Planning and scheduling for animal shelters

Master thesis Industrial Engineering and Management

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Management summary

The Dutch animal protection is a non-governmental organization, which shelters and treats homeless animals and finds them a new home. This research focused on the animal shelters located in A, B, and C since these three lie in close proximity to each other. Analyzing the work processes of veterinarians and vet technicians, a gap is experienced between the demand and supply at the animal shelters. This is expressed in the placement of animals without legal treatment and overtime hours for staff members. To try to reduce this gap, the following main research question was formulated for this research:

How can the animal shelters in A, B, and C be in control as much as possible of how to deploy staff members to be able to meet the demand?

To answer this question, we formulated supporting research questions that all touch upon their own part of this research. First, we defined the desired situation. In the desired situation, the animal shelters located in A, B, and C integrate their staff planning and standardize their work methodologies, with the goal that veterinarians and vet technicians can work independently of each other.

Next, we developed a forecasting model to determine the expected demand per animal shelter for the year 2023, based on the performed procedures in the years 2019 until 2022. The models that we used are the double exponential smoothing method and the Holt-Winter model. The models are built, trained, and validated internally and externally. A sensitivity analysis was performed to show the dependency of the input of the forecasting models.

The performance of the current block schedule was determined using the expected demand and the duration per procedure. We use the lognormal distribution for the determination of expected work hours per week. During the analysis of the block schedule, we used overtime as the key performance indicator, since this was the main problem arising at the work floor. The probability of working overtime was considered to be acceptable when it is below the threshold of 30%. Together with the probability, we determined the expectation and standard deviation of overtime, per staff member and per animal shelter. Analyzing the performance of the current block schedule, we could conclude that in many weeks the expected amount of work does not comply with the available work hours.

To reduce the gap between demand and supply, we proposed thirteen improvement ideas to the current staff scheduling and used work methodologies. The improvement ideas have been placed in the hierarchical framework of planning and control. Together with the management of the animal shelters, the choice is made to develop an implementation plan for three proposed improvement ideas. The first improvement idea is to reallocate capacity differently over the animal shelters per quarter. In that way, the animal shelters can cooperate to all be able to handle their demand. The second improvement idea is to outsource the cleaning activities of the vet technicians, since these activities are relatively simple and mostly performed in overtime. The last improvement idea is to parallelize the work processes of the veterinarians and vet technicians, to improve the efficiency of the work methodologies and make it possible that the staff members can work as separate teams. The analysis of the improvement ideas shows that these three improvement ideas provide a decrease in overtime probability. In two cases the implementation will lead to a probability of overtime below the predetermined threshold of 30%.

To make sure the improvement ideas will be implemented properly, we have developed an implementation plan where the three selected improvement ideas are combined into one solution. We used the PDCA-cycle during the development of the implementation plan. Every part consists of preparation, realization, and evaluation activities which all correspond to a phase of the PDCA-cycle. An overview is shown in Figure 1.

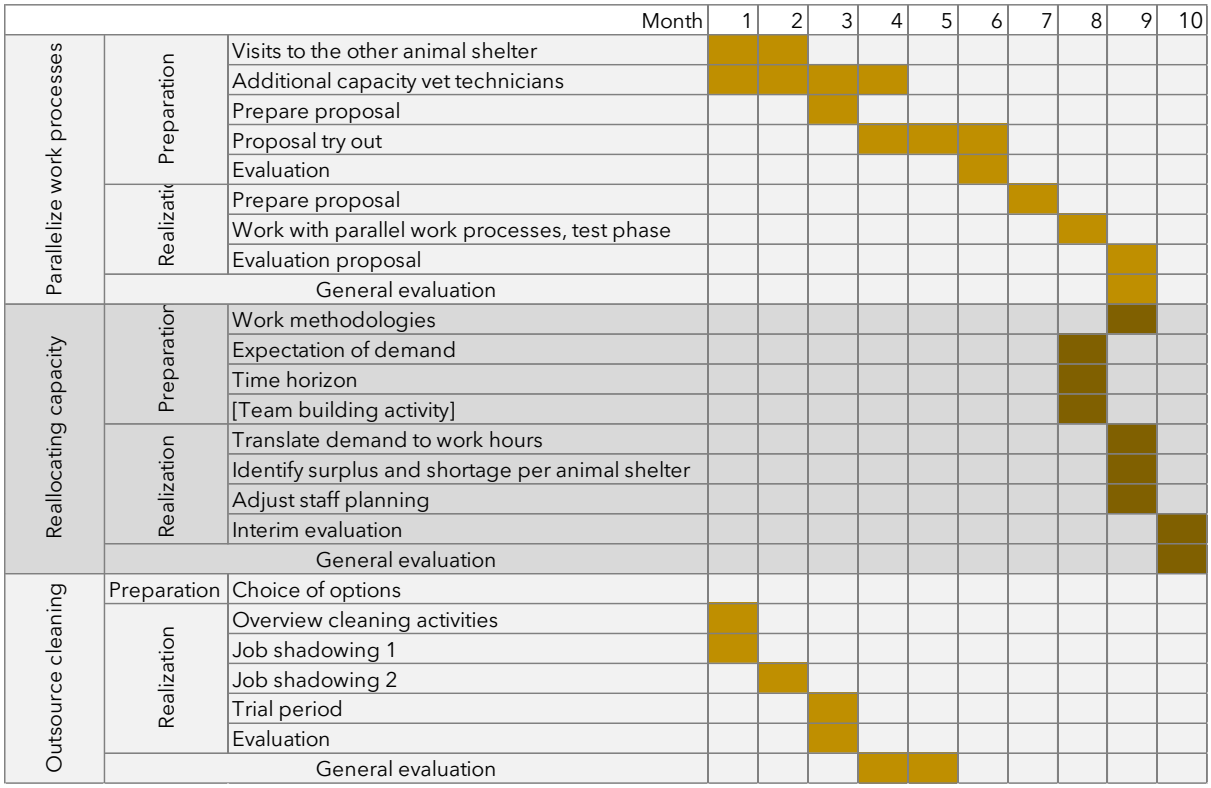

Figure 1 Implementation roadmap

When all defined steps are followed and the first activity is started in April 2023, the expected improvements of this research can be achieved before the beginning of 2024. Since the solution shows a decrease in the probability, expectation, and standard deviation of overtime for almost every staff member and animal shelter, we can conclude that the animal shelters will be more in control of handling their expected demand.

The animal protection is advised to keep improving their organization around staff scheduling and work methodologies since the probability of working overtime has not dropped below the threshold of 30% for every staff member. We advise implementing additional improvement ideas and developing smart methods for staff scheduling and the block schedule layout. During this process, attention needs to be paid to changeability and change readiness of the organization.

Acknowledgments

Hereby, I present my Master thesis entitled 'Planning and scheduling for animal shelters'. This thesis concludes my five-and-a-half year student life at the University of Twente in A. During the first three years, I completed the bachelor study Health Sciences. The last two-and-a-half years I followed the master study Industrial Engineering and Management, with the track Production and Logistics Management and a specialization in Operations Management in Healthcare.

First of all, I would like to thank everyone involved from the animal shelters in A, B, and A. In particular, I would like my supervisor from the animal protection, Claire Laane, for her advice, enthusiasm, and answers to all my questions. In addition, I would like to thank all other veterinarians and vet technicians for your openness and enthusiasm. You have welcomed me in your organization with open arms.

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Over the past five-and-a-half years I have had the pleasure to meet a lot of great people. I have found my home here in A, within my student association, but also beyond. I have been able to experience many beautiful moments. I would like to thank my close friends, family, and boyfriend for their support. You have supported me in any way possible.

I hope you enjoy reading my thesis.

Elize Albertsboer,

February 2023

Table of Contents

1. Introduction

This chapter introduces the study carried out at animal shelters of the animal protection (AP) located in A, B, and C and is structured as follows. Section 1.1 contains a company description and Section 1.2 contains the work process at the animal shelters. Further, Section 1.3 provides the research motivation. Section 1.4 contains the problem context and the problem cluster. Next, Section 1.5 gives the research objective, which is followed by Section 1.6, containing the research design together with the research questions. Then, Section 1.7 contains the deliverables of the research. Lastly, Section 1.8 provides the outline of the thesis.

1.1. Company description

The AP wants to protect animals in the Netherlands. It is a non-governmental organization (NGO) and has the dream to live in a world where the interests of animals are self-evident in the way humans think and act (Dierenbescherming, 2022b). To achieve this dream, the AP tries to change the conscious and unconscious actions of humans. The strategic plan of the AP describes four goals that need to be achieved in the coming years by society: animal-friendly living, animal-friendly entrepreneurship, govern animal-friendly, and animal-friendly use of public places. The goal of the AP is to prevent animal harm so that in the end fewer animals need to be saved. To achieve this, the AP wants to increase the quality of their shelter and transport by adjusting their capacity optimally to what is really needed (Dierenbescherming, 2022b). This research is mostly in line with this last part of the AP's goal.

Every year, the AP takes in about 25.000 animals in its shelters. These animals require care. The AP provides many components of care to animals, such as emergency or regular, scheduled care. Under emergency care falls sheltering of animals, the animal ambulances, and the National Inspection service of animal protection (in Dutch: Landelijke Inspectiedienst Dierenbescherming (LID)). With regular care, the care that can be scheduled days or weeks in advance is meant. Besides emergency and regular care, the AP provides preventive animal care, provides education about owning a pet, and influences animal policy at both national and European levels. The organization of the AP consists of about 160.000 members and donors, almost 400 paid employees, and more than 4.000 volunteers.

As an NGO, the AP is a non-profit organization, which gets financed in a lot of different ways. A business can support the AP with a one-time financial donation or with the donation of IT equipment. Individual people can also support the AP. You can donate once, monthly, or on a flexible basis. It is also possible to include the AP in your will. To come into action for the AP and raise money is also possible. Table 1 gives an overview of the ways how the AP gets financed.

Table 1 Ways of financing the AP

Business	**Individual**
One-time financial donation	Donate (once, monthly, or flexible)
IT equipment	Include AP in the will
	Start a fundraiser

The AP has various locations located throughout the Netherlands. The locations can be classified into five categories: animal shelters, animal ambulances, dog schools, wildlife sanctuaries, and animal pensions. This research will focus on three animal shelters, which will be indicated as A, B, and C in the remainder of this research.

1.2. Work process

The animal shelter in A houses mainly dogs, cats, and rabbits. Besides these animals, also guinea pigs, songbirds, and other animals are sheltered regularly. In B, mostly cats and dogs are sheltered. And in C generally, shelter is provided to cats, dogs, and rabbits.

Zooming in on the work process within an animal shelter, we can distinguish four types of staff members: veterinarians, vet technicians, animal caretakers, and volunteers. A veterinarian performs medical procedures and determines the treatment plans of the animals. Vet technicians help the veterinarian with preparations, medical procedures, and administration. Animal caretakers and volunteers take care of the daily care the animals need. There is a difference in the education of these staff members. The veterinarian has completed veterinary medicine (university education), a vet technician has followed higher professional education and animal caretakers have followed secondary vocational education.

When an animal arrives at the animal shelter, it is examined by the veterinarian. When needed, vaccinations are administered and possible health issues are treated. Common health issues are ear infections, bad dentures, skin inflammations, obesity, or being underweight (Dierenbescherming, 2022a). Sometimes it is even necessary to perform surgery.

1.3. Research motivation

Several years ago, the AP decided that there was too much distance between the veterinarian and the animals sheltered in the shelters. Therefore, the choice was made to employ instead of hire veterinarians. During these past years, the organization has tried to find a good way of employing staff to provide a good quality of care to all animals in need. Additionally, vet technicians were employed to assist and reduce the workload of the veterinarians.

The AP works, just like other organizations, with supply and demand. The demand of an animal shelter is the care requested by animals. Both animals that are sheltered and adopted animals require care. The care that is requested covers who is requesting the care, but also which type of care. The care that adopted animals require is generally predictable and can be planned in advance. Sheltered animals require, besides predictable care, in general, more emergency care compared to adopted animals. With providing care, also the quality of care needs to be considered.

On the other hand, we have the supply of animal shelters. The supply is the amount of care that can be provided by the veterinarians together with the vet technicians. In the current situation, we see that the care that can be provided by the animal shelters is less than the requested demand. This can for example be noticed by the fact that animals are placed in their new homes without receiving all legally determined treatments. So, a gap is experienced between the demand and supply at the animal shelters.

1.4. Problem context

Section 1.3 outlined the first problems that are currently noticeable on the work floor at the animal shelters. To get a complete overview of all the problems, a problem cluster is created. A problem cluster is often used to show an experienced problem has multiple causes. Besides, it helps to bring order in the problem context and can identify the core problem(s). A potential core problem has no direct causes itself. However, when a potential core problem is not influenceable, we cannot identify this problem as a core problem (Heerkens, 2017). Figure 2 displays the problem cluster. In Figure 2, the arrows show the causal relationships between the problems. Looking at the problem cluster, we can distinguish two possible core problems. After consideration the choice has been made to handle the following core problem in this research:

"There exists a gap between the demand and supply of the animal shelters."

In the following paragraphs, all the underlying problems of the core problems that are identified within the organization of the animal shelters are further explained. The underlying problems can be classified into four categories: in-house, organization of processes, staff members, and staff scheduling. The classification is based on the experienced problems at the animal shelters.

1.4.1. In-house

As stated in Section 1.3, there exists a gap between the demand and supply of animal shelters. Because the animal shelters located in A, B, and C cannot meet all their demand, it happens regularly that an animal is placed in a new forever home without all the legally determined treatments. It is

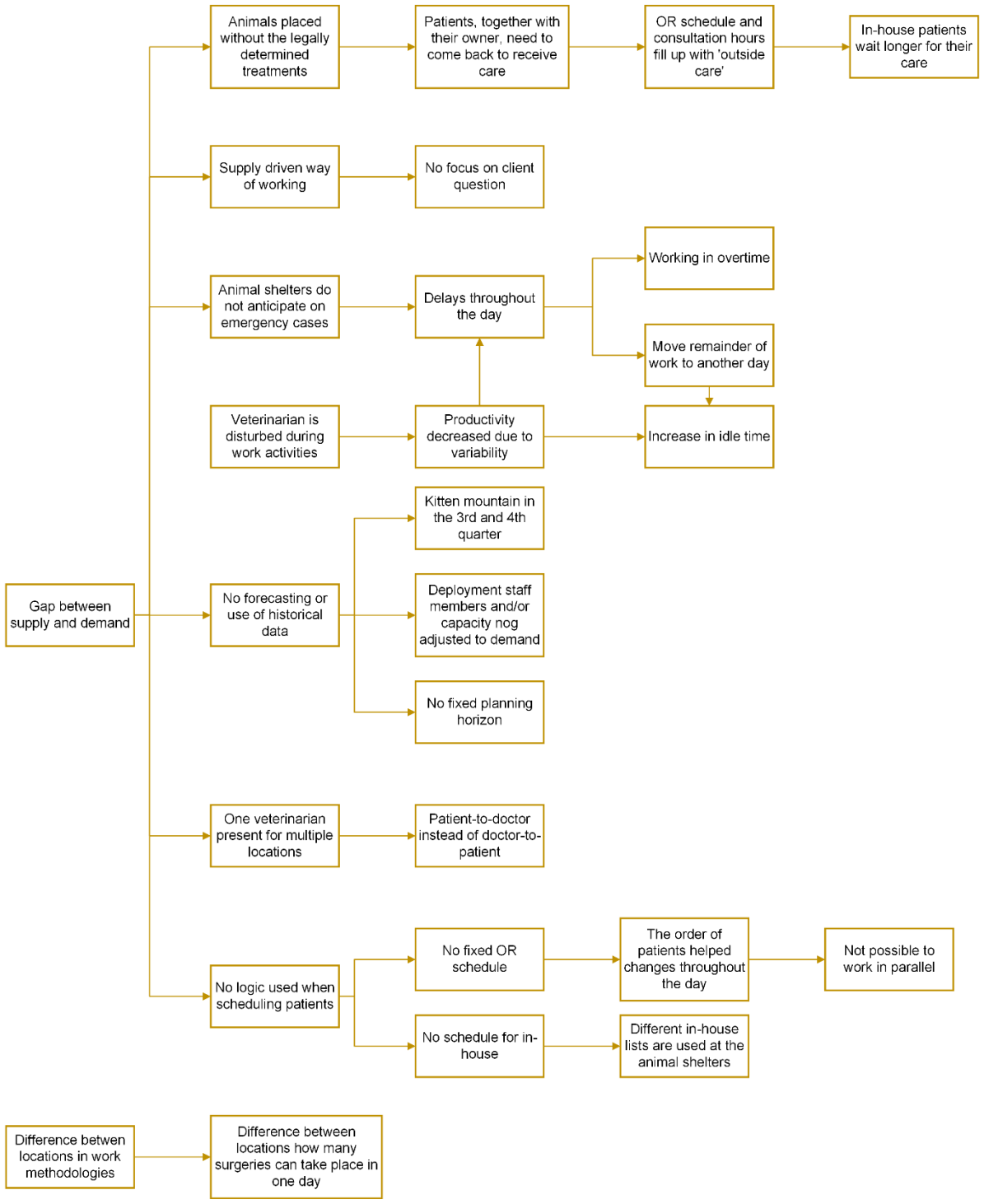


Figure 2 Problem cluster

determined by law in the Netherlands that before an animal can be placed, it should receive a health check and vaccinations. Furthermore, an animal needs to be treated against endo- and ectoparasites and it should be neutralized. Neutralization is the medical procedure to stop an animal's ability to reproduce. It happens often that an animal is placed without neutralization and/or its last vaccination. Placement without neutralization can have two reasons. The first possibility is that the animal is too young to receive this surgery. It is advised to neutralize an animal when it is between six and nine months. The second option is that when a new owner is found, there is no space left in the operating room (OR) schedule within a short period of time to neutralize the animal. When an animal is placed without its second, or when needed third, vaccination it is usually because a certain period of time

has to pass before an animal can receive its next shot. Then the AP does not want to wait with placement. Whether an animal needs a third vaccination depends

on the age of the animal at the moment of the first vaccination. Because these treatments still need to take place, the animal, together with its new owner, needs to come back to the animal shelter. Because many patients come back for treatment, both the OR schedule and consultation hours are filled up with 'outside care' way in advance. As a result, in-house clients wait longer for their care. This creates a vicious circle, because then animals again are placed without legally determined treatments.

Besides a filled-up schedule with outside care, most animal shelters also experience a rise in demand for care for cats in the third and fourth quarters of the year (Kilgour & Flockhart, 2022). In literature, this is referred to as the kitten mountain. To prevent unwanted nests, cats need to be neutralized. Since many kittens are born in spring and the advice is to neutralize a cat when it is between six and nine months, the amount of care requested builds up towards the last two quarters of the year. We see this kitten mountain not only in a raise of requested neutralizations for the OR but also in the raise of shelters. The animal shelters are not prepared for this rise in demand, since their staffing levels are the same throughout the entire year.

1.4.2. Organization of processes

The animal shelters located in A, B, and C have a supply-driven way of working. This shows from the organization of their processes. Therefore, the focus does not lie on the client's question but on the services that the animal shelters can offer. This section will further elaborate on the organization of the processes of the animal shelters.

On most days, all surgeries in the animal shelters are scheduled for the morning. For a certain day, x amount of surgeries are scheduled. In the current situation, all animals that come from outside the shelters arrive at the shelter around 9:00 AM. The animals are put into one of the little kennels in the preparation room. Animals that are already present in the shelter are brought to the preparation room. The veterinarian waits until every animal is present before he or she starts operating. For every day, a list of patients that are scheduled for surgery is made. It is more a list than a schedule since the order of the patients treated changes throughout the day. The order of patients treated can change since the schedule for the OR is not fixed. When surgeries are scheduled in animal shelters, only the duration of the surgeries is taken into account. When the average time of a certain procedure still fits into the total time that is available in the morning, the surgery is planned. No other planning logic is taken into account. Since the order of animals is not fixed, staff members decide at the moment which patient is operated on next. Because of this, veterinarians and vet technicians cannot work in parallel, since the vet technician does not always know for which animal to start the preparations next.

Besides the OR, the animals are treated in other ways at the animal shelters. When an animal is sheltered in an animal shelter, it still needs care. Within the animal shelters, this is called in-house care. Usually at the end of the day, the veterinarian, together with a vet technician, makes a round along all the animals that need a check-up. Whether an animal ends up on the list is determined by the animal caretaker. The vet technician adds animals to this list that require vaccinations. These animals can be found in the Electronic Patients File (EPF). Also here, no schedule is made. The staff members try to work from clean to dirty, meaning that they try to work from the most healthy animals to the sick ones, to try and prevent cross infections. On most days, the prepared list does not contain this same order. Since there is no clear logic used for these in-house lists, a difference in use originated in the animal shelters. For example, in A and B they use a plain table and the animals are added in random order. But in C they have a list of all the animals present per room and behind the name of the animal, it is added whether it requires a check-up, vaccination, or both.

Another problem we can identify on the work floor has to do with the transport of the animals and the way how the care is provided. We can distinguish two ways of providing care to patients: doctor-to-patient and patient-to-doctor. In the case of the first option, the patient stays in one place and the

doctor goes from patient to patient. For example, in a hospital, a patient stays in bed in their room and different doctors visit that patient. With the second option, it is the other way around. In that case, the doctor stays in one place and all the patients travel. An example of the patient-to-doctor principle is a consultation hour. Here the doctor helps patients in his or her office and all the patients come and visit the doctor. In the work process of the veterinarians we can, besides the consultation hours, identify another process which is patient-to-doctor. On a day, only one veterinarian is present for the animal shelters in A and B. This means that every day, at only one of these locations surgeries and consultations can take place. For example, when the veterinarian that is on duty is present in A and there is a very sick animal present in B that needs a consult from a veterinarian, that animal needs to be transported to A. So, because only one veterinarian is on duty for more than one animal shelter causes that very sick animals need to be transferred.

1.4.3. Staff members

One of the problems experienced at the animal shelters regarding staff members is that they often work overtime. Working overtime can have multiple causes. In animal shelters, it is mostly caused by delays throughout the day. These delays arise from emergency patients that disturb the regular OR schedule and/or consultation hours, or when treatments take longer than expected. Emergency patients can delay the schedule since no room is reserved for emergency patients. All available time is scheduled, no spots are left open for possible emergency patients and no time is reserved for treatments that take longer than expected. The animal shelters do not anticipate emergency cases partly because of the gap between supply and demand.

Working overtime is one of the consequences of delays throughout the day. The differences between staff members are caused by differences in work methodologies and mindsets. We can determine two types of staff members when we look at the work that is left to be done at the end of a day. One staff member will stay and work overtime, but another will leave, regarding how much work still needs to be done, and moves the workload to another day. The care that is shifted to another day is usually care regarding in-house care. This type of care can more easily be caught up on another day compared to outside care.

The difference in approach to handling work that is left at the end of a working day is not the only difference between staff members that can be identified in the animal shelters. Differences in work methodologies between the animal shelters emerge in multiple areas. Veterinarians and vet technicians are present at the animal shelters during different hours of the day. This could be a reason why there can be more surgeries or appointments scheduled at a certain animal shelter. Also, the work methodology for performing surgeries is different. One veterinarian is more precise than the other. Some veterinarians calculate the dosage of sedation per animal based on their weight, another always uses the average dosage. Some veterinarians always intubate their clients for every kind of surgery to keep track of the vital values and another only sedates their clients and does not intubate at all. These again could be reasons why one animal shelter performs more surgeries compared to another. Another difference in work methodology is the usage of an EPF between the animal shelters. Not all investigated animal shelters use the same information system and therefore do not register the medical procedures and other activities in the same way.

Another thing to notice on the work floor is that veterinarians are being disturbed by other staff members during their work activities. Due to this variability, the productivity of veterinarians decreases. Disturbances in the work activities of veterinarians cause two things. Because of this, there arise delays and they disturb the rest of the activities planned for that day. Also the idle time of veterinarians increases. With idle time we mean the time that a veterinarian, or another staff member, is unproductive due to controllable or uncontrollable factors.

1.4.4. Staff scheduling

The deployment of staff members and/or the use of capacity is not adjusted to the requested demand. The employability of the staff members per animal shelter is the same for an entire year. When the demand is variable during a period and the standard available supply is not enough, the supply should be adjusted to meet all expected demand. When an organization wants to adjust the

deployment of its staff members to be able to meet all its demand, the organization should use a fixed planning horizon for its staff scheduling.

1.5. Research objective

As mentioned in Section 1.3 and Section 1.4, there exists a gap between the supply and demand of animal shelters. The problem cluster in Figure 2 also showed that this is a very broad concept. It is not a single problem that can be tackled. This problem had many consequences and expresses in many areas of the organization. Therefore, the objective of this research will be to suggest improvements to decrease this gap between supply and demand. During the research, we will focus mostly on the scheduling of veterinarians and vet technicians, with the goal that the animal shelters will become more in control of the deployment of staff members to be able to manage the demand.

1.6. Research design

Given the research objective and scope in Section 1.5, the main research question is formulated as follows:

How can the animal shelters in A, B, and C be in control as much as possible of how to deploy staff members to be able to meet the demand?

Since this is a broad main research question, we can break it down into several research questions.

Research question 1: What is the current situation in the animal shelters?

1.1 What is the journey of a single animal in an animal shelter?
1.2 Which procedures are mostly performed in the current situation?
1.3 How are the staff members deployed at the different locations in the current situation?
1.4 How is the demand handled in the current situation?

This first research question will give more inside into the current situation of the animal shelters, to identify the gap between supply and demand more clearly. Therefore, some additional sub-questions are set up. The current situation starts with mapping the journey of an animal in an animal shelter. Furthermore, it includes the most performed medical procedures to gain more inside into the work methodologies of the animal shelters. This can be seen as the demand. The next sub-question focuses more on the staff members of the animal shelters. How many are employed per shelter and what are the differences between the shelters? This can be seen as the supply, what can be offered per shelter. The last sub-question focuses on the gap between supply and demand. Which part of the care requested is handled and in which area lies the biggest gap? The data that is required to answer this research question is provided by the animal shelters.

Research question 2: What is the desired staff scheduling situation for animal shelters?

2.1 What does the desired staff scheduling situation look like?
2.2 Which activities need to be introduced to achieve this desired situation?

The next research question handles the desired staff scheduling situation. We investigate this desired situation to create a goal and direction for this research. With the sub-research questions that are linked to this research question, we want to investigate what the desired situation looks like for the animal shelters and identify which activities need to be introduced to achieve this desired situation.

Research question 3: Which techniques can be used to plan staff members?

3.1 What is already known about staff scheduling in the field of shelter medicine?
3.2 What is known about staff scheduling in other research fields?
3.3 What are the different possibilities for veterinarian and vet technician staff scheduling?

