0.1024
	Expected Cost of Foregoing Preventative care			26.4875
High Risk States	Fleas	82.1147	86.6447%	71.1480
	Parvovirus	1550.8202	2.6447%	41.0140
	Heartworm	743.9722	5.5567%	41.3401
	Kennel Cough	72.9708	22.0207%	16.0687
	Lyme	167.4771	11.2367%	18.8188
	Leptospirosis	276.74	0.0370%	0.1024
	Expected Cost of Foregoing Preventative care			188.492

Table 10: Summary of Expected Cost of Prevention for Large Dogs

	Prevention	Cost to Prevent	Probability of Contracting Disease	Cost of Treatment	Expected Cost of Prevention (Cost to Prevent + [Risk x Cost to Treat])
Low Risk State	Frontline (Canine)	22.01	0.0252%	82.11	22.03
	Parvovirus Vaccine	24.48	0.0130%	1550.82	24.68
	Leptospirosis Vaccine	21.68	0.2220%	276.74	22.29
	Advantix II	20.54	0.0000%	743.97	20.54
	Kennel Cough	21.09	0.0321%	72.97	21.11
	Lyme Vaccine	30.1	0.0661%	167.48	30.21
	Expected Cost of Preventative Care		0.3584%		140.87
Medium Risk State	Frontline (Canine)	22.01	0.2539%	82.11	22.22
	Parvovirus Vaccine	24.48	0.1029%	1550.82	26.08
	Leptospirosis Vaccine	21.68	0.2220%	276.74	22.29
	Advantix II	20.54	0.0000%	743.97	20.54
	Kennel Cough	21.09	0.1724%	72.97	21.22
	Lyme Vaccine	30.1	0.4251%	167.48	30.81
	Expected Cost of Preventative Care		1.1763%		143.16
High Risk State	Frontline (Canine)	22.01	1.8629%	82.11	23.54
	Parvovirus Vaccine	24.48	0.5289%	1550.82	32.68
	Leptospirosis Vaccine	21.68	0.2220%	276.74	22.29
	Advantix II	20.54	0.0000%	743.97	20.54
	Kennel Cough	21.09	0.8808%	72.97	21.73
	Lyme Vaccine	30.1	4.4610%	167.48	37.57
	Expected Cost of Preventative Care		7.9556%		158.36

Tables 11: Summary of Difference in Expected Cost of Prevention from Expected Cost of Treatment for Small dogs

Prevention	Expected Cost of Foregoing Prevention	Expected Cost of Prevention	Difference in Expected cost of Foregoing Prevention and the Expected Cost of Prevention
Frontline (Canine)-HR	61.8019	22.54	39.2619
Advantix II-HR	40.1514	18.46	21.6914
Seresto Collar (Dog)-HR	61.8019	53.88	7.9219
Parvovirus Vaccine-HR	37.5398	31.99	5.5498
Bordetella Vaccine-HR	14.9445	21.69	-6.7455
Revolution-HR	40.1514	49.77	-9.6186
Frontline (Dog)-MR	8.4238	21.67	-13.2462
Advantix II-MR	3.6645	18.46	-14.7955
Parvovirus Vaccine-MR	7.3	25.94	-18.0265
Advantix II-LR	0.4335	18.46	-18.0265
Bordetella Vaccine-MR	2.9255	21.21	-18.2845
Revolution-MR	3.6645	23.79	-20.1255
Lyme Vaccine-HR	16.4097	36.61	-20.2003
Bordetella Vaccine-LR	0.5444	21.11	-20.5656
Frontline (Dog)-LR	0.8345	21.54	-20.7055
Revolution-LR	0.4335	21.49	-21.0565
Leptospirosis Vaccine	0.0998	22.28	-22.1802
Parvovirus Vaccine-LR	0.9226	24.66	-23.7374
Heartgard-HR	40.1514	66.21	-26.0586
Lyme Vaccine-MR	1.5636	30.72	-29.1564
Lyme Vaccine-LR	0.243	30.2	-29.957
Heartgard-MR	3.6645	40.3	-36.6355
Heartgard-LR	0.4335	38.01	-37.5765
Sentinel-HR	40.1514	83.26	-43.1086
Seresto Collar (Dog)-MR	8.4238	52.12	-43.6962
Seresto Collar (Dog)-LR	0.8345	51.87	-51.0355
Sentinel-MR	3.6645	65.82	-62.1555
Sentinel-LR	0.4335	64.28	-63.8465

Tables 12: Summary of Difference in Expected Cost of Prevention from Expected Cost of Treatment for Large dogs

Prevention	Expected Cost of Foregoing Prevention	Expected Cost of Prevention	Difference in Expected cost of Foregoing Prevention and the Expected Cost of Prevention
Frontline-HR	71.148	23.03	48.118
Advantix II-HR	41.3401	20.54	20.8001
Parvovirus Vaccine-HR	41.014	32.68	8.334
Seresto Collar-HR	71.148	62.83	8.318
Bordetella Vaccine-HR	16.0687	21.69	-5.6213
Revolution-HR	41.3401	51.33	-9.9899
Frontline-MR	9.6977	22.15	-12.4523
Advantix II-MR	3.773	20.54	-16.767
Bordetella Vaccine-MR	3.1456	21.21	-18.0644
Parvovirus Vaccine-MR	7.9756	26.08	-18.1044
Lyme Vaccine-HR	18.8188	37.57	-18.7512
Advantix II-LR	0.4464	20.54	-20.0936
Bordetella Vaccine-LR	0.5853	21.11	-20.5247
Revolution-MR	3.773	24.58	-20.807
Frontline-LR	0.9607	22.03	-21.0693
Revolution-LR	0.4464	22.21	-21.7636
Leptospirosis Vaccine	0.1024	22.29	-22.1876
Parvovirus Vaccine-LR	1.008	24.68	-23.672
Lyme Vaccine-MR	1.7932	30.81	-29.0168
Lyme Vaccine-LR	0.2787	30.21	-29.9313
Sentinel-HR	41.3401	75.15	-33.8099
Heartgard-HR	41.3401	88.44	-47.0999
Seresto Collar-MR	9.6977	60.8	-51.1023
Sentinel-MR	3.773	57.19	-53.417
Sentinel-LR	0.4464	55.6	-55.1536
Heartgard-MR	3.773	61.77	-57.997
Heartgard-LR	0.4464	59.41	-58.9636
Seresto Collar-LR	0.9607	60.51	-59.5493

Table 13: Break-Even Cost for Small Dogs

		Net Benefit of Prevention	BE Inconvenience Cost
Low Risk	**Frontline (Small Dog)**	-20.71	1730.04
	Seresto (Small dog)	-51.03	4217.93
	Parvovirus Vaccine	-23.74	29965.17
	Leptospirosis Vaccine	-22.18	8101.06
	Advantix II	-18.03	30044.09
	Revolution	-21.05	19900.59
	Heartgard	-37.57	36022.06
	Sentinel	-63.84	71509.66
	Bordetella Vaccine	-20.57	2460.30
	Lyme Vaccine	-29.95	12800.20
	Frontline (Cat)	-17.99	4316.15
	Seresto (cat)	-51.58	13495.80
Medium Risk	**Frontline (Dog)**	-13.29	107.14*
	Seresto (Small dog)	-43.69	353.60
	Parvovirus Vaccine	-18.64	2546.85
	Advantix II	-14.80	2917.73
	Revolution	-20.13	1716.95
	Heartgard	-36.64	3624.74
	Sentinel	-62.16	7825.79
	Bordetella Vaccine	-20.86	3035.88
	Lyme Vaccine	-29.16	1866.26
	Frontline (Cat)	-15.19	274.98*
	Seresto (cat)	-48.50	999.55
High Risk	**Frontline (Canine)**	38.94	-47.00
	Seresto (Small dog)	7.92	-13.41
	Parvovirus Vaccine	5.55	-648.09
	Advantix II	21.69	-390.37
	Revolution	-9.62	499.94
	Heartgard	-26.06	325.82*
	Sentinel	-43.11	57.54*
	Bordetella Vaccine	-6.74	24.22*
	Lyme Vaccine	-20.20	45.71*
	Frontline (Feline)	1.67	-18.51
	Seresto (cat)	-29.96	92.02*

Table 14: Break-Even Cost for Large Dog

		Net Benefit of Prevention	BE Avoidance Cost
Low Risk	Frontline	-21.07	1759.42
	Seresto	-59.55	4922.03
	Parvovirus Vaccine	-23.67	29833.80
	Leptospirosis Vaccine	-22.19	8093.92
	Advantix II	-20.09	33489.36
	Revolution	-21.76	20570.54
	Heartgard	-58.96	56848.62
	Sentinel	-55.16	61702.48
	Bordetella Vaccine	-20.53	2455.20
	Lyme Vaccine	-29.93	12778.76
Medium Risk	Frontline	-12.52	100.34*
	Seresto	-51.10	413.64
	Parvovirus Vaccine	-18.10	2415.48
	Advantix II	-16.77	3306.51
	Revolution	-20.80	1777.34
	Heartgard	-58.00	6069.91
	Sentinel	-53.42	6646.29
	Bordetella Vaccine	-20.85	3030.78
	Lyme Vaccine	-29.02	1844.82
High Row	Frontline	47.60	-57.24
	Seresto	8.32	-14.54
	Parvovirus Vaccine	8.33	-779.46
	Advantix II	20.80	-374.33
	Revolution	-9.98	513.86
	Heartgard	-47.10	122.09*
	Sentinel	-33.81	69.53*
	Bordetella Vaccine	-5.66	19.12*
	Lyme Vaccine	-18.75	24.27*

CHAPER 4: OLS REGRESSION

Clients want to know that their investment in prevention will lead to reduced treatment costs in the future. Clients want to be convinced that their investments in prevention have value. The second model used to evaluate the value of prevention measures compared to the risk and cost of treatment was an ordinary least squares (OLS) regression model. This model looks at the variables that affect the total spent on treatment for a pet over the span of five years. This model used invoice data provided by a small companion animal veterinary clinic in order to determine what variables affect total spending on treatment and how these variables affect spending on treatment.

4.1: OLS Methods and Data

Invoice data was used to determine the effect wellness has on the total out of pocket cost of treatment for a pet. The data was provided by a local veterinary clinic in Fort Collins, Colorado. This clinic provided invoice data of the last five years the clinic has been in business while using an electronic invoice system. In this data, each consultation was organized by consultation type. The three forms of consultations are wellness exam, diagnostic exam and emergency exam. “Wellness exam” represents all exams that are scheduled with the intention of a yearly or bi-yearly physical check-up. “Diagnostic exam” represents a client bringing in their pet with the suspicion that their pet is ill and will most likely be diagnosed with an illness. “Emergency exam” represents a client needing to see a veterinarian immediately due to a life or death situation. For the purposes of this study, “Emergency exam” was placed under the category of “Diagnostic exam”, as emergency visits are more urgent diagnostic exams.

The invoice data was organized by spending on treatment, spending on wellness, number of each specific exam type (with emergency falling under diagnostic exams), spending on "other", and other pet specific variables, such as species, being microchipped, or if the pet was spayed or neutered at the clinic. In order to determine if a procedure or item purchased was a wellness measure or treatment measure, the invoice line item was researched for purpose and organized accordingly. For items that could be used for both wellness and treatment, the type of exam (wellness vs diagnostic) was looked at, as well as the other items listed for that date. Invoice items that could not be defined with confidence were discussed with the hospital that provided the data. After the hospital clarified the discrepancy, the item would be placed in the appropriate category. Spending on treatment was studied at as a function of the spending on wellness procedures, the number of times each exam type was performed, and other pet specific factors.

Due to not having a working paper as a model for evaluating the invoice data provided, multiple forms of regressions were tested and compared. When testing a quasi-linear OLS regression (1), where each applicable variable was logged, three thousand two hundred and eighty-seven observations were dropped by the programming software. This was due to the fact that the value of zero cannot be logged and so where the program was told to log zero, the observation was dropped. Three thousand two hundred and eighty seven pets had zero dollars spent on them for either total spent on treatment, total spent on wellness, total spent on flea products, total spent on heartworm prevention or total spent on vaccines. Due to this fact, only seventy observations were left in this model, with an adjusted R^2 value of sixty four percent. Due to this fact, this model was not chosen. When logging only the dependent variable, total spent on treatment, and keeping the independent variables unlogged (2), one thousand and forty four were dropped and the adjusted R^2 was reduced to forty-nine percent. This was due to the fact that six hundred and fifty four of the pets in the study had zero dollars spent on treatment. When logging these values, the software removed the observations, as zero values cannot be logged. There were also unexpected signs on the independent variables total number of wellness exams, total number of dentals and total spent on heartworm prevention. Due to the reduced R^2, dropped observations and inconsistent variables, this model was also not chosen.

(1) lnTSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + B_2 lnTSoW + \beta_3 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 lnTSoFP + \beta_9 lnTSoHW + \beta_{10} lnTSoV + \beta_{11} Fixed + B_{12} Mirco + \beta_{13} Shelter + et}$

(2) lnTSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + B_2 TSoW + \beta_3 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + B_{12} Mirco + \beta_{13} Shelter + et}$

Finally, an OLS regression was chosen keeping all variables unlogged (3). Due to the upper bounds of all the monetary variables being in the thousands, the decision was made to not use ratios. Instead, each variable was left unlogged and the result kept each of the observations and produced an adjusted R^2 of seventy eight percent. This indicates that seventy eight percent of the variation in total spent on treatment for a pet over the span of five years can be explained using this model. The coefficients for each of the independent variables in this model had the expected signs. When performing an F test for the significance of the model, the p value was significant at the five percent level with a value of <.0001. Both the tests for multicollinearity and heteroscedasticity were negative, indicating that there is no evidence that the independent variables are a linear combination of one another, nor that the variance of the dependent variable is changed with the independent variables. The attribute variables included in the final model are summarized in Table 15.

(3) $\textbf{TSoT=}\boldsymbol{\beta_0 + \beta_1 Canine + B_2 TSoW + \beta_3 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + B_{12} Mirco + \beta_{13} Shelter + et}$

4.2: OLS Results

Tables 16 and 17 summarize the significance of the model and numerical results used to evaluate the direction and statistical significance of the explanatory variables. Eleven of the thirteen variables were found to be statistically significant in affecting the total spent on treatment for a pet. These variables were Species (Canine), Total Spent on Wellness (TSoW), Total Number of Wellness Exams (TNoWE), Total Number of Diagnostic Exams (TNoDE), Chronic Illness (Chronic), Number of Surgeries (NoS), Total Spending on Flea Products (TSoFP), Total Spending on Heartworm (TSoHW), Total Spending on Vaccines (TSoV), Microchipped (Micro), Procured from the Shelter (Shelter).

Canine had a negative coefficient of -18.76 and was significant at the one percent level. This suggests that owning a canine will decrease the total spent on treatment by $18.76 over the span of five years. This may be explained due to canines being ill less often, having less expensive illnesses or due to cats being brought it only when clients felt it was absolutely necessary (Volk et al. 2011b). When surveyed, cat owners were less inclined to bring their pets into the clinic and so the severity and cost of the illness may be higher when seen.

TSoW had a positive coefficient of .41 and was significant at the one percent level. This suggests that for every additional dollar spent on wellness, $.41 more is spent on treatment. This is opposite to what was expected, but may be explained due to the fact that owners that invest more on wellness, may also invest more on treatment. Total spent on treatment only includes dollars spent and not treatments suggested by veterinarians and declined by the owner.

TNoDE and Chronic both had positive coefficients of 157.62 and 403.88 respectively. Both values were significant at the one percent level and the positive coefficients are expected. For each additional diagnostic exam attended, $157.62 more dollars is spent on treatment. This is expected as visiting a veterinarian due to noticing abnormal symptoms in a pet tends to lead to a treatment for the cause of the abnormal symptoms. A pet with a chronic illness spends $403.88 dollars more on average for treatment than a pet without a chronic illness over five years. This is expected as a pet that is continuously ill must be continually treated. NoS also has a positive coefficient of 624.38, significant at the one percent level. This is expected as an increase in non-preventative surgeries will increase the total spent on treatment. For each additional non-preventative surgery, $624.38 is spent on treatment. These variables that are related to treatment, are causing an increase in total spent on treatment, which is expected and provides evidence of the model working the way it should be.

Shelter had a negative coefficient of -718.16 and was statistically significant at the one percent level. The magnitude of the coefficient is unexpected but may be due to wellness or to client preference. Owning a shelter pet decreases the total cost of treatment by $718.16. Pets adopted from a shelter tend to come fully vaccinated when adopted and so the appropriate wellness measures may have been performed on the shelter pets and so the spending on treatment decreases. It is also possible that people that adopt shelter pets are less inclined to spend on their pets, as shelter adoption fees are significantly less than the fees to purchase a pet from store or breeder.

The variables NoD and Fixed were not significant at any level. NoD had a negative coefficient of -14.02, but had a p value of .318. Fixed had an unexpected positive coefficient of 8.69, with a p value of .135. Micro had an expected negative coefficient of -22.88 and was significant at the ten percent level. Microchipping a pet reduces the total spent on treatment by $22.88 over five years. This may be due to pets being lost for a reduced period of time, and so having fewer chances of being injured while lost. NoD and Fixed being insignificant may be explained by the low number of pets that received dentals or were fixed. Three thousand six hundred and seventy five pets did not have a single dental performed, while three thousand two hundred and sixty two pets were not spayed in the last five years at this clinic.

TSoFP, TSoHW, and TSoV were each statistically significant at the 1 percent level and had negative coefficients of -.54, -.49, and -.44 respectively. Each of these are wellness measures and so the signs of each coefficient are consistent with expectations. With the increase of a dollar of spending for flea products, $.54 less is spent on treatment. $.49 less is spent on treatment for each additional dollar spent on heartworm medication, and $.44 less is spent on treatment for each additional dollar spent on vaccines. These results are significant in supporting the value of wellness in reducing treatment costs. Clients that wish to spend less on treatment should invest more on wellness preventatives such as flea prevention and vaccinations.

One of the most important results of the analysis was TNoWE had a negative coefficient of -29.49 and was significant at the one percent level. This is interpreted as for each additional wellness exam attended, $29.49 less dollars is spent on treatment. This is as expected as veterinarians are able to catch an illness early on if seen during a wellness exam. Fifteen percent of the wellness exams performed over the last five years this clinic has been in business, had illnesses found during a wellness exam. This value shows the importance of attending wellness exams to reduce the cost spent on treatment.

When evaluating the validity of this model, three areas of concern became apparent. The first issue was the possibility of simultaneous equations for the variables TSoW and Shelter. Simultaneous equations occur when an independent variable is not actually exogenous. The unexpected sign of TSoW indicated concern for simultaneous equations, as well we the large coefficient value for Shelter. Investing more into wellness is unlikely to cause an increase in treatment spending, as per previously cited studies; and purchasing a pet from a shelter is unlikely to be the reason that treatment spending decreases by $718.16. The second area of concern is in the variable Micro. It is unlikely that microchipping a pet has the effect of decreasing total spending on treatment by $22.88, as pet owners responsible enough to microchip their pets are unlikely to lose them, and so there is a chance that Micro also has simultaneous equations. The third area of concern is the possibility of bias in the model. The presence of one thousand and forty four of zeros in the independent variable presents possibility of bias in an OLS model.

In order to address these areas of concern and create improved models, multiple actions were taken. The first was to create a second model using the same number of observations, but removing the two variables with the highest possibility of simultaneous equations, TSoW and Shelter (4). In order to address the concerns around the Micro variable, a third new model was created dropping all three variables with risk of simultaneous equations, TSoW, Shelter and Micro (5). In order to address the concern around bias in the model, the original model, as well as the two new models (4 and 5) are recreated without the total spent on treatment observations that were zero, models 3b, 4b, and 5b respectively. One thousand and forty four of dependent variables were zero and so these values were dropped from the model.