To answer this research question, literature will be used. Literature could help provide additional insights into frameworks and/or methods. First, we focus on what is already known about staff scheduling within the field of shelter medicine. Then, other research fields such as Operations

Research/Management Science (OR/MS) and healthcare are investigated to broaden our perspective. The last sub-question of this research question will focus more on methods that could be used for veterinarian and vet technician scheduling, instead of staff members of organizations in general.

Research question 4: Which model or technique would be best suited for the staff scheduling at the animal shelters?

4.1 Which method of staff scheduling will be integrated at the different levels of organization of the animal shelters?
4.2 Can the staff scheduling be comparable for the different locations?
4.3 Can the staff scheduling be adjusted for different times of the year?
4.4 Is there a way to incorporate emergency patients in the planning?
4.5 Which tool needs to be designed to implement and support the staff scheduling method?

A new way of scheduling staff members starts with selecting the most suitable method for the AP. After selecting a method, we want to integrate that method at the different levels of organization at the animal shelters. By different levels, we mean the decision moments together with their planning horizons. The staff scheduling needs to fit in with the current work process at the animal shelters. It will be most convenient that the integration will be the same for all the animal shelters. Next, we want to look at whether the scheduling method can be adjusted for the different times of the year since the demand varies throughout the year. Lastly, we want to look at whether it is possible to incorporate emergency patients together with buffer capacity in the planning so that they will not cause overtime anymore. To make it possible to see whether this new way of planning works for animal shelters, a prototype needs to be created.

At the beginning of this research we were convinced that introducing a new model or technique into the organization of the animal shelters would help them in scheduling their staff members more efficient, and at the same time reduce the gap between demand and supply. During the research we had to conclude that introducing a new model or technique would not help the AP reducing the gap between demand and supply as long as the work processes were not carried out efficiently. Therefore, the direction of the research shifted towards organizing work processes more efficiently. With this new direction of research, the following research questions arose.

4.1 What is the performance of the current work processes?
4.2 Which inefficiencies of the current work processes can be identified?
4.3 How can these inefficiencies be improved?

Research question 5: How can staff scheduling be integrated at the different levels of planning and control?

5.1 Can planning meetings contribute to the integration of a new staff scheduling method?
5.2 What will be the expected gain in performance?

After choosing which kind of staff scheduling methods will be implemented, we will find a way how to implement them. Planning meetings will be scheduled to determine the schedule for the next planning horizon. It needs to be determined who needs to attend these conferences and when these will take place. To help the AP, an implementation plan needs to be set up. Together with this implementation plan, an expectation of gain in performance will be provided for the animal shelters.

Since the approach of the previous research question changed during the research, also some changes had to be made to this research question. Still an implementation plan will be developed. This plan will no longer describe how to implement a new staff scheduling method, but now it will describe the improvement ideas of the current inefficiencies in the work processes. Also, still the expected gain in performance is included.

1.7. Deliverables

This research will provide the following deliverables:

- An improved method of staff scheduling, including the expected gain in performance
- An implementation plan for the proposed method
- A prototype for the animal shelters to be able to use the proposed scheduling method

Since some research questions have changed during this research, also a part of the deliverables are changed. This research will still deliver improvements regarding staff scheduling and an implementation for those improvements, only no prototype since no new staff scheduling method is selected.

1.8. Thesis outline

The remainder of this study is structured as follows. Chapter 2 describes the current situation at the animal shelters. In Chapter 3, the desired situation of staff scheduling in animal shelters is described. Chapter 4 discusses the relevant literature concerning this research. Followed by Chapter 5, in which the performance of the current block schedule is analyzed. Chapter 6 provides improvement ideas to decrease the gap between the expected demand and supply of the animal shelters. Next, Chapter 7 discusses the integration of the improvement ideas in the organization of animal shelters in an implementation plan. Lastly, in Chapter 8, the conclusions, discussion, and recommendations can be found.

2. Current situation

This chapter will describe in more detail the current situation at the animal shelters in A, B, and C. Section 2.1 describes the journey of an animal in an animal shelter and a patient in a human hospital. Next, Section 2.2 zooms in on the arrival process of the animal shelters. Furthermore, Section 2.3 describes the main medical procedures that are performed in animal shelters and Section 2.4 handles the current way of staff scheduling. These two aspects can be seen as the supply and demand of animal shelters. As mentioned in Section 1.4, there exists a gap between these two in the current situation. Therefore, Section 2.5 highlights areas in the organization of animal shelters where the gap is most noticeable. Section 2.6 describes the capacity for change in the animal shelters. This chapter finishes with a conclusion in Section 2.7.

2.1. Patient journey

A patient or client journey is the sequence of events a single patient or client follows in their care process, from admission until discharge. The journey in an animal shelter largely corresponds to a patient journey in a human hospital. Since the processes are so similar, we can make a comparison between the two. Section 2.1.1 describes the journey of an individual client in an animal shelter and Section 2.1.2 describes the journey of an individual patient in a human hospital.

2.1.1. Patient journey in animal shelters

In the process of an animal shelter, four main activities can be distinguished when we look at the care that is provided to the animals. The animals enter via an intake and then transfer to the quarantine. After the animals have spent some time in quarantine, they are transferred to a kennel for their stay. The last step in the journey of an animal through the shelter is adoption. The activity where medical care is provided to the animals is integrated within the other four main activities. Figure 3 gives a graphical visualization of the journey of an animal through a shelter, where the main activities are shown on the left.

An animal can enter the shelter in nine possible ways. The intake can be a stray, return to shelter, from an owner, social, preventive, from justice, an exchange, Trap Neuter Return (TNR), or via an animal ambulance.

After intake, the animals are placed in quarantine. The duration of stay in quarantine depends on whether the animal is vaccinated or not and whether the animal is a stray. In quarantine, the health status is checked. The veterinarian provides preventive care, treats infectious diseases, and looks at overdue health issues. Animals also receive their first vaccination. In this step of the care chain, the animal receives housing and basic care. Animal feed, hygiene, and stress management fall under basic care.

Next, the animals are transferred for their stay. Animals can be transferred within the animal shelter to another kennel or room, but they also can be transferred to a foster family. When an animal is taken in by a foster family, it is still seen that the animal stays in-house. During the stay of an animal, many activities take place, besides basic care. An appointment is scheduled with a veterinarian and the animal receives its booster vaccination. It is determined by law that an animal receives a consult within five working days, with an exception for kittens and wanderers. Wanderers can receive a consult after fourteen days since the animal shelter is the legal owner after fourteen days. It can be possible that the animal still needs to be neutralized. Since this is not an emergency surgery, it will be scheduled for a later day, assuming there is no OR time left on the day that the animal is brought in. Furthermore, an animal can receive additional medical care when needed during its stay. Animals can also receive training during their stay. The training contains basic training, a problem-oriented approach, and psychopathology.

Before an animal can be adopted, preparations have to be made. When an animal is ready for adoption pictures have to be made and an advertisement for the website has to be written. When people are interested in an animal, an appointment has to be made for a physical acquaintance.

When there is a match, the animal can be adopted. After adoption, there still is the aftercare for the animal shelter. This could be related to the behavior of the animal or be medical.

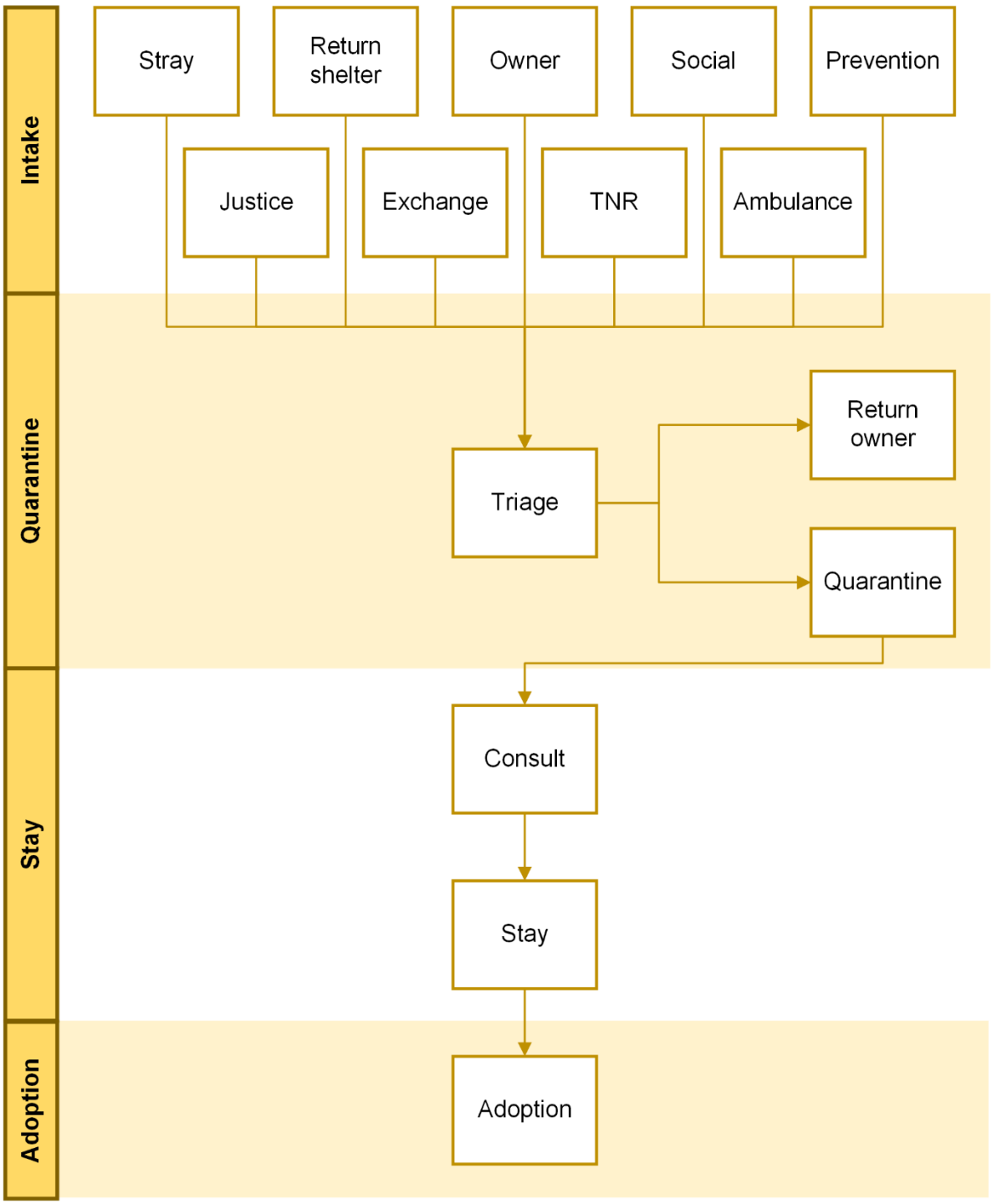


Figure 3 Patient journey animal shelter

2.1.2. Patient journey in human hospitals

To be able to make the comparison between an animal shelter and a human hospital later on in this research, we also discuss the patient journey of a patient in a human hospital. The patient journey of a surgical patient in a human hospital starts with a referral to the hospital. Patients can be referred to the hospital by a general practitioner (GP), an internal department, or the emergency department (ED). When a patient is referred by a GP or an internal department, an appointment with a surgeon is scheduled before going into surgery. During this appointment, a general check-up will take place.

When a patient enters the pathway through the ED, he or she usually has a high urgency. Therefore, those patients are transferred directly to the OR. After surgery, the patient will be brought to the recovery room where he or she can wake up. In some cases, the pathway will end here, since some surgeries do not require that the patient stays overnight. However, some surgeries are very heavy and patients need to recover. In that case, the patient needs to stay one or a couple of nights. Then the patient is transferred to the nursing ward before going home. Figure 4 gives a graphical display of the patient journey of a surgical patient in a human hospital.

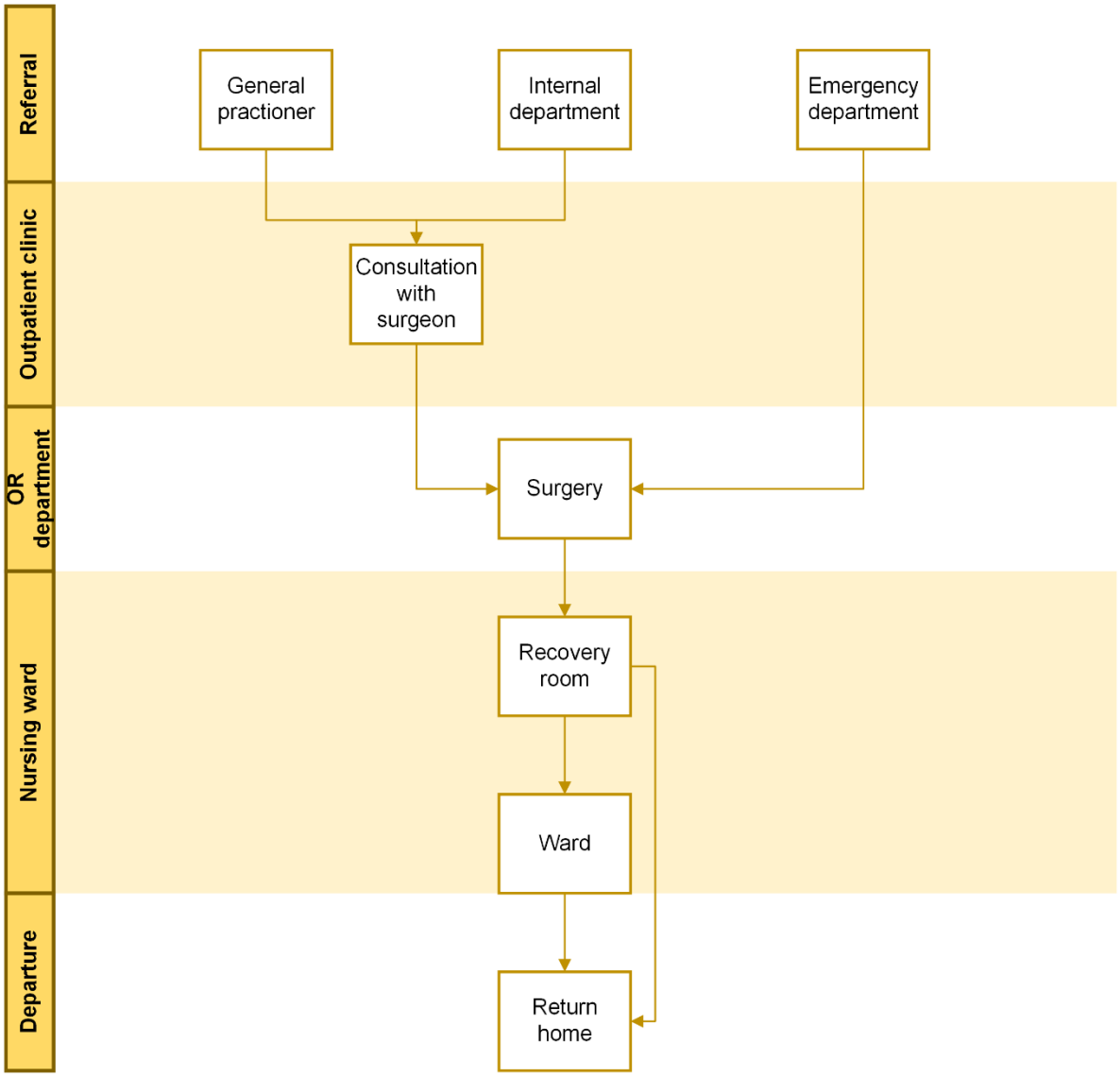


Figure 4 Patient journey human hospital

2.1.3. Conclusion

From this section we can conclude that the main activities of an animal shelter match the main activities from a surgical department of a human hospital. Therefore, later on in this research a comparison can be made between these two research fields.

2.2. Animal population

Section 2.1 discussed the possibilities of arrival for animals per animal shelter. The arrivals of animals in animal shelters can be analyzed even further by making comparisons between the shelters. We provide the number of animals that have arrived per animal shelter for the years 2019, 2020, and 2021. Figure 5 shows the total number of animals arriving per animal shelter per year, and Figure 6 shows the numbers per specific animal species. The number of animals that arrives at the animal

shelter in A is stable over the three years and lies at around 870 arrivals. The number of animals arriving at the animal shelter in B is about the same for the years 2019 and 2020, then the number of arrivals is about 770. The number of animals arriving in the year 2021 is higher in B. Then the arrivals are about 930, which is an increase of about 20%. Looking at the number of animals arriving at the animal shelter in C, we see that the number of arriving animals is about the same for the years 2019 and 2021, this number of arriving animals equals 1940. The number of animals arriving in the year 2020 lies 14% lower than in the other two years. Looking at Figure 5, we can conclude that the animal population at the animal shelter in C is about two times as high as for the animal shelters in A and B.

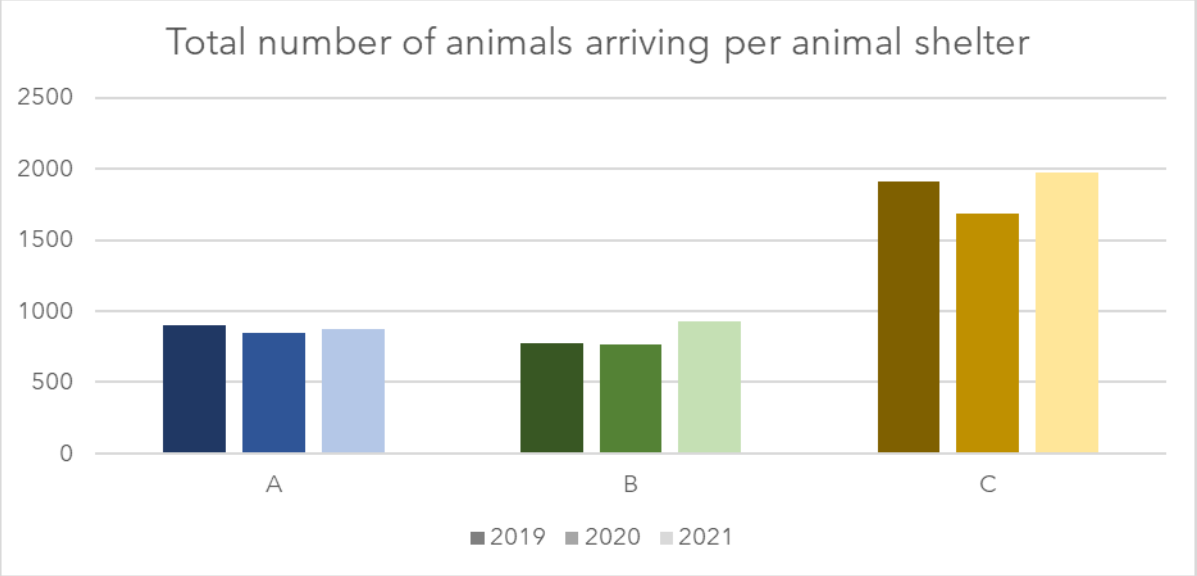


Figure 5 Number of animals arriving at the animal shelters in A (n=2617), B (n=2469), and C (n=5576) in the years 2019, 2020, and 2021 (years displayed from left to right, dark to light)

Looking further into the animals arriving per animal species, we can see in Figure 6 that the animals arriving per species are quite stable over the years for every animal shelter and every species. When we compare the animal shelters with each other, we see a difference in the animal population.

Table 2 shows the distribution of arriving animals over the species at the animal shelters for the years 2019, 2020, and 2021. Here we see that the percentage of dogs arriving in A and B are about the same, but the percentage of dogs arriving in C is much lower. For cats, the percentages of B and C are much closer to each other, compared to A. The percentage of rabbits and other animal species that are arriving is different for the three animal shelters.

Table 2 Distribution of arriving animals over animal species at the animal shelters in A (n=2617), B (n=2469), and C (n=5576) over the years 2019, 2020, and 2021 per animal species

	A	B	C
Dogs	22.97 %	20.54 %	9.79 %
Cats	54.01 %	74.58 %	71.51 %
Rabbits	13.63 %	2.48 %	9.28 %
Other	9.40 %	2.40 %	9.42 %

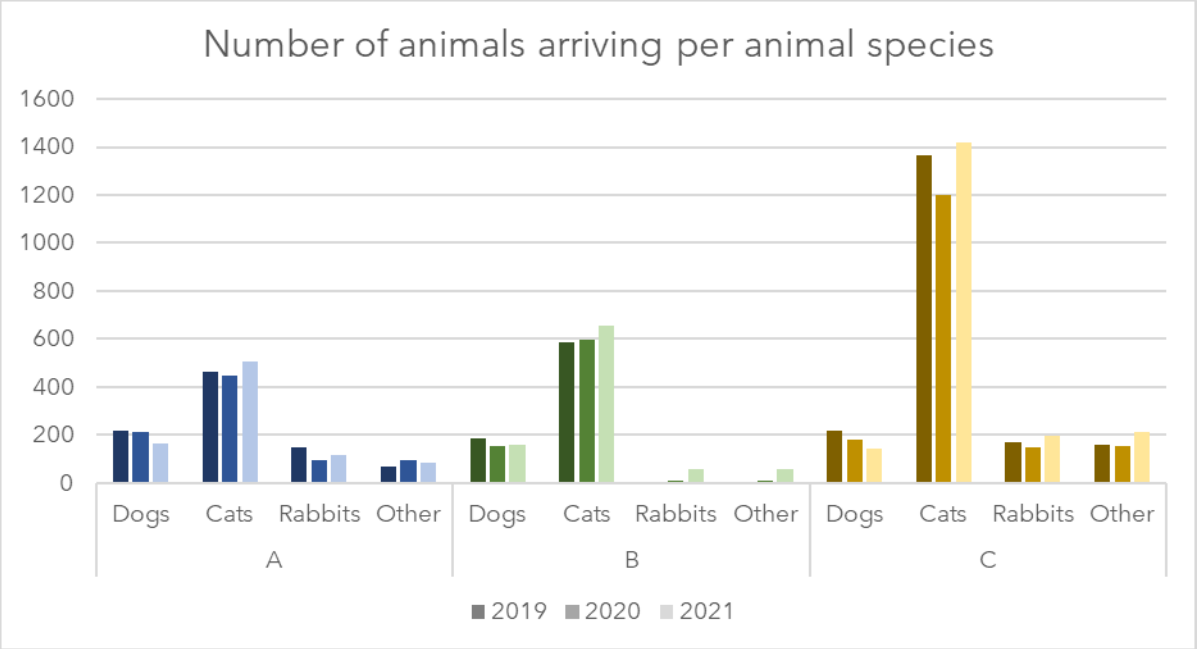


Figure 6 Number of animals arriving at the animal shelters in A (n=2617), B (n=2469), and C (n=5576) in the years 2019, 2020, and 2021 per animal species(years displayed from left to right, dark to light)

After arriving, animals usually stay at an animal shelter. Figure 7 shows per animal species and animal shelter, the number of animals present in the shelters per month. For the dogs (graphs A, B, and C) and rabbits (graphs G, H, and I), a subtle pattern can be identified, but not as clear as for the cats (graphs D, E, and F). We see that the numbers for June, July, August, and sometimes September are generally the highest. And this pattern repeats itself every year for the years 2019 until 2021. This pattern corresponds to the afore mentioned kitten mountain.

Now that we have gained more insight into the client population that was present at the animal shelters, we can analyze and compare the medical procedures performed at every animal shelter.

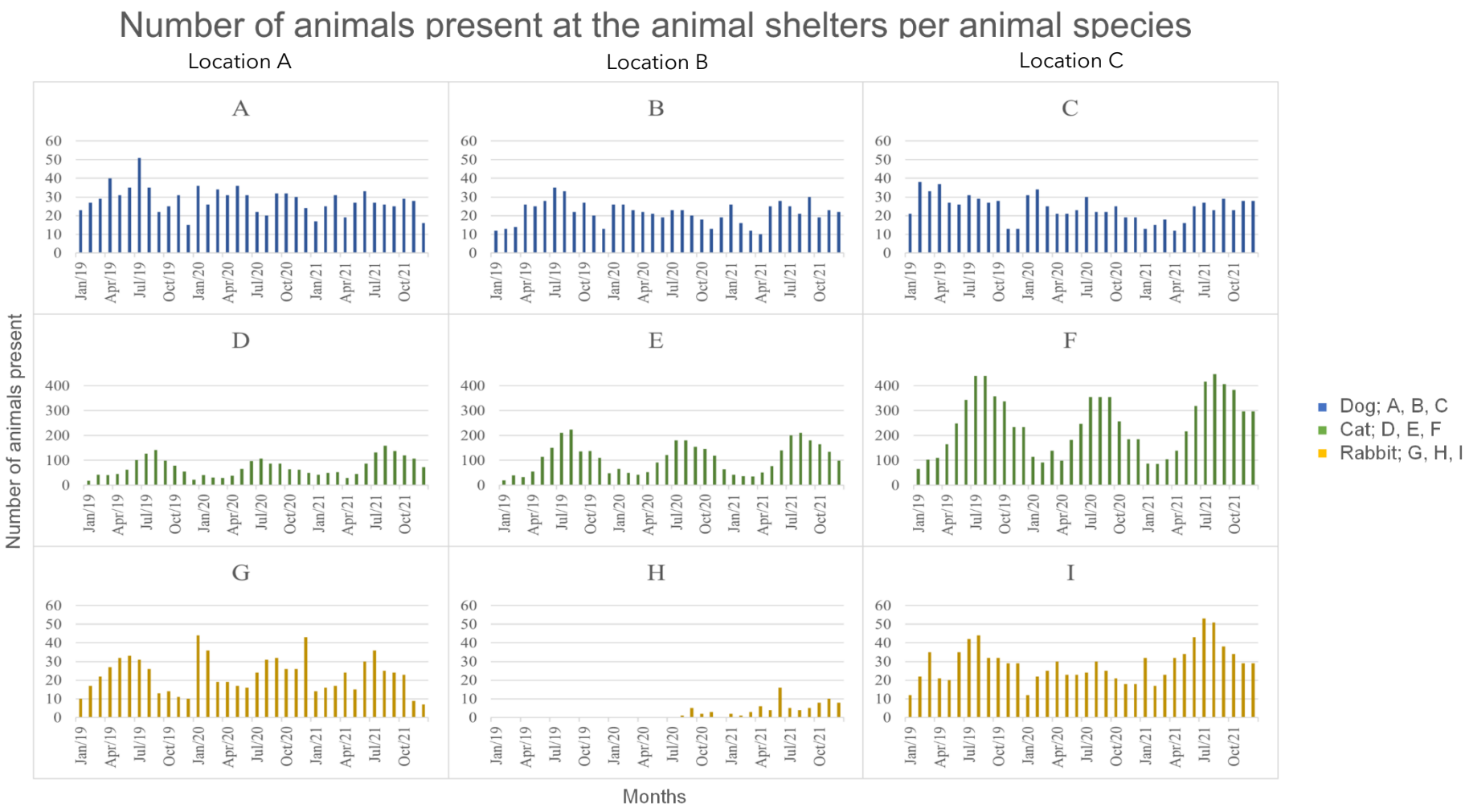


Figure 7 Number of animals present at the animal shelters per animal species A (left, n=2617), B (middle, n=2469), and C (right, n=5576) for the years 2019, 2020, and 2021

2.3. Medical procedures

Looking at a typical day in an animal shelter, we can distinguish three main activities: surgeries, outpatient clinic, and inpatient clinic. In the outpatient clinic, this is also called outside care, animals are treated from outside the animal shelter. In the inpatient clinic, this is also called in-house care, animals from within the animal shelter are treated. By zooming in a bit further into these activities, we see that the animal shelters perform five medical procedures: surgeries, X-rays, dental remediations, appointments, and in-house rounds. In this section, the main medical procedures of an animal shelter will be described.