4.2.1 Model 4 Results

(4)TSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + \beta_2 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + B_{12} Mirco + et}$

The new model created (4) removed the endogenous variables TSoW and Shelter. This model had an F test significant at the one percent level and a R2 value of sixty six percent. The results of model 4 are summarized in Tables 18 and 19. The Canine variable stayed negative and significant at the one percent level but increased in magnitude from 18.76 to 29.85. TNoWE changed significantly, going from negative to positive and increasing in magnitude from 29.49 to 49.88. While this value is significant at the one percent level, it is unexpected that an additional wellness exam would increase the cost of treatment by almost $50. Eighty-five percent of wellness exams have no treatment costs involved and so this value is not in line with expected findings.

TNoDE, Chronic and NoS all continue to be positive and significant at the one percent level in the second model. These values are expected and show the model is working the way it should be, as variables related to treatment should increase treatment costs.

NoD and Fixed both become significant at the one percent level in this model. NoD has a positive coefficient of 158.08 and Fixed has a negative coefficient of -88.48. The sign for NoD is unexpected as dental procedures are wellness procedures that reduce the risk of dental disease and so reduce the cost of treatment. These procedures are done in order to remove plaque buildup and only increase treatment costs in cases where a tooth must be removed due to damage. The sign for Fixed is expected as one of the reasons for spaying or neutering a pet is in order to reduce risk of breast cancer in female dogs and testicular cancer in male dogs. Having an animal fixed is expected to reduce treatment costs in the future.

The wellness measures of TSoFP and TSoHW become insignificant in this model. These values are shown to not have an effect on the total spent on treatment. TSoV is significant at the one percent level and the coefficient goes from -0.44 in model 3 to -1.09. This indicates that for every dollar spent on treatment, $1.09 less is spent on treatment. This value is expected as previous research indicates the vaccinations are cost effective compared to risk and cost of treatment.

4.2.2 Model 5 Results

(5) TSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + \beta_2 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + et}$

Model 5 (the third new model) removed the endogenous variables TSoW, Shelter and Micro. This had an R2 value of sixty-five percent and the F test for the significance of the model was significant at the one percent level. The results of model 5 are summarized in Tables 20 and 21. The results of this model were similar to those of model 4. Canine was negative and significant at the one percent level, with a slight increase in the coefficient from 29.85 to 30.38. In this model, owning a canine decreases the total cost of treatment by $11.62 more compared to the original model (model 3) and $0.53 more compared to model 4.

TNoWE again has an unexpected positive coefficient and is significant at the one percent level. The coefficient increases in this model to 50.85. Presenting that an additional wellness exam causes an increase in spending on treatment of $50.85. This value is unexpected for the same reasons as previously presented. Wellness measures should not cause an increase in treatment spending.

TNoDE, Chronic and NoS continue to be significant at the one percent level and continue to have positive coefficients with expected magnitudes. These variables continue to indicate that the model is behaving the way it should be.

NoD and Fixed are again both significant at the one percent level and have the same signs for the coefficients as they did in model 4. Again, the positive coefficient for NoD is unexpected as wellness measures should not increase treatment costs. The increase in treatment cost for each additional dental performed increases slightly from 158.08 to 159.54. Fixed is again negative, as expected as wellness measures should decrease treatment costs, and the effect decreases slightly from 88.48 to 87.64.

TSoFP becomes significant at the one percent level, as it was in model 3, and has a negative coefficient of -.63. TSoFP has a greater effect on reducing treatment costs in this model, than in the original model (3). In model 3 TSoFP reduces treatment costs by $0.54, while total spending on treatment reduces treatment cost by $0.63 in this model (5). TSoHW continues to be insignificant in this model and may be explained by the fact that clients must remember to give their pet their heartworm prevention every month and clients may not follow the listed directions as rigorously as they should.

Fortunately, TSoV continues to be significant at the one percent level and is still negative as expected. For every dollar spent on vaccination, $1.21 less is spent on treatment, a slightly higher value than model 4. The consistency of this variable indicates that vaccinations do play a significant role in reducing treatment costs, which provides important evidence that can be relayed to clients on the value of investing in vaccinations for their pets.

4.2.3 Model 3b Results

(3b) TSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + B_2 TSoW + \beta_3 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + B_{12} Mirco + \beta_{13} Shelter + et}$

Model 3b uses all the same variables as the original model (3) but drops one thousand and forty-four of observations. The model goes from three thousand three hundred and seven number of observations to two thousand three hundred and thirteen observations. When performed, the F test for the significance of the model was significant at the one percent level, and the R2 was seventy-five percent. Results for model 3b are summarized in Tables 22 and 23.

Eleven of the thirteen variables in the model were significant at the one percent level. As in the original model (3), Canine has a negative coefficient. The coefficient increases in magnitude from 18.76 in model 3 to 34.86 in this model (3b). This indicates an owner will spend $34.86 less owning a dog compared to owning a cat. As previously stated, this may be due to owners reluctance to bring their cats to the veterinarian and so illnesses presented are more severe and more expensive.

In contrast to the original model (3) as well as models 4 and 5, TSoW is insignificant at all levels. TNoWE has a positive coefficient of .19. While this is unexpected, as wellness measures should not cause an increase in treatment, the value is negligible as it indicates that for each additional wellness exam performed on a pet, the owner pays $0.19 more on treatment.

TNoDE, Chronic and NoS continue to have positive coefficients with expected magnitudes significant at the one percent level. These variables continue to indicate that the model is working the way it should be, with variables related to treatment increase treatment costs. NoD and Fixed are both insignificant in this model, as they were in model 3, but in contrast to models 4 and 5. Again this may be due to low number of observations of pets that had dentals performed on them or were fixed.

Micro and Shelter are again significant, with a negative coefficient of -66.10 and -836.99 respectively. The decrease in spending on treatment when a pet is microchipped goes from $21.88 in model 3 to $66.10 in this new model. The Shelter coefficient increase in magnitude from 718.16 to 836.99 in this model. The magnitude of these coefficients are unexpected and so again there is concern over these variables being endogenous and so are removed in the following models.

The three-wellness measures of TSoFP, TSoHW and TSoV are all significant in this model and are all above one. Each variable has a negative coefficient greater than one, indicating that each of these measures reduces treatment costs by more than the investment in wellness. For every additional dollar spent on flea prevention, $1.23 less is spent on treatment. For each additional dollar spent on heartworm prevention, $1.34 less is spent on treatment, and for each additional dollar spent on vaccines, $1.85 less is spent on treatment. Each of these variables indicates the value of prevention in reducing treatment costs. Especially significant is the TSoV, as in each of the corrected models, an additional dollar spent on vaccines, reduces treatment costs by greater than a dollar. When presented to clients, these values can show clients that investing in prevention for their pet will reduce their future spending on treatments.

4.2.4 Model 4b Results

$$\textbf{(4)TSoT=}\boldsymbol{\beta_0 + \beta_1 Canine + \beta_2 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + B_{12} Mirco + et}$$

Model 4b is structured the same way as model 4, but uses the two thousand three hundred and thirteen non-zero treatment costs observations. Results for model 4b are summarized in

Tables 24 and 25. TSoW and Shelter are both removed from this model and when tested, the F statistic for the significance of this model was significant at the one percent level. The R^2 for the model was sixty-two percent, indicating that sixty-two percent of the variation in total spending on treatment can be explained with this model.

The results for model 4b are similar to those of model 4. The coefficient for Canine is again negative and significant at the one percent level. The coefficient goes from -18.76 in model 3, to -29.85 in model 4 and -36.40 in model 4b. The effect of owning a canine on total spent on treatment increases when removing the bias and two of the possibly endogenous variables. Similar to model 4, the coefficient of TNoWE becomes unexpectantly positive, and increases in magnitude compared to model 3. This model indicates that for every additional wellness exam performed on a pet, an additional $54.04 is spent on treatment. This is unexpected as visiting a veterinarian for a wellness exam should not increase treatment costs unless an illness is found, which is only the case in fifteen percent of these visits.

TNoDE, Chronic and NoS continue to be significant at the one percent level, with positive coefficient of expected magnitudes. These variables continue to indicate that the model is working the way it should. The coefficient for TNoDE decreases slightly when compared to model 4, from 193.03 to 182.42. Chronic also decreases compared to model 4, from 405.56 to 398.89. NoS increases from 345.17 in model 4 to 423.41 in model 4b. Despite these slight variations in coefficient value, each variables acts in the expected way.

As seen in model 4, NoD, Fixed and Micro are all significant at the one percent level. Again NoD has an unexpected positive coefficient, increasing slightly compared to model 4, going from 158.08 to 158.67. This is unexpected, as previously stated, for the reason that wellness measures should not increase treatment costs, especially not at such a great magnitude.

Fixed has an expected negative coefficient of -101.15. This indicates that spaying or neutering your pet will cause a decrease in spending of $101.15. The effect this variable has on reducing treatment cost is greater in this model, compared to its value of 88.48 in model 4. The coefficient on Micro increases from 173.85 in model 4 to 210.70 in model 4b. The magnitude of this value is unexpected and may be explained due to simultaneous equations, and is removed in the following model.

Similarly to model 4 and in contrast to models 3 and 3b, TSoFP and TSoHW become insignificant in this model. Similarly to models 3, 4, 5, and 3b, TSoV in this model is significant at the one percent level and has an expected negative coefficient of -1.34. This indicates that for every additional dollar spent on vaccination, $1.34 less is spent on treatment. The consistency of this value being a negative value greater than one in each model strengthens the evidence that investing in vaccines is cost effective and cost reducing for the small animal veterinary client.

4.2.5 Model 5b Results

(5) TSoT=$\boldsymbol{\beta_0 + \beta_1 Canine + \beta_2 TNoWE + \beta_4 TNoDE + \beta_5 Chronic + B_6 NoD + \beta_7 NoS + B_8 TSoFP + \beta_9 TSoHW + \beta_{10} TSoV + \beta_{11} Fixed + et}$

Model 5b accounts for all the concerns faced in the original model (3). This model removes the zeros in the dependent variable to correct for model bias, and removes all variables that may be endogenous. When testing for the significance of the model, the F statistic was significant at the one percent level, and the R2 was sixty-one percent. The results of the model are summarized in Tables 26 and 27. When comparing the results of this model to model 5, the results are similar to those in model 5.

Similarly to model 5, the coefficient for Canine was negative and significant at the one percent level, with an increase in the coefficient from 30.38 to 37.82. In this model, owning a canine decreases the total cost of treatment by $19.06 more compared to the original model (model 3) and $6.99 more when compared to model 5.

TNoWE again has an unexpected positive coefficient and is significant at the one percent level. The coefficient increases in this model to 55.79 compared to 50.85 in model 5. Presenting that an additional wellness exam causes an increase in spending on treatment of $55.79 This value is unexpected for the same reasons as previously presented. Wellness measures should not cause an increase in treatment spending.

TNoDE, Chronic and NoS continue to be significant at the one percent level and continue to have positive coefficients with expected magnitudes. These variables continue to indicate that the model is behaving the way it should be.

NoD and Fixed are again both significant at the one percent level and have the same signs for the coefficients as they did in model 4 and 5. Again, the positive coefficient for NoD is unexpected as wellness measures should not increase treatment costs. The increase in treatment cost for each additional dental performed increases slightly from 158.08 to 159.54 from model 4 to model 5 and increases again to 161.35 in model 5b. Fixed is again negative, as expected, as wellness measures should decrease treatment costs, and increases from 87.64 to 98.81. This indicates that spaying or neutering a pet decreases total treatment spending by $98.81. This is expected as keeping a pet intact increases its risk for reproductive diseases.

TSoFP becomes significant at the five percent level and has a negative coefficient of -.63, exactly the same as in model 5. TSoFP has a greater effect on reducing treatment costs in this model, than in the original model (model 3). In model 3 TSoFP reduces treatment costs by $.54, $.09 less than this model. TSoHW continues to be insignificant in this model and may be explained again by the fact that clients must remember to give their pet their heartworm prevention every month and clients may not follow the listed directions as rigorously as they should. Fortunately, TSoV continues to be significant at the one percent level and is still negative as expected. In this model, for every dollar spent on vaccination, $1.53 less is spent on treatment, a slightly higher value than model 5 and 1.09 higher than model 3. The consistency of this variable being negative with a coefficient greater than one in five out of six models indicates that vaccinations do play a significant role in reducing treatment costs, which provides stronger evidence that can be relayed to clients on the value of investing in vaccinations for their pets. Veterinarians can explain to their clients that in all six of the models, vaccinations were shown to be cost reducing, and in five of the six models, for every dollar invested in vaccines, more than a dollar was saved on treatment spending.

Each of these models varies slightly in what variables effect total spending on treatment and how much they affect total spending on treatment. In model 3, TSoW was significant, but became insignificant when model bias was removed in model 3b. TNoWE was cost reducing in model 3, but was not cost reducing in any of the other 5 models. This is opposite of what is expected and unfortunately the majority of the models do not support that visiting a veterinarian for an annual wellness exam reduces the spending on treatment.

TSoFP and TSoHW are cost reducing in the models in which these variables are significant, but are otherwise insignificant in other models. In model 3 where these variables reduce the spending on treatment, the value is less than one dollar but after removing the bias in 3b, the coefficients are greater than one. TSoHW being insignificant in the majority of models may be due to the fact that clients must remember to administer these prevention methods on a monthly basis and may forget to administer the prevention method as listed on the produce label.

TNoDE, Chronic and NoS are all significant at the one percent level with the expected signs for each model. These values indicate that each model is behaving in the way it should be. With variables related to treatment causing an increase in treatment cost.

The most important results of the six models was that coefficient for total spending on vaccines was significant and negative in every model. In each model, an additional dollar invested in vaccinations, results in a decrease in the total spent on treatment. For models 4, 5, 3b, 4b, and 5b, the reduction in treatment spending was greater than one dollar, indicating that for every dollar spent, more than a dollar was saved in treatment spending. These results are extremely significant evidence that can be presented to clients in order for them to have confidence that their investment in vaccinations will have a positive result in their lives by reducing out of pocket treatment costs. Clients that indicated that they would comply with wellness measures if they knew it would reduce treatment costs in the future, will be more inclined to follow their veterinarians vaccination recommendations if they know that it will save them on returning to the veterinarian to spend more on treatments for preventable illnesses.

Table 15: Summary of Statistics of Explanatory Variables

Variable	Definition	Observations	Mean	Std Dev
TSoT	Total sum of all treatment spending on pet over 5 years	3357	154.06	253.54
Canine	Dummy Variable for pet species 1 if Canine 0 if Feline	3357	.667	.471
TSoW	Total sum of all wellness spending on pet over 5 years	3357	139.65	201.68
TNoWE	Total number of wellness exams attended by the pet over 5 years	3357	.84	.949
TNoDE	Total number of diagnostic exams attended by the pet over 5 years	3357	.660	.918
Chronic	Dummy Variable 1 if pet has a chronic illness 0 if pet does not have a chronic illness	3357	.021	.145
NoD	Total number of preventative dental procedures performed on pet over 5 years	3357	.044	.226
NoS	Total number of non-preventative surgeries performed on the pet over 5 years	3357	.092	.298
TSoFP	Total sum of spending on flea infestation prevention over 5 years	3357	1.38	10.11
TSoHW	Total sum of spending on heartworm preventative over 5 years	3357	21.32	58.65
TSoV	Total sum of spending on preventative vaccinations over 5 years	3357	33.79	45.30
Fixed	Dummy Variable 1 if pet was spayed or neutered 0 if pet was not spayed or neutered	3357	.182	.386
Micro	Dummy Variable 1 if pet was microchipped at the clinic	3357	.028	.166
Shelter	Dummy Variable 1 if pet was procured from shelter 0 if pet was not procured from shelter	3357	.069	.253

Table 16: OLS Model (3) Results

Number of Observations	3357
F(13,3342)	923.77
Prob > F	0.0000
R-squared	0.7822
Root MSE	113.87

Table 17: OLS (3) Coefficient Results

Variable	**Coefficient**	**p-value**
Intercept	38.595	0.000
Canine	-18.76	0.000
TSoW	.41	0.000
TNoWE	-29.49	0.000
TNoDE	157.62	0.000
Chronic	403.88	0.000
NoD	-14.02	0.381
NoS	624.38	0.000
TSoFP	-.54	0.007
TSoHW	-.49	0.000
TSoV	-.44	0.000
Fixed	8.69	0.135
Micro	-21.88	0.000
Shelter	-718.16	0.000

Table 18: OLS Model (4) Results

Number of Observations	3357
F(13,3342)	623.93
Prob > F	0.0000
R-squared	0.6614
Root MSE	192.26

Table 19: OLS (4) Coefficient Results

Variable	Coefficient	p-value
Intercept	28.65	0.000
Canine	-29.85	0.000
TNoWE	49.88	0.000
TNoDE	193.03	0.000
Chronic	405.56	0.000
NoD	158.08	0.000
NoS	345.17	0.000
TSoFP	-.47	0.047
TSoHW	-.10	0.131
TSoV	-1.09	0.000
Fixed	-88.48	0.000
Micro	-173.85	0.000

Table 20: OLS Model (5) Results

Number of Observations	3357
F(13,3342)	664.60
Prob > F	0.0000
R-squared	0.6541
Root MSE	194.29

Table 21: OLS (5) Coefficient Results

Variable	Coefficient	p-value
Intercept	28.65	0.000
Canine	-30.38	0.000
TNoWE	50.85	0.000
TNoDE	193.52	0.000
Chronic	404.88	0.000
NoD	159.54	0.000
NoS	325.09	0.000
TSoFP	-.63	0.008
TSoHW	-.09	0.161
TSoV	-1.21	0.000
Fixed	-87.64	0.000

Table 22: OLS Model (3b) Results

Number of Observations	2313
F(13,2299)	540.13
Prob > F	0.0000
R-squared	0.7533
Root MSE	183.8

Table 23: OLS (3b) Coefficient Results

Variable	Coefficient	p-value
Intercept	55.16	0.000
Canine	-34.86	0.000
TSoW	.88	0.979
TNoWE	.19	0.000
TNoDE	159.52	0.000
Chronic	368.55	0.000
NoD	-176.13	0.381
NoS	666.23	0.000
TSoFP	-1.23	0.007
TSoHW	-1.34	0.000
TSoV	-1.85	0.000
Fixed	-32	0.980
Micro	-66.10	0.004
Shelter	-836.99	0.000

Table 24: OLS Model (4b) Results

Number of Observations	2313
F(11,2301)	346.50
Prob > F	0.0000
R-squared	0.6236
Root MSE	226.97

Table 25: OLS (4b) Coefficient Results

Variable	Coefficient	p-value
Intercept	54.05	0.001
Canine	-36.40	0.000
TNoWE	54.04	0.000
TNoDE	182.42	0.000
Chronic	398.89	0.000
NoD	158.67	0.000
NoS	423.41	0.000
TSoFP	-.43	0.133
TSoHW	-.07	0.418
TSoV	-1.34	0.000
Fixed	-101.15	0.000
Micro	-210.70	0.000

Table 26: OLS Model (5b) Results

Number of Observations	2313
F(11,2301)	365.19
Prob > F	0.0000
R-squared	0.6134
Root MSE	229.97

Table 27: OLS (5b) Coefficient Results

Variable	Coefficient	p-value
Intercept	52.98	0.000
Canine	-37.82	0.000
TNoWE	55.79	0.000
TNoDE	183.93	0.000
Chronic	398.33	0.000
NoD	161.35	0.000
NoS	401.33	0.000
TSoFP	-.63	0.029
TSoHW	-.06	0.510
TSoV	-1.53	0.000
Fixed	-98.81	0.000

CHAPTER 5: CONCLUSION

The veterinary industry is seeing a decrease in client visits and in annual wellness exams. The veterinary community has increased their focus on preventative medicine and there has been a positive shift in the veterinary field towards the value of wellness. Unfortunately, clients often do not see the value of wellness, but indicate that they would follow their veterinarian's advice for preventative measures, and would see their veterinarian for annual wellness exams, if it saved them money on treatment and they knew it would keep their pets healthy. Clients need to have the value of prevention measures communicated to them by their veterinarian. This study used two methods, decision trees and OLS regressions, in order to provide clients with information on what is the best course of action for them to take for their pets. These results were then used to create an example communication method for veterinarians, in order for them to feel confident in making their medical recommendations and in order for clients to feel confident in their investment in prevention methods for their pets.

The first method used to answer the research objective was the use of decision trees. Clients indicated they needed to know that investing in prevention would reduce future problems and expensive treatments in the future. Decision trees were created in order to determine the cost effective option between purchasing prevention and foregoing prevention using the expected costs of prevention and treatment. Each disease was looked at using varying levels of risk and cost. Clients indicated that if they believed prevention would reduce their risk of spending on expensive treatments, they would be more inclined to follow preventative measures. These trees can be used by veterinarians to provide clients with information on which of their options are the most cost effective.

The decision trees indicated that prevention is the cost effective option depending on which illness and prevention option are being looked at, as well as the risk level for the state a client lives in. In the cases of purchasing Frontline or the Seresto Collar for flea infestation prevention, Advantixx II for heartworm prevention and the Canine parvovirus vaccine for Canine parvovirus prevention, are all cost effective in high risk states for both large and small dogs. The expected cost of foregoing flea prevention in large and small dogs was $71.14 and $61.80 respectively, while the expected cost of purchasing Frontline was $23.03 and $22.54 respectively; and the expected cost of purchasing the Seresto Collar was $62.83 and $53.88 respectively. Advantix II heartworm prevention had an expected cost of purchasing prevention of $20.54 and $18.46 for large and small dogs respectively, with an expected cost of not purchasing Advantix II of $41.34 and $40.15 respectively. The expected cost of foregoing the Canine parvovirus vaccine was $41.01 and $37.53 respectively, while the expected cost of purchasing the Canine parvovirus vaccine was $24.48 for all sized dogs. These values can be presented to clients by their veterinarian in order for them to see that investing in prevention will cost them less when compared to the cost and risks of treatment. For the clients that responded to surveys indicating if they would comply with wellness if they knew it would prevent problems and expensive treatments in the future, these are the no brainers.

In cases where prevention is not the cost effective option, veterinarians must convey the costs and risks that clients face when foregoing prevention. Veterinarians must also ask their clients what their time and energy is worth. When looking at the break-even analysis, the additional cost in order for prevention and treatment to be equally desirable can be presented to clients as an inconvenience cost. Veterinarians can ask their clients if the time and energy they must invest in treating their pet should it contract the illness, is worth more than the additional costs to reach the break-even point. In the example of the Lyme vaccine in large dogs, veterinarians can ask their clients if the time and energy necessary to get their pet treated is worth more to them than the $24.27 necessary to make preventing Lyme and treating it equally desirable. If the client indicates their time and energy is worth more than that value, preventing Lyme becomes the cost effective option. Veterinarians must ask their clients if they are willing to pay less now or risk treating in the future, even if the expected cost of foregoing prevention is less than the expected cost of prevention. Veterinarians can use the results from these decision trees in order to present to their clients the most cost effective option when looking at expected costs. Veterinarians can use the information provided to inform the clients in their state of practice about whether or not the prevention is cost effective, and if it not, they can relay that while there is a negative expected cost of prevention in certain areas, the value is modest. Clients can then use this information to decide what is best course of action for themselves and their pets. Based on previous research, clients should be willing to pay for the wellness measures that they are confident will reduce risk and high cost of treatment

The second method used to determine if prevention was cost effective to the small animal veterinary client was an OLS regression. Clients want to know that investing in prevention will reduce their future treatment costs. The OLS regressions use data from a small animal veterinary clinic in order to determine the affect wellness has on the total amount spent on treatment for a pet over the span of five years.

An OLS regression was completed on current veterinary patients to determine if following wellness measures leads to a decrease in the total spending on treatment for a pet. The regression looked to see how total spending on wellness, number of wellness exams, total spending on vaccines/flea prevention/heartworm prevention and other pet factors affects the total spending on treatment. When surveyed, clients indicated that if they truly believed wellness would save them from spending on future expensive treatments, they would be more inclined to comply with veterinary suggestions for wellness.

The original OLS regression model indicates that there is value in prevention when looking to reduce total treatment cost for a pet. Increased spending in flea prevention, heartworm prevention and vaccinations yield a decrease in the total cost of treatment. Increased number of wellness exams decreases the total spending on treatment by $29.49, indicating to clients the value of visiting their veterinarian for wellness exams.

Veterinarians may use the information gathered from this OLS model as a communication method to inform their clients of the benefits of following suggested wellness measures Veterinarians can relay to their clients that if they choose to attend their annual wellness exam, they will save almost $30 on treatment in the future. Veterinarians can use the information from the regression in order to present to their clients the benefits of reduced treatment cost when following prevention measures for flea products, heartworm products and vaccinations.

A R^2 value of seventy-eight percent shows that there is still twenty-two percent variation in total spending on treatment that could not be explained by the variables studied. Future research may look at the treatments that were not performed, to determine the true total cost of treatment. Since the total spending on treatment is only the treatments that clients agreed to, adding the treatment costs for treatments that clients did not agree to may show wellness having a larger impact than is currently shown. Being able to determine which of the specific treatments were preventable may also have a significant impact on the role wellness plays for clients and pets.

When correcting for possible errors in the model, 5 new models were created, 2 removing endogenous variables, 1 removing only model bias and 2 removing both endogenous variables and model bias. Each of these models had slight variations from one another. When removing bias, the total spent on flea products, heartworm, and vaccines all caused a decrease in the total spent on treatment by greater than one dollar. This model indicates that investing in these wellness measures is cost effective to the veterinary client. These results support the decision trees that show flea prevention, heartworm prevention and the Canine Parvovirus vaccine as being cost effective.

In models where bias and endogenous variables were removed, spending on flea prevention and heartworm prevention were either insignificant or decreased the spending on treatment by less than the investment in prevention. Despite this, every model indicated that vaccinations were cost reducing. In five of the six models, an additional dollar spent on vaccinations decreased spending by greater than one dollar. These results are significant in supporting the value of vaccinations. Veterinarians must express to their clients that when looking at real world data, investing in vaccinations causes a decrease in spending on treatment. With this knowledge, clients will feel confident in complying with their veterinarians recommendations.

Future research may also look at a wider range of veterinary clinics practicing in a variety of areas. This study looks at spending at a small companion animal clinic in Colorado. Future studies may look for clinics in other regions and compare the results to these other clinics.

In future research decision trees that are specific on state or regional level may be done to determine a more accurate assessment for clients in specific areas. The decision trees in this study look at risk based on the categories of low, medium and high risk. Localizing to specific states or specific areas may show a different set of results than looking at risk over a board geographic region. These values can then be compared the regressions done for clinics in specific areas.

Future research may also look to take into account the risk these illnesses present to humans. Flea infestation and Leptospirosis are two examples of zoonotic diseases that can be passed on to pet owners. Incorporating the cost of removing fleas from the home may change the cost effectiveness of prevention. Incorporating the risks and medical costs of Leptospirosis may also drastically change the cost effectiveness of prevention. Medical costs as well as days missed from work can be incorporated in the cost to treat Leptospirosis. These costs are inferred in the inconvenience cost, but including them will allow clients to see exactly how much the cost of treatment really is.

There is value in preventing illnesses in areas that have high prevalence of disease contraction. Flea infestation, Canine parvovirus and heartworm are examples of illnesses that are cost effective to prevent for in high risk areas. For preventative measures that are not indicated as cost effective, veterinarians must relay the information to their clients of the expected costs and losses to their clients should they forego prevention, as well as the inconvenience cost associated with treating a preventable illness. In cases where vaccinations are shown to not be cost effective and the inconvenience cost is high, veterinarians can present the findings that investing in vaccinations is shown to reduce treatment costs. Clients must then decide if they are willing to invest in wellness to keep their pets healthy and safe.

The information gathered in this study will be used in the future in order to provide veterinarians sources of information and communication for their clients. Many veterinarians fear that their clients believe they are only making wellness suggestions in order to make money.

The information in this study will be used to create concise and informative documents that allow veterinarians to support their medical suggestions with economic evidence. Veterinarians can use these documents to feel more confident in their recommendations, and clients can use these documents to make well informed decisions for themselves and their pets. An example of a possible communication method is presented in Table 28.

Table 28: Example of Communication Method

Disease	What is the prevention measure?	Is it Worth it to Prevent?	What if I Do Not Follow Prevention and My Pet Gets Sick?
Fleas- Canine	Topical solutions and collars • Frontline • Seresto collar	Studies on cost effectiveness of flea prevention found that investing in Frontline flea prevention saves you an expected $39.26-$48.11, and investing in Seresto Collar flea prevention saves you an expected $7.92-$8.32	Pet Suffers: • mild skin redness • severe scratching • open sores • skin infections Owner Has to: • Take pet to veterinarian • Vacuum and sanitize home to remove fleas • Pay treatment cost of $71.33-$82.11 Owner Risk: • Owners can contract fleas from pet • Fleas can spread diseases to owners
Fleas- Feline	Topical solutions and collars • Frontline • Seresto collar	Studies on cost effectiveness of flea prevention found that investing in Frontline flea prevention saves you an estimated $2.23	Pet Suffers: • mild skin redness • severe scratching • open sores • skin infections Owner Has to: • Take pet to veterinarian • Vacuum and sanitize home to remove fleas • Pay treatment cost of $71.33 Owner Risk: • Owners can contract fleas from pet • Fleas can spread diseases to owners
Heartworm	Chewables and tablets • Advanix II • Heartgard • Revolution • Sentinel	Studies on cost effectiveness of heartworm prevention found that investing in Advantix II you an estimated $20.80-$21.69,	Pet Suffers: • mild cough • lethargy & fatigue • noticeable weight loss • Worms in heart and blood stream Owner has to: • Take pet into clinic on at least 4 separate occasions

			• Put pet on monthly heartworm prevention • Control physical activity of pet (required cage rest) • Pay treatment fee of $722.58-$743.97
Leptospirosis	Vaccination	In a study conducted on the value of prevention methods, it was found that for every dollar you invest on your pets vaccinations, $1.09-$1.85 is saved on treatment costs	Pet Suffers: • Fever • Muscle tenderness • Dehydration • Vomiting • Diarrhea • Jaundice • Death Owner has to: • Take pet to the veterinarian • Risk losing beloved pet • Medicate for two weeks • Pay treatment cost of $269.60-$276.74 Owner Risk: • Condition can be transmitted to humans from contact with animal urine • Lethal if untreated • If infected, owner suffers: high fever, muscle aches, jaundice, abdominal pain, kidney damage, liver failure
Canine Parvovirus	Vaccination	In a study conducted on the value of prevention methods, it was found that for every dollar you invest on your pets vaccinations, $1.09-$1.85 is saved on treatment costs	Pet Suffers: • Vomiting • Bloody diarrhea • Body temperature extremes • Abdominal pain • Death Owner has to: • Leave pet at clinic for 7-10 days • Risk losing their beloved pet • Pay treatment fee of $1419.45-$1550.82

Kennel Cough	Vaccination	In a study conducted on the value of prevention methods, it was found that for every dollar you invest on your pets vaccinations, $1.09-$1.85 is saved on treatment costs	Pet Suffers: • Consistent Coughing • Consistent Gagging • Vomiting Owner Has to • Take pet to veterinarian • Medicate pet for ten days • Pay treatment fee of $67.87-$72.97
Lyme	Vaccination	In a study conducted on the value of prevention methods, it was found that for every dollar you invest on your pets vaccinations, $1.09-$1.85 is saved on treatment costs	Pet Suffers: • Fever • Recurrent lameness • Joint swelling Owner has to: • Take pet to the veterinarian • Medicate for six weeks • Pay treatment fee of $146.04-$167.48

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APPENDIX A

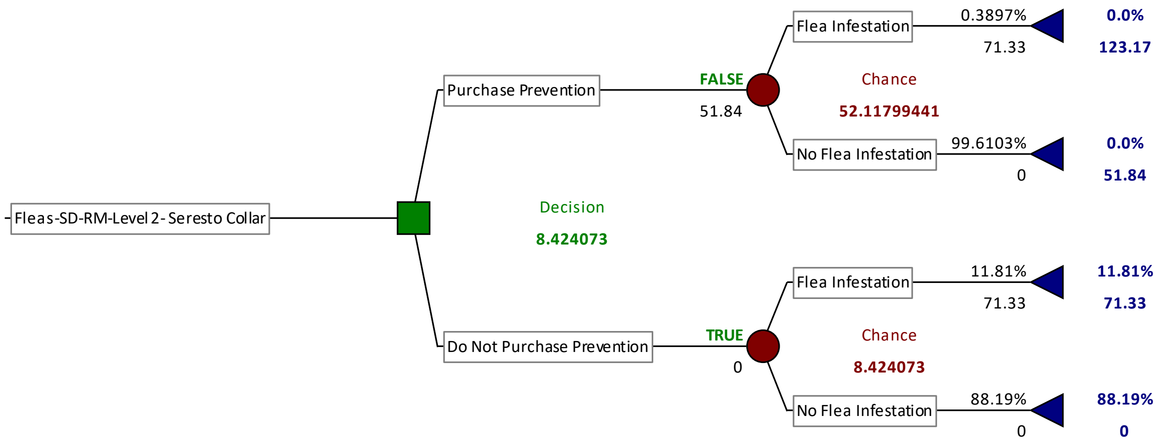

Figure 2: Decision Tree for Seresto Collar Flea Prevention in Medium Risk State for Small Dog

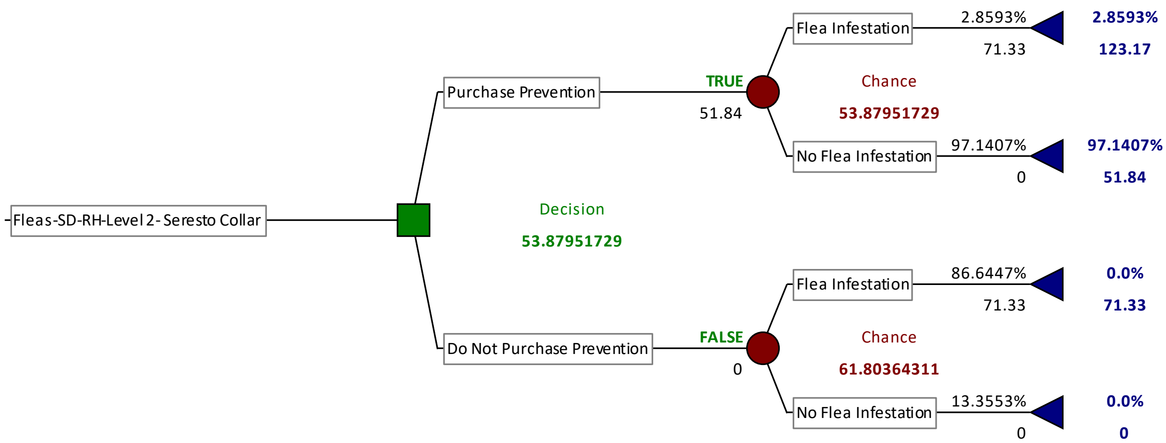

*Figure 3: Decision Tree for Seresto Collar Flea Prevention in High Risk State for Small Dog

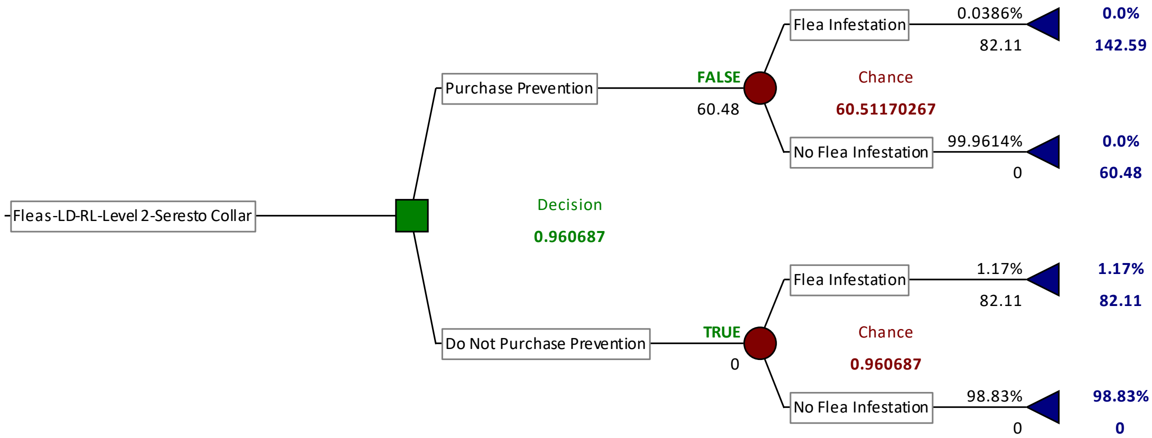

Figure 4: Decision Tree for Seresto Collar Flea Prevention in Low Risk State for Large Dog

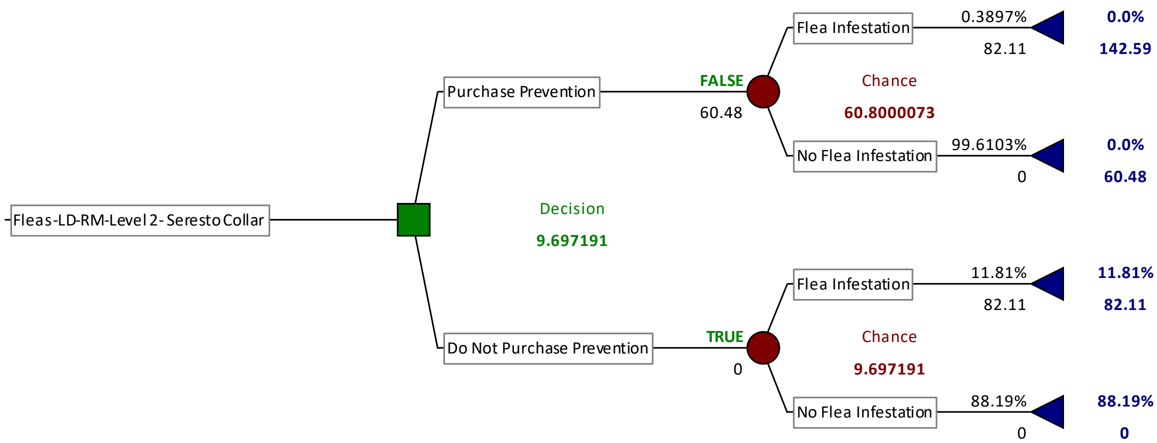

Figure 5: Decision Tree for Seresto Collar Flea Prevention in Medium Risk State for Large Dog

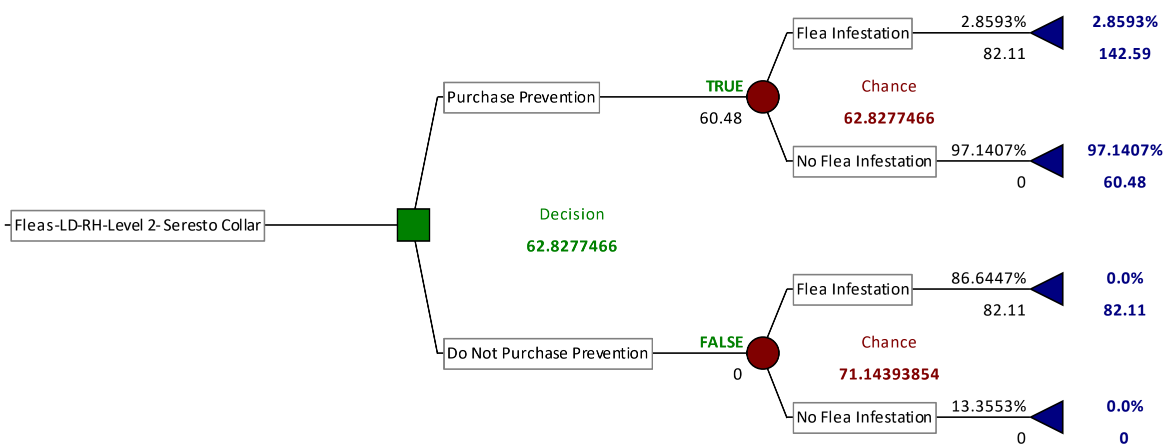

*Figure 6: Decision Tree for Seresto Collar Flea Prevention in High Risk State for Large Dog