To be able to analyze the performed medical procedures, some data preparation had to be done. Two datasets with different types of information on the same animals had to be combined. Since not every type of information was known about every animal, some data got lost in this step of preparation. Since the animal shelter in C is in transition from one EPF to another, a third, very different, dataset needed to be consulted.

2.3.1. Surgeries

Animal shelters perform many surgeries in their ORs. For the most part, these are neutralizations of dogs, cats, and rabbits. Neutralizations for female and male animals differ. For female animals, a neutralization is called a sterilization and for male animals a castration. The procedure of sterilization is more complicated compared to a castration and takes more time. Therefore, these surgeries are analyzed separately. Next to the castrations and sterilizations, also other surgeries are performed, such as the amputation of a tail or leg. In this section, we first discuss the castrations, next the sterilizations, and lastly the other performed surgeries in the animal shelters.

2.3.1.1. Castrations

Castrations are performed for both inpatient and outpatient clinics, so animals that are sheltered are neutralized as well as animals that come for the surgery from outside the shelters. Figure 8 shows the ratio of castrations performed in the inpatient clinic per number of admissions per animal shelter and Figure 9 shows the ratio of castrations performed in the outpatient clinic per number of animals arriving in the outpatient clinic. The number of admissions to an animal shelter refers to the number of animals to which shelter is offered. Since castrations are only performed on male animals, only the number of male admissions and arrivals in the outpatient clinic are taken into account.

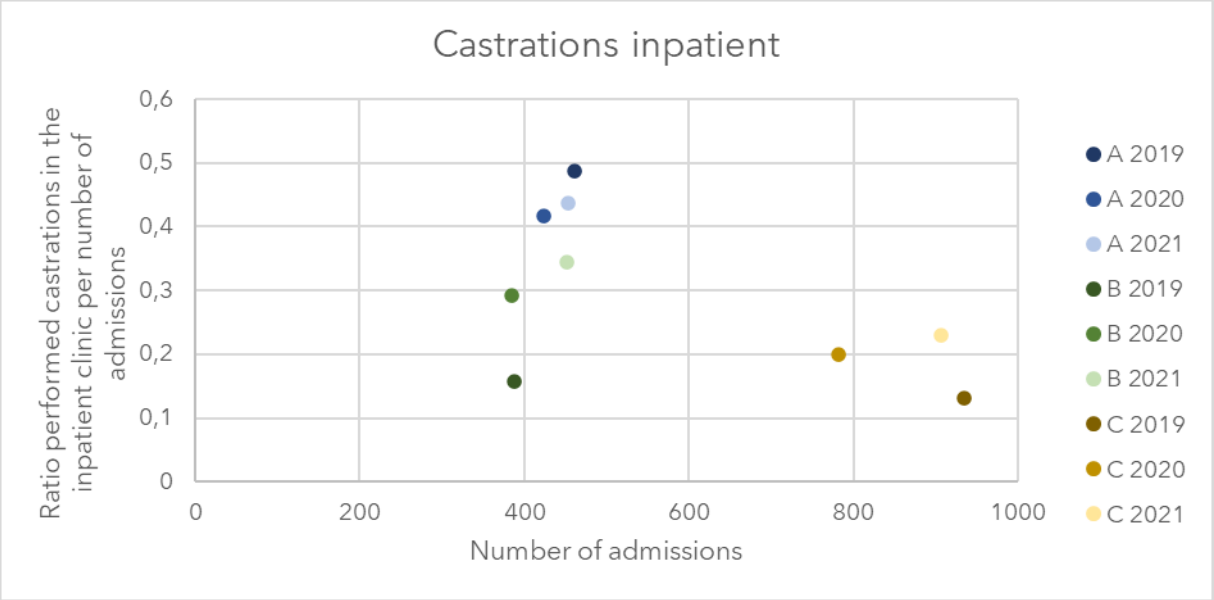


Figure 8 Ratio of in-house performed castrations per number of admissions in A (n=1338), B (n=1224), and C (n=2622) for the years 2019, 2020, and 2021

Looking at Figure 8, we see that the ratios of the animal shelters are clustered but there are some differences between the years. Something to notice is that the number of admissions are comparable

for the animal shelters in A and B, but this number is much higher for the animal shelter located in C. We also see that the ratio of the animal shelter in A is higher than B with a comparable amount of admissions. The difference in the number of admissions can be explained by the animal populations present at the shelters, but we would have expected that the animal shelter in C also then would perform more castrations in the inpatient clinic. This difference between the animal shelters could imply a difference in working methodology. It cannot be explained by a difference in staff hours employed, since those are the same over the years for the animal shelters.

Besides in-house, the animal shelters also perform castrations for animals that are not sheltered. These animals usually have been placed in a new home, before the castration could take place. These animals come back to the animal shelters for the surgery and leave the same day. It is desired that the graph in Figure 9 show as low values as possible. Low values in this graph would mean that very few animals had to come back for their surgery.

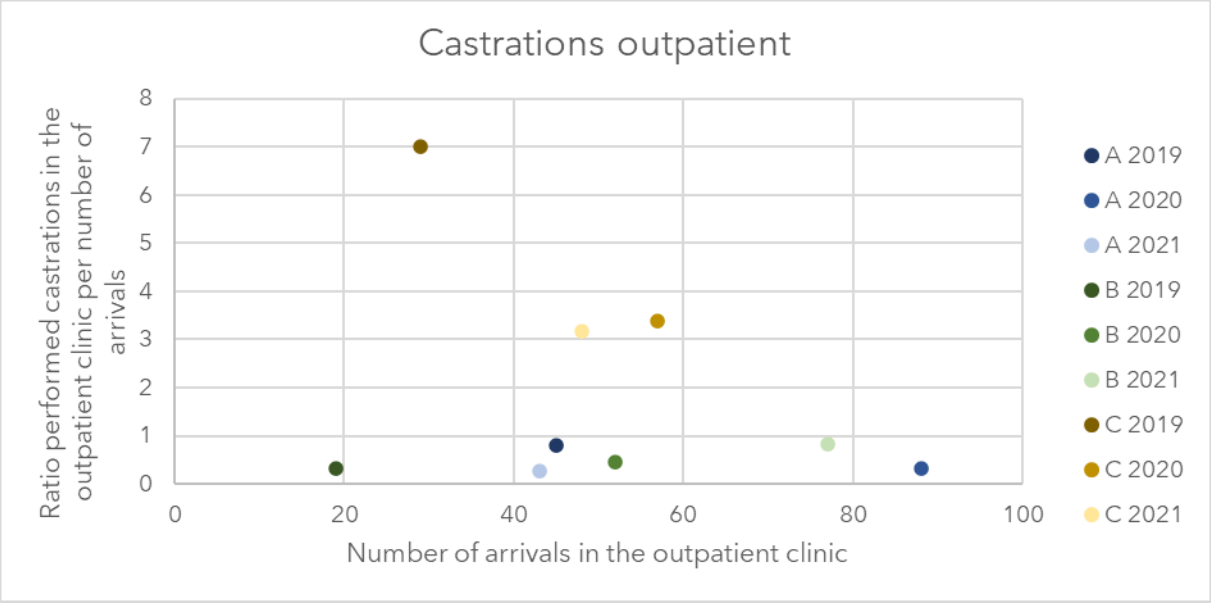


Figure 9 Ratio of performed castrations in the outpatient clinic as part of the number of arrivals in the outpatient clinic in A (n=176), B (n=148), and C (n=134) for the years 2019, 2020, and 2021

Figure 9 shows that the number of arriving animals in the outpatient clinic is different per animal shelter per year. For the animal shelter located in B, we see an increasing trend in both the animals arriving in the outpatient clinic and the ratio of performed outpatient castrations. The animal shelter in A has an outlier for the ratio of performed castrations in the outpatient clinic for the year 2019, a ratio of 0.8 compared to 0.3. No clear explanation for the increase in the ratio of performed outpatient castrations can be found. The animal shelter in C shows a ratio of performed castrations higher than one, which should not be possible. This animal shelter is in transition of their EPF. Therefore three very different datasets needed to be combined. Since the number of performed castrations are stored in another dataset than the arrivals of animals, a mismatch can be identified in this graph.

Comparing Figure 9 with Figure 8, we see that the arriving population in the outpatient clinic is much lower than the population in the inpatient clinic. So, also the number of performed castrations is lower in the outpatient clinic. When we look at the number of performed castrations per arriving population, we see that these are comparable for the animal shelter in A. For both the performed inpatient and the outpatient castrations, it is about 40% of the animals arriving. In B, they perform on average more castrations in the outpatient clinic compared to the inpatient clinic, 62% compared to 27%, respectively. In C, they perform on average about the same number of castrations in the outpatient clinic as in the outpatient clinic. For this location, no percentages can be presented because of the previous mentioned reason.

2.3.1.2. Sterilizations

Next to castrations, also sterilizations are performed in the inpatient and outpatient clinics. Figure 10 shows the ratio of performed in-house sterilizations per animal shelter as a function of the number of admissions per year. Figure 11 shows the ratio of sterilizations performed in the outpatient clinic per number of arrivals in the outpatient clinic. Since sterilizations are only performed on female animals, only the admissions and arrivals of female animals are taken into account.

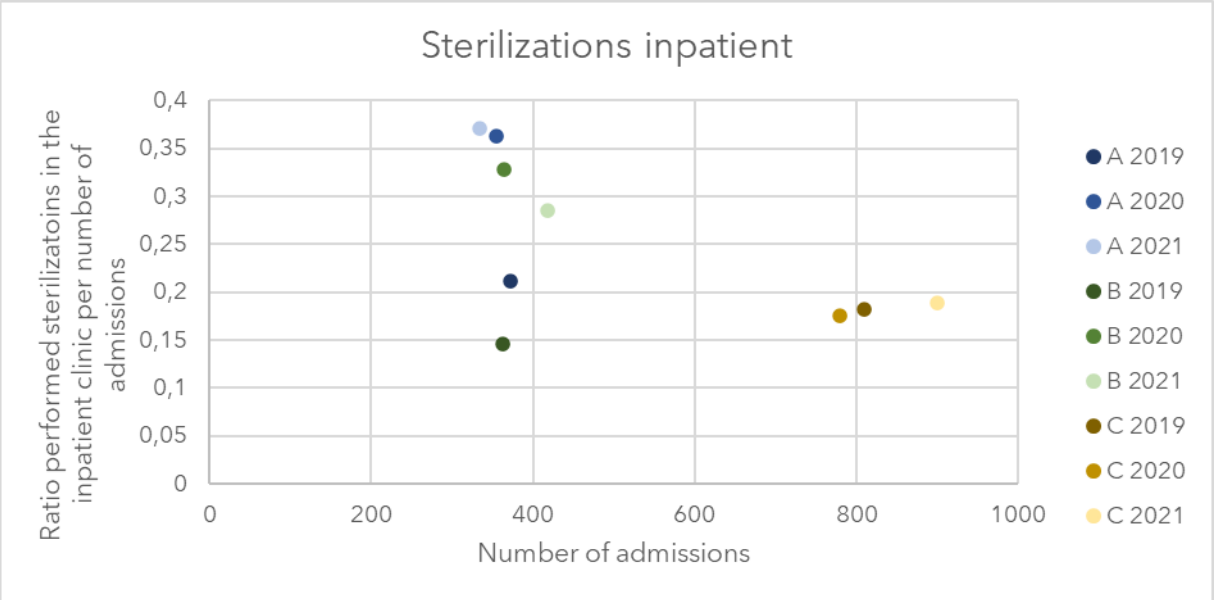


Figure 10 Ratio of in-house performed sterilizations per number of admissions in A (n=1062), B (n=1146), and C (n=2488) for the years 2019, 2020, and 2021

Looking at the differences between the number of admissions of female animals at the animal shelters, we see something comparable to the number of admissions of male animals. The number of admissions of C lies between the numbers 730 and 930 and the number of admissions of A and B lie between the numbers 330 and 530. This shows that the populations of male and female animals do not differ much. There are small differences between the number of performed sterilizations in the inpatient clinic. No clear explanation for these differences is found. Again, the same as for the performed castrations, we would have expected that the animal shelter in C performed more sterilizations because of the higher number of admissions.

The animal shelters also perform sterilizations in their outpatient clinics. Just as for the number of admissions, we can conclude that the numbers of male and female animals in the outpatient clinic are quite comparable. For the animal shelter located in A, we see that the ratio of performed sterilizations in the outpatient clinic has one outlier in the year 2019, regarding the number of female animals arriving in the outpatient clinic. The ratio of outpatient sterilizations performed in B shows the effect that we would have expected, although it is a small increase per year. The more female animals arrive in the outpatient clinic, the higher the number of performed sterilizations. In this case, this is a negative effect for the animal shelter, since we wanted as least as possible neutralizations performed in the outpatient clinic. The ratio of performed sterilizations in the outpatient clinic in relation to the number of arriving animals for the animal shelter in C shows a negative trend. And again the ratio has a value above one. This means that the number of performed sterilizations in the outpatient clinic decreases over the years, which is a positive effect.

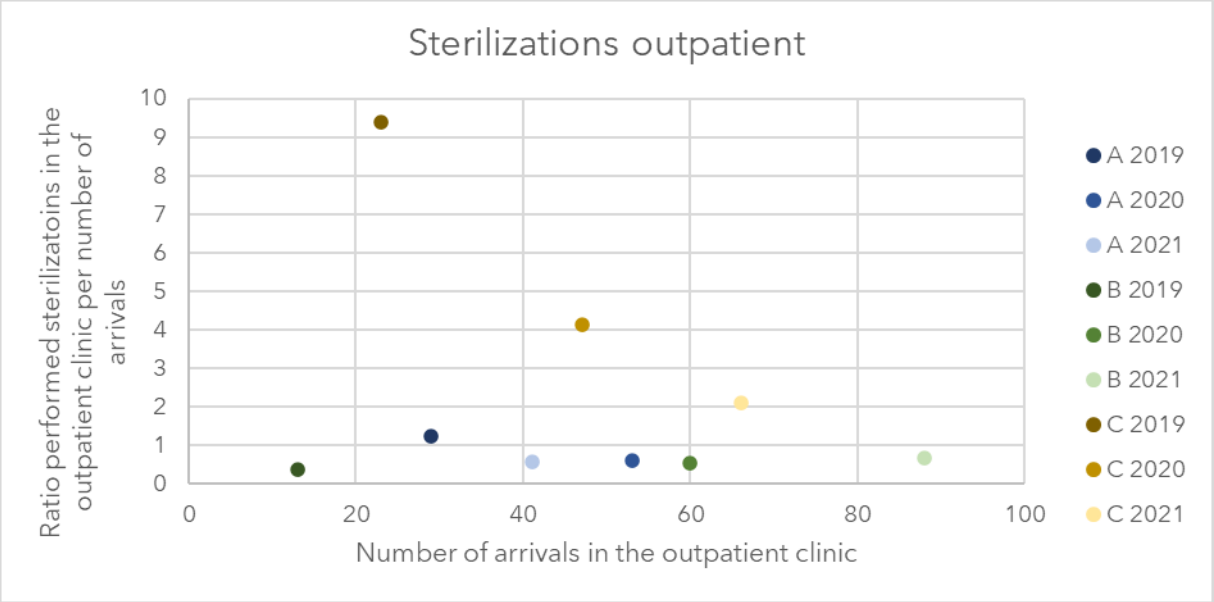


Figure 11 Ratio of performed sterilizations in the outpatient clinic as part of the number of arrivals in the outpatient clinic in A (n=123), B (n=161), and C (n=136) for the years 2019, 2020, and 2021

2.3.1.3. Other surgeries

Besides neutralizations, also other types of surgeries are performed in the ORs of the animal shelters. The ratio of surgeries performed is plotted against the number of admissions since most surgeries, besides castrations and sterilizations, are performed in the inpatient clinic. When animals are adopted and require care, besides neutralization and vaccinations, they go to their own veterinarian instead of the animal shelter. Figure 12 shows the ratio of other types of surgeries performed per number of admissions.

Again, we see that the numbers of animals arriving for the animal shelters in A and B are comparable and that the animal shelter in C has a bigger population. Since the population present in C is about twice as high, we would also expect that the ratio of performed surgeries is also twice as high. When we compare the average performed surgeries per animal shelter with each other, we see that these are comparable for all the three animal shelters. When we compare the ratios per year with the number of admissions, we can conclude that the animal shelter in C performs less other surgeries compared to the other two shelters. This could imply a difference in work methodology or that the animals that were sheltered in the animal shelters in A and B suffered from worse injuries.

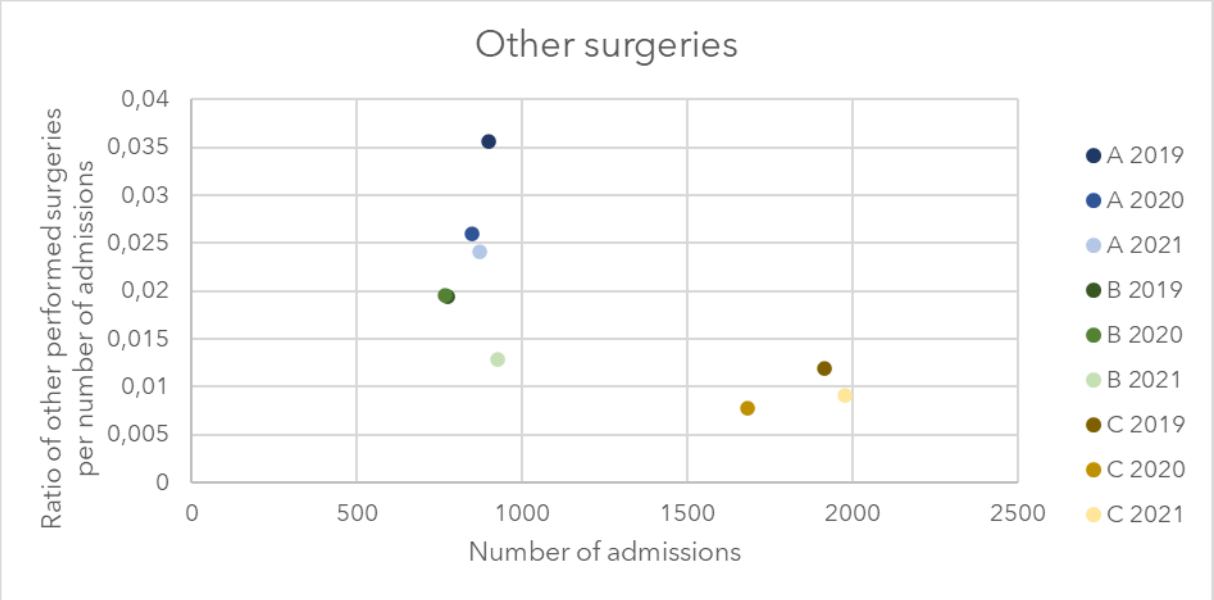


Figure 12 Ratio of other performed surgeries per number of admissions in A (n=2617), B (n=2469), and C (n=5576) for the years 2019, 2020, and 2021

2.3.2. X-ray

In some cases, the veterinarian needs more information about an animal, than can be obtained from a physical check, before a diagnosis can be made. To obtain this additional information, a veterinarian can perform an X-ray. Figure 13 shows the ratio of X-rays performed per the number of admissions. The performed X-rays are plotted against the number of admissions since most X-rays are performed for the inpatient clinic.

For the animal shelters in A and B we see that both the number of admissions and the ratio of performed X-rays are quite stable over the years. From the graph, we can conclude that on ratio, a similar amount of X-rays are performed in C compared to A and B.

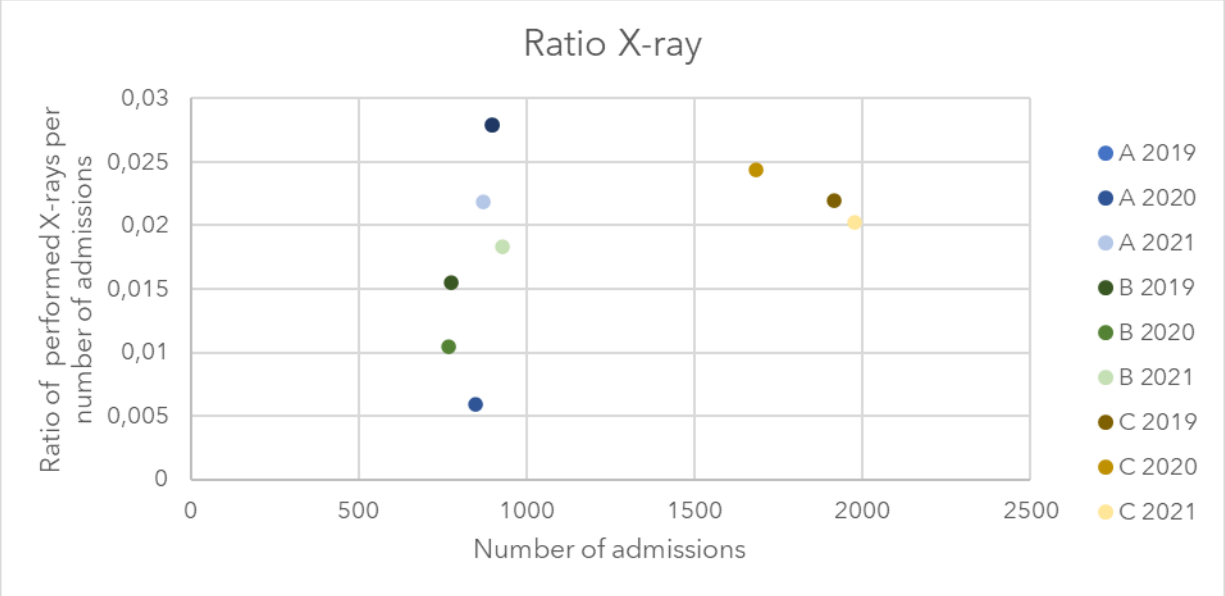


Figure 13 Ratio of performed X-rays per number of admissions in A (n=2617), B (n=2469), and C (n=5576) for the years 2019, 2020, and 2021

Besides comparing the performed X-rays with the number of admissions, it is also interesting to look at the performed X-rays plotted against the number of surgeries. One could argue that when there are more surgeries performed, also the number of performed X-rays should be higher. Figure 14

shows the ratio of performed X-rays per number of performed surgeries. In these graphs, we see some bigger differences between the years for the same animal shelter. Therefore, no clear conclusion can be drawn.

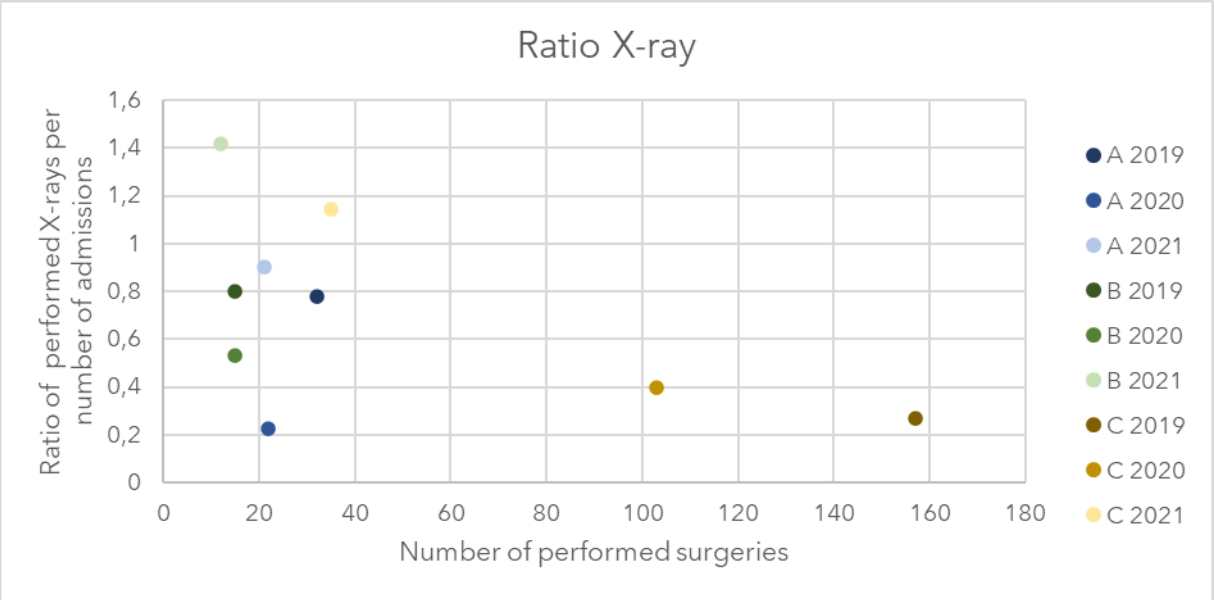


Figure 14 Ratio of performed X-rays per number of performed surgeries in A (n=75), B (n=42), and C (n=295) for the years 2019, 2020, and 2021

2.3.3. Dental remediation

The next main medical procedure that is performed in an animal shelter is dental remediation. It is the main treatment for early tartar and gum disease. Therefore it is a preventive treatment. Dental remediations are performed mostly in the inpatient clinic since placed animals go to their own veterinarian for this type of care. Therefore, the ratio of performed dental remediations per year is plotted against the number of admissions in Figure 15.

The graph shows that the animal shelters in A and B perform very few dental remediations. Therefore, no clear conclusion can be drawn for this medical procedure for these animal shelters. Compared to A and B, the animal shelter in C performs more dental remediations but the difference with the other two animal shelters is minimal.

2.3.4. Appointments

In the outpatient clinic, animals come from outside the shelter at a predetermined appointment time. These appointments can include a vaccination, chipping, or a physical check-up. Figure 16 shows the ratio of scheduled appointments per animal shelter per the total number of animals arriving per year.