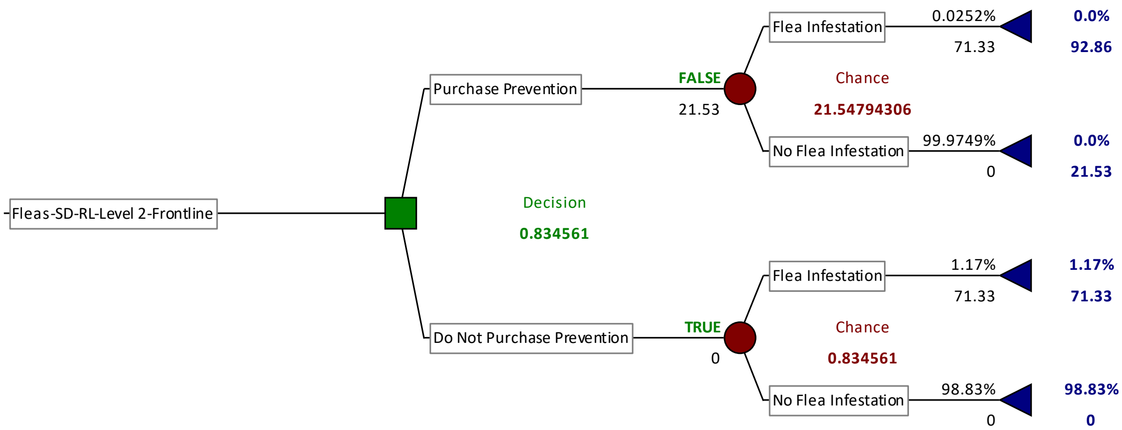

Figure 7: Decision Tree for Frontline Flea Prevention in Low Risk State for Small Dog

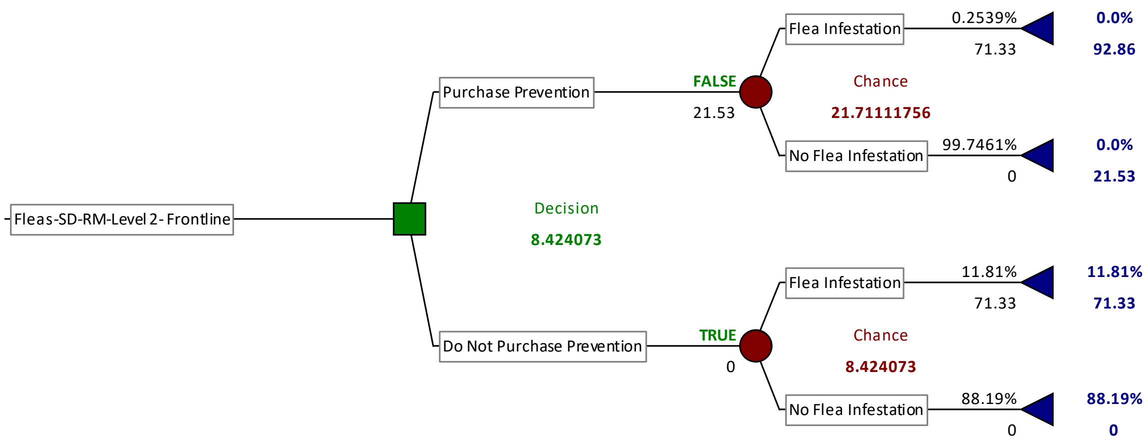

Figure 8: Decision Tree for Frontline Flea Prevention in Medium Risk State for Small Dog

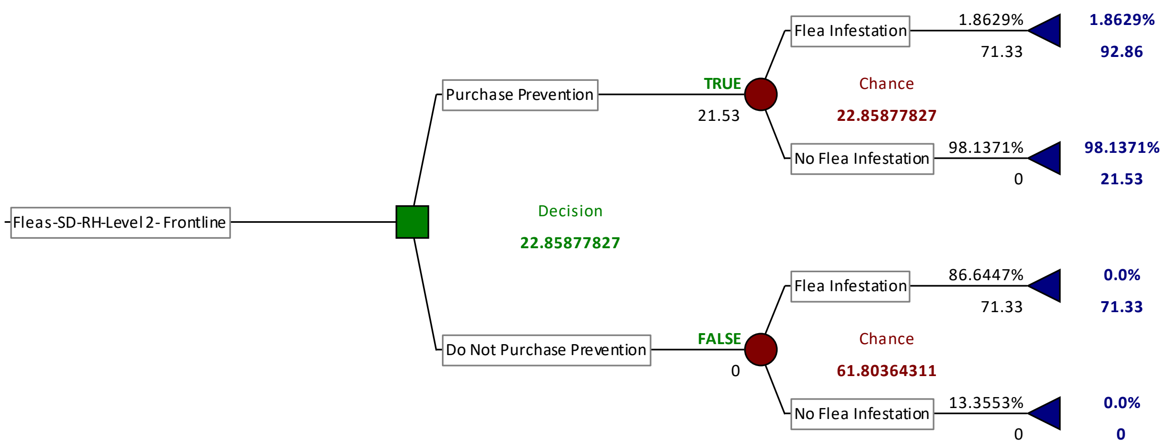

*Figure 9: Decision Tree for Frontline Flea Prevention in High Risk State for Small Dog

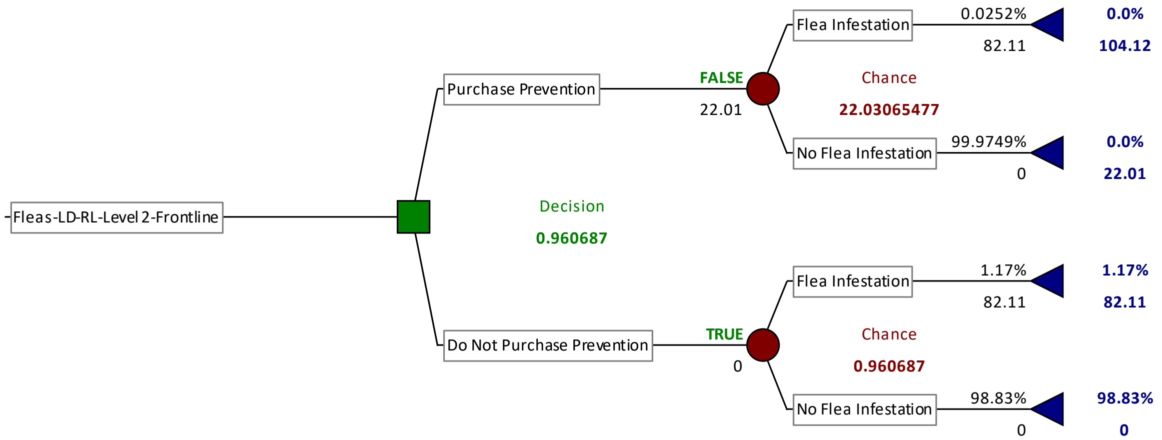

Figure 10: Decision Tree for Frontline Flea Prevention in Low Risk State for Large Dog

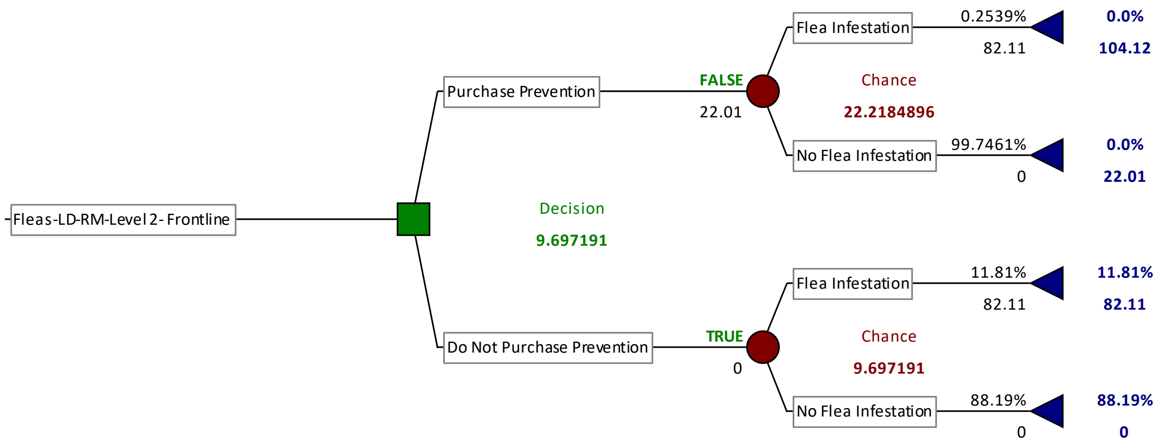

Figure 11: Decision Tree for Frontline Flea Prevention in Medium Risk State for Large Dog

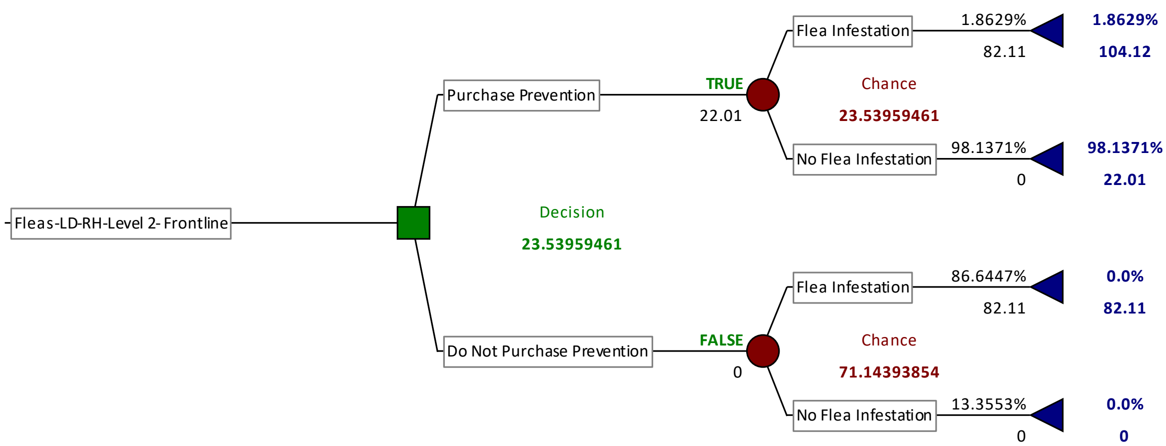

*Figure 12: Decision Tree for Frontline Flea Prevention in High Risk State for Large Dog

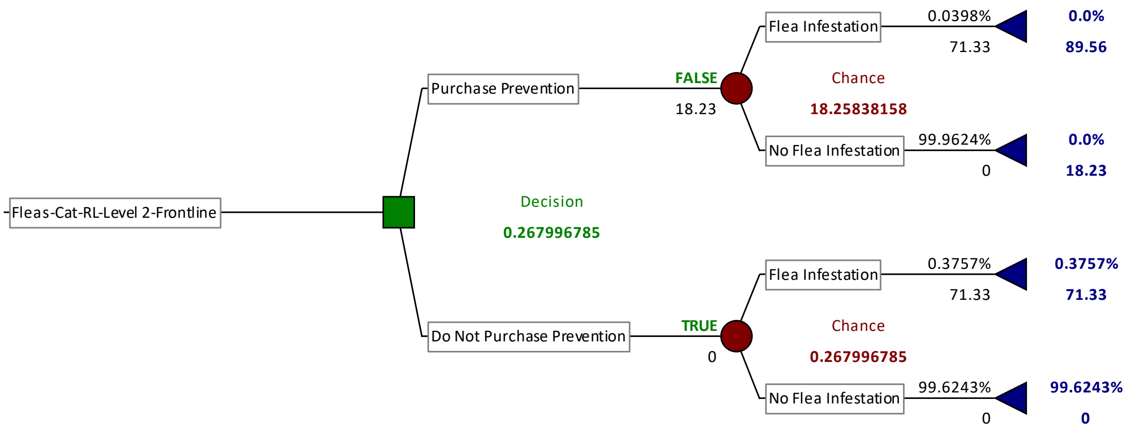

Figure 13: Decision Tree for Frontline Flea Prevention in Low Risk State for Cat

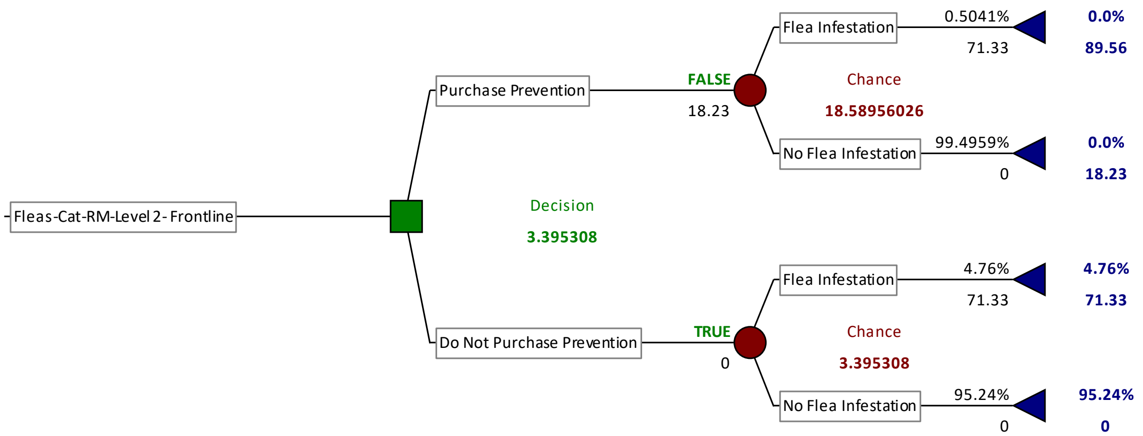

Figure 14: Decision Tree for Frontline Flea Prevention in Medium Risk State for Cat

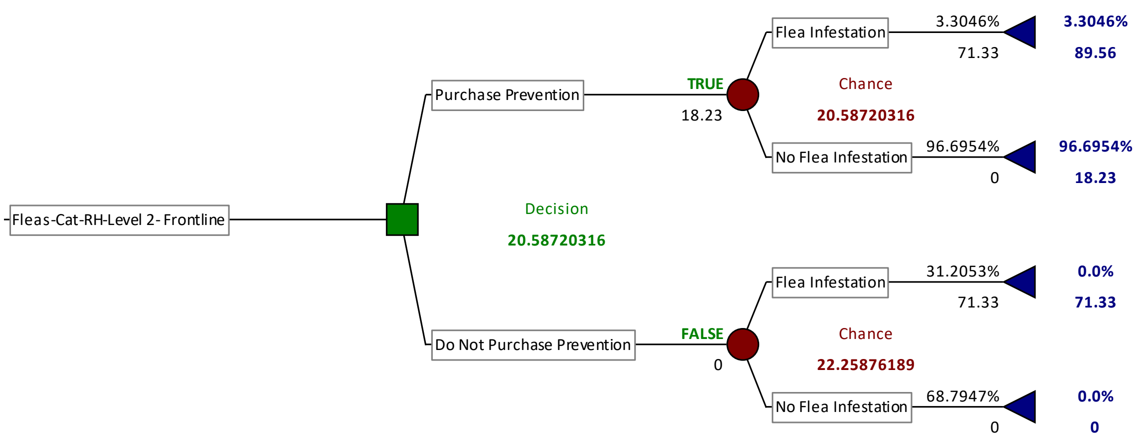

*Figure 15: Decision Tree for Frontline Flea Prevention in High Risk State for Cat

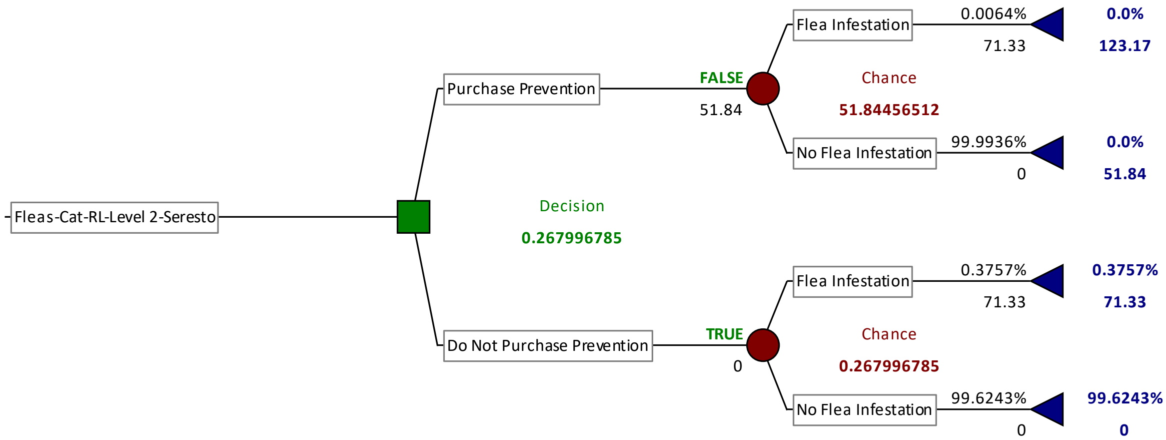

Figure 16: Decision Tree for Seresto Collar Flea Prevention in Low Risk State for Cat

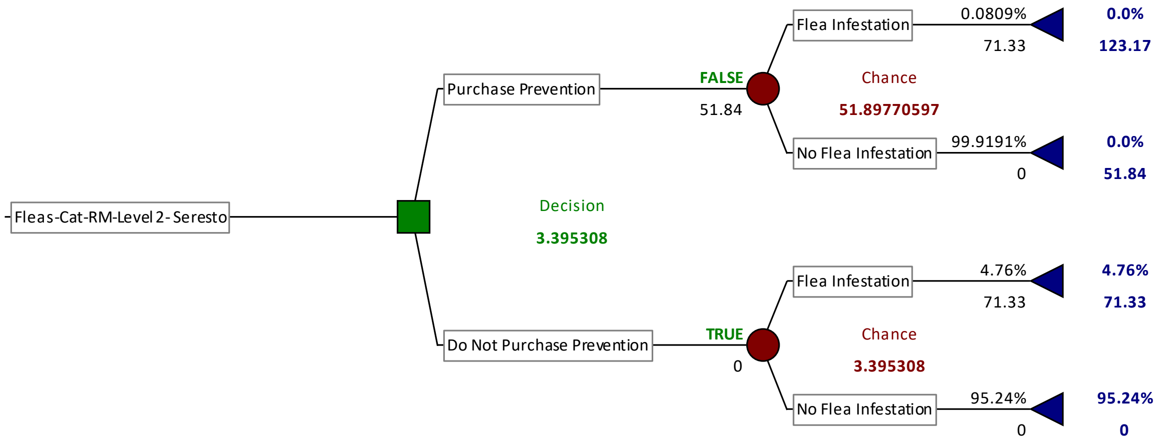

Figure 17: Decision Tree for Seresto Collar Flea Prevention in Medium Risk State for Cat

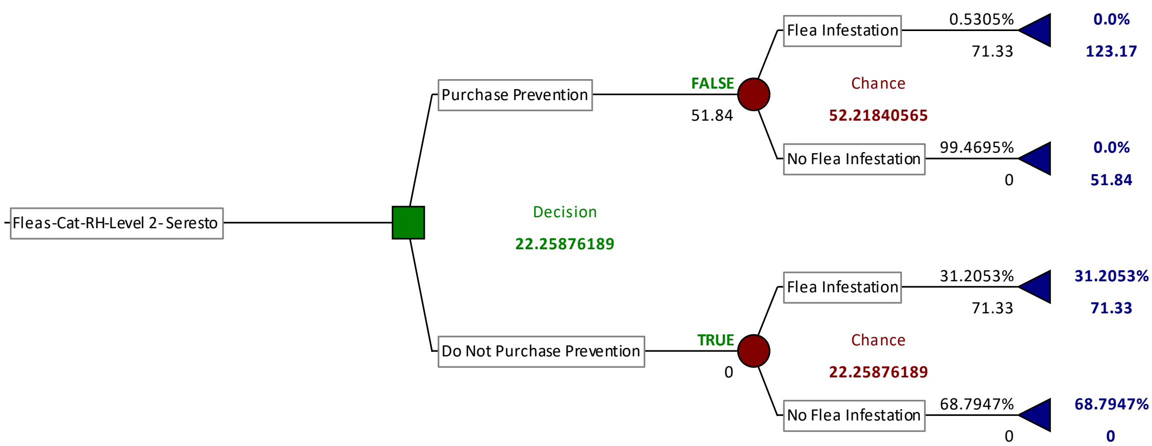

Figure 18: Decision Tree for Seresto Collar Flea Prevention in High Risk State for Cat

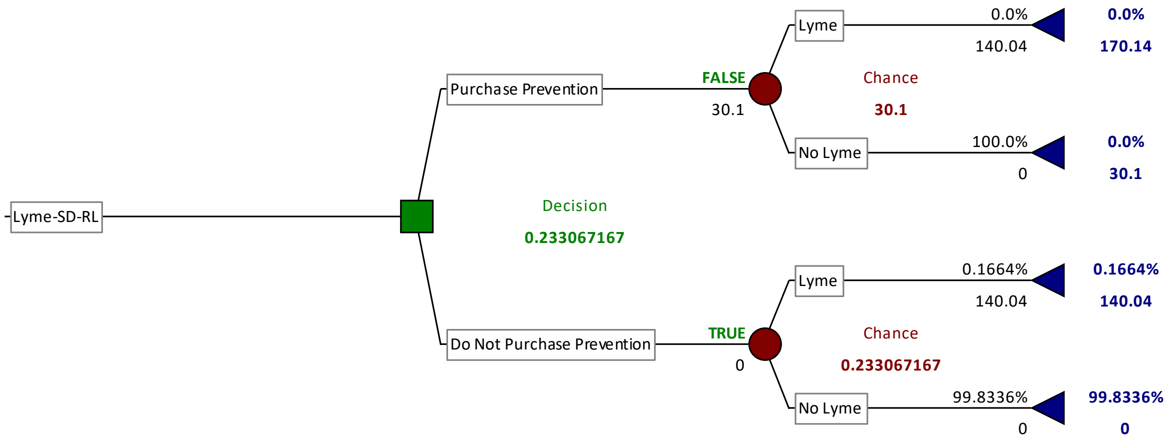

Figure 19: Decision Tree for Lyme Vaccine Lyme Disease Prevention in Low Risk State for Small Dog

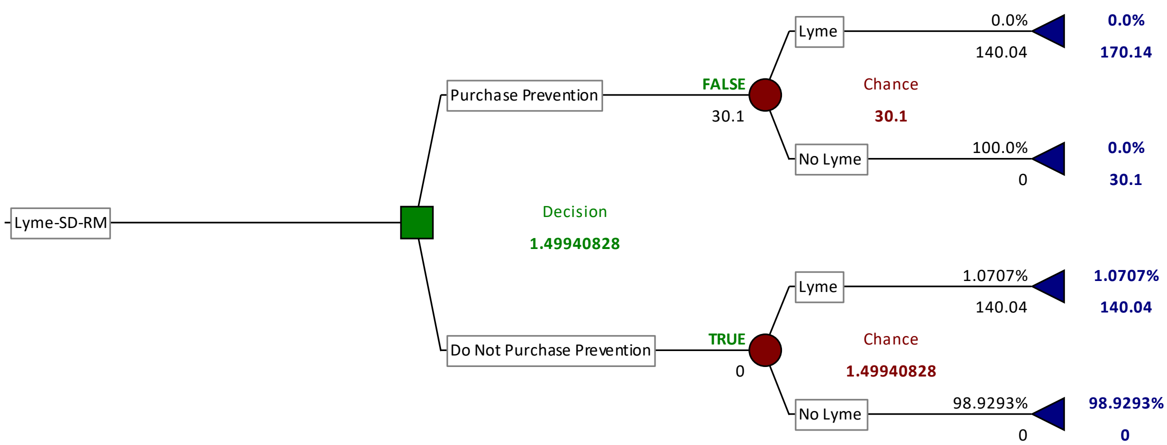

Figure 20: Decision Tree for Lyme Vaccine Lyme Disease Prevention in Medium Risk State for Small Dog

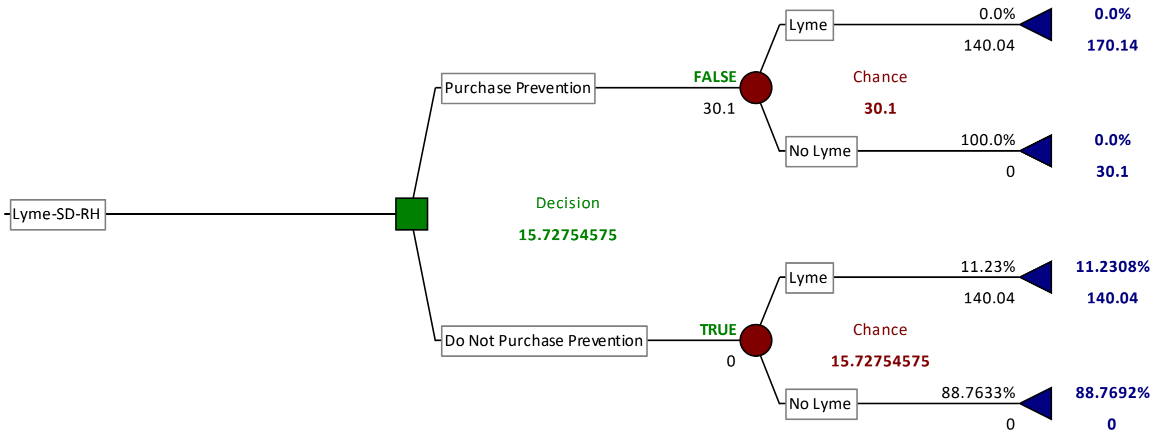

Figure 21: Decision Tree for Lyme Vaccine Lyme Disease Prevention in High Risk State for Small Dog

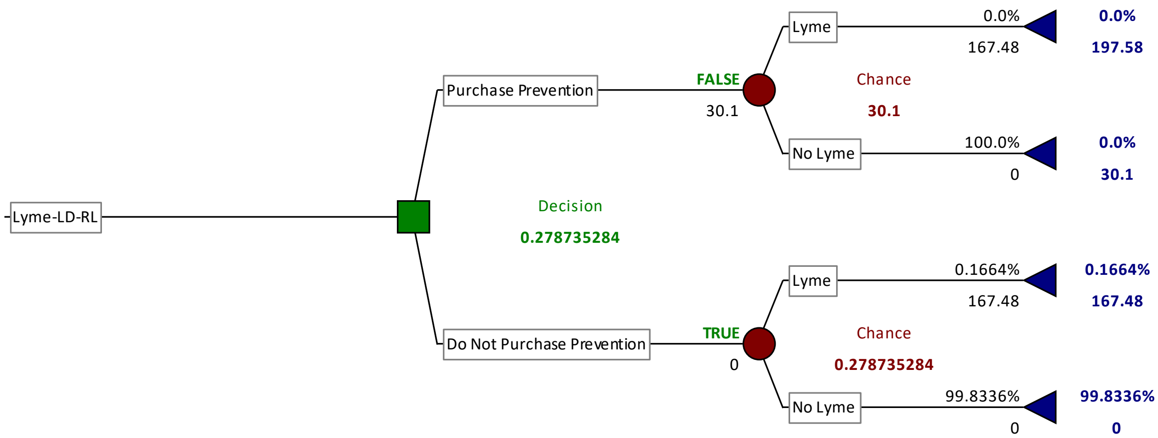

Figure 22: Decision Tree for Lyme Vaccine Lyme Disease Prevention in Low Risk State for Large Dog

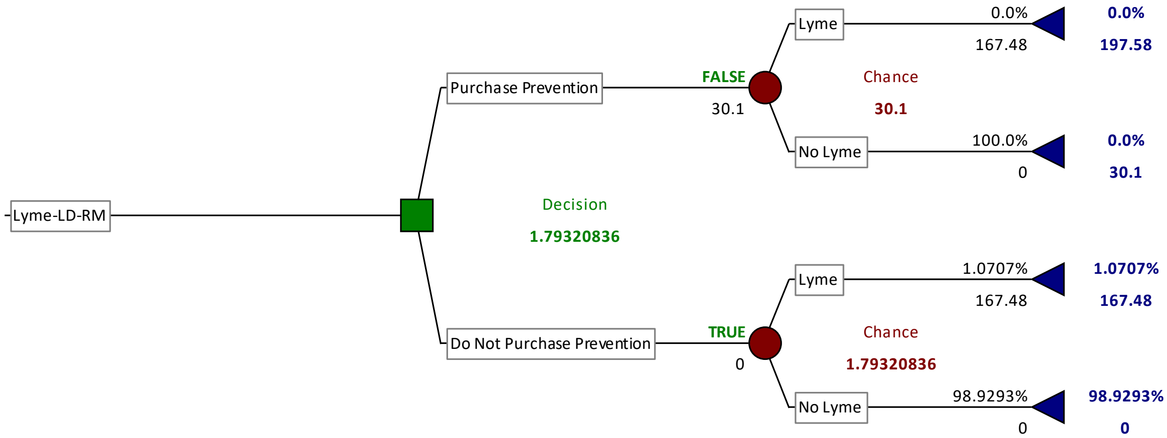

Figure 23: Decision Tree for Lyme Vaccine Lyme Disease Prevention in Medium Risk State for Large Dog

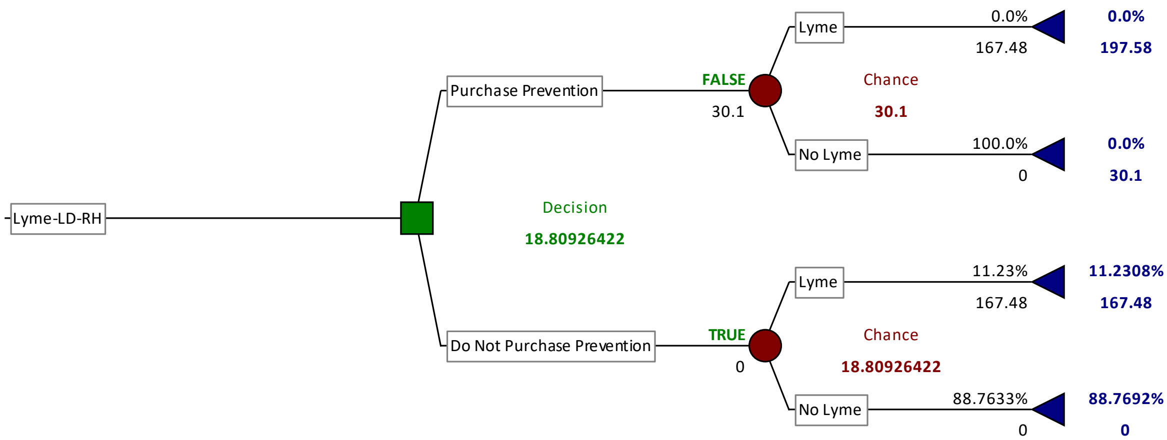

Figure 24: Decision Tree for Lyme Vaccine Lyme Disease Prevention in High Risk State for Large Dog

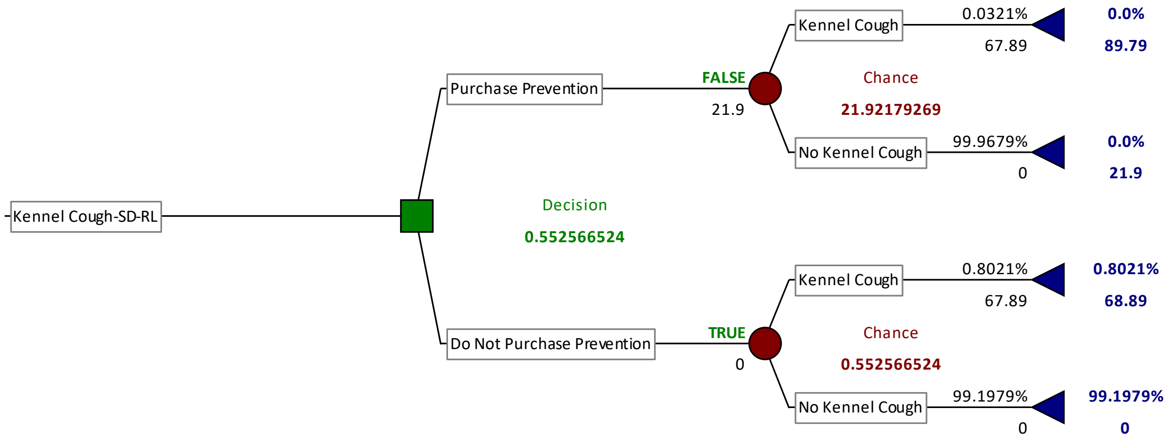

Figure 25: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in Low Risk State for Small Dog

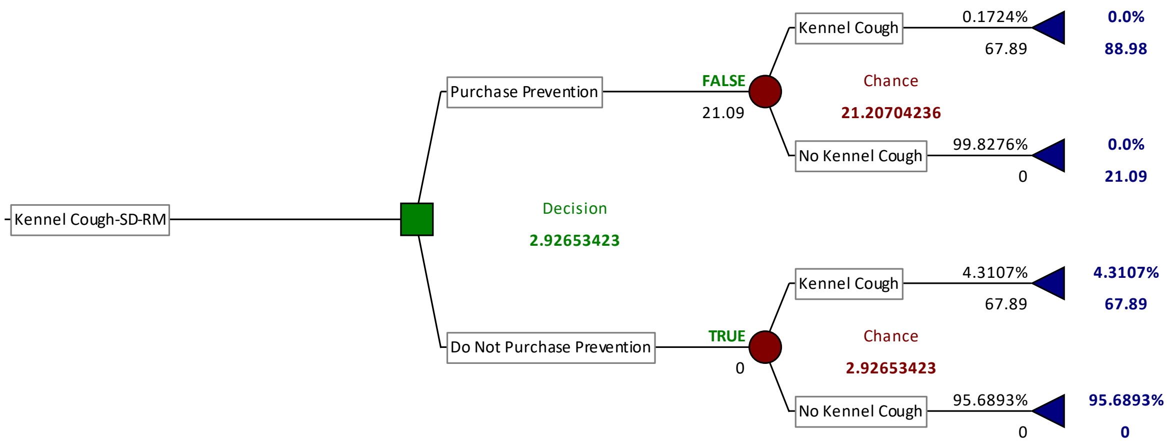

Figure 26: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in Medium Risk State for Small Dog

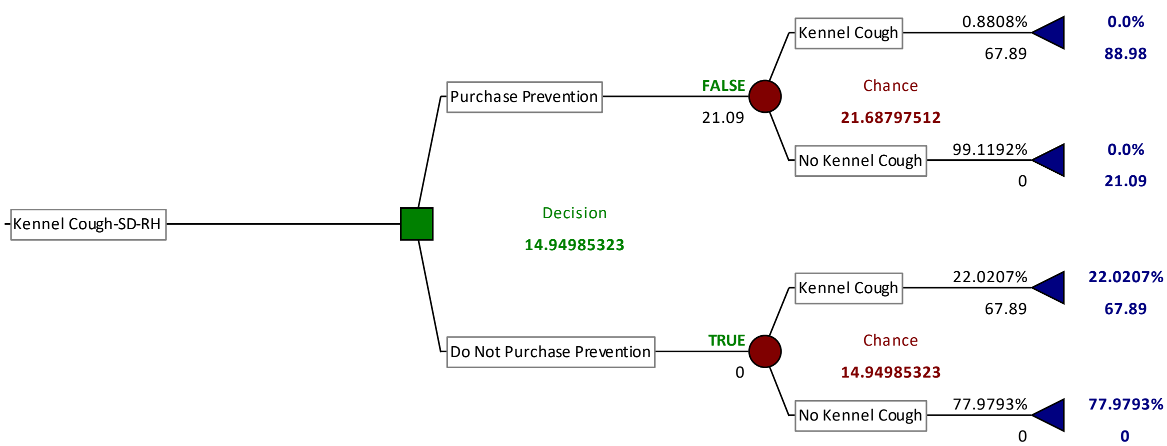

Figure 27: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in High Risk State for Small Dog

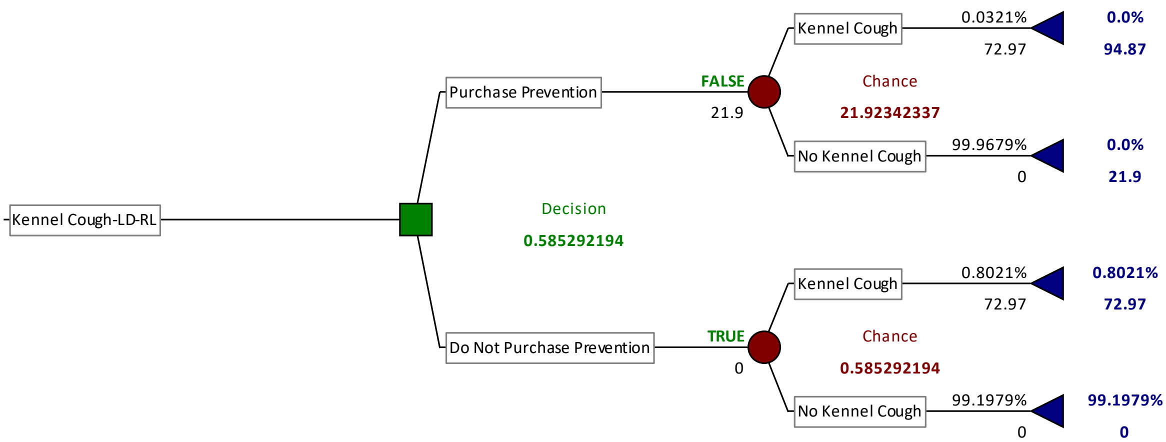

Figure 28: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in Low Risk State for Large Dog

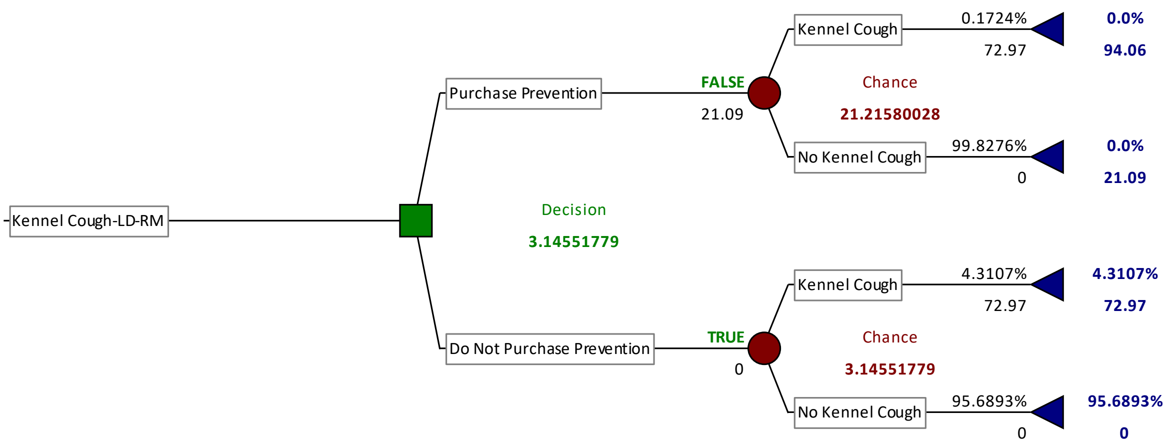

Figure 29: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in Medium Risk State for Large Dog