The animal shelter located in A has a varying number of animals arriving in the outpatient clinic. No clear connection between the number of arriving animals and the ratio of scheduled appointments in the outpatient clinic of this animal shelter can be found. The animal shelter in B has a high ratio of scheduled appointments in the year 2021, compared to the other two years. This increase in appointments is caused by the way of reporting. In the years 2019 and 2020, a veterinarian was hired and he reported every appointment in his own EPF. In 2021, this care was taken over by an internal veterinarian. So from this year onward, the appointments are reported in the EPF of the AP. The ratio of scheduled appointments for the animal shelter in C is low in the year of 2019 compared to the other two. In the years 2020 and 2021 this animal shelter has a ratio higher than one. This is caused by earlier explained reasons.

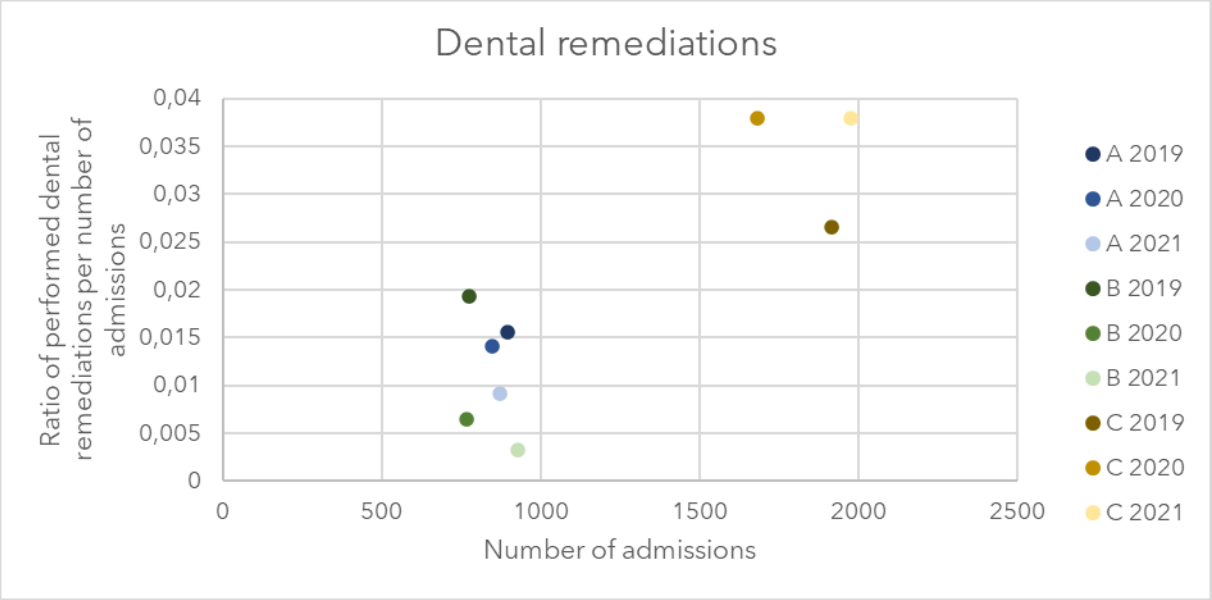


Figure 15 Ratio of performed dental remediations per number of admissions in A (n=2617), B (n=2469), and C (n=5576) for the years 2019, 2020, and 2021

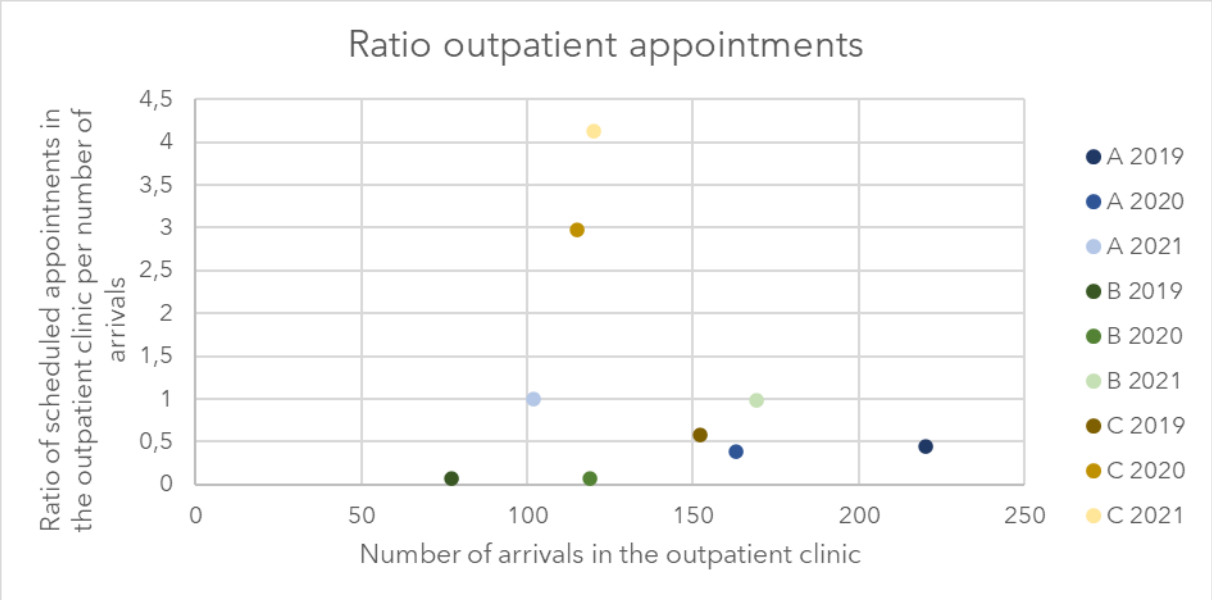


Figure 16 Ratio of scheduled appointments in the outpatient clinic as part of the number of arrivals in the outpatient clinic in A (n=485), B (n=365), and C (n=387) for the years 2019, 2020, and 2021

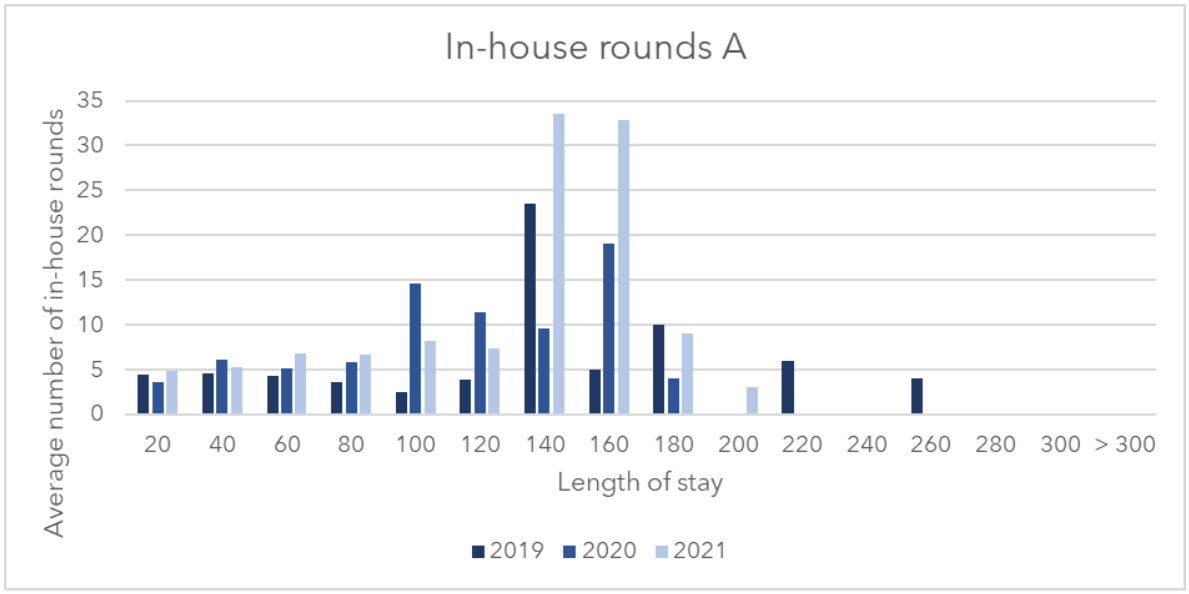
2.3.5. In-house rounds

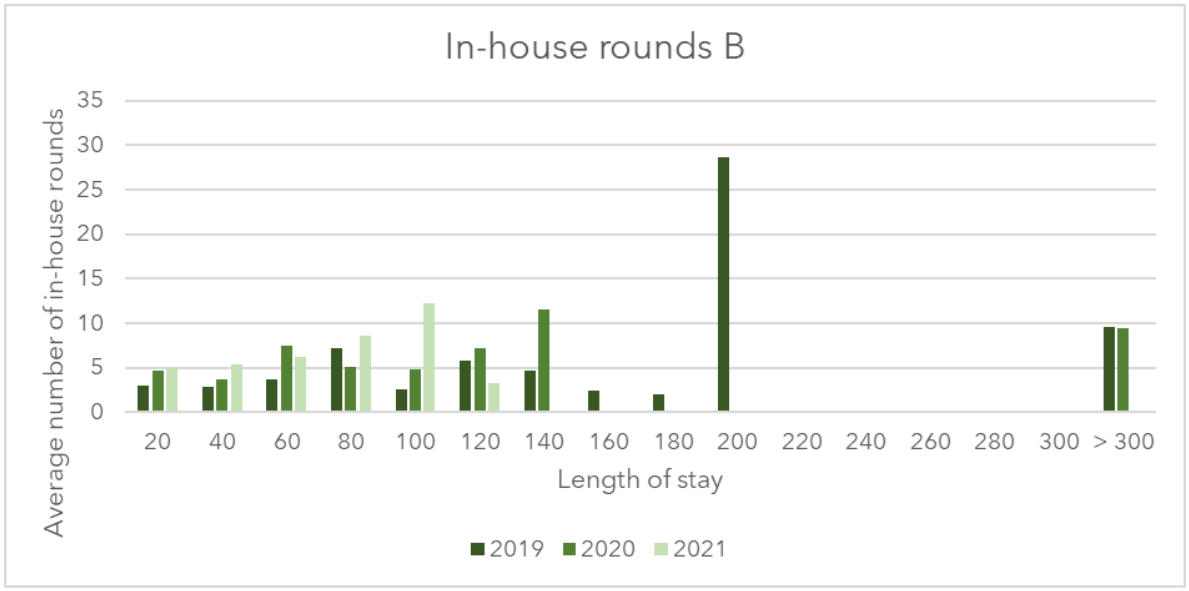
The inpatient clinic at an animal shelter contains the 'in-house' rounds. During these rounds, a veterinarian together with a vet technician will visit all the sick animals in need of a check-up in the animal shelter. The animals that need to be visited are on the in-house list. Animals present at the animal shelter are taken care of by an animal caretaker. This caretaker sees the animal daily. Therefore, they can see whether the animal gets better or worsens. For that reason, the caretakers determine whether an animal ends up on the in-house list or not.

The total amount of scheduled in-house rounds per animal shelter can be a bit misleading. In practice, we do not see such a big difference between the number of scheduled appointments in the outpatient clinic and the scheduled in-house rounds. When a kitten is sheltered, it is usually taken in by a foster family, to make sure the animal is enough socialized. These animals are still registered as in-house since they are not placed yet, but they come to the animal shelter during outpatient

appointment hours. Also, more time for their appointments is scheduled compared to the actual in-house animals.

In Figure 17, the average number of in-house rounds per length of stay per year and location are shown. The lengths of stay are divided into bins with the size twenty. We would expect that the average number of in-house rounds per animal increases when the length of stay becomes longer. This pattern is not seen clearly in Figure 17. The clearest pattern we see for C, until an average length of stay of 240. Therefore, we cannot conclude that the scheduled in-house rounds increases with the length of stay.





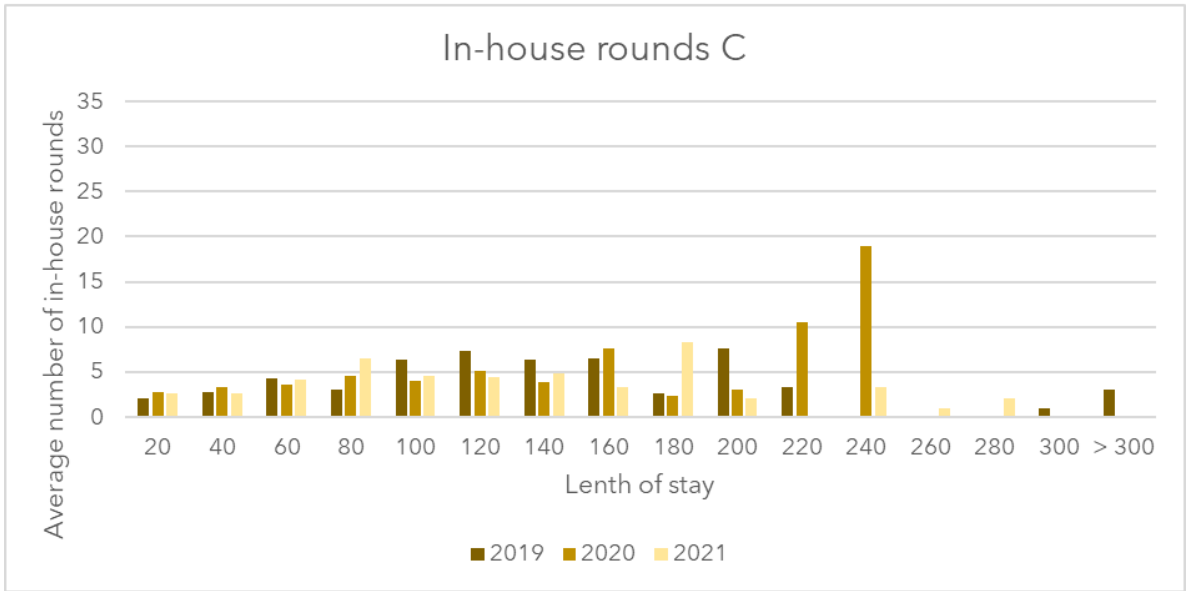


Figure 17 Average number of inhouse rounds per length of stay in A (n=5402), B (n=3416), and C (n=3347) for the years 2019, 2020, and 2021

2.4. Staff scheduling

After describing and analyzing the medical procedures performed at the animal shelters, we want to take a look at the supply of the animal shelters, the available staff hours per animal shelter per year. Table 3 shows the available staff hours per animal shelter per year. Looking at the available staff hours per year, we see that the employment of staff members has changed over the years. The available staff hours are equal during the years 2019 and 2020 for all animal shelters. The first changes can be identified in the year 2021.

- From September, the available vet technician hours decrease with eight hours at the animal shelter in A.
- From this year onward, a veterinarian is employed instead of hired in B. They started with eight hours employed hours for a veterinarian and vet technician. These hours increased to both sixteen in September.

For the year 2022, again some changes took place.

- From the beginning of this year, the animal shelters in A and B work together and share their staff members. Veterinarians and vet technicians work at both locations. The hours that are available for these two animal shelters together are 36 hours for veterinarians and 48 for vet technicians.
- For the animal shelter in C, the veterinarian hours are increased by ten and the vet technician hours are increased by forty.

Table 3 shows the available staff hours per animal shelter per year. The main changes are indicated in bold.

We can conclude that the animal shelters do not have the same available staff hours. So the supply differs per animal shelter. Not a single employee works a fulltime job at the animal shelters. This means that everyone works a part of the week and/or day. On this aspect, another difference between the animal shelters can be identified. In the animal shelters located in A and B, both veterinarians and vet technicians work from 9 AM to 5 PM. At the animal shelter in C, veterinarians work from 9 AM to 2 PM and vet technicians from 9 AM to 3 PM. The difference in working times between the locations seems to be of personal preference. Although the working hours are different between the locations, the division of tasks between veterinarians and vet technicians is the same.

Furthermore, the planning horizon is also a part of staff scheduling in organizations. A planning horizon is the amount of time an organization will look into the future when preparing a plan or developing a schedule. All three animal shelters do not use such a planning horizon for staff scheduling. This means that they do not look ahead for a certain period and plan their staff for that demarcated period. The division of staff members over the days of the week is the same for the entire year.

Table 3 Available staff hours per animal shelter per year, for veterinarians and vet technicians

Veterinarian		January	February	March	April	May	June	July	August	September	October	November	December
A	2019	16	16	16	16	16	16	16	16	16	16	16	16
	2020	16	16	16	16	16	16	16	16	16	16	16	16
	2021	16	16	16	16	16	16	16	16	16	16	16	16
	**2022	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**
B	*2019	16	16	16	16	16	16	16	16	16	16	16	16
	*2020	16	16	16	16	16	16	16	16	16	16	16	16
	2021	16*	16*	**8**	**8**	**8**	**8**	**8**	**8**	**16**	**16**	**16**	**16**
	**2022	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**
C	2019	20	20	20	20	20	20	20	20	20	20	20	20
	2020	20	20	20	20	20	20	20	20	20	20	20	20
	2021	20	20	20	20	20	20	20	20	20	20	20	20
	2022	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**

Vet technician		January	February	March	April	May	June	July	August	September	October	November	December
A	2019	24	24	24	24	24	24	24	24	24	24	24	24
	2020	24	24	24	24	24	24	24	24	24	24	24	24
	2021	24	24	24	24	24	24	24	24	**16**	**16**	**16**	**16**
	**2022	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**
B	*2019	24	24	24	24	24	24	24	24	24	24	24	24
	*2020	24	24	24	24	24	24	24	24	24	24	24	24
	2021	24	24	**8**	**8**	**8**	**8**	**8**	**8**	**16**	**16**	**16**	**16**
	**2022	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**	**48**
C	2019	20	20	20	20	20	20	20	20	20	20	20	20
	2020	20	20	20	20	20	20	20	20	20	20	20	20
	2021	20	20	20	20	20	20	20	20	20	20	20	20
	2022	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**

2.5. The gap between demand and supply

Section 2.3 described the medical procedures performed in the animal shelters during the years 2019, 2020, and 2021. We see these medical procedures as the demand of the shelters. Then followed Section 2.4, where we displayed the staff hours that were available during these years. These staff hours can be seen as the supply. As mentioned in Section 1.4, there exists a gap between the demand and supply of animal shelters in A, B, and C. The gap between demand and supply can be demonstrated by data on the first appointments and missed neutralizations. Section 2.5.1 handles the first appointments and Section 2.5.2 the missed neutralizations. This section on the gap between demand and supply closes with the usage of staff hours.

2.5.1. First appointments

As mentioned in Section 2.1.1, animal shelters are legally obligated to provide an appointment to an animal within five working days, except for kittens and wanderers. Before we can look at the number of appointments that were performed too late, we have to determine the date of arrival and the days until the appointment. The date of arrival was determined by subtracting the days present at the animal shelter from the departure date and the days until the appointment was determined by subtracting the date of arrival from the day of the appointment. Some animals were planned for multiple appointments. Only the date of the first appointment was taken into account in this calculation. The last step was to determine whether the number of days until the appointment falls below the threshold of five. Table 4 shows the absolute number of too-late appointments, as well as the percentages.

Table 4 Percentage of consultations that were performed too late in the years 2019, 2020, and 2021 for the animal shelters in A (n=1337) and B (n=513)

Location	Year	Total number of appointments	Number of appointments that were not on time	Percentage
A	2019	431	148	34.34%
	2020	414	135	32.61%
	2021	492	196	39.84%
B	2019	6	3	50.00%
	2020	10	8	80.00%
	2021	497	249	50.10%

Table 4 does not contain data about the animal shelter located in C. This animal shelter is in the transition from one EPF to another, therefore the dataset containing the scheduled appointments does not fully correspond to the dataset containing the arriving animals. Therefore, no conclusions about the performed appointments can be drawn for this location, since we do not know on which day the animals arrived which received an appointment. For the animal shelters in A and B we see quite a high percentage of consultations that were performed too late. The percentages of the animal shelter in A are quite stable over the years, so we can conclude that on average about 35% of first consultations were performed late. For the animal shelter in B, only for the year 2021 sufficient data on consultations is known because of the earlier mentioned reason that from this year onward a veterinarian is employed instead of hired. In that year, half of the first consultations were performed late.

2.5.2. Missed neutralizations

As mentioned in Section 1.4.1, not all neutralizations can be performed before placement. Therefore, the animals need to come back to the animal shelter for their neutralization. It is interesting to look at the number of neutralizations that are missed per animal shelter. By missing, we mean the animals that are placed or evicted and never got neutralized. Missed neutralizations can cause later problems for animal shelters. These animals can cause unwanted nests, which then again increases the demand. Only animals that were old enough to receive a neutralization on the day of departure are taken into account in this analysis. Table 5 and Table 6 show the average missed

neutralizations missed over the years 2019, 2020, and 2021 per animal shelter per animal species. Table 5 shows the number of missed castrations and Table 6 the missed sterilizations.

Table 5 Average performed and missed castrations over the years 2019, 2020, and 2021 for animal shelters located in A (n=2617), B (n=2469), and C (n=5576) per animal species, with percentages of the average performed castrations

	Dog	**Cat**	**Rabbit**	**Other**
Average performed castrations				
A	42	145	38	0
B	4	127	9	0
C	34	247	32	32
Average missed castrations				
A	6 [14%]	2 [1%]	1 [3%]	12 [100%]
B	32 [864%]	6 [5%]	0 [0%]	0 [100%]
C	18 [52%]	13 [5%]	2 [5%]	30 [91%]

Table 6 Average performed and missed sterilizations over the years 2019, 2020, and 2021 for animal shelters located in A (n=2617), B (n=2469), and C (n=5576) per animal species, with percentages of the average performed sterilizations

	Dog	**Cat**	**Rabbit**	**Other**
Average performed sterilizations				
A	21	116	4	0
B	2	127	1	0
C	33	240	31	32
Average missed sterilizations				
A	7 [32%]	1 [1%]	32 [800%]	7 [100%]
B	20 [857%]	11 [8%]	0 [0%]	0 [100%]
C	18 [56%]	23 [10%]	47 [151%]	27 [84%]

Looking at the number of missed neutralizations, some stand out. We see that the missed castrations for dogs for the animal shelters in B and C are quite high. The numbers of missed castrations are almost eight and twice as high as the average performed castrations during these years, respectively. A similar conclusion can be drawn for the missed sterilizations of dogs. Here the average missed sterilizations are respectively ten and six times as high as the average performed sterilizations. Furthermore, we see that the animal shelters located in A and C on average missed quite some sterilizations on rabbits. Lastly, looking at the missed neutralizations for other animal species, we see that A and C missed quite some castrations and sterilizations.

2.5.3. Usage of staff hours

In Section 2.4 we saw that for the years 2019, 2020, and 2021 the available staff hours per animal shelter were quite similar. No big differences between the shelters can be indicated. When we look at the absolute number of performed medical procedures, then we see that the animal shelter in C performs a lot more compared to B and A. Mainly for the following procedures: outpatient castrations and sterilizations, x-rays, outpatient appointments and dental remediations. From here we can conclude that the animal shelters probably have another work methodologies, since one animal shelter can perform way more procedures with the same available staff hours.

2.6. Capacity for change

An important thing to take into consideration is the capacity for change in the organization. When an organization does not have the capacity to change, then it does not make sense to try to implement many new methods or changes because then you experience a lot of resistance.

The concept of change has changed a lot over the past couple of years. Nowadays, organizations face change with an increasing pace, high complexity, and change that is unpredictable (Burnes, 2004b; Kerber & Buono, 2005; Miller, 2004). Change of an organization can be triggered internally as well as externally. Furthermore, change became more divers with the years, it comes in all shapes, forms and sizes (Burnes, 2004b). Therefore, organizations from all industries are interested in change. In order to survive in the current competitive environment, it is crucial for organizations to manage their change successfully (Balogun & Hailey, 2008; Lawler, 2007).

According to Balogun, Hailey and Pellettiere the failure rate of a change program in an organization is about 70% (Balogun & Hailey, 2008; Pellettiere, 2006). This implies that there is no method on how to successfully implement and manage change in an organization. This method is desirable, since change in an organization is usually partially compulsory. Heckmann et al. propose such a method (Heckmann et al., 2016).

Change management can be based on two approaches. First we have the traditional approach with equilibrium assumptions. This approach states that there are three steps in the change process: unfreezing, moving, and refreezing. Next, we have the punctuated equilibrium. According to this approach the organization is in an equilibrium before a disruption takes place. A period, usually short, with shifts and transitions takes place, which is followed by a new period of stability. Both approaches imply that change management is distinctive, but in reality we see that it is an continuous process (Burnes, 2004a; Schreyögg & Noss, 2000).

Many variables have influence on whether a change program will succeed in an organization. There exists a positive relation between the environmental performance of an organization and the organization's capacity to change. Also the firm performance has a positive influence (Judge & Douglas, 2009; Judge et al., 2009). Kral and Kralova state that a change program will only be successful when there is open, explanatory, frequent, and continuous communication (Král & Králová, 2016).

Applying this to the situation present in the animal shelters, we have to take into account that the change program should be a continuous process and that the communication regarding the change program also needs to be continuous, frequent and open.

2.7. Conclusion

This chapter discussed the current situation of the animal shelters located in A, B, and C. This current situation was split into the journey of a single animal through an animal shelter, the arrival population, the performed medical procedures, the employed staff hours, the current gap between demand and supply, and the capacity for change. What we can conclude from this chapter is that the number of medical procedures performed shows that the animal shelters work supply oriented. The number of medical procedures that are performed is related to the staff members that are available to the animal shelters.

Because the animal shelters work supply oriented, they cannot meet all the demand that is requested. Section 2.5 highlighted the three main parts within the organization of the animal shelters which identify the gap between demand and supply. The legally determined days within an animal needs to be seen for an appointment are not met in many cases. This section also showed the average missed neutralizations per animal shelter. For some animal shelters and some animal species, these numbers are quite high. Another thing this section showed was that the animal shelters have different work methodologies, since the animal shelter in C performs a lot more surgeries and other procedures with a comparable amount of available staff hours.

When the staff scheduling is handled differently, and the work methodologies are standardized, more care can be provided and the gap between demand and supply will decrease.

3. Desired situation

To decrease the gap between demand and supply, the staff scheduling should be handled differently and the work methodologies of both veterinarians and vet technicians need to be standardized. To show the direction of this study, this chapter will describe the desired situation concerning staff scheduling and the design of the work methodologies for animal shelters.

In the desired situation, the animal shelters located in A, B, and C integrate their staff planning and standardize their work methodologies. They standardize not only their work processes regarding staff scheduling but also in other areas such as determining treatment plans for a certain disease types. To be able to integrate the three locations, staff scheduling should be arranged generally, instead of arranging the staff planning per animal shelter. By arranging generally we mean that the staffing levels per day and/or week are determined in one go for the three animal shelters.