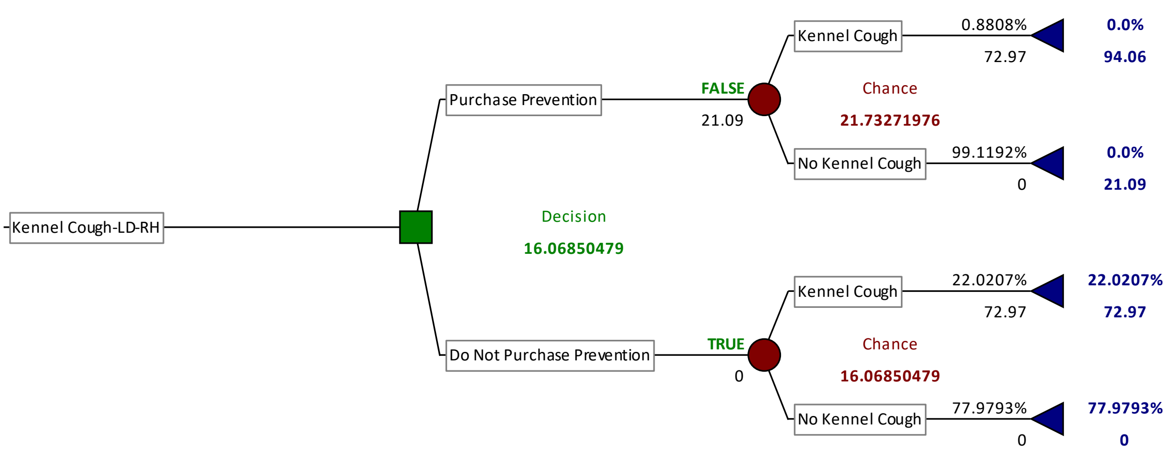

Figure 30: Decision Tree for Bordetella Vaccine Kennel Cough Disease Prevention in High Risk State for Large Dog

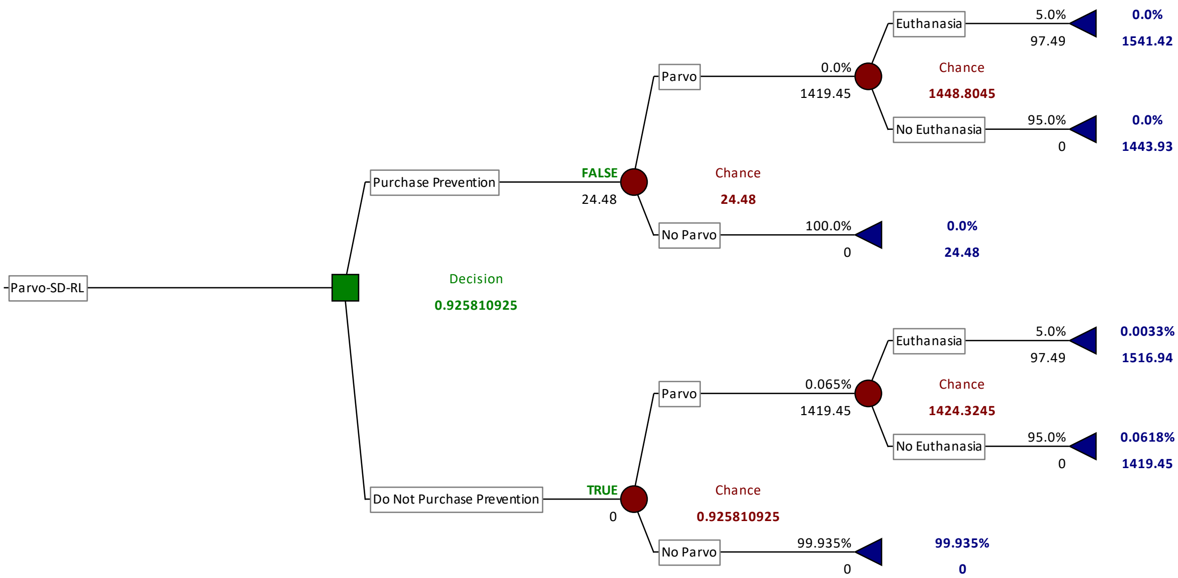

Figure 31: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in Low Risk State for Small Dog

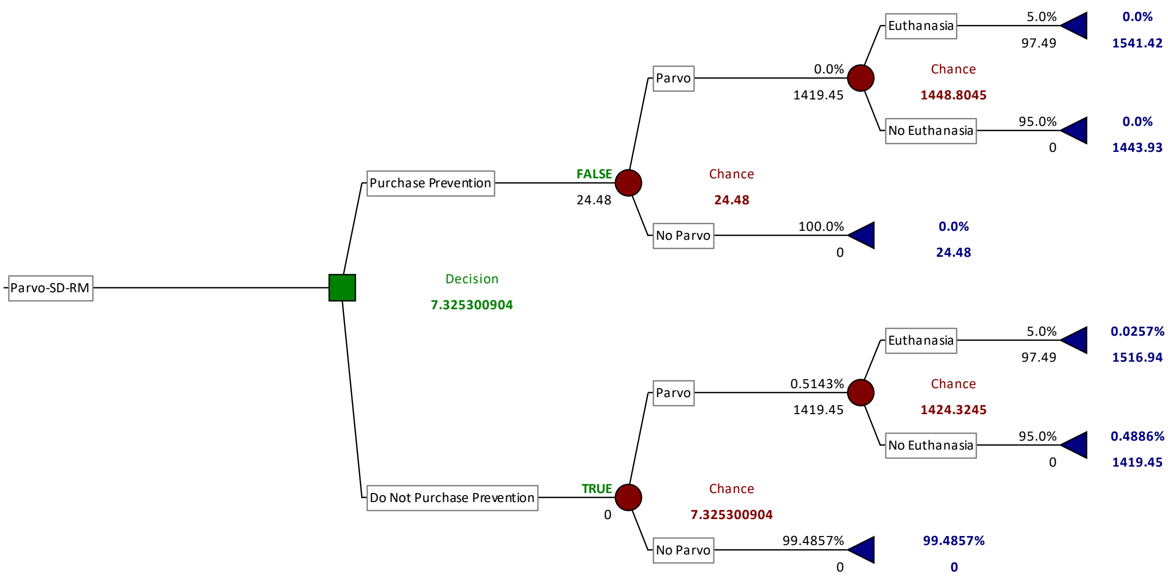

Figure 32: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in Medium Risk State for Small Dog

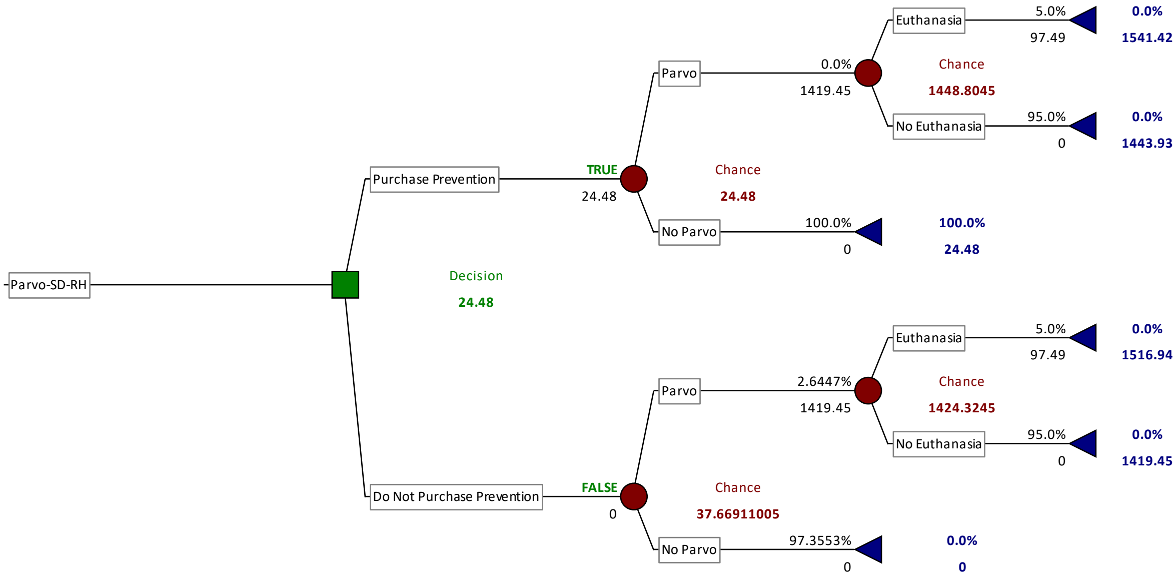

*Figure 33: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in High Risk State for Small Dog

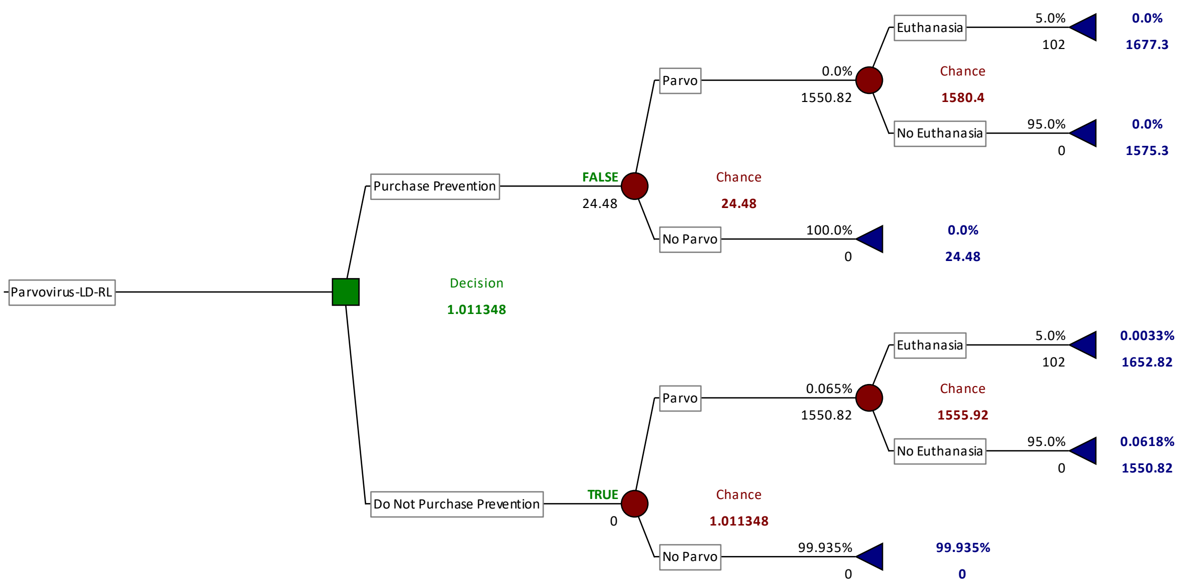

Figure 34: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in Low Risk State for Large Dog

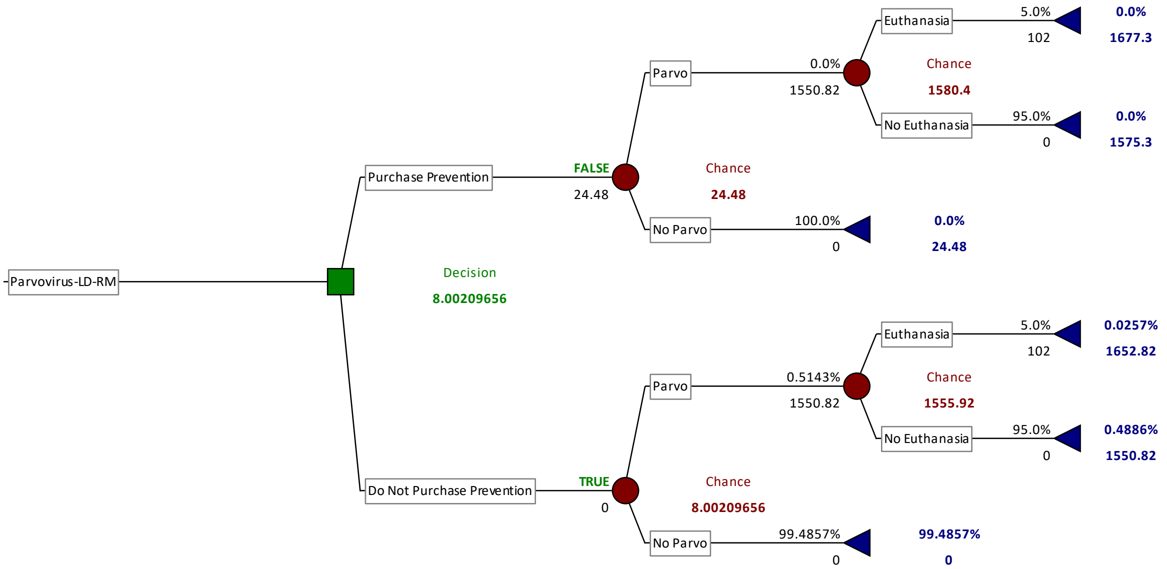

Figure 35: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in Medium Risk State for Large Dog

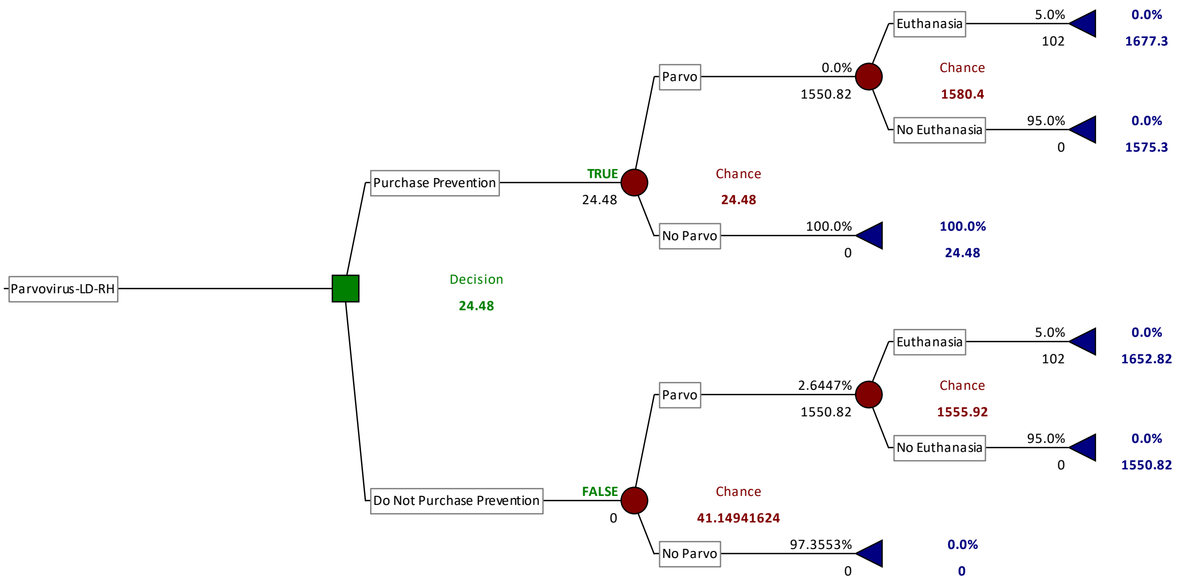

*Figure 36: Decision Tree for Parvovirus Vaccine Parvovirus Disease Prevention in High Risk State for Large Dog

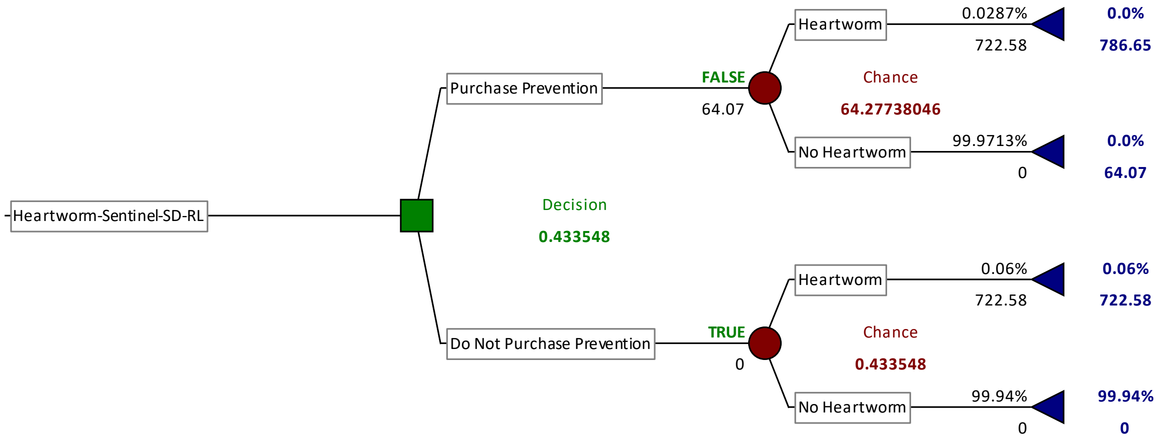

Figure 37: Decision Tree for Sentinel Heartworm Disease Prevention in Low Risk State for Small Dog

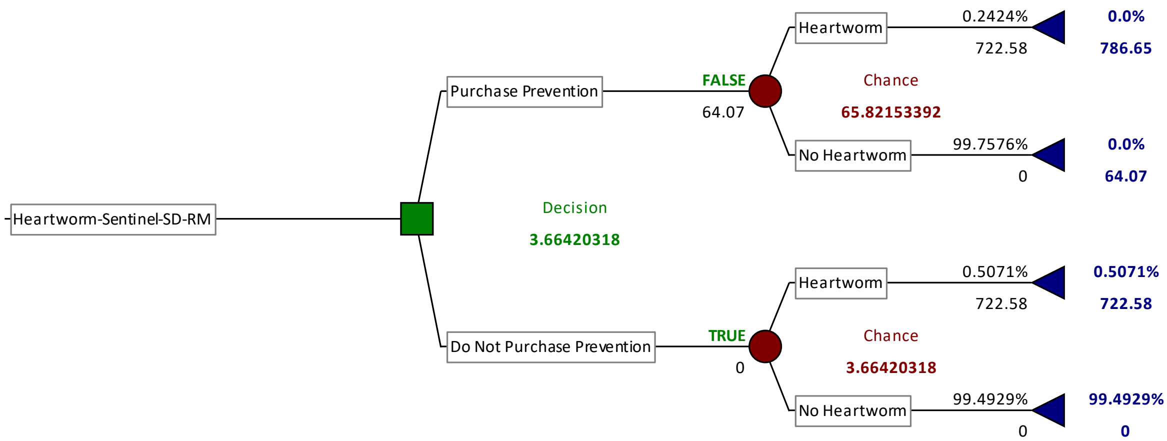

Figure 38: Decision Tree for Sentinel Heartworm Disease Prevention in Medium Risk State for Small Dog

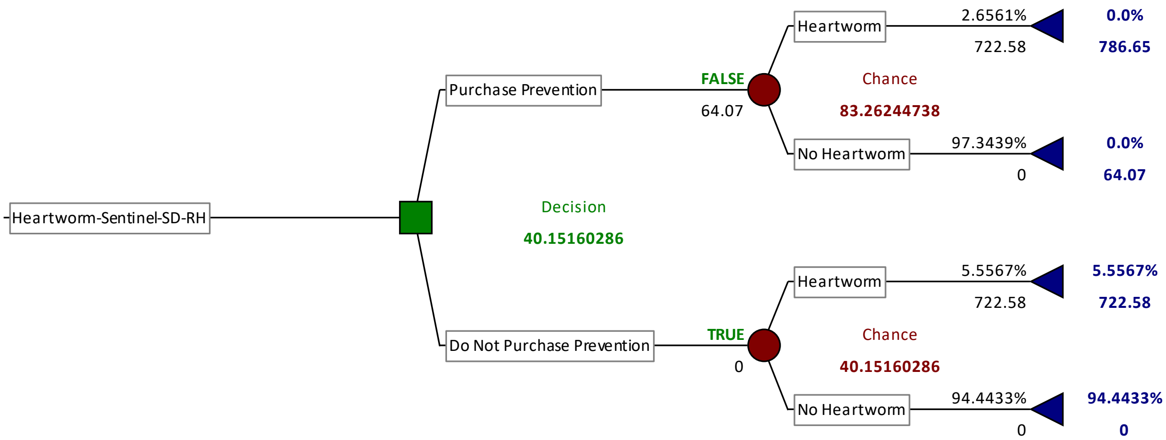

Figure 39: Decision Tree for Sentinel Heartworm Disease Prevention in High Risk State for Small Dog

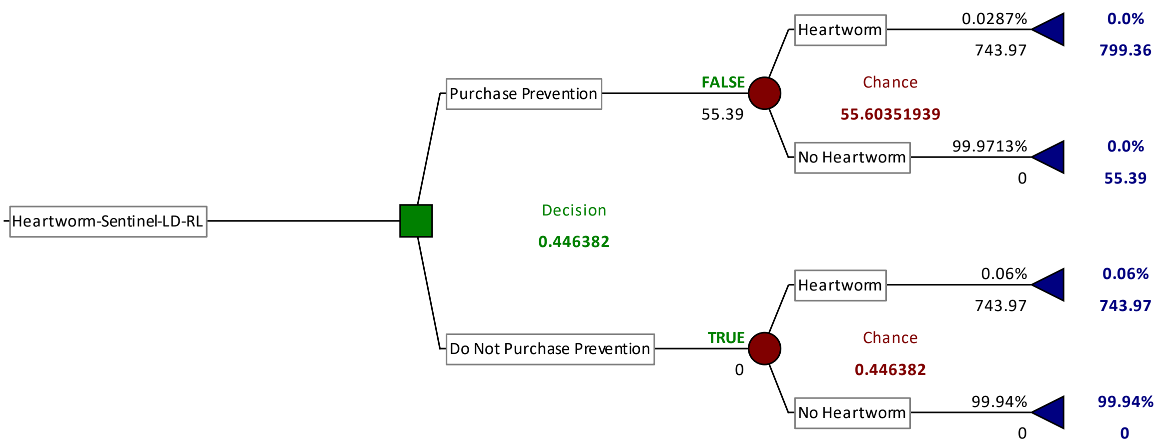

Figure 40: Decision Tree for Sentinel Heartworm Disease Prevention in Low Risk State for Large Dog

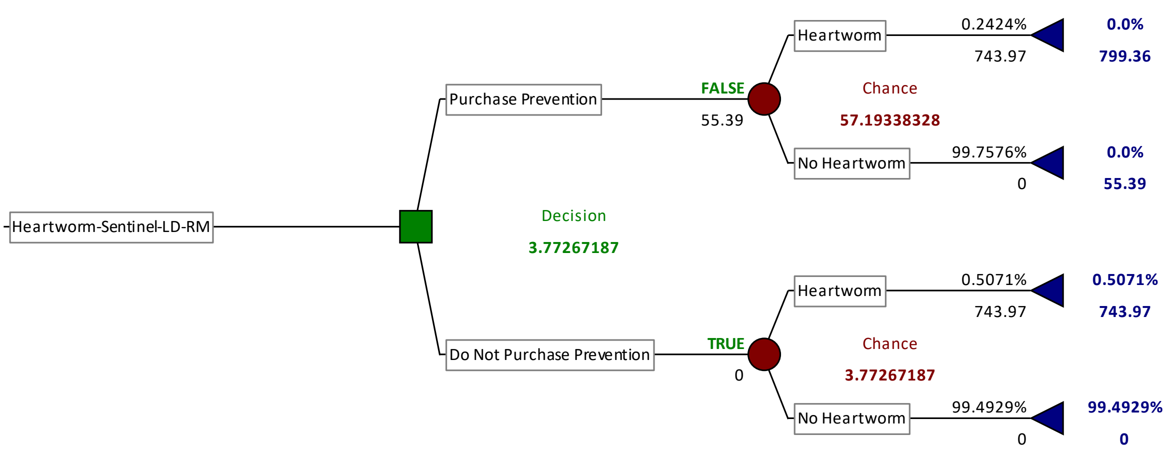

Figure 41: Decision Tree for Sentinel Heartworm Disease Prevention in Medium Risk State for Large Dog

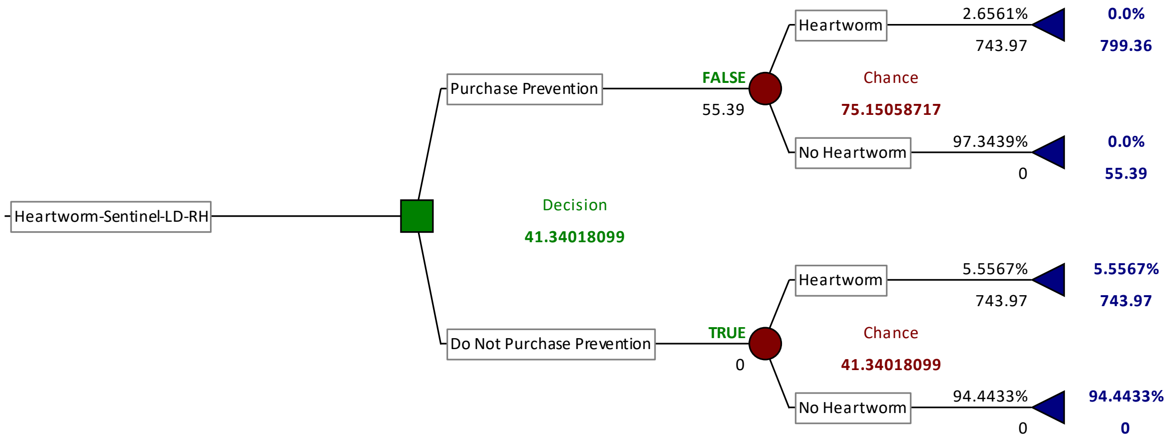

Figure 42: Decision Tree for Sentinel Heartworm Disease Prevention in High Risk State for Large Dog

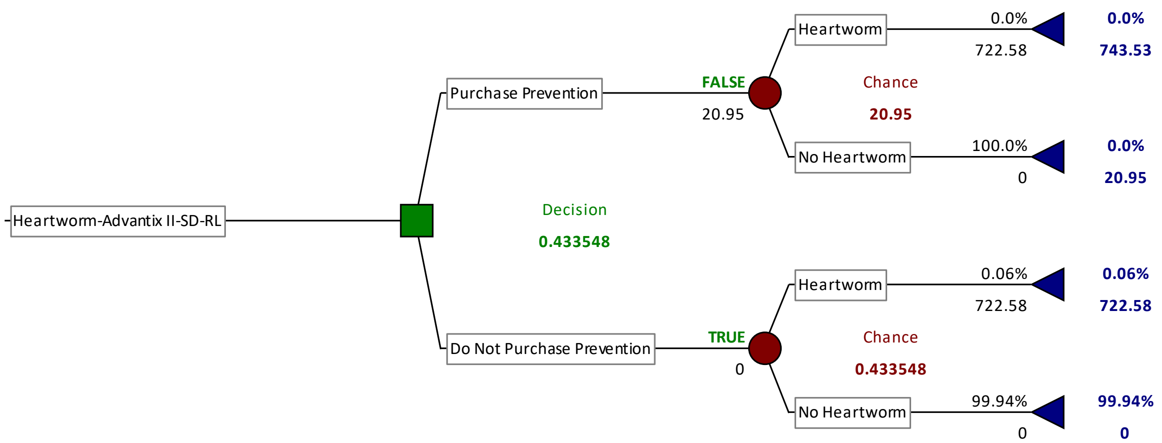

Figure 43: Decision Tree for Advantix II Heartworm Disease Prevention in Low Risk State for Small Dog

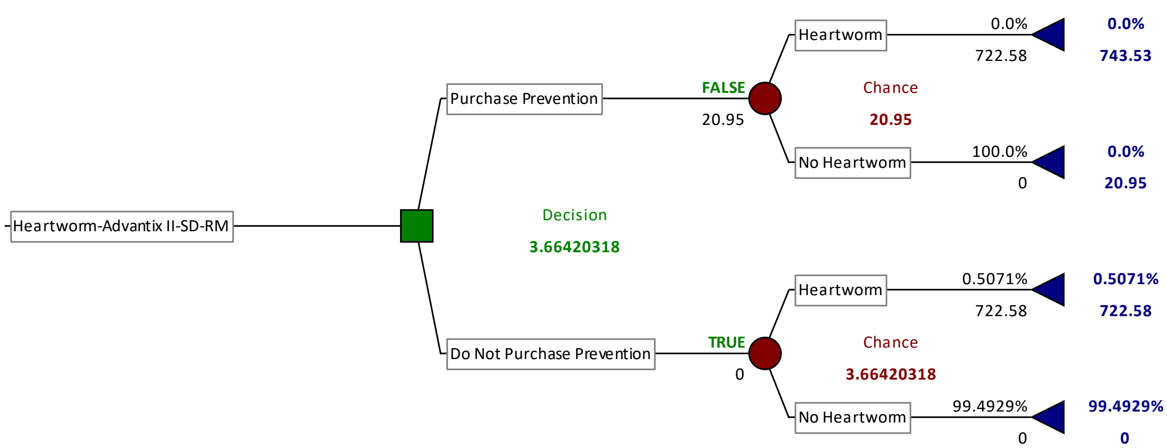

Figure 44: Decision Tree for Advantix II Heartworm Disease Prevention in Medium Risk State for Small Dog

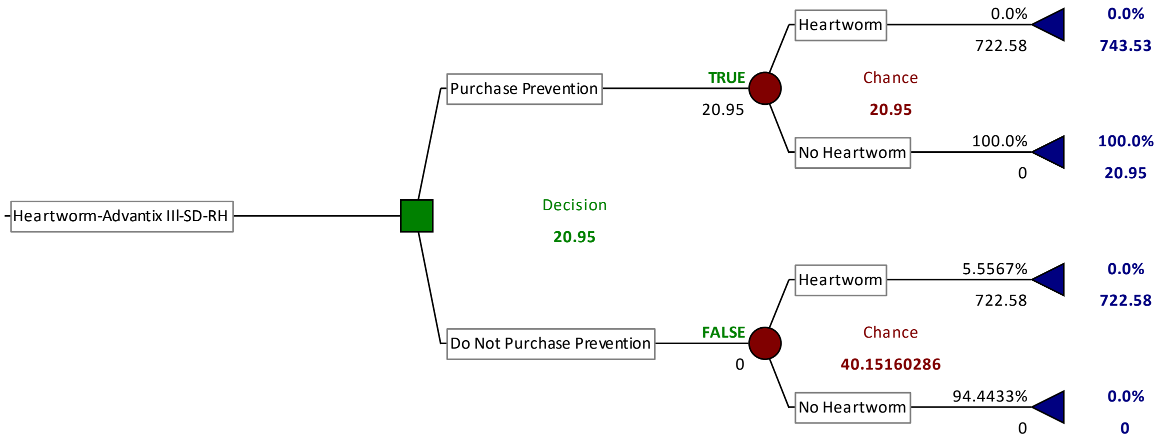

*Figure 45: Decision Tree for Advantix II Heartworm Disease Prevention in High Risk State for Small Dog

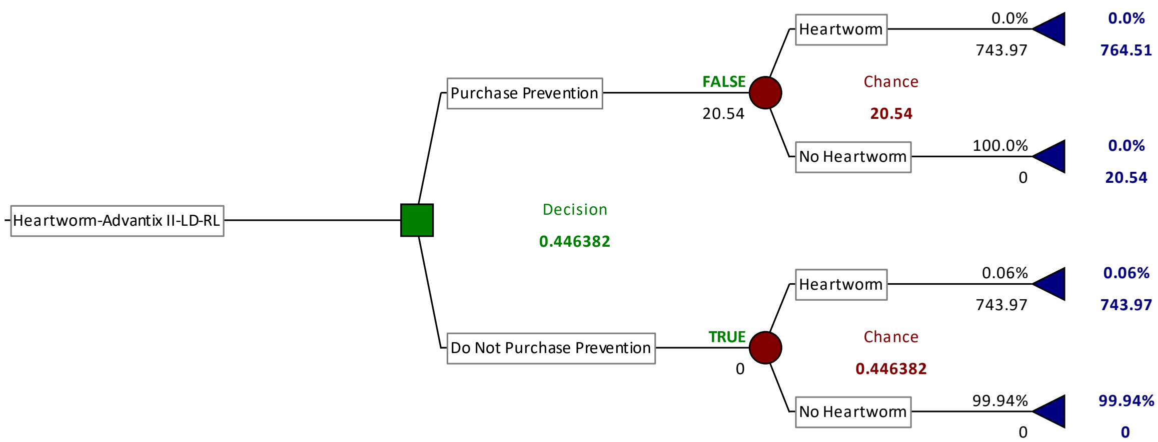

Figure 46: Decision Tree for Advantix II Heartworm Disease Prevention in Low Risk State for Large Dog

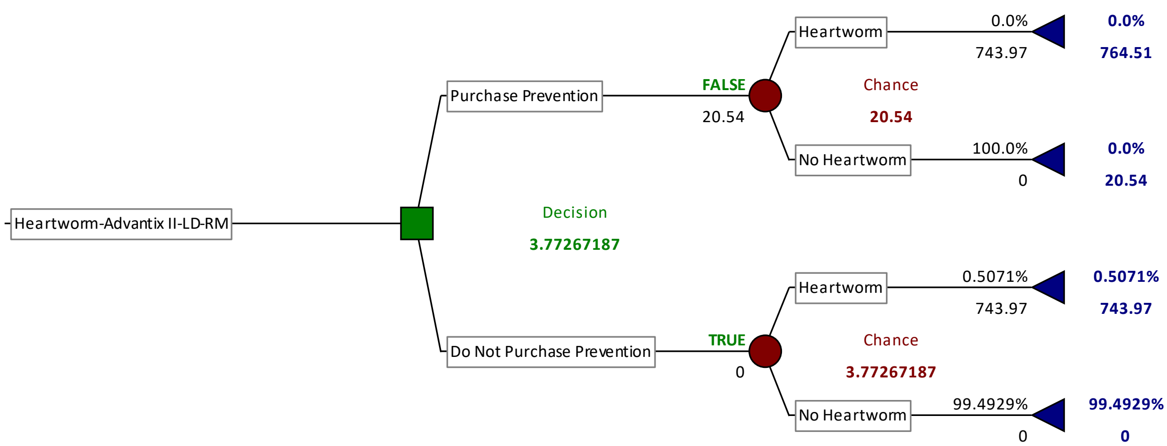

Figure 47: Decision Tree for Advantix II Heartworm Disease Prevention in Medium Risk State for Large Dog

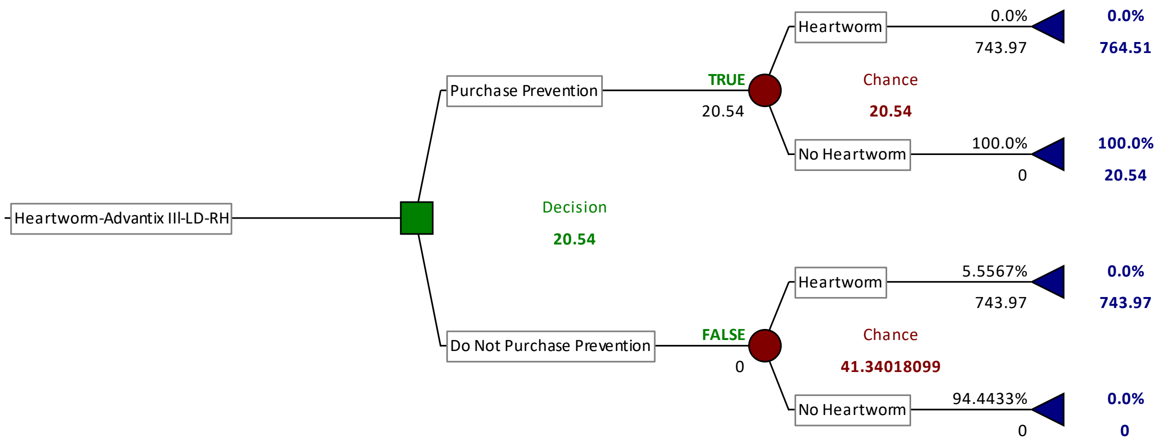

*Figure 48: Decision Tree for Advantix II Heartworm Disease Prevention in High Risk State for Large Dog

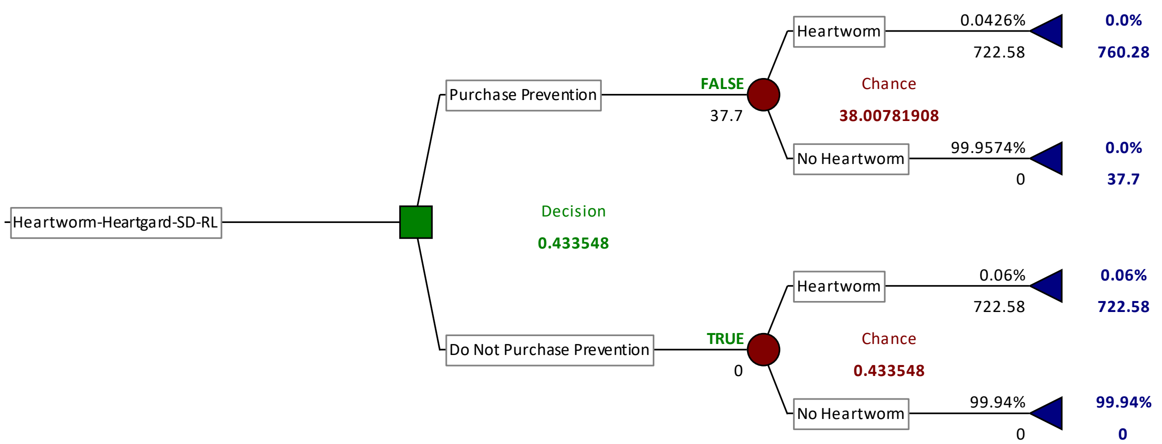

Figure 49: Decision Tree for Heartgard Heartworm Disease Prevention in Low Risk State for Small Dog

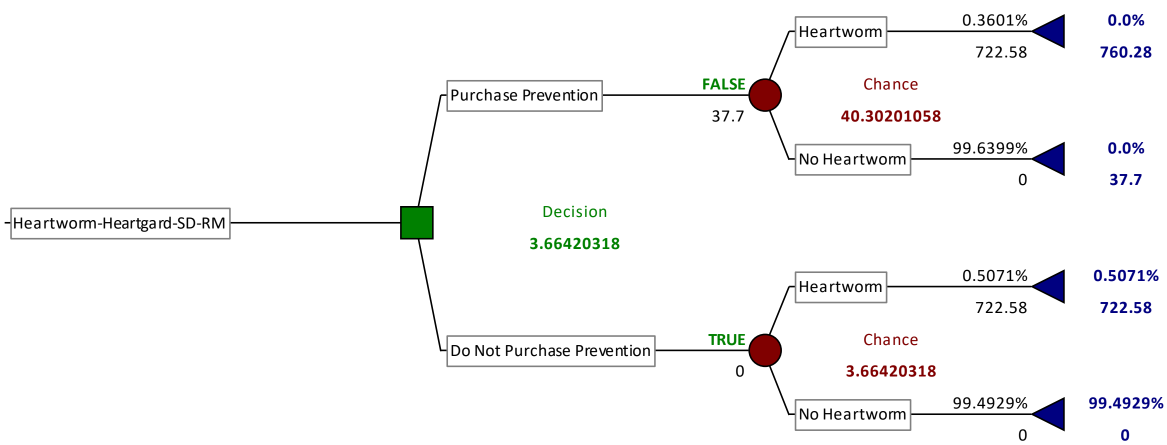

Figure 50: Decision Tree for Heartgard Heartworm Disease Prevention in Medium Risk State for Small Dog

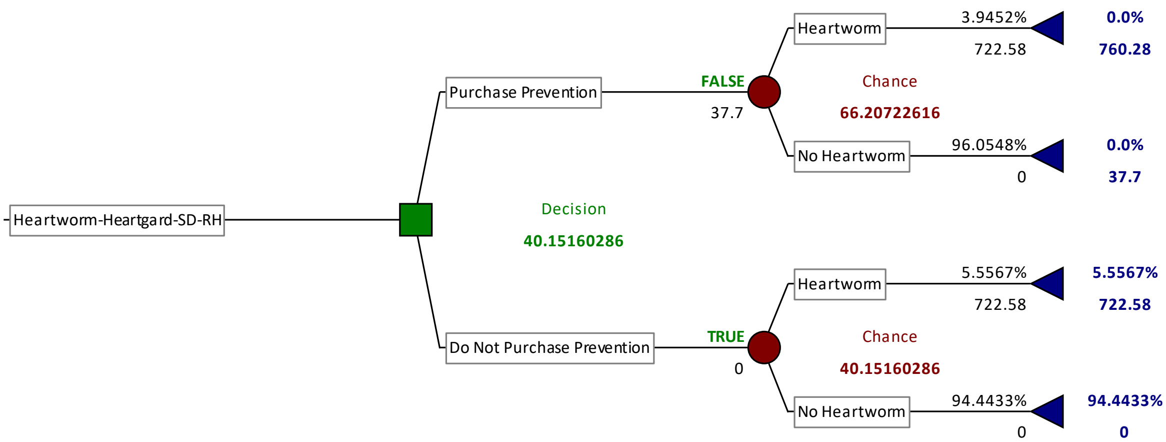

Figure 51: Decision Tree for Heartgard Heartworm Disease Prevention in High Risk State for Small Dog