3.1. Staffing levels

When an organization determines which staffing levels are needed for a certain shift or a certain period, a buffer capacity is taken into account. This buffer capacity accounts for the predictable fluctuation in demand. The demand can fluctuate because patient arrivals are stochastic. In the current situation, the animal shelters individually plan their staffing levels. So at every location, this buffer capacity needs to be taken into account. When the staffing levels are determined for all locations at once, there is a chance that the total buffer capacity can be lowered, and thereby the chance of overstaffing will be lower.

Another advantage of arranging the staff schedule generally for the three animal shelters is that the staff schedule can be made at once instead of three times separately. This will create more unity between the animal shelters. It also will save some time, since the schedule can be made at once instead of three times separately.

To determine the staffing levels for a certain period per animal shelter, some things will have to change in the organization of the animal shelters. Once per year, at the end of the calendar year, the case mix of the animal shelters needs to be determined for the coming year. Case mix refers to the client mix or type that requires care from the animal shelters, so how many animals will require which types of treatment. Furthermore, a forecast of the emergency cases is being made on historical data. The case mix together with the forecasted emergency cases forms the expected demand. Next to this, an overview of treatments with their expected duration is required. After combining these parts, the total time required for treatments for the upcoming year can be determined. The staffing levels should be adjusted to the forecasted demand.

3.2. Work methodologies

Furthermore, the design of work methodologies will be the same at the three animal shelters in the desired situation. The goal is that the teams, by which we mean veterinarians and vet technicians, can work independently of each other. It should be clear which task belongs to which team and how these tasks should be carried out.

3.3. Conclusion

After determining the desired situation regarding staff scheduling at the animal shelters, we can identify a gap. The current situation does not correspond to the desired situation. To try to minimize the gap between the desired and current situation, the next step is to consult the literature to look for methods designed or studies performed on these topics and find a method that suits the current working methodologies used in animal shelters.

4. Theoretical framework

This chapter describes the literature consulted for this research with the goal to reduce the gap between the current and desired situation. It is too big of a gap to close at once, therefore multiple sources and research fields are investigated to search for methods and theories. To work towards the desired planning situation, we investigated the research fields of shelter medicine and human hospital care. A part of the searches in databases were performed to gain common knowledge, other searches were performed more systematically. Appendix A contains in more detail information about the systematic literature research.

This theoretical framework is structured as follows. Section 4.1 will introduce the research field of shelter medicine. After that, Section 4.2 will discuss the different planning levels and Section 4.3 will describe different ways of staff scheduling.

4.1. Shelter medicine

Shelter medicine addresses the well-being of individual animals as well as entire populations. Decreasing the number of stray animals and releasing healthy animals back into society are the two goals of shelter medicine (Cho et al., 2015). Shelters can be overwhelmed by animal intake at certain times of the year (Karsten et al., 2017). This causes additional stress for the animals and increases the disease and euthanasia rates. The population density can grow very quickly and can become untenable when there are not enough resources available to provide the care that is needed (S. J. Hobson et al., 2021). To overcome these problems, the management strategy Capacity for care (C4C) arose in shelter medicine in the past few years. C4C describes the properties of a best-practice approach (S. J. Hobson et al., 2021). This approach mentions that all needs of an animal are met regardless of how, when, at which age, or with which health status, they came into the shelter. Also, the personality of the animal should not matter (Koret Shelter Medicine Program, 2016; Weiss et al., 2015).

Within shelter medicine, already some research is conducted on capacity management. The main topics of capacity management in this research area are infrastructure (Koret Shelter Medicine Program, 2022) and the employment of staff members (Laderman-Jones et al., 2016; Powell et al., 2021; Yannessa, 2017). For example, some formulas are composed to help shelters determine how many staff members are needed for kennel cleaning and feeding. Cho et al. looked at the staff capacity for daily care (SCDC) and the required staffing capacity for daily care (RSDC). By daily care, we mean daily cleaning, feeding, possible medical care, and monitoring of every animal. SCDC is determined by the total number of animals that can be taken care of daily. It can be calculated by dividing the number of minutes staff is available for basic care per day, by the number of minutes that is required per animal. The required staffing capacity, RSDC, can be calculated by multiplying the number of animals present in a shelter by the number of minutes required for basic care per animal per day. The obtained value is then divided by 60. The required time for basic care can vary with species, age, housing type, and population needs (Cho et al., 2015).

Not much attention in the literature is given to the deployment of veterinarians and vet technicians in animal shelters. This study will try to fill this gap in the literature, and provide a proposal for staff schedules for veterinarians and vet technicians. To be able to come to a proposal, literature from other research fields is introduced. Since the organization in an animal shelter is very similar to the organization in human hospitals, as mentioned in Section 2.1, literature that is focused on human health care is included in this study.

4.2. Planning levels

Planning and control decisions are made by organizations to design and operate processes. Decisions have to be made in various areas of organizations, for long-term, medium-term, and short-term decision-making. Hans et al. have introduced a hierarchical framework in literature to structure and break down planning and control in healthcare. Besides, the framework can also be used to

identify planning problems in an organization. Figure 18 shows the hierarchical framework for healthcare planning and control, including an example of a general hospital.

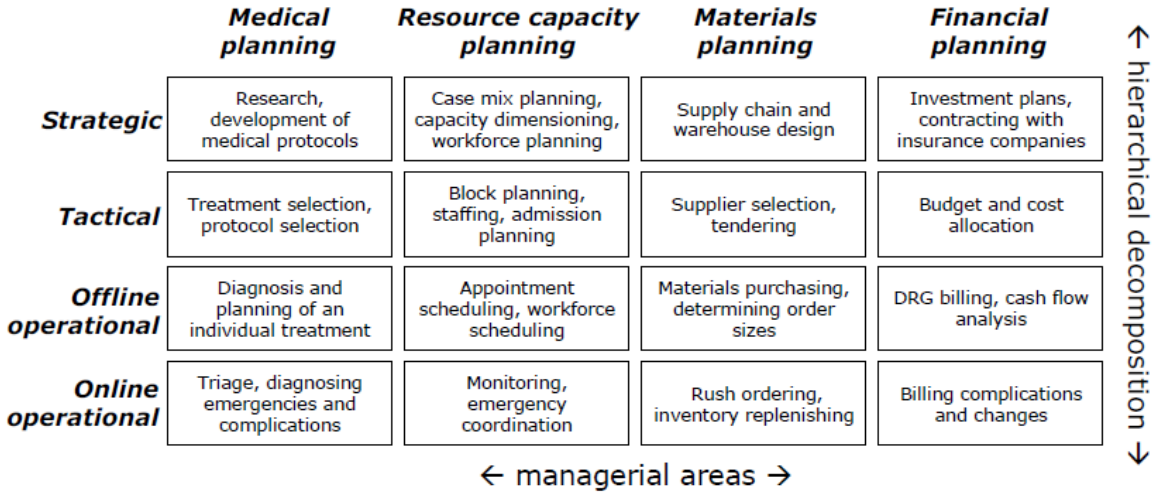


Figure 18 Hierarchical framework for healthcare planning and control, including an example of a general hospital (Hans et al., 2012)

The framework for planning and control contains four managerial areas, medical planning, resource capacity planning, materials planning, and financial planning. Medical planning refers to the decision-making by clinicians. This includes decisions regarding protocols, triage, diagnoses, and treatments. Here, clinicians get more autonomy when a process becomes more complex. Resource capacity planning addresses renewable resources. It refers mainly to their planning, scheduling, monitoring, and control. Renewable resources are equipment, facilities, and staff. Materials planning focuses on consumable resources and materials. Examples of consumable resources are blood, bandages, and food. With the materials planning, we look at the storage, distribution, and retrieval of the resources and materials. Therefore often knowledge about warehouse design and/or inventory management and purchasing is needed in this managerial area. The last managerial area is financial planning. In this area, we focus on managing the costs and revenues of an organization, for both the present and the future. It has a big influence on the way processes are organized and managed (Hans et al., 2012).

On the horizontal axis of the framework, the hierarchical dimensions are positioned. As time progresses, usually more information becomes available. Therefore, a distinction between strategic, tactical, and operational planning levels is made in the framework. The operational level is again broken down into offline and online.

4.2.1. Strategic level

The strategic level is the highest level of planning and control. Therefore, it has a long planning horizon and the information at hand is mostly based on forecasts. At this level of planning the strategy or direction of the organization is determined (Hans et al., 2012). Decisions made at the strategic level can be seen as the building blocks of an organization (Li et al., 2002).

At the strategic level, usually, the case mix is determined. Methods that are used to determine the case mix of an organization are computer simulation, heuristics, and mathematical programming (Hulshof et al., 2012). Blake and Carter proposed two linear goal-programming methods to determine the case mix in a human hospital. The first model is used to set the case mix, where the service costs are fixed. With the second model, the case mix is translated to changes for physicians in practice (Blake & Carter, 2002).

In other research fields, other methods such as forecasting are proposed to determine the upcoming demand (Silver et al., 2016). Which forecasting model to use depends on the trend and seasonality of the demand data. The method Double Exponential Smoothing (DES) can be used when the data

only shows seasonality and the Holt-Winter (HW) method can be used when the demand data also shows a trend, besides seasonality. The trend is the persistent change in demand over time. When the demand data shows a repeating pattern over time, seasonality has to be included in the forecast model.

4.2.2. Tactical level

The tactical level refers to medium-term planning (Gupta, 2007). On this level, strategic planning choices are translated into operational planning decisions (Hulshof et al., 2012) and guidelines are given for the decisions that need to be made on the operational level (Zhu et al., 2019). First, the patient groups are identified. This can be done based on the diagnosis, urgency, and resource requirements of patients. Next, the available resources are distributed among these patient groups. Usually, this is done by dates or time slots. An important method that is often used at the tactical planning level is forecasting. To create a good tactical planning, seasonal demand, waiting list information, and the downstream demand further in the care pathway need to be forecasted (Hulshof et al., 2012).

A frequently mentioned problem in the tactical planning literature is the Master Surgery Scheduling Problem (MSSP) (Zhu et al., 2019). MSS is a cyclic schedule, usually on a monthly or quarterly basis, which provides opening times of ORs to surgeons or specialties. Using this schedule, an organization can allocate the available time over specialties according to specific requirements. MSS is important for the scheduling process since it can distribute the workload.

In literature, we can distinguish three different strategies for scheduling problems: block scheduling strategy, open strategy, and modified block scheduling (Hulshof et al., 2012). In block scheduling, the OR schedule is divided into blocks that are assigned to specialties. Here, the resources are blocked in advance and the surgeons receive a specific OR and time. This schedule is a good option to implement when the organization wants to bundle the work per staff member instead of scattering the cases over the day (Zhu et al., 2019). There is however also a drawback to block scheduling. Once a block in the OR schedule is blocked for a surgeon, other surgeons cannot use that time, even when the reserved surgeon is not using the OR time. Open scheduling is more flexible compared to block scheduling. It follows the first-come-first-serve (FCFS) principle. In this strategy, any surgeon of any specialty can choose any available time at any OR. In that way, two different specialties can be scheduled in the same OR session (Agnetis et al., 2014). Under this strategy, the utilization of the ORs is usually higher compared to the block scheduling strategy. However, long waiting times can arise as of stochastic operation times and dynamic patient arrivals (Zhu et al., 2019). Modified block scheduling combines the previously mentioned strategies. When there is a high chance of underutilization at an upcoming OR block, this block will be opened to other surgeons to use this OR time.

Furthermore, a staff-shift schedule is made on this planning level. Within a staff-shift schedule, the required staffing levels are determined. Common methods that are used to make a staff-shift schedule are computer simulation, heuristics, mathematical programming, and queueing theory (Hulshof et al., 2012). Beliën and Demeulemeester investigated the possibility of integrating nurse scheduling with the OR schedule, which would lead to cost savings (Beliën & Demeulemeester, 2008).

4.2.3. Offline operational level

Both offline and online operational planning address short-time decision-making. At this level, the least flexibility is experienced since the above levels have narrowed the scope of decision-making. In this context, offline refers to in-advance planning. At this level of planning and control, organizations have detailed information on processes. Examples of offline operational planning are nurse rostering and appointment scheduling (Hans et al., 2012).

Nurse rostering, also known as staff-to-shift scheduling, assigns staff members to shifts for a certain period. The staff schedule resulting from the nurse rostering needs to satisfy the determined staffing levels set at the tactical level. Mathematical programming and heuristics are often used to make a

staff schedule (Hulshof et al., 2012). Many examples of nurse rostering can be found in literature. Typically used methods are mixed integer programming or heuristic (local) search methods. Bester et al developed a model, using a tabu search approach, to create a nurse rostering decision support system (Bester et al., 2007). Valouxis and Housos created a monthly work shift model for nurses combining integer linear programming, local search, and tabu search (Valouxis & Housos, 2000).

4.2.4. Online operational level

Online operational planning addresses reactive decision-making. This additional level is needed because of the stochastic processes in healthcare. At the online operational level control mechanisms are needed that monitor processes and react to unanticipated events. An example of online operational planning is the add-on scheduling of emergencies (Hans et al., 2012).

Emergency cases have a high urgency and require surgery as soon as possible, but it is desired that they disturb the scheduled cases as little as possible. A method that is used in literature to schedule emergency cases is mathematical programming (Hulshof et al., 2012).

4.2.5. Conclusion

Translating this hierarchical framework of planning and control to this research, we see that we focus mainly on the resource capacity planning, since we want to introduce a new staff scheduling method within the organization of the AP. Improvements will be introduced at (almost) all planning levels to improve the staff planning and work methodologies used at the animal shelters.

4.3. Staff planning

Staff planning touches multiple hierarchical planning levels, with different plan horizons. Choices made at the different planning levels are interdependent. Options at a certain planning level are constrained by choices made at a higher planning level or flexibility in later planning levels.

The workload of a nursing ward is highly dependent on arrivals and length of stay (LOS). Both of these aspects are variable, but the fluctuation is to a certain extent predictable. There are multiple ways of scheduling staff members, and taking these variable aspects into account. Kortbeek et al. looked at deploying a flexible nurse pool together with the use of dedicated nurses. They determined how many staff members should be deployed for all working shifts during a fixed planning horizon (Kortbeek et al., 2015). Dedicated nurses are deployed to staffing levels to account for the predictable variation. Later on, float nurses are introduced to account for the random demand fluctuations. Without the deployment of float nurses, the buffer capacity of dedicated nurses has a high chance of causing overstaffing.

Another way of staffing nurses in an organization is employing the staff members according to a patient-to-nurse ratio. This ratio looks at how many patients one nurse can take care of in a single working shift (Kortbeek et al., 2015; Yankovic & Green, 2011), so for example one nurse is employed per four hospitalized patients. When an organization works with these kinds of ratios, the care units should be sufficiently large (Kortbeek et al., 2015).

Sarin et al. looked at the staff scheduling of surgeons in a hospital. Scheduling surgeons is quite difficult since both the time that is required for surgery and the arrivals of patients are stochastic. This study looked at what would be the best start time for each operation and in which OR it should take place. It is already predetermined which surgeon performs which surgery (Sarin et al., 2016).

4.4. Work processes

There are many ways of improving already consisting work processes in an organization. One of them is the theory of constraints (Cox III et al., 2010). This theory of E. Goldratt focuses on the bottleneck. The entire work process is displayed in a process chain. The bottleneck is identified as the part of the process which slows the entire process down. According to the theory of constraints, an hour can be won on the entire process when we win an hour on the bottleneck. If we improve the processing time on one bottleneck, another bottleneck in the process chain will appear. That is why process improvements are continuous improvements.

Another theory to improve the efficiency of a process is the changeover time reduction, also known as SMED. This theory increases the efficiency of a process on the basis of eight steps (Theisens, 2020):

1. Define the process that needs improvement
2. Determine the baseline performance of the process
3. Define the internal and external activities of the process
4. For which activities it is possible, turn internal activities into external activities
5. Streamline the process
6. Test the proposed changes of the process
7. Verify the testing results
8. Implement improvements

The eight steps of changeover time reduction can be linked to the Plan-Do-Check-Act (PDCA) cycle. This is a continuous improvement method. The Plan-phase defines the objectives and processes to make sure the desired results are achieved. During the Do-phase, the objectives are carried out. Next, in the Check-phase the gathered data is examined. During this phase, also a comparison is made with the expected outcomes. In the last phase, the process is improved and a planning is made for the next PDCA-cycle. Every time a cycle starts, it starts with a better baseline (Theisens, 2020).

4.5. Conclusion

This chapter provided information about shelter medicine, planning levels, staff scheduling, and work processes. The framework for planning and control provides a good overview of the planning levels present in organizations. Using these planning levels, a structure can be created in the planning process of staff members. Looking at the current work methodologies that are used in the organization of animal shelters, the choice has been made to implement the following methods. For the determination of the case mix that will be present in the coming year, the combination of the DES- and HW forecasting methods will be used. For analyzing the block schedules, the case mix and data about the expected duration of medical procedures will be combined. Proposed improvements for staff scheduling and work processes will be placed in the hierarchical framework for planning and control. Lastly, we will use the PDCA-cycle for mapping and improving the work processes at the animal shelters.

5. Performance current block schedule

The goal of this chapter is to look at the performance of the currently used block schedules at the animal shelters located in A, B, and C. Before we can analyze the performance of the block schedules, we first have to determine the case mix of the year 2023. We propose two ways of determining the case mix: a naïve method and an exponential smoothing method. The complexity of the exponential smoothing method will be higher compared to the naïve method. Together with the case mix, also the duration of procedures will be determined. Next, the current block schedules can be analyzed. For this analysis, we need the durations per expected procedure.

5.1. Forecast case mix

To determine the case mix for the coming year per animal shelter, the first step is to make a forecast. For this research, we made the choice to make a forecast of the demand per week for the main medical procedures performed at the animal shelters. The arrivals at the animal shelters are also included in the forecast.

In literature, many forecasting methods are discussed. These models can be classified in cumulative, naïve, moving average, and exponential smoothing models. The classification can be made by looking at the way the models use historical data. For this research, we chose to look into two of these forecasting methods, the naïve and exponential smoothing forecasting methods. A naïve forecasting method uses no historical data and an exponential smoothing forecasting method looks for a balance between historical and new data.

5.1.1. Naïve forecasting method

When we use the naïve forecasting method, we do not use history. In other words, we assume that the demand for a certain week in the coming year is the same as the demand for that same week last year. In this research, it would mean that we use the demand requested per week in the year 2022 to forecast the demand per week for the year 2023. Since our dataset contains the demand until June 2022, we use the demand data for the second half year of 2021.

5.1.2. Exponential smoothing forecasting method

Within the classification of exponential smoothing forecasting methods fall many different forecasting methods. In this research, we will look at the double exponential smoothing (DES) and Holt-Winter (HW) models. These models are more complicated to implement compared to the naïve forecasting method. The method used to forecast the case mix can differ per animal shelter and medical procedure. To choose a model per situation, we have to introduce three forecasting patterns with their value names. First, we have a level (a). The level refers to the base level of the demand. Next, we have trend (b). The trend is the persistent change in demand over time. It can be positive or negative and follows a linear pattern. Lastly, we have seasonality (F). When the demand data shows a repeating pattern over time, we have to include seasonality in our forecasting model. In this research, we take monthly and weekly seasonality into account. The forecasting pattern seasonality shows the difference between the DES- and HW model. DES takes into account the level and seasonality, the HW model also takes into account the trend.

After developing a forecast model, we want to perform a goodness of fit test. We cannot perform a goodness of fit test on data that is already used to create the forecast model. Therefore, the available demand data is divided into three parts. Table 7 shows the division of the dataset and the usage per period. Since our dataset contains data until June 2022, we assumed that the demand in the second half year of 2022 is equal to the second half year of 2020.

Table 7 Division of dataset

Period	Usage
01/01/2019 - 31/12/2020	Find initialization values for level, trend, and seasonality
01/01/2021 - 30/06/2021	Fine-tune parameters for level, trend, and seasonality
01/07/2021 - 31/12/2022	Parameters from the naïve dataset to perform the forecast

The first step in forecasting the case mix is to determine per medical procedure per animal shelter whether the data shows seasonality. We create multiple graphs to show the average per month and week. The determination of seasonality per medical procedure is done with visual interpretation. For the determination of the seasonality, the first two and a half years on data are used. Table 8 shows the type of seasonality identified as well as the forecasting model used per animal shelter and per medical procedure.

Table 8 Type of seasonality (W = weekly, M = monthly) and forecasting model (DES = double exponential smoothing, HW = Holt-Winter) used per animal shelter and per medical procedure

	A		B		C	
	Seasonality	**Model**	**Seasonality**	**Model**	**Seasonality**	**Model**
Castration	W + M	DES	W	DES	W	HW
Sterilization	W	DES	W	DES	W	HW
Other surgeries	W	DES	W + M	HW	W + M	HW
X-ray	W + M	DES	W	DES	W + M	DES
Dental remediation	W	DES	W	DES	W + M	DES
Appointments	W + M	HW	W + M	HW	W	HW
In-house	W	HW	W	DES	W	HW
Neutralizations	W	DES	W	DES	W	DES
Arrivals	W	DES	W	DES	W	DES

To determine the start values for the level and trend per medical procedure, we need demand data that is de-seasonalized. To obtain the de-seasonalized data, the demand per week is divided by its seasonal factor. The way the seasonal factors are determined per medical procedure per animal shelter depend on their seasonality and the forecasting model that is used. In case we use DES, the average per month or week is determined. The HW-model uses the moving average per month or week. The F-value is determined by dividing the average per month or week by the average of the total demand. The last step of determining the F-values is to normalize them, since the total sum of F-values have to add up to the value P, which is equal to the number of time periods within the seasonality. Next, we can initialize the values for the level (a) and, when needed, trend (b). The level can be found by calculating the intercept of the de-seasonalized data and the trend by calculating the slope. When we use DES for a medical procedure, the value for b will be equal to zero.

After initializing the values for a, b, and F with the first two years of the data, we use the next half year of data to update and fine-tune the values for a, b, and F. The tuning of the forecast parameters can be seen as the internal validation. The updating procedures differ per forecasting model used. Table 9 shows the forecasting models with their updating procedures.

Table 9 Forecasting models with their updating procedures

Model	Forecasting model	Updating procedures
Holt-Winter	$\hat{x}_{t,t+p} = (\hat{a}_t + \tau\hat{b}_t)\hat{F}_{t-P}$	$\hat{a}_t = \alpha\left(\frac{x_t}{\hat{F}_{t-P}}\right) + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$ $\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\hat{b}_{t-1}$ $\hat{F}_t = \gamma\left(\frac{x_t}{\hat{a}_t}\right) + (1-\gamma)\,\hat{F}_{t-1}$
Double Exponential Smoothing	$\hat{x}_{t,t+p} = \hat{a}_t\hat{F}_{t-P}$	$\hat{a}_t = \alpha\left(\frac{x_t}{\hat{F}_{t-P}}\right) + (1-\alpha)\hat{a}_{t-1}$ $\hat{F}_t = \gamma\left(\frac{x_t}{\hat{a}_t}\right) + (1-\gamma)\,\hat{F}_{t-P}$

Now that we have built, trained and internally validated the forecast model it is time to test its performance. We test the performance of the model by forecasting the demand of the year 2022 with the current values of a, b, and F. After forecasting the demand per week for the year 2022, we compare our forecasts to the actual demand per week of 2022. So the demand of 2022 is not known to the forecast model.

5.1.3. Results forecasting models

To show the accuracy of our forecasting models, we calculated some measures of forecasting errors. Before calculating the measures of forecasting errors, the one-period ahead forecasting error needs to be determined. This error is the difference between the actual and forecasted demand. The first measure of forecasting error is the Mean Squared Error (MSE). The MSE is a direct estimate of the variance. A disadvantage of the MSE is that one large forecasting error has a big impact on the value of this measure. Therefore, also the Mean Absolute Deviation (MAD) is calculated. This measure is a more robust estimation of the variability compared to MSE and is less influenced by one odd observation. As a third measure, we also determined the bias of the forecast. The bias is the structural deviation between the forecast and actual demand. It is desired that the bias lies close to zero. When this is not the case, then the parameters of the forecast need to be adapted or another forecast method needs to be selected.

Table 10 Results forecasting models, bias

	A	B	C
Castration	0.0	0.2	0.6
Sterilization	-1.0	0.4	0.6
Other surgeries	0.3	0.0	-279.0
X-ray	-0.1	0.3	0.5
Dental remediation	0.0	0.0	0.0
Appointments	-2786.0	-1704.8	-416.0
In-house	-15.6	-6.7	-0.9
Neutralizations	0.8	0.8	1.0
Arrivals	-2.6	-2.5	-2.7

After developing the forecasting models per (medical) procedure, their accuracy were judged by the value of the bias. The values of the bias per forecasting model can be found in Table 10. When the value of the bias is between -1 and +1, we conclude that the developed forecasting model for the given (medical) procedure is accurate and that forecasting model will be used. When the value of the bias is bigger, the values of the parameters will be adjusted. For the other surgeries performed in A and B and in-house rounds scheduled in C, the values of the parameters could be adjusted so that the value of the bias falls within the aforementioned boundaries. When adjustments of the updating procedures did not have any influence on the value of the bias, the choice has been made to use the naïve forecasting method. Table 11 shows the forecasting models used per (medical) procedure per animal shelter. Furthermore, in Appendix B.1 the values of the updating parameters

can be found and Appendix B.2 shows the number of forecasted (medical) procedures per week per animal shelter.

Table 11 Forecasting models used per (medical) procedure per animal shelter

(medical) procedure	A	B	C
Castrations	ES	ES	ES
Sterilizations	ES	ES	ES
Other surgeries	ES	ES	Naïve
X-ray	ES	Naïve	Naïve
Dental remediation	ES	Naïve	Naïve
Appointments	Naïve	Naïve	Naïve
In-house	Naïve	Naïve	ES
Neutralizations	ES	ES	ES
Arrivals	Naïve	Naïve	Naïve

5.1.4. Assumptions

During the development of the forecasting model, some assumptions needed to be made. The first assumption that is made regards the input of the model. The forecast is based on the procedures performed during the years 2019 until 2021 and the first half year of 2022. Since we concluded in Section 2.5 that at all three animal shelters the performed neutralizations and first appointments are too low or are performed too late, this would also show in our forecast. To account for these missing procedures, and make an estimation for the input of our forecast, we looked at the percentages of the missed procedures. The known performed procedures where therefore multiplied by the factor of missed procedures.

Also an assumption needed to be made for the input data of the animal shelter located in C. As mentioned earlier in this report, it was unsure whether the dataset regarding this animal shelter was complete. Therefore, the choice was made to perform an additional analysis on the input data of the performed procedures of C. We made an assumption based on the arrivals of all the animal shelters. Analyzing the arrivals of animals we see that the arrivals in C are on average 185% of the arrivals in A and 503% of B. With these percentages, the input of the forecasting model for the animal shelter in C are determined. Assuming that when there are more animals arriving, that also the number of procedures increase.

5.1.5. Sensitivity analysis

The proposed forecasting model is dependent on the input. When the input changes, the output of the forecasting model would also change. Therefore, a small sensitivity analysis is performed to see the effect of the input on the output of the forecasting model. The input of the entire forecast is increased with 10%, 20% or 30% and also for the comparison decreased with 10%. Appendix C shows the numerical outcomes of the sensitivity analysis.

The sensitivity analysis shows that when the input data increases or decreases, in the most cases this leads to no effect in the output of the forecasting models. It is remarkable that the sensitivity analysis shows the most effect when the naïve forecasting method is used. From here we can conclude that the forecast model is very dependent on the input that is used.

5.2. Block schedule

The next step is to analyze the current block schedule at the animal shelters located in A, B, and C. As mentioned earlier, the animal shelters in A and B make use of the same group of staff members regarding the veterinarians and vet technicians. Therefore, also their block schedules are integrated. We can see when staff members are working in A, no one works in B and the other way around. Some logic is used within the block schedule of the animal shelter in B. To handle the peak in demand of surgeries, they schedule one day per two weeks only for surgeries. Figure 19 shows the current block schedules that are used at the animal shelters. These schedules are used for every

week of the year. During the light colored blocks only (a) vet technician(s) is/are working, during the darker colored blocks both veterinarians and vet technicians are working. The abbreviation "prep" means preparation and "admin" means administration.

A	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday										
Tuesday	prep	OR				OR	Consultation hours		Rounds	
Wednesday										
Thursday										
Friday		prep	OR			OR	Consultation hours		Rounds	

B (odd weeks)	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	OR			OR	Consultation hours		Rounds	
Tuesday										
Wednesday		prep	OR			OR				
Thursday		prep	OR			OR	Consultation hours		Rounds	
Friday										

B (even weeks)	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	OR			OR	Consultation hours		Rounds	
Tuesday										
Wednesday										
Thursday	prep	OR				OR	Consultation hours		Rounds	
Friday										

C	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	OR+Consultation hours			OR+Round	Admin			
Tuesday		prep	OR			Rounds	Admin			
Wednesday		prep	OR			Rounds	Admin			
Thursday		prep	OR			OR	Admin			
Friday		prep	OR	Consult		Rounds	Admin			

Figure 19 Current block schedule for the animal shelters of A, B, and C

5.2.1. Duration procedures

To be able to assess the performance of the current block schedules, we need the duration of expected procedures. To make a prediction for the treatment durations for the year 2023, observations at the three animal shelters have taken place. During these observations, the time of the different medical procedures is tracked. During this process, a distinction between the tasks of a veterinarian and vet technician is made. From these observations, an average duration together with a standard deviation per procedure could be identified. Table 12 shows the mean and standard deviation per procedure, obtained from the observations.

Table 12 Mean and standard deviation per procedure

	Mean [minutes]	**Standard deviation [minutes]**
Castration	8	6
Sterilization	25	14
Other surgeries	12	10
X-ray	10	7
Dental remediation	5	8
Appointments	10	5
Inhouse rounds	3	2
Preparation vet technician	23	13

Research towards operating room planning shows that operating times usually are distributed according to a lognormal distribution (May et al., 2011; Zhu et al., 2019). For that reason, we made the choice to draw random durations per procedure from a lognormal distribution with their own mean and standard deviation. The durations are obtained using the statistical program RStudio.

Appendix D shows the code that was used to obtain these values. These durations will later be used to evaluate the current block schedules.

For determining the expected time per activity, one assumption is made. For castrations and sterilizations of cats and dogs the same average and standard deviations are used. This assumes that the duration of these procedures lie close to each other. But in reality, both castrations and sterilizations on dogs take longer than the same procedures on cats. Since it made the forecast model and the determination of the performance of the current block schedule that much more implicated we made the choice to include the durations of castrations and sterilizations on dogs and cats under one category. And thus determine one average and one standard deviation for all castrations and all sterilizations. Therefore, it could be that the OR time in one week is overestimated and another week is underestimated. The OR time will be overestimated when there would be more neutralizations on cats and it will be underestimated when there would be more neutralizations on dogs.

5.2.2. Performance of the current block schedule

The performance of the block schedule is judged by comparing the forecasted time of procedures with the working hours that are available according to the block schedule. For the veterinarians, the mean time of procedures is taken into account together with the time of additional operations and idle time. For vet technicians, the time of the preparation of procedures is taken into account instead of the procedure itself. Only this time is taken into account, since it is desirable that veterinarians and vet technicians work in parallel. Furthermore, the time of additional operations and idle time are taken into account. The time of additional operations include administration, transition between animals, cleaning of the OR, and receiving animals.

The determination of the idle time needs further explanation. The idle time for both staff members consist of two categories. Throughout the day, veterinarians and vet technicians are disturbed with questions from animal caretakers. These can include questions about medication administration or when a sheltered animal deteriorates. These questions usually do not take long, but the veterinarians and vet technicians are taken out of their concentration which causes additional idle time. Another cause of idle time appears when veterinarians and vet technicians are not able to fully work in parallel. This occurs mainly when there is only one vet technician present, since the preparation of a surgery in most cases takes longer than the surgeries itself.

Figure 20 and Table 13 show the results of the current block schedules. The expected work per week in hours are displayed together with the supply the animal shelters can deliver. Looking at the results, there are a few areas that stand out where we can identify a surplus or shortage of capacity.

Surplus of capacity

When we look at the block schedules of the veterinarians, we see a surplus of capacity in the second quarter of the year for the animal shelters located in A and C. For the veterinarians working in B, we can identify a surplus of capacity for about the entire year. For the vet technicians working at this animal shelter, we can identify a surplus of capacity in the second quarter.

Shortage of capacity

Looking at the block schedules of the vet technicians, we can identify the opposite effect. For these staff members, we identify a shortage of capacity for every quarter of the year, at every animal shelter, except the second quarter. During this quarter the capacity fits the forecasted amount of work for the animal shelters in A and C, and in B, we saw a surplus of capacity. Looking at the block schedules of the veterinarians, we can identify a shortage of capacity at the animal shelter in C for all quarters except the second quarter of the year.

5.3. Conclusion

This chapter analyzed the performance of the currently used block schedules at the animal shelters. For this analysis, the available capacity is plotted against the expected demand per animal shelter. For most of the quarters, we can identify either a surplus of capacity or a shortage. Therefore, we can

conclude that in the current situation the supply of the animal shelters does not match the expected demand. This means that in this part of the research it does not make sense to make alterations to either the block schedule or staff scheduling. To decrease the gap between the supply and demand of the animal shelters, we would like to propose some improvements of both work methodologies and organization.

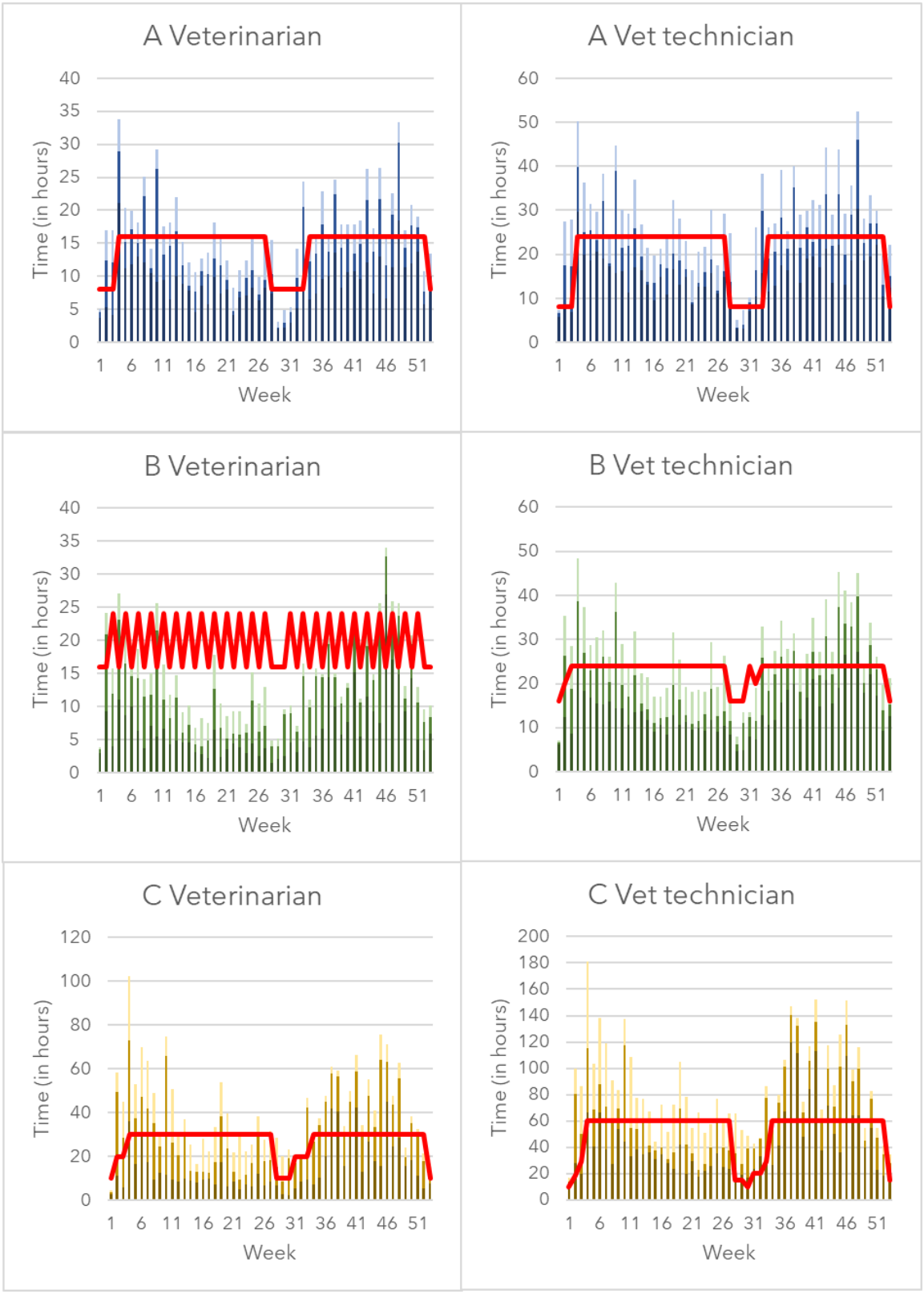


Figure 20 Results of current block schedules

Table 13 Average surplus and shortage of capacity per animal shelter per year and per quarter in hours

		Surplus capacity					**Shortage capacity**				
		Year	Q1	Q2	Q3	Q4	Year	Q1	Q2	Q3	Q4
Veterinarian	A										
	OR	2	1	2	2	2	4	4	1	3	5
	Consultation hours	2	2	3	2	2	4	5	1	4	3
	In-house	2	2	1	2	2	2	2	2	3	1
	Total	4	3	4	2	6	6	8	2	7	6
	B										
	OR	7	8	9	8	5	5	3	0	2	7
	Consultation hours	2	2	2	2	2	4	5	2	3	3
	In-house	3	2	2	3	3	1	1	1	2	0
	Total	8	7	10	8	6	8	8	0	0	8
	C										
	OR	7	6	10	7	5	13	16	0	14	12
	Consultation hours	4	5	4	0	4	13	18	7	11	12
	In-house	1	1	1	1	1	8	12	9	6	3
	Total	6	6	6	1	8	21	28	12	15	22
Vet technician	A										
	OR	2	1	2	1	2	6	7	3	6	8
	Consultation hours	3	3	4	3	3	5	7	0	4	4
	In-house	2	1	1	2	2	4	4	3	5	3
	Total	3	1	4	2	5	12	14	6	11	12
	B										
	OR	4	3	4	5	3	6	5	2	4	7
	Consultation hours	3	4	3	2	2	4	6	3	4	4
	In-house	2	2	1	2	2	4	4	3	4	3
	Total	6	9	5	6	5	8	10	5	5	10
	C										
	OR	10	5	12	14	11	24	15	3	25	32
	Consultation hours	7	4	7	0	7	16	24	8	14	15
	In-house	2	0	2	3	2	18	25	19	15	7
	Total	9	0	9	0	10	41	51	15	38	49

6. Work methodologies

In the previous chapter, we concluded that in many weeks the expected amount of work does not comply with the available workhours. In many quarters of the year there is a surplus or shortage of capacity at all animal shelters. Therefore, this chapter will discuss the work methodologies and how to change them or their organization to reduce the difference between the demand and supply.

Chapters 2 and 5 both showed that the demand of the animal shelters fluctuates strongly over the weeks and quarters. Chapter 5 also showed that in many quarters of the year either a surplus or a shortage of capacity is forecasted. These surpluses and shortages in hours can be translated to a Full-time equivalent (FTE). These results can be found in Table 14.

Table 14 Forecasted surplus and shortage capacity in FTE with the current block and staff schedule

		Surplus capacity				**Shortage capacity**			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Veterinarian	A	-	0.1	-	-	0.05	-	0.1	0.05
	B	0.025	0.3	0.275	-	-	-	-	0.075
	C	-	-	-	-	0.7	-	0.325	0.225
Vet technician	A	-	-	-	-	0.325	0.05	0.25	0.175
	B	-	-	0.025	-	0.05	-	-	0.125
	C	-	-	-	-	1.3	0.15	0.975	1

Overtime has a negative effect on the performance of staff members, because they can lose focus after a long day of work. This again has a negative effect on the quality of care that is delivered. To ensure the care provided remains of a certain quality, we want to set a threshold for the overtime probability. In the research field of health care, often a threshold of 30% is used (Hans & Vanberkel, 2012).

Table 15 shows the current probability of working in overtime per animal shelter and per staff member together with the expected overtime and the standard deviation. The expected value is the average amount of hours a staff member would probably work in overtime, when he or she has to work in overtime. The standard deviation is the amount of hours the overtime can deviate from the mean overtime. The probability, expected value and the standard deviation are calculated according to a probability distribution. First we calculated the probability of working x hours in overtime per kind of staff member with the formula:

$$P(X = x) = \frac{n(X=x)}{n(T)},$$

where T is the maximum amount of overtime hours.

Next, the expected value is equal to:

$$E(X) = \sum x * P(X = x)$$

For the determination of the standard deviation we need $E(X^2)$ and $V(X)$. We use the following formulas:

$$E(X^2) = \sum x^2 * P(X = x) \text{ and } V(X) = E(X^2) - [E(X)]^2.$$

Lastly, the standard deviation can be determined by taking the square root of the variance $V(X)$. During the determination of the probability, expectation, and standard deviation, we assumed that the overtime will be equally distributed over the staff members.

Table 15 Current probability of working in overtime per week

	Veterinarian			Vet technician		
	Probability	E(X) [h]	SD(X) [h]	Probability [%]	E(X) [h]	SD(X) [h]
A	0.55	1.8	2.4	0.72	2.7	2.7
B	0.17	0.6	1.8	0.60	1.8	2.2
C	0.64	2.4	2.7	0.81	3.8	3.3

We see that almost every combination of animal shelter and staff member shows a probability of working in overtime above the mentioned threshold. Also the mean overtime per week is quite high, on average this is equal to 2.2 hours per week. To lower both the probability and expectation of overtime, we propose some improvement ideas.

In Section 4.2 the hierarchical framework of planning and control was discussed. This section stated that there are four levels of planning and control, namely strategic, tactical, offline operational, and online operational. The improvement ideas to reduce the difference between the demand and supply at the animal shelters, so the probability of working in overtime, will be handled according to and placed in this hierarchical framework. Table 16 shows the improvement ideas within the hierarchical framework of planning and control. The following sections will discuss the improvement ideas separately and in more detail.

Table 16 Developed improvement ideas placed into the hierarchical framework of planning and control

Improvement ideas		
Strategic	Capacity dimensioning	Work together with regular veterinarian practice
		Outsource neutralizations
		Reallocating the available capacity between the animal shelters
		Reallocating the available capacity over the year
	Workforce planning	Outsource cleaning activities
Tactical	Block planning	Daily schedule
		Changes in block schedule per quarters of the year
	Admission planning	Spread neutralizations over the quarters
		Shorten length of stay before busy periods
		Planning of capturing animals in the wild
Offline operational	Appointment scheduling	Plan multiple castrations within one timeslot
	Workforce scheduling	Parallelize work of veterinarians and vet technicians
	Other	Worklist for questions of animal caretakers

6.1. Strategic

The first hierarchical level is strategic. Some possible improvement ideas that are proposed to the AP have their effect on the long term. The improvement ideas can be classified into capacity dimensioning and workforce planning, and will be discussed in this order.

6.1.1. Capacity dimensioning

By dimensioning the available capacity of the animal shelters differently, we could decrease the probability of working in overtime. We want to decrease the shortage of capacity in the quarters during the year, and at the same time use the surplus of the capacity. The first improvement idea is to work together with a regular veterinarian practice and the second is to outsource certain work activities. Furthermore, there is an improvement idea to use the surplus of capacity of one animal

shelter to help with the shortage at another animal shelter. The three options will be discussed in the following sections.

6.1.1.1. Work together with regular veterinarian practice

Generally, we see that there is a surplus of capacity in the second quarter of the year and a shortage for the rest of the quarters of the year at the animal shelters. This is equivalent to the expected demand. It is known that the division of demand over the year of a regular veterinarian practice is the opposite. Here, the demand will be the highest in the second quarter of the year and it will be lower in the second half year.

Therefore, we propose to conclude an agreement with a regular veterinarian practice to share some FTE. This veterinarian and/or vet technician will then work at both locations when there is a shortage of capacity. This means that he/she will work at the regular veterinarian practice in the second quarter of the year and the remainder of the year in an animal shelter. A reason not to hire additional FTE for the entire year, is that the surplus of capacity in the second quarter than only increases.

To realize this, an investment is needed since additional FTE needs to be hired. Salary calculations and investments are very difficult, a lot of different factors are involved. Therefore, we want to make an estimation which is as good as possible. First, we need the salary of a veterinarian and vet technician. We received the entire salary tree from the AP. Assuming a new hired veterinarian or vet technician will be in the first step of the salary scale, we take into account the following salaries: €2.943 for a veterinarian and €2.135 for a vet technician. Next, we need to calculate the employers costs. These account for 20% to 35% of the gross salary. For the calculation of the salaries, we used the employers costs equal to 30% and we assumed that the parttime salary will be determined proportionally. Furthermore, we need to make a choice about how many FTE additionally needs to be hired. The more additional FTE is hired, the lower the probability will be that staff members have to work in overtime and the more demand can be handled. On the other hand, the investment should be worth it. Therefore, we worked out some different scenarios. We looked at how many additional FTE was needed per kind of staff member and per animal shelter to get a probability of working in overtime below the threshold of 30%. For every staff member we increased the additional FTE by steps of 0.1, until the threshold was reached. Table 17 shows the results of this analysis.

Table 17 Additional FTE needed per kind of staff member to attain a change of working in overtime lower than the threshold, with its investment and improvement

FTE	Investment	Probability of overtime	E(X) [h]	SD(X) [h]
0.2 FTE veterinarian A	€765,18	0.55 → **0.15**	1.7 → 0.4	2.4 → 1.2
0.6 FTE veterinarian C	€2.678,13	0.64 → **0.28**	2.4 → 0.7	2.7 → 1.5
0.4 FTE vet technician A	€1.110,20	0.72 → **0.25**	2.7 → 0.5	2.7 → 1.1
0.2 FTE vet technician B	€555,10	0.60 → **0.26**	1.8 → 0.7	2.2 → 1.3
1.7 FTE vet technician C	€4.718,35	0.81 → **0.28**	3.8 → 0.6	3.3 → 1.2

To make sure both kind of staff members will have a chance of working of overtime lower than 30% at all three animal shelters, an investment of €9.826,96 per year needs to be made. This amount is based on the part of the salary corresponding to the amount of additional FTE hired, including the employers costs. Besides the improvement in probability of overtime, we can also identify an improvement in the expectation, so the mean, of the overtime. The animal shelters pay overtime hours as 'time for time'. Therefore, no clear calculation can be made on cost savings of this improvement idea. But since we lower the probability of working in overtime with this improvement idea, the expectation is that also the hours worked in overtime will be lower.

6.1.1.2. Outsourcing neutralizations

In the previous improvement idea we hired extra staff to better handle the demand. Another idea is to outsource this additional demand, especially neutralizations. Then the neutralizations will be performed by an external practice. This will lower the demand at the animal shelters, and also the probability of working in overtime, but this will increase the operating costs of the animal shelters. When a neutralization is performed by an external practice this will cost the AP double the cost per neutralization. These expected costs include both labor and material costs.

If we want to look at the improvement of this idea, we only look at the probability of working in overtime for the scheduled OR-blocks. Since neutralizations only are performed in these blocks and do not have influence on the consultation hours and rounds. Table 18 shows the current overtime probability, expectation and standard deviation of the OR blocks.

Table 18 Current probability of overtime for the OR-blocks

	Veterinarian			**Vet technician**		
	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.53	1.1	1.4	0.72	1.6	1.4
B	0.15	0.4	1.3	0.40	0.8	1.3
C	0.23	0.5	1.2	0.47	1.5	2.3

Taking into account the same threshold for the probability of working in overtime of 30%, we see that only for the veterinarians in A this probability is too high and for the vet technicians at all animal shelters. The high probabilities of the vet technicians can be explained by the large amount of cleaning activities. These are further discussed in Section 6.1.2.1. Therefore we now only focus on the veterinarians in A.

Analyzing the overtime of the veterinarians in A, we see that it is expected that the overtime will be the highest in Q1 and Q4. The expected amount of neutralizations that need to be performed for these quarters are on average 14 per week. We propose to outsource the half of the neutralizations (4 castrations and 3 sterilizations) during these two quarters. Doing this, the probability of overtime will decrease to 0.23, the expectation to 0.5 and the standard deviation to 1.0, taking into account that the costs will double for these neutralizations. This new probability of working in overtime is below the threshold.

6.1.1.3. Reallocating the available capacity between the animal shelters

A second option for the capacity allocation within the AP is to rearrange the current hired FTE between the animal shelters to lower the chance of working in overtime and use the current surplus of capacity. This option will only work for the veterinarians, but it will not need as a large investment as the option of working together with a regular veterinarian practice.

Table 13 shows that there is a surplus of capacity for veterinarians working at the animal shelter in B for the first three quarters of the year. As mentioned earlier, in the second quarter none of the animal shelter has a shortage of capacity. So, for this quarter no capacity has to be rearranged. The surplus of capacity in the first and third can be used to lower the chance of working in overtime at the other animal shelters.

In the first quarter the animal shelter in B has a surplus of 0.025 FTE. This corresponds to 1 working hour. Therefore the choice is made not to reallocate this capacity. The surplus of capacity in the third quarter is equal to 0.275 FTE, which is equal to 11 working hours. We have two options of reallocating these working hours, since both the animal shelters in A and C have a shortage of capacity in this quarter of the year. When the hours will be allocated to A, this will be equal to one working day of 8 hours and for C this will be equal to two working days of 5 hours.

Table 19 Results of reallocating the surplus of capacity of the animal shelter in B in the third quarter of the year

FTE	Probability of overtime	E(X) [h]	SD(X) [h]
0.2 FTE to A in Q3	0.55 → **0.45**	1.8 → 1.4	2.4 → 2.3
0.25 FTE to C in Q3	0.64 → **0.58**	2.4 → 2.2	2.7 → 2.7

For both options it is checked that the reallocating of the capacity will not lead to a probability of working in overtime above the threshold for the animal shelter in B. Analyzing the results in Table 19, we can identify that reallocating the surplus of capacity to the animal shelter in C will make a smaller improvement in the expectation of overtime compared to A. Unfortunately, neither of the options ensures that the probability of overtime decreases to under the predefined threshold.

6.1.1.4. Reallocating the capacity over the year

Currently, all staff members of the animal shelters have a so-called 'time-for-time' contract. This means that when a staff member works overtime, this time later can count as a day off. So, the hours worked overtime are not paid. This system can work when there is as much surplus of capacity compared to the shortage of capacity. Assuming this is the case, this can be taken into account at the beginning of the year.

When the demand for the coming year is forecasted, it can be translated to work hours per staff member. Then expected shortages and surpluses per month or quarter can be determined. When it is known in advance during which months or quarters there will probably be a surplus, less capacity per type of staff member can be planned. This capacity can then be used during months or quarters for which a shortage is expected. This still takes into account the 'time-for-time' principle, but now we plan ahead instead of staff members having to work overtime and then later taking days off.

To see whether this improvement idea will work, we determined the total hours of surplus and total hours of shortage of capacity for the year 2023. Table 20 shows the determined surplus and shortage hours per animal shelter.

Table 20 Determined surplus and shortage hours per animal shelter for the year 2023

	Veterinarian		Vet technician	
	Hours surplus	Hours shortage	Hours surplus	Hours shortage
A	64	194	40	432
B	337	65	85	291
C	71	783	70	1801

Since the determined surplus and shortage hours per animal shelter do not match, we can conclude that this improvement idea will not work for the current situation.

6.1.2. Workforce planning

6.1.2.1. Outsource cleaning activities

Analyzing the activities and how the working hours of the vet technicians are used, we see that a large part is used for cleaning activities. There are two times in the day when cleaning activities take place: between the treatment of two animals and at the end of the day. There are also quarterly cleaning activities. For this improvement idea, the last category is left out of scope. Every cleaning activity is divided into dry cleaning, wet cleaning and disinfection. Table 21 and Table 22 show every task of every cleaning activity of the vet technicians.