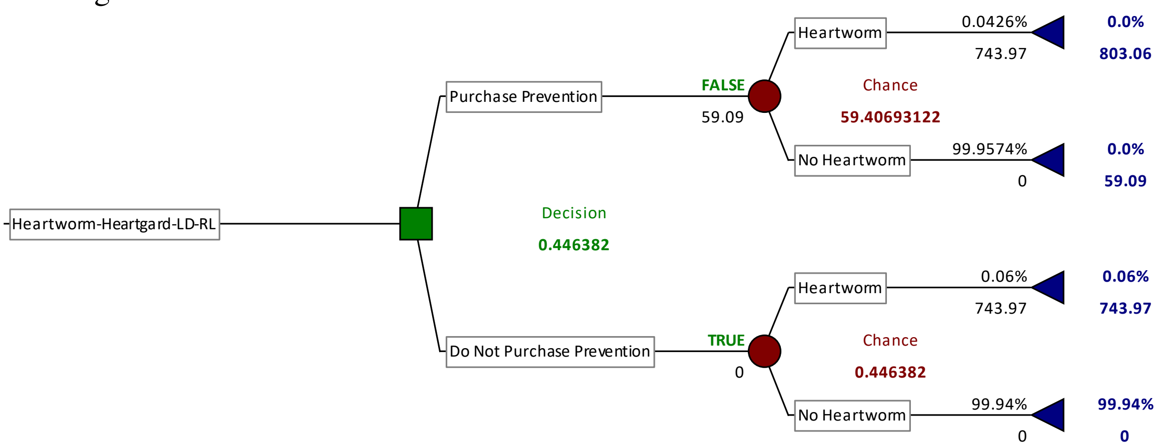

Figure 52: Decision Tree for Heartgard Heartworm Disease Prevention in Low Risk State for Large Dog

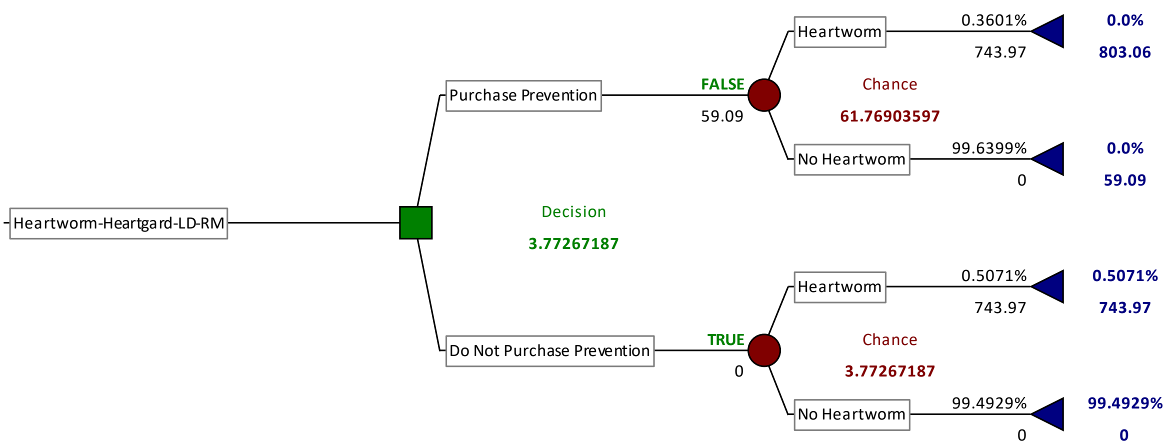

Figure 53: Decision Tree for Heartgard Heartworm Disease Prevention in Medium Risk State for Large Dog

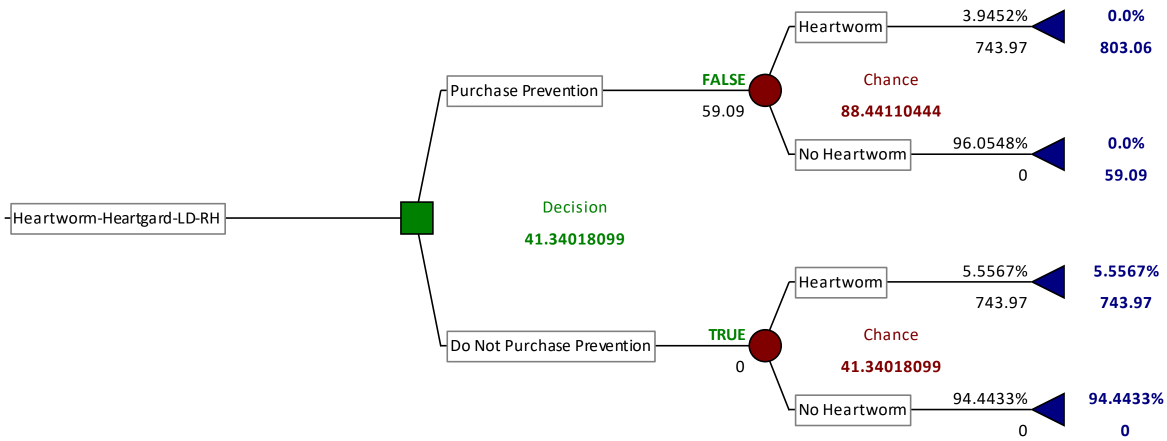

Figure 54: Decision Tree for Heartgard Heartworm Disease Prevention in High Risk State for Large Dog

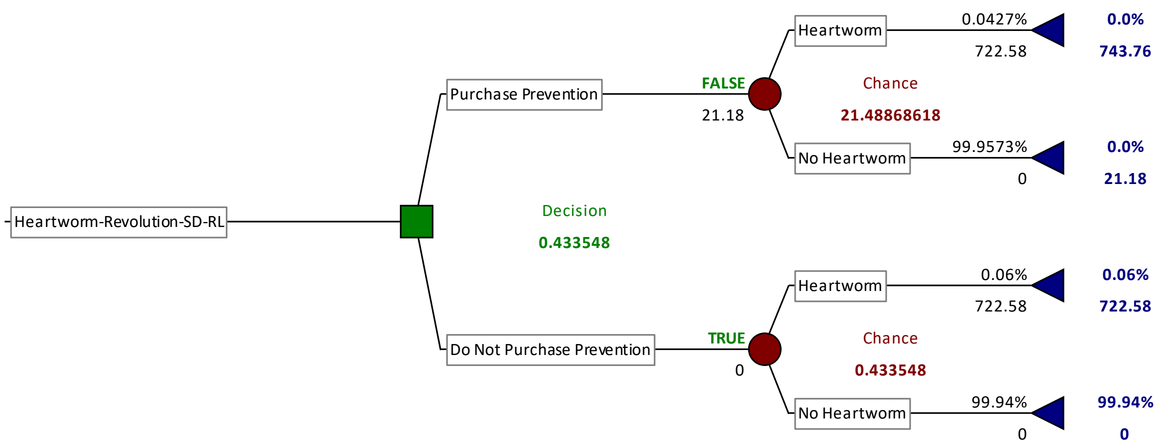

Figure 55: Decision Tree for Revolution Heartworm Disease Prevention in Low Risk State for Small Dog

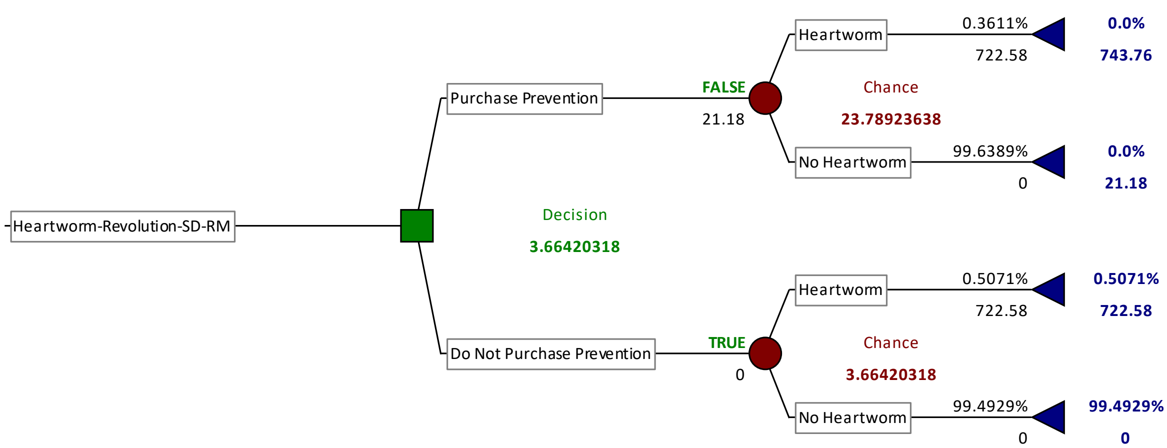

Figure 56: Decision Tree for Revolution Heartworm Disease Prevention in Medium Risk State for Small Dog

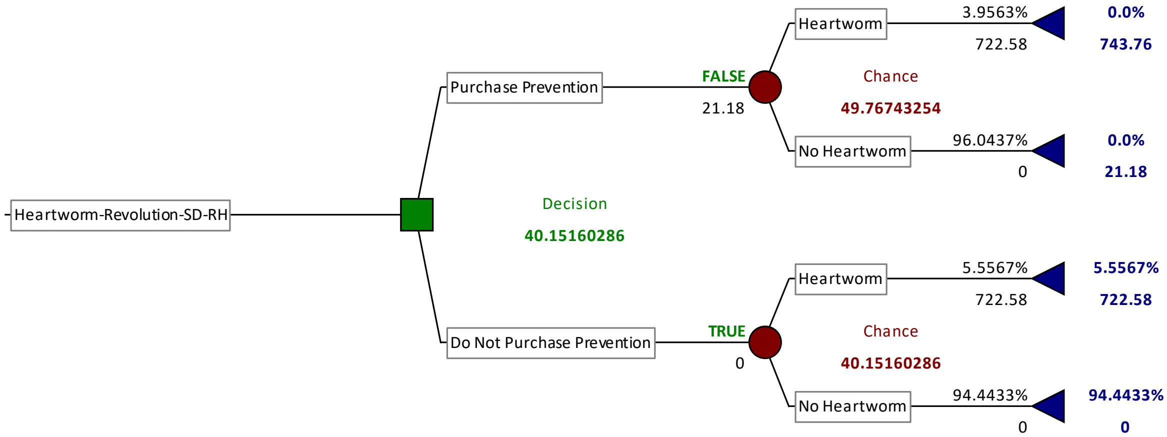

Figure 57: Decision Tree for Revolution Heartworm Disease Prevention in High Risk State for Small Dog

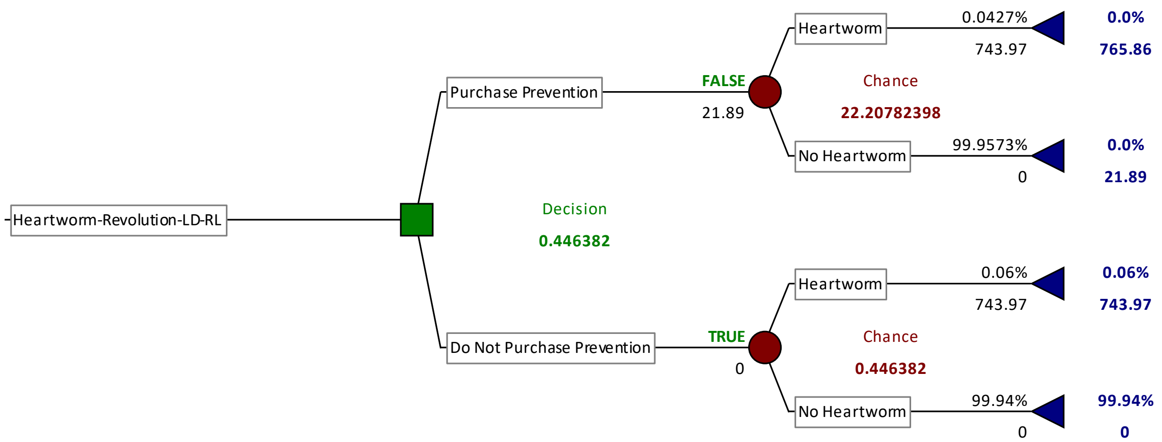

Figure 58: Decision Tree for Revolution Heartworm Disease Prevention in Low Risk State for Large Dog

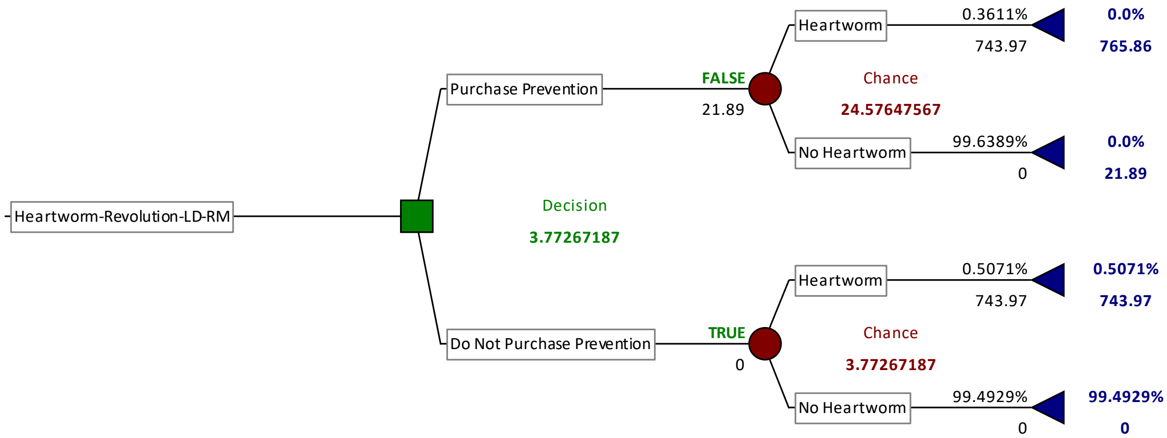

Figure 59: Decision Tree for Revolution Heartworm Disease Prevention in Medium Risk State for Large Dog

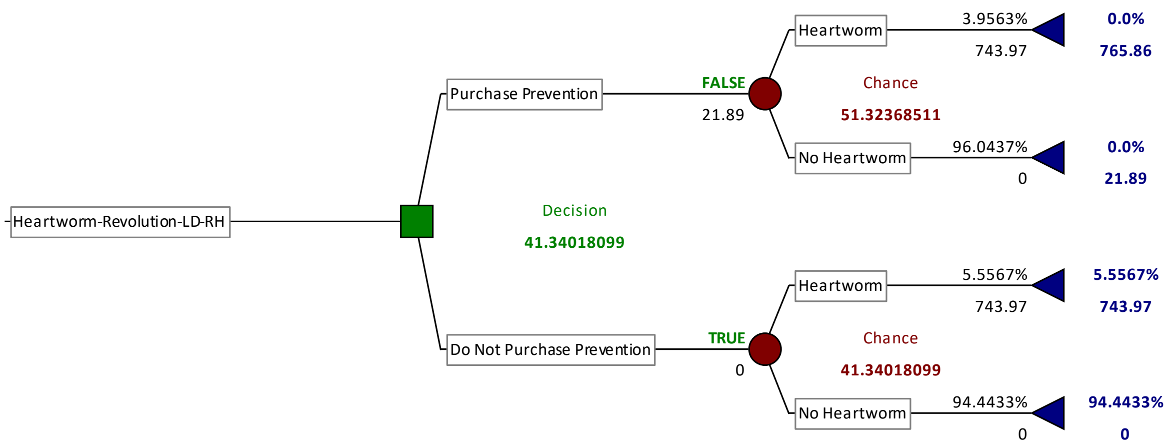

Figure 60: Decision Tree for Revolution Heartworm Disease Prevention in High Risk State for Large Dog

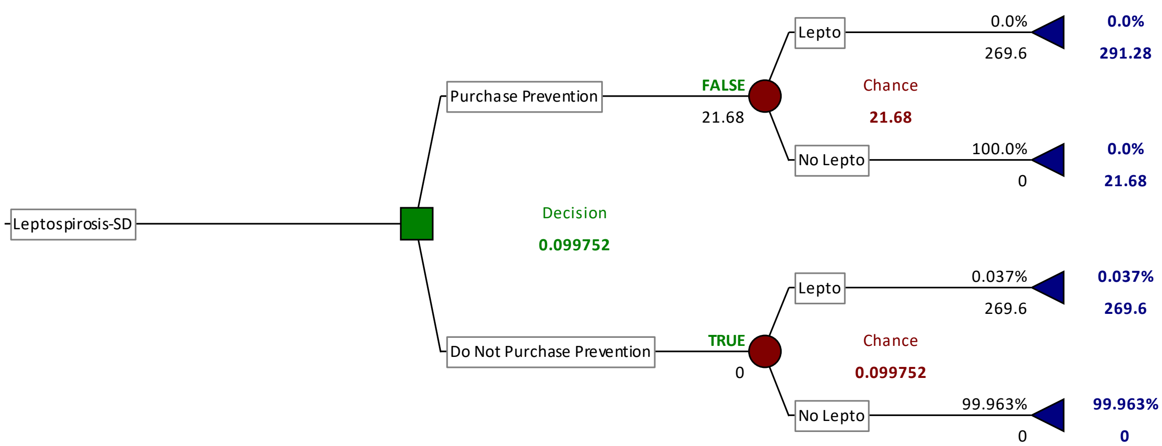

Figure 61: Decision Tree for Leptospirosis Vaccine Leptospirosis Disease Prevention for Small Dog

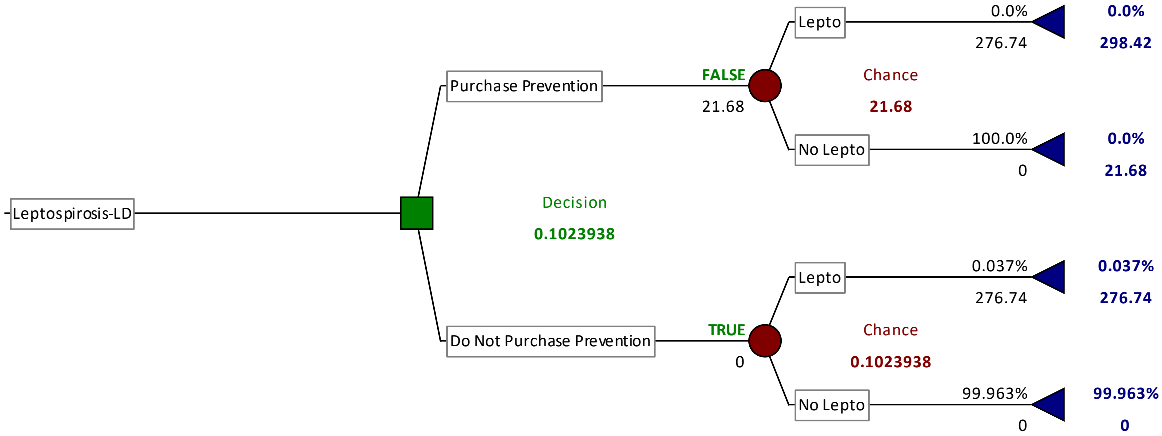

Figure 62: Decision Tree for Leptospirosis Vaccine Leptospirosis Disease Prevention for Large Dog