Table 21 Cleaning activities vet technician, part 1

	Dry cleaning	**Wet cleaning**	**Disinfection**
Between two surgeries or appointments	Clean counter Used towels in the laundry Clean up bulky waste from the table and floor When needed: dry wipe wash	Spray the tabletop with cleaning agent, wipe and dry with paper, think of the edge under the rubber mat Wet clean the scale If necessary, also clean the shelf next to the table Remove used materials (thermometer, otoscope, etc.) from visible dirt	Always disinfect table top and scale after use Disinfect used materials (thermometer, otoscope, stethoscope, etc.).
Treatment room (kennels), end of the day	Remove the pad from the kennel and dispose of it in the waste bin Clothes/towels in laundry bag Remove bulky loose dirt from the floor of the kennel with (possibly damp) tork paper	Spray the entire kennel with cleaning agent Think of the door, ceiling, side walls and doorknob Wipe dry thoroughly with a towel or paper	Disinfect every day
Treatment room (room), end of the day	Clean up everything, dishes from the counter, empty trash cans Dry wipe floor	Wipe all horizontal surfaces with a cloth and detergent, such as window ledges, RX device, shelf, countertop and wall behind it Wipe the table from top to base, also wet wipe under the rubber mat Clean all contact surfaces (door knobs, cabinet handles, faucet, feeding pots) Mop the floor in case of light soiling. Scrubbing with heavy soiling (blood, defecation)	Disinfect table every day, floor and surfaces in consultation

Table 22 Cleaning activities vet technician, part 2

	Dry cleaning	Wet cleaning	Disinfection
OR room, end of the day	Enable gas anesthesia device and hang hoses away (first wet wipe hoses) Clean up everything, loose instruments, packaging, strings, etc. Use paper to first collect blood/urine from the table, warming mats and floor	Wipe the table from top to bottom, including under the rubber mat Wipe all horizontal surfaces, such as lamp, RX device, and instrument table Thoroughly wipe dry with a cloth or paper Also wipe the gas anesthesia device with cleaning agent on a cloth, carefully wipe off all edges and wires	Disinfect table every day, floor and surfaces in consultation
Office space, end of the day	Tidy up the desk Empty garbage can when needed Dry wipe the floor	Clean all surfaces with detergent Clean contact surfaces (doorknob, drawers, keyboards) Wet mop the floor, especially the passage to the treatment room	With alcohol disinfection wipes from the jar, all contact surfaces

Outsourcing the cleaning activities between two animals makes no sense, since these are small tasks and do not take a lot of time. The cleaning activities at the end of the day together count on average for one and a half hour of work. Since the cleaning activities are not very difficult and they are elaborated extensively, it could be possible to outsource these activities to a cleaning company or assign these tasks to animal care takers. Both options are investigated, and the results are shown in Table 23.

Table 23 Results outsourcing cleaning activities

	Investment		Probability working overtime	E(X) [h]	SD(X) [h]
Hire cleaning company for 1.5 hours per day	€12.064,05	A	0.72 → **0.45**	2.7 → 1.7	2.7 → 2.5
		B	0.60 → **0.36**	1.8 → 1.0	2.2 → 1.8
		C	0.81 → **0.58**	3.8 → 2.6	3.3 → 3.0
Reallocate activities to animal care takers	€10.492,09	A	0.72 → **0.45**	2.7 → 1.7	2.7 → 2.5
		B	0.60 → **0.36**	1.8 → 1.0	2.2 → 1.8
		C	0.81 → **0.58**	3.8 → 2.6	3.3 → 3.0

For both options the results, so the improvements in probability of working in overtime together with the expectation and standard deviation per animal shelter, will be the same since in both cases all end of the day cleaning activities will be reallocated to another staff member other than vet technicians. With the calculation for the investments, the assumed hourly wage for a cleaning company is equal to €12,97 and the hourly wage of an animal caretaker is equal to €11,28. Again, employer costs of 30% are included. Unfortunately, this improvement idea alone will not lower the

probability of working in overtime below the preset threshold of 30%. Since the assumed investment of the second option is lower and the cost saving will be the same, the second option would be the preferred one. Implementing this solution could lead to a net cost saving of €52.706,04 per year. Unfortunately, the probability of working in overtime for an entire day for every animal shelter will not fall below the threshold of 30%.

6.2. Tactical

The second hierarchical level is tactical. In this level, the improvement ideas that effect the planning horizon on a medium term are discussed. This hierarchical level can be divided into block planning and admission planning. First the improvement ideas for the block planning are discussed, followed by the improvement ideas for the admission planning.

6.2.1. Block planning

Analyzing the current block schedule, improvement ideas are proposed on the daily and quarterly level. First we discuss an improvement idea on the daily level and next an improvement idea on the quarterly level.

6.2.1.1. Daily schedule

Looking at the current block schedule used at the animal shelters, some improvements can be made to reduce the idle time of both veterinarians and vet technicians. As mentioned earlier, most days start with surgeries, followed by appointments for animals from outside the animal shelter and the day ends with rounds by animals sheltered within the shelter. For surgeries, usually animals also come from outside the shelter. The animals are brought in between 08:30 and 08:45 o'clock at the animal shelters in A and B. For the animal shelter in C, the animals are brought in between 08:45 and 09:00 o'clock. Most staff members are already present at the animal shelter at 08:00 or 08:30 to prepare all procedures that have to be performed on that day. Only when this takes less time then there is idle time between the arrival of the staff members and the time the animals are brought in. So they have to wait until they can start with their day until all animals are brought in that need surgery that day.

On most days something unexpected happens at the animal shelters. Either a surgery is delayed because it takes longer than expected or an emergency case is brought in by an animal ambulance. Both events delay later procedures of that day. Therefore, it happens often that the rounds along sheltered animals are performed in overtime or they finish just within the regular working hours and then all the administration has to be done in overtime.

A reason to schedule the rounds at the beginning of the day, especially in the beginning of the week, is that animal caretakers often have questions about the care they provide to the sheltered animals. For example, over the weekend some animals became more ill and they need immediate attention from the veterinarian. The animal caretakers will disturb the work processes of the veterinarian and vet technician. When we introduce the rounds at the beginning of the day, the idle time during the day caused by disturbances will also decrease.

Therefore, we want to propose an adaptation to the block schedule of the animal shelters. This adaptation is shown in Figure 21. We see that on most days the rounds along sheltered animals is performed right at the beginning of the day, after the preparation of the vet technicians. This is the only activity for which the staff members are not dependent of the arrival of animals. When the arrival time that is communicated to the owners of the animals stays the same, so between 08:30 and 08:45 o'clock or 08:45 and 09:00 o'clock, the idle time of the staff members will reduce. At the same time, the overtime of staff members will also decrease since now the administration of the rounds can be done within working time, during the idle time over the day. When only surgeries are performed on a day, we propose to start operating on an animal that is sheltered within the animal shelter for the same effect.

A	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday										
Tuesday	prep	Rounds		OR		OR		Consultation hour	Admin	
Wednesday										
Thursday										
Friday		prep	Rounds		OR		OR		Consultation hour	Admin

B (odd weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR		Consultation hour	Admin
Tuesday										
Wednesday		prep			OR			OR	Admin	
Thursday		prep	Rounds		OR		OR		Consultation hour	Admin
Friday										

B (even weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR		Consultation hour	Admin
Tuesday										
Wednesday										
Thursday	prep	Rounds		OR		OR		Consultation hour	Admin	
Friday										

C	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep		OR+Consultation hours		OR+Rounc	Admin			
Tuesday		prep	Rounds	OR		OR	Admin			
Wednesday		prep	Rounds	OR		OR	Admin			
Thursday		prep		OR		OR	Admin			
Friday		prep	Rounds	OR		Consult	Admin			

Figure 21 Proposed block schedule

For the calculation of the idle time and overtime, some assumptions have been made. For determining the idle time, we assumed that 5% of the animals arriving will be late and that they will be on average 5 minutes late. The proposed block schedule mostly has a positive effect on the decrease of idle and overtime when more than one vet technician is working on a day, because then one vet technician can prepare the OR when the other goes on rounds with the veterinarian. Then when the second veterinarian returns from the rounds, the first one has prepared the OR and the surgeries can start immediately. When there is only one vet technician working, this effect will be lower. That is why we only accounted for this effect on days there is more than one vet technician present. Furthermore, we assume that this possible solution will reduce the idle time caused by questions of animal caretakers by half, since there could still arise questions about sheltered animals during the day. Table 24 shows the expected improvement when introducing this proposed new block schedule.

Table 24 Expected improvement based on idle time hours per year of the proposed block schedule

	Current block schedule	**Proposed block schedule**	**Improvement**
A	1447.6 hours	1084.5 hours	-363.1 hours
B	1693.2 hours	1522.8 hours	-170.4 hours
C	4821.7 hours	2890.8 hours	-1930.9 hours

Translating this decrease of absolute idle hours, we can identify a decrease of idle hours in A of 25%, in B of 10% and in C of 40%.

6.2.1.2. Quarterly block schedule

Analyzing the graphs in Figure 20, some trends stand out. As stated earlier, there are quite some quarters for which a shortage of capacity is predicted. Proposing changes to the current block schedule will not lead to an option where there is no overtime expected, but improvements can lead to a higher job satisfaction.

At every animal shelter, we see a similar pattern for the activities OR, consultation hour and in-house rounds. The demand for surgeries, so OR-activities, is higher in Q1 and Q4 compared to the other two quarters. For consultations, the demand is the highest in Q1 and Q3 and is lower in Q2 and Q4. For the last activity, the in-house rounds, the demand is the highest in Q1 and Q2, and lower in Q3 and Q4. We see that the demand for all activities is relatively high in the first quarter. Therefore we propose to keep using the block schedule as discussed earlier during this quarter. For the other three quarters we propose to use the block schedules of Figure 22, Figure 23, and Figure 24. During Q2 the available time for rounds is increased with a half hour per day and the consultations are decreased with half an hour. During Q3, the OR time is decreased with an hour and the consultations increased with an hour. During the last quarter the OR time is increased with an hour and the available time for rounds and consultations are both decreased by half an hour.

With this solution no cost savings can be earned, but there is a high change that the job satisfaction will increase since staff members have a better insight into their activities per quarter.

A	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday										
Tuesday	prep	Rounds		OR		OR		Consultation	Admin	
Wednesday										
Thursday										
Friday		prep	Rounds		OR		OR		Consultation	Admin

B (odd weeks)	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	Rounds		OR		OR		Consultation	Admin
Tuesday										
Wednesday		prep		OR			OR		Admin	
Thursday		prep	Rounds		OR		OR		Consultation	Admin
Friday										

B (even weeks)	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	Rounds		OR		OR		Consultation	Admin
Tuesday										
Wednesday										
Thursday	prep	Rounds		OR		OR		Consultation	Admin	
Friday										

C	**08:00**	**09:00**	**10:00**	**11:00**	**12:00**	**13:00**	**14:00**	**15:00**	**16:00**	**17:00**
Monday		prep	OR+Consultation hours			OR+Rounc	Admin			
Tuesday		prep	Rounds	OR		OR	Admin			
Wednesday		prep	Rounds	OR		OR	Admin			
Thursday		prep		OR		OR	Admin			
Friday		prep	Rounds	OR		Consult	Admin			

Figure 22 Block schedule quarter 2

A	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday										
Tuesday	prep	Rounds		OR			Consultation hour		Admin	
Wednesday										
Thursday										
Friday		prep	Rounds		OR		OR	Consultation hour		Admin

B (odd weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR	Consultation hour		Admin
Tuesday										
Wednesday		prep		OR				OR		Admin
Thursday		prep	Rounds		OR		OR	Consultation hour		Admin
Friday										

B (even weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR	Consultation hour		Admin
Tuesday										
Wednesday										
Thursday	prep	Rounds		OR			Consultation hour		Admin	
Friday										

C	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep		OR+Consultation hours		OR+Round	Admin			
Tuesday		prep	Consult	OR		OR	Admin			
Wednesday		prep	Rounds	OR		OR	Admin			
Thursday		prep		OR		OR	Admin			
Friday		prep	Consult	OR		Consult	Admin			

Figure 23 Block schedule quarter 3

A	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday										
Tuesday	prep	Rounds		OR		OR		Consultation	Admin	
Wednesday										
Thursday										
Friday		prep	Rounds		OR		OR		Consultation	Admin

B (odd weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR		Consultation	Admin
Tuesday										
Wednesday		prep		OR				OR		Admin
Thursday		prep	Rounds		OR		OR		Consultation	Admin
Friday										

B (even weeks)	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep	Rounds		OR		OR		Consultation	Admin
Tuesday										
Wednesday										
Thursday	prep	Rounds		OR			OR		Consultation	Admin
Friday										

C	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Monday		prep		OR+Consultation hours		OR+Round	Admin			
Tuesday		prep		OR		OR	Admin			
Wednesday		prep	Rounds		OR		OR	Admin		
Thursday		prep		OR		OR	Admin			
Friday		prep	Rounds		OR		Consult	Admin		

Figure 24 Block schedule quarter 4

In all block schedules proposed we see that there still is a shortage in time available to perform all expected procedures. We see this mainly on the days only one vet technician is available. The time that is left at the end of the day to do administration and clean the OR is only half an hour. This duration is way too short to perform all tasks. Therefore, some additional improvement ideas are proposed and discussed in the following sections.

6.2.2. Admission planning

The second point of improvement in the tactical level has to do with the admission planning. Improvement areas for admission planning can be divided into three different ideas: spreading of the neutralizations over the quarters, shorten the length of stay when you know there follows a busy period, and the planning of capturing animals in the wild. The last two have some characteristics in common. The three improvement ideas will be discussed in the following sections.

6.2.2.1. Spreading neutralizations over the quarters

As mentioned in Section 1.4.1, it is preferred that an animal is neutralized between the age of six and nine months. In the current situation the animal shelters adhere to these rules. The consequence of this is that we see a peak in expected surgery time for the first and fourth quarter of the year. Then all the kittens and puppies that are born in the spring are old enough for their neutralization and they are planned. Since kittens and puppies are bought by a new owner as a 'total package', so including a neutralization, the animal shelters need to execute the neutralizations. One option is to outsource some of the neutralizations, as discussed in Section 6.1.1.2. This option means that one neutralization will cost the AP double the costs. Another option is to spread the neutralizations over the quarters. In this case the rule of neutralizing an animal between the age of six and nine months is relaxed. Some animals will be neutralized at a younger age and some at an older age. Since the demand for neutralizations is the highest in the first and fourth quarter a part of the neutralizations requested in the first quarter is delayed and a part of the neutralizations requested in the fourth quarter is planned in advance. The outcome showed in Table 25 is obtained by shifting 10% of the neutralizations between the quarters. Which means that 10% of the neutralizations is performed three months later or three months earlier.

Table 25 Change in probability, expectation, and standard deviation of overtime after spreading the neutralizations

	Veterinarian			**Vet technician**		
	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.55 → **0.42**	1.8 → 1.2	2.4 → 2.0	0.72 → **0.77**	2.7 → 2.8	2.7 → 2.7
B	0.17 → **0.19**	0.6 → 0.6	1.8 → 1.4	0.60 → **0.57**	1.8 → 1.7	2.2 → 2.0
C	0.64 → **0.57**	2.4 → 2.1	2.7 → 2.5	0.81 → **0.83**	3.8 → 3.7	3.3 → 3.2

The results in Table 25 show in most cases a small decrease in the probability of working in overtime. This improvement idea alone will not ensure that the probabilities will fall below the threshold, except for the veterinarians in B for which this was already the case. For the vet technicians in A and C we see an opposite effect than we desire, the probability of working in overtime increases. A possible explanation of these outcomes could be that during most weeks the available OR time is already used, so also in the second and third quarter. The probability of working in overtime is a probability per week. So if we try to flatten the demand, the vet technicians will still work in overtime during the first and fourth quarter but the expectation will slightly decrease. Since most of the available OR time is already used in the second and third quarter, now the surgeries performed in these quarters increase and therefore vet technicians are more likely to work in overtime. Since we calculated the probability of working in overtime per week, this number will increase.

6.2.2.2. Shorten length of stay

The more animals are sheltered in an animal shelter, the more attention and time is asked from a veterinarian and therefore also from a vet technician. The more animals are present inhouse, the more animals need to be seen during the rounds. Therefore we want to propose the improvement idea to try shorten the length of stay during or before a known busy period at the animal shelters. A disadvantage with which the AP has to deal is that they can only start with the treatment of an animal 14 days after arrival. So the minimum length of stay of an animal will always be 14. Table 26 shows the average length of stay of animals at the animal shelters per quarter of the year. We can identify that on average the length of stay of animals is shorter in the first half year, compared to the second

half year, at all three animal shelters. The workload of both vet technicians and veterinarians are high during the quarters where the average length of stay is also higher. To lower their workload, we want to shorten the length of stay of animals during the third and fourth quarter.

Table 26 Average length of stay per quarter per animal shelter

	Q1	**Q2**	**Q3**	**Q4**
A	23	25	33	31
B	23	23	34	42
C	23	25	37	38

We have to lower the average length of stay of the third and fourth quarter by 25% to get equal values compared to the average length of stay for the first and second quarter. When the decrease of 25% can be reached, we assume that the inhouse rounds for these quarters can be decreased with 10%. The decrease of length of stay and requested inhouse rounds are not equal since we already concluded in Section 2.3.5 that the number of received inhouse rounds and length of stay of an animal have no linear relationship.

Table 27 Change in probability, expectation, and standard deviation of overtime after shortening the length of stay

	Veterinarian			**Vet technician**		
	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.55 → **0.53**	1.8 → 1.7	2.4 → 2.4	0.72 → **0.72**	2.7 → 2.6	2.7 → 2.7
B	0.17 → **0.15**	0.6 → 0.6	1.8 → 1.8	0.60 → **0.58**	1.8 → 1.7	2.2 → 2.1
C	0.64 → **0.64**	2.4 → 2.4	2.7 → 2.7	0.81 → **0.79**	3.8 → 3.7	3.3 → 3.3

Assuming the inhouse rounds will be decreased by 10%, we see a little or no decrease in the probability of working in overtime in Table 27. The same trends can be identified for the expectation and its standard deviation. This improvement idea is a good goal for the AP to have a more equal length of stay for animals throughout the year, but it will not have much effect on the probability of working in overtime for veterinarians and vet technicians.

6.2.2.3. Planning of capturing animals in the wild

The last improvement idea that regards the admission planning touches the planning of capturing animals in the wild. The idea behind this improvement idea is a bit the same as the idea of shortening the length of stay. It does not make sense to capture animals in the wild, treat and shelter them when there is already a peak of animals that are sheltered inhouse. Since the capturing activities cause a lot of work, the veterinarians in A and B refuse to take on these animals. In C, these capturing activities do take place and they are not planned. So the AP and animal ambulance decide without consulting the veterinarians to plan a capturing activity. With this improvement idea we want to plan the capturing activities during a more calm period to avoid a sudden increased workload for the veterinarians and vet technicians.

Looking at the animals that are present per month in C, we see a peak in the third quarter. This can be explained by the kittens and puppies that are born and are brought to a shelter. Further analyzing the animals present in C, we can identify a dip in the first and fourth quarter. Since there is already a peak in requests of inhouse rounds in the first quarter, we could propose to focus on capturing animals in the wild in the second and fourth quarter.

Table 28 Average arrivals from capturing activities for wild animals

Q1	**Q2**	**Q3**	**Q4**
59	49	78	101

Table 28 shows the average number of arrivals of wild animals at the animal shelter in C, based on the data gathered from the years 2019 until 2022. The effect of not planning the capturing activities is not entirely as we would have wanted. The arrivals of wild animals is already high in the fourth quarter, but they are also high in the third quarter which we have identified as a peak quarter. When the capturing activities are better planned, we estimate that 35% of the wild animals can be captured in the second quarter instead of in the third.

With the calculation of this improvement idea, some assumptions needed to be made. We assumed that 75% of the arriving wild animals still need to be neutralized. Thereby we assumed that the animals are 50/50 male and female. The last assumption is that every arriving wild animal requires a minimum of one consultation of a veterinarian, during the inhouse rounds. This is the minimum required care by the animals, therefore the improvement of Table 29 is a minimal improvement.

Table 29 Change in probability, expectation, and standard deviation of overtime after planning the capturing activities

	Probability working overtime	**E(X) [h]**	**SD(X) [h]**
Veterinarian	0.64 → **0.64**	2.4 → 2.4	2.7 → 2.7
Vet technician	0.81 → **0.79**	3.8 → 3.7	3.3 → 3.3

Table 29 shows that this improvement idea will not have much effect on the probability of working in overtime for the veterinarians. It does have a small effect on the probability, expectation and standard deviation of the vet technicians. This shows that a shift of 35% of the wild animals will not be sufficient to lower the workload of the veterinarians. It could increase the job satisfaction of the staff members, since they can better anticipate the arrival of a large group of animals when the capturing activities are planned.

6.3. Operational offline

The third and last hierarchical level is operational offline. At this level we want to introduce improvement ideas in the categories appointment scheduling and workforce scheduling. The improvement ideas will be handled according this order in the following sections.

6.3.1. Appointment scheduling

The first improvement idea on the operational level of planning will look at the efficiency of appointment scheduling and the possibility of planning multiple animals at the same time or in the same time slot. Looking at all surgeries performed in the OR of the animal shelters, a castration is by far the least complicated surgery. Especially when the castration is performed on cats. It can also be seen as assembly line work.

Looking at the proceedings of both the veterinarian and vet technician, they do not differ that much of the other surgeries. First the animal needs to be sedated. When the anesthetics have worked in properly, the vet technician starts with the preparations for the OR. These exist of shaving, washing/disinfect, checking the chip, ears, fleas, and sex, and administer painkillers. Then usually the animal is transferred to the OR and is connected to the gas anesthesia device. With the castrations of cats, this step differs from the other surgeries. Cats that are castrated are not transferred to the OR, but are treated on the treatment table. This entire process takes on average about 20 minutes. Then the intervention from the veterinarian only takes 3 to 4 minutes.

Comparing the actual surgery time of the veterinarian with the preparation time of a vet technician we see that these times differ a lot. In the time a veterinarian castrates a cat, the vet technician can never prepare the next animal for surgery. Since the castration of a cat can be seen as assembly line work, we propose to plan and perform three castrations of cats at the same time. A vet technician can prepare three cats for castration at the same time and a veterinarian also can castrate three cats at the same time. Then the total preparation time will decrease and the veterinarian and vet technician can better work in parallel.

In the current situation, the preparation of three cats will take about an hour and the surgery time will take about 12 minutes. With this proposed adjustment of appointment scheduling the surgery time will stay the same but the preparation time will decrease to 25 minutes in total.

When we look at the surgeries performed in the years 2019, 2020, and 2021, we see that on average 64% of the total performed castrations in A are on cats. For the animal shelter in B this percentage is equal to 92% and in C 62%. Assuming these percentages stay the same for the year 2023, we expect that there will be performed 186 castrations on cats in A, 189 in B, and 400 in C. In the current situation this will account for 62 hours of preparation time per year in A, 63 hours in B, and 133,3 hours in C. When we introduce this adjustment of appointment scheduling, the preparation time of the vet technicians can be decreased to 25,83, 26,25, and 55,56 hours respectively. This is an decrease of 58% per animal shelter for the castrations on cats.

6.3.2. Workforce scheduling

6.3.2.1. Parallelize work of veterinarians and vet technicians

As shortly mentioned in previous sections, we could decrease the total working time of veterinarians and vet technicians when we parallelize work activities of both staff members because then the idle time is decreased. During observations at the animal shelters in A, B and C we noticed that mostly the veterinarians have idle time. The idle time of a veterinarian increases when only one vet technician is present on a day. As mentioned in Section 5.2.2, the time it takes a veterinarian to prepare an animal for surgery sometimes is longer than the surgery itself. Furthermore, a veterinarian tends to take on tasks that are defined in the job description of a vet technician. A veterinarian takes on tasks such as additional administration or some cleaning tasks to avoid doing nothing. From the AP's point of view, these tasks are more expensive then when they are carried out by a vet technician.

As a first step in the process of parallelizing the work processes of veterinarians and vet technicians we created a work schedule for a day where there would be one veterinarian and one vet technician present. The chosen surgeries are semi random to what fitted in the predefined OR-time. The work schedule with the work processes per staff member can be found in Figure 25 and Figure 26. In this work schedule we see that there is a lot of idle time for the veterinarian. We did some suggestions of filling up this time, such as administration although this usually fits into the job description of the vet technician. We can identify that there are only 10 minutes available at the end of the first OR block as buffer for surgeries that possibly take longer than expected. This time could be used for administration when every surgery takes as long as expected. The second OR block a little over a quarter as buffer. We made the choice to schedule the administration of the appointments directly after the appointment itself. In that way we build in a buffer for when owners show up to late with their animals for their appointment. The choice can also be made to schedule all appointments one after another. Then the administration block will come at the end of the consultation hour block. At the end of the day, we see that there is only half an hour left to clean the OR, treatment room and do all the additional administration such as pharmacy management and placing orders. This is way too little time, so the probability that the vet technician has to work in overtime is very big. Therefore we also looked at the possibility of assigning two vet technicians to work per day. A work schedule where two vet technicians are working is shown in Figure 27 and Figure 28.

In this work schedule we have placed exactly the same work activities for a veterinarian and we have tried to organize the work processes of the three staff members as much as possible. One thing that is different for the veterinarian between the two work schedules is that he/she now works from 08:30-16:30 o'clock instead of from 09:00-17:00 o'clock. The biggest difference between the two schedules in the OR block is that we see that work activities better can be parallelized when two vet technicians are working. In that case we can realize a buffer of almost two hours. This time can be partially used as buffer, but also as time to perform additional surgeries. The block for appointments looks similar to the other schedule, but the difference is that one of the two vet technicians now already has the opportunity to start with cleaning of the OR so that this does not need to be done at the end of the day. Then at the end of the day, there is half an hour (or in case of the second vet technician an hour) left to clean the treatment room, finish the administration, and other activities.

Table 30 and Table 31 show the most important changes for this improvement idea.

Table 30 Results parallelizing work processes, part 1

	Investment per year	**Possible improvement**
A	€2.220,40	24% decrease in OR time used for same activities, decrease of overtime per day
B	€4.440,80	
C	€346,94	

Table 31 Results parallelizing work processes, part 2

	Veterinarian			**Vet technician**		
	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.55 → **0.30**	1.8 → 1	2.4 → 1.9	0.72 → **0.62**	2.7 → 2.0	2.7 → 2.4
B	0.17 → **0.15**	0.6 → 0.5	1.8 → 1.4	0.60 → **0.43**	1.8 → 1.2	2.2 → 1.8
C	0.64 → **0.55**	2.4 → 1.9	2.7 → 2.5	0.81 → **0.74**	3.8 → 3.2	3.3 → 3.1

Table 30 shows the investment and possible improvement of the decreased OR time. The investments per year are the estimated increase of staff costs to ensure that every day an animal shelter is opened a minimum of two vet technicians are present. The possible improvement of a decrease of 24% in OR time is based on a day with an OR block of 4 hours. This decrease in OR time can be achieved on days that the occupation of vet technicians is lower than two. We assume that in the current situation the veterinarians and vet technicians already work more in parallel when there are two or more vet technicians present, compared to a day when there is only one vet technician present. But still some improvements can be made, so we assume that on these days the maximum decrease in OR time is equal to 10%.

Analyzing the results in Table 31, we see for the veterinarians in A and B that the probability of working in overtime decreases to under the threshold. Unfortunately this is not the case for the veterinarians in C and vet technicians at all animal shelters. Here, the probability decreases slightly, but not below the threshold of 30%.

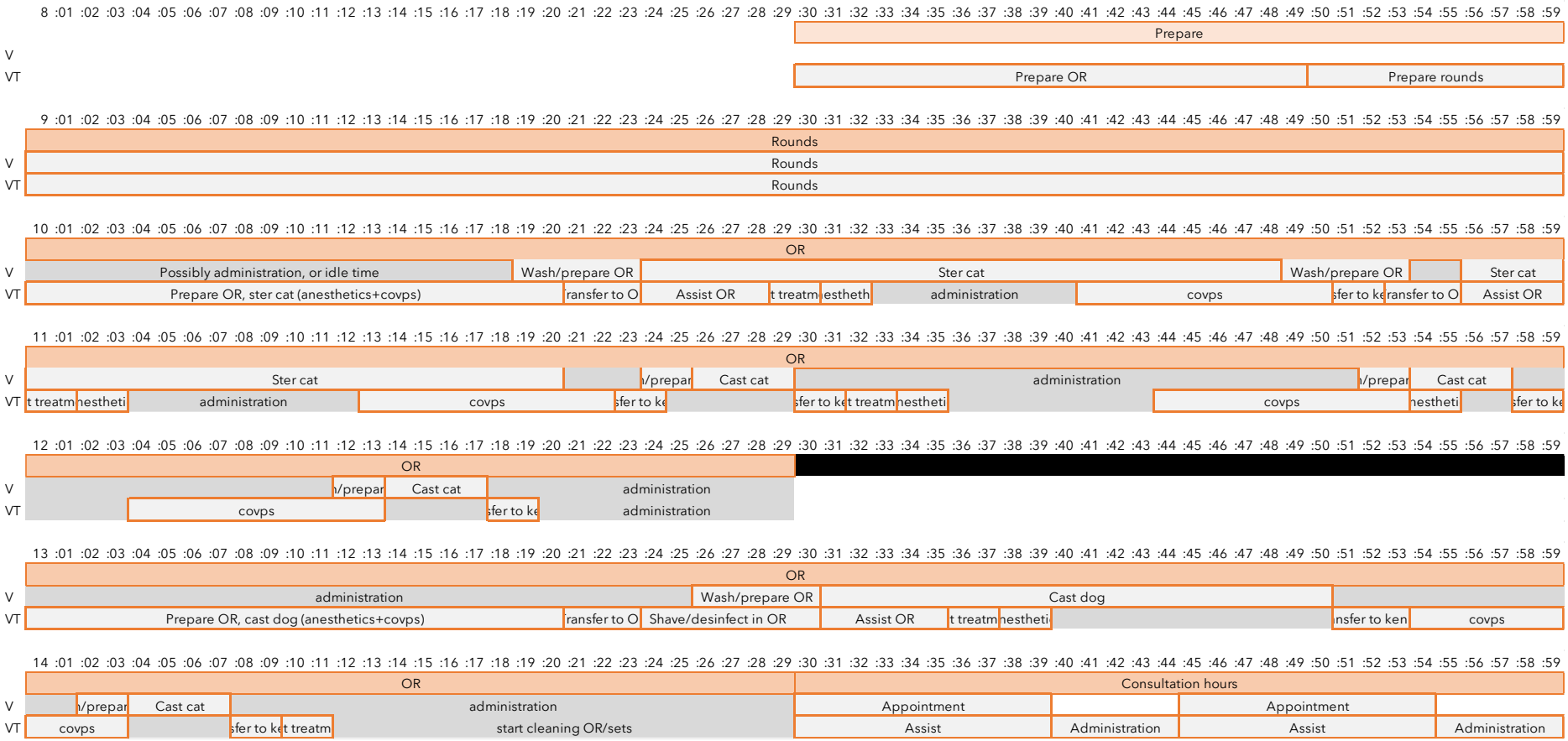


Figure 25 Parallelizing work processes, one vet technician present part 1

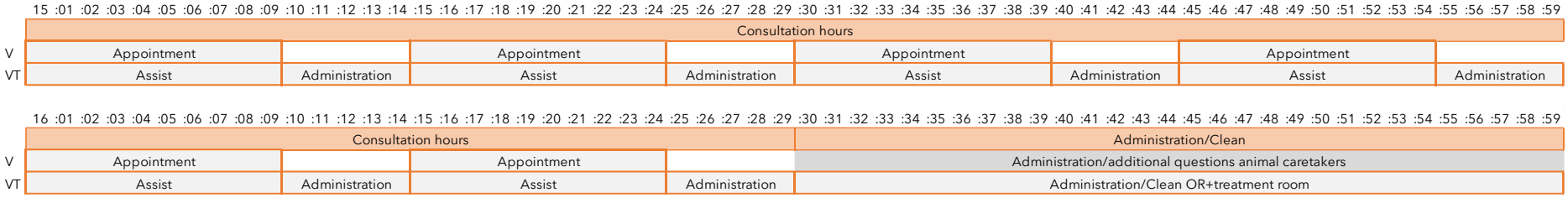


Figure 26 Parallelizing work processes, one vet technician present part 2

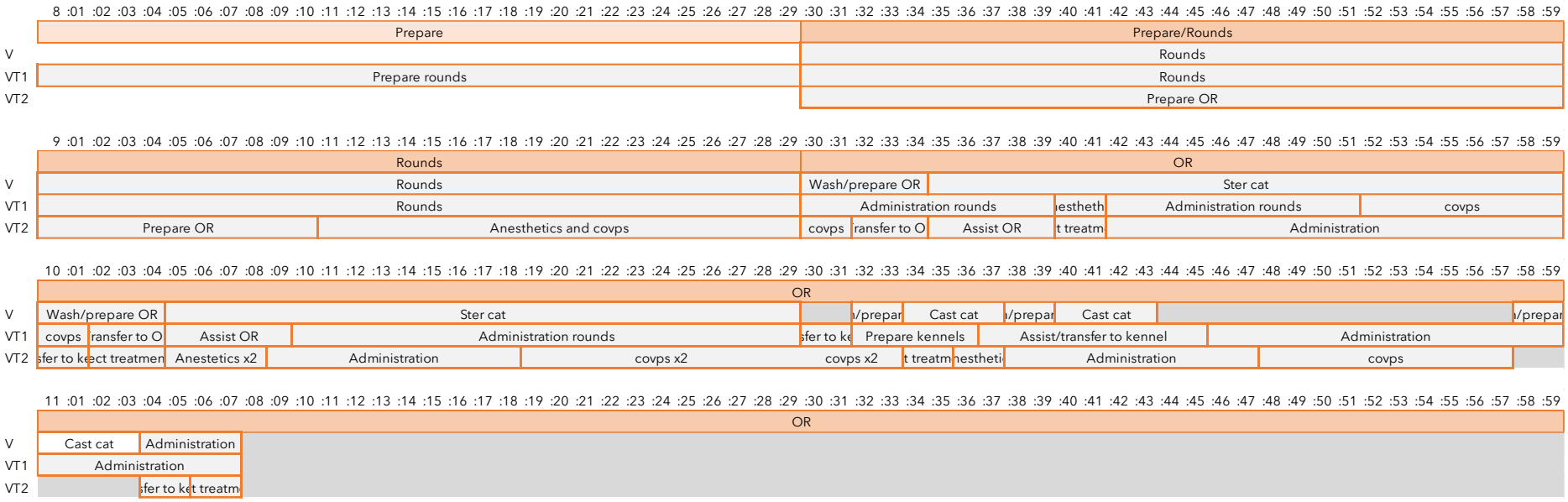


Figure 27 Parallelizing work processes, two vet technicians present part 1

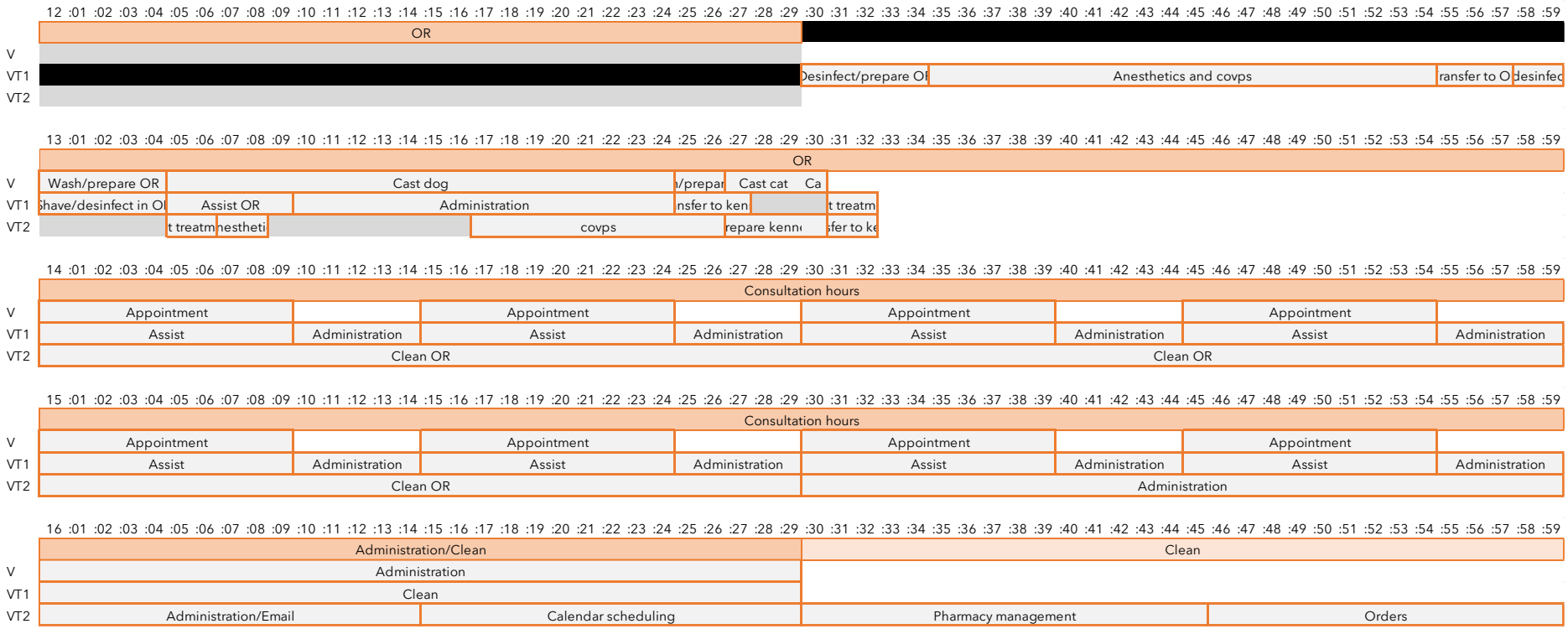


Figure 28 Parallelizing work processes, two vet technicians present part 2

6.3.3. Other

The last improvement idea focuses on reducing the idle time caused by interruptions of animal caretakers. Throughout the day caretakers come inside the OR- and treatment room with questions regarding the care that needs to be provided to the sheltered animals. When veterinarians and vet technicians are asked a question, it can be seen as idle time regarding their normal activities. This idle time not only counts for the time the animal caretaker asks the question, but they are also idle for a longer period of time since they are taken out of their concentration. We have come up with two improvement ideas that touch upon this problem. The first one is introducing work lists where animal caretakers can state their questions during the day. Half an hour, at the end of the day, is then reserved in the work schedule of the veterinarian to handle these questions. With this solution, we create a work environment where the animal caretakers have the feeling their questions are being heard and we keep the disturbances for the veterinarians and vet technicians to a minimum. Another option would be to install a (red) light above the OR- and treatment rooms. When the light is switched on, veterinarians and vet technicians cannot be disturbed by questions. When the light is switched off, animal caretakers can enter. This solution will lead to a comparable outcome. We believe that with this improvement idea, the idle time caused by disturbances can decrease by 50%.

6.4. Conclusion

This chapter discussed thirteen improvement ideas to reduce the gap between the demand and supply of the animal shelters located in A, B, and C. The improvement ideas were placed in the hierarchical framework of planning and control. We expressed the reduction of this gap in the decreasing probability of overtime. Together with the overtime probability we also provided the expectation and the standard deviation of the overtime.

Analyzing the improvement ideas, we saw that only hiring additional capacity and parallelizing work processes will ensure the overtime probability for all staff members will decrease to under the preset threshold of 30%. The other improvement ideas will ensure that the overtime probability and the expectation will decrease, but not below the threshold. For the improvement ideas quarterly adaptation of the block schedule, spreading the neutralizations, shorten the length of stay and planning the capturing of wild animals we saw little to no improvement.

Implementing these thirteen improvement ideas all at once can be confusing, since different ideas concern the same staff members and their work processes. Therefore three improvement ideas have been selected, together with the AP, for which an implementation is developed. The selection is based on the expected improvement and feasibility in practice. The ideas that will be implemented are reallocating the capacity of staff members differently over the shelters per quarter, outsourcing the cleaning activities, and parallelize the work processes of veterinarians and vet technicians.

7. Implementation plan

This chapter will discuss the steps that need to be taken to implement the selected improvement ideas from Chapter 6 and achieve the mentioned goals. During the development of the implementation plan it was discovered that the improvement ideas relate to each other. For example, one improvement idea is needed as the preparation of another idea. Therefore, the three improvement ideas are combined and presented as one solution. Figure 29 shows the implementation roadmap, where every activity of the implementation plan is displayed with its deadline. We made the roadmap general by indicating in which month the activity needs to take place after starting with the implementation. In that way, the AP can start with start with the implementation of the solution at any point in time. In the preferred situation, the implementation starts in April 2023. Then all changes can be implemented before the start of 2024.

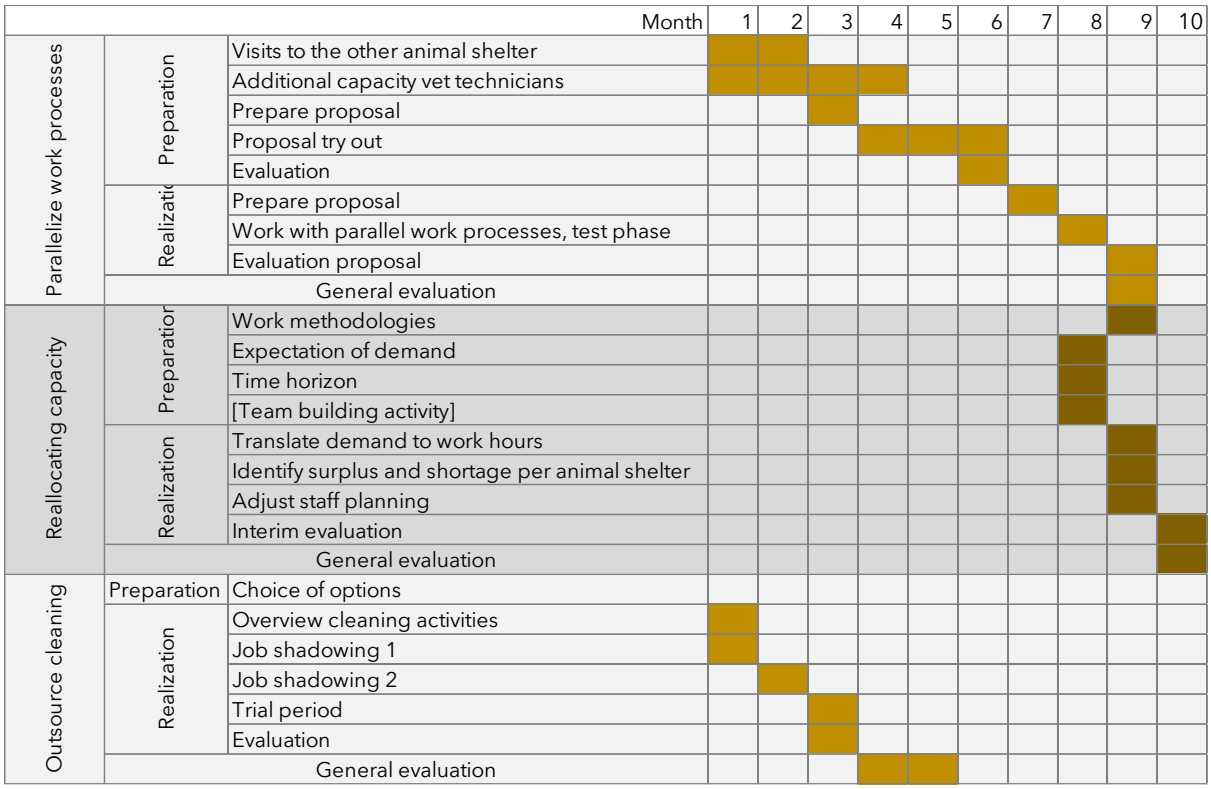


Figure 29 Implementation roadmap

In Section 4.4, we discussed the strategy changeover time reduction. The steps of this strategy are linked to the better known PDCA-cycle. Since Section 2.6 concluded that the change program that will be introduced should be a continuous process, we chose to use the PDCA-cycle for our implementation plan. The following sections each describe a part of the solution, which are built up from preparation, realization, and evaluation activities. Preparation activities can be linked to the Plan activities of the PCDA-cycle. Similarly, realization activities can be linked to the Do activities and evaluation to the Check activities.

7.1. Parallelize the work processes of veterinarians and vet technicians

The first part of this implementation plan deals with parallelizing of the work processes of veterinarians and vet technicians. This is an operational change, which means that it can be implemented on the short term. Besides, the synchronization of work processes between the animal shelters is needed as a preparation of other implementations. Therefore, we start the implementation plan with this part of the solution.

7.1.1. Preparation

Some preparations need to be made before we can start with parallelizing the work processes of veterinarians and vet technicians. In the current situation, the staff members work in two teams. Two veterinarians and two vet technicians work for the animals shelters in A and B, where both locations are opened two or three times per week. The animal shelter in C is opened five times per week. For this shelter work two veterinarians and three vet technicians. For some procedures, the teams have different work methodologies. If we want to parallelize the work processes, and later reallocate capacity, it is convenient that all procedures are performed the same by both teams. We have defined different activities that need to be performed in a certain order. These are listed in Table 32. Per activity we mention the goal, responsible, and deadline.

Table 32 Preparation activities before parallelizing work processes

Activity	Goal	Responsible	Deadline
Visits to the other animal shelter	Get familiar with the work methodologies of the other animal shelter	[All] veterinarians [All] vet technicians	End second month
Additional capacity vet technicians	Increase the total capacity of the vet technicians, such that every day an animal shelter is opened two vet technicians can be present	Management animal shelters	End fourth month
Prepare proposal	Write down a proposal which entails the work methodologies per procedure	One veterinarian and one vet technician of every veterinary team	End third month
Proposal try out	Try out the composed proposal, look for bottlenecks and improvements	All veterinarians and vet technicians	Month four and five, and the first two weeks of month six
Evaluation	Evaluate the 'new' work methodologies and make adjustments where needed	One veterinarian and one vet technician of every veterinary team	Third week of month six

Visits to the other animal shelter

The first activity of creating general work processes are the visits of veterinarians and vet technicians to another animal shelter. Since there are two veterinary teams, it is sufficient to visit one other animal shelter of the other team. So for example, a veterinarian that works in C visits either A or B for a day and a veterinarian that works in A visits C for a day. The same holds for the vet technicians, which preferably take place together with the veterinarian visits. The goal of this activity is to get familiar with the work methodologies of the other veterinary team, and identify differences and similarities. We plan two months for this activity since this activity can be time consuming, because staff members may have to visit the other animal shelter during their day off. The activity will take place during the first two months of the implementation period.

Additional capacity vet technicians

Parallel to the activity of visiting another animal shelter for veterinarians and vet technicians, the management of the animal shelters responsible for assuring there will become additional capacity available for veterinarian hours. This can be arranged in two ways, as described in Section 6.1.2.1. One option is to assign additional hours to the current vet technicians. Whether this is a possibility, has to be discussed with the vet technicians themselves. Staff members can have their own reasons to not want to work additional hours. When the additional hours needed cannot be filled with the

current staff members, the management of the animal shelters need to hire (a) new staff member(s). The deadline for the additional capacity is the fourth month of implementation. When (a) new staff member(s) need to be hired, this person still has one month left to be incorporated with the new proposal of work methodologies.

Prepare proposal
After the mutual visits have taken place, a proposal can be prepared. This proposal will entail the work methodologies per procedure and how they will be carried out from now on. A work group consisting of one veterinarian and one vet technician from both veterinary teams will be formed. This work group will be responsible for drawing up this proposal. The deadline of this activity is the end of the third month, which gives the work group one month to draw up the proposal and present it to the remainder of the veterinary teams.

Proposal try out
During the following months the proposal of work methodologies has to be tested and used at all animal shelters. Therefore, all veterinarians and all vet technicians are responsible. In this test period, the staff members get the opportunity to look for possible bottlenecks and improvements of the drafted proposal. We also included the first two weeks of the sixth month. We made this choice, since months four and five will be July and August if the implementation starts in April. During these months, staff members usually take their vacation days. The identified bottlenecks and/or improvements can later be discussed in the evaluation of the new work processes.

Evaluation
The last activity of this preparation will be an evaluation. During the third week of the sixth month the work group that drafted the proposal for the work processes will meet again and discuss the bottlenecks and/or improvements which they encountered within their veterinary team. Adjustments to the work processes can be made where needed.

7.1.2. Realization

Now that the animal shelters use the same work processes for all procedures and enough capacity for the vet technicians is hired, the process of parallelizing the work processes of veterinarians and vet technicians can start. Again, we identified some activities that have to be performed. Per activity we defined a responsible, goal, and deadline. The activities are listed below in Table 33.

Table 33 Realization activities for parallelizing the work processes

Activity	Goal	Responsible	Deadline
Prepare proposal	Write down a proposal which entails the parallel work processes	One veterinarian and one vet technician of every veterinary team	Second week month seven
Work with parallel work processes, test phase	Try out the composed proposal, look for bottlenecks and improvements	All veterinarians and vet technicians	End month eight
Evaluation proposal	Evaluate the parallel work methodologies and make adjustments where needed	One veterinarian and one vet technician of every veterinary team	First week month nine

Prepare proposal
Since it could be possible that a few new changes are made to the work methodologies of the veterinarians and vet technicians in the third week of month six, we would like to give the staff members some time to adjust to these changes. Therefore it is planned to start with drawing up a proposal for parallel work processes during the first two weeks of month seven. Composing this

proposal can seem more complicated compared to the proposal of identical work processes. But since Chapter 6 of this research can be used as a starting point, we reserve two weeks of time for this activity. It is important that it becomes clear in this proposal which task and activity has to be carried out by which staff member. Again, a work group is composed of one veterinarian and one vet technician of every veterinary team. This could be the same team as the work group that proposed the general work processes, but for the variety it would be good to compose the work group of other staff members.

Work with parallel work processes
From the third week of month seven, and onwards, the parallel work processes need to be used in practice. There will be a test phase of one and a half months. Compared to the general work processes, this test phase is longer since we expect that the changes for the staff members will have a greater impact. We build in a test phase to be able to identify bottlenecks and possible improvement points. Therefore, all veterinarians and all vet technicians are responsible for this phase of the implementation.

Evaluation proposal
After the test phase, the proposal of parallel work processes needs to be evaluated. We organize this evaluation similar to the evaluation of the proposal of general work processes. The work group that composed the proposal meets again during the first week of month nine, and makes adjustments to the parallel work processes when and if needed. Again, the members of the work group take into account the bottlenecks they and their veterinary teams encountered over the test phase of one and a half months. If the implementation starts in April 2023, the deadline of this activity will fall in the first week of December. In that way, the staff members can work with the finished parallel work processes for a minimum of three weeks before the next year starts.

7.1.3. Evaluation
After the parallel work processes are finalized and integrated in the daily work processes of the staff members at the animal shelters, the final step is to carry out a general evaluation for which the manager of the animal shelters is responsible. This evaluation takes place at the end of month nine, which preferably will be the end of 2023. The goal of the evaluation is to see whether the expected improvements, as described in Section 6.3.2.1, have been achieved. When comparable improvements have been achieved in the overtime hours of staff members, the implementation can be seen as a success and the composed new parallel work processes can be used in the following years. When the outcomes are not comparable, the conclusion has to be drawn that the adjustments of the work processes are not sufficient yet and the realization steps from the implementation plan have to be carried out again, preferable with another work group.

7.2. Reallocate the capacity of staff members differently over the shelters
The second part of this implementation plan touches on the reallocation of the capacity of staff members. This is a strategic change, therefore activities regarding this part of the solution take place towards the end of a calendar year. If the implementation of the entire solution starts in April, activities regarding reallocating capacity take place in months eight, nine, and ten.

7.2.1. Preparation
Before the implementation of reallocating capacity of staff members can start, some tasks as preparation need to be carried out. The work methodologies used at the animal shelters need to be the same, otherwise it is difficult for one staff member to work at another shelter. Furthermore, the expectation of demand per week or month is required. With this the capacity surplus and shortage can be determined per quarter. The last preparation step will be to determine for which time horizon staff members will be shifted between animal shelters. After these preparation steps, we can identify how to reallocate the capacity of staff members over the shelters.

7.2.1.1. Work methodologies

When a staff member is reallocated to another animal shelter where they use very different work methodologies, it takes a long time to get used and the benefit of additional capacity is lost. Therefore, the work methodologies should be synchronized before capacity can be reallocated. The Sections 7.1.1 and 7.1.2 already discussed the activities that need to be executed to make sure the animal shelters perform the procedures in a general way. Therefore, these activities need to be executed as preparation for the implementation of reallocating the capacity of staff members can take place.

7.2.1.2. Expectation of demand

Besides general work methodologies, also the expectation of demand is needed before this part of the implementation plan can be carried out. The medical manager of the animal shelters is responsible to make sure that this expectation is determined before the next year starts. This activity can be outsourced to another staff member, but the medical manager stays responsible. This expectation of demand has to be a forecast for the next year, per animal shelter. In the preferred situation, this is the year 2024. An example of such a forecast can be found in Chapter 5 of this research.

7.2.1.3. Time horizon

The last preparation step, before the reallocation can take place, will be on the choice of on time horizon for which time period the staff members will be reallocated. In Section 6.1.1.3 the proposal has been made to shift staff members per quarter, since then staff members have more time to get familiar with the animal shelter they are working for. However, after the work methodologies have been generalized, the choice can also be made to shift staff member between the animal shelters per week. Shifting staff members between animal shelters per week takes more effort, but the shortages and surpluses per animal shelter can be determined more precisely. The medical manager will be responsible for making this choice, with a deadline before the end of month six, in the preferred situation.

7.2.1.4. Optional: teambuilding activity

An optional preparation activity before the capacity is reallocated is a teambuilding activity with all veterinarians and vet technicians working at the animal shelters. Until now the staff members have worked in two separate teams. But during this implementation they will become one team and work more intimate with each other. To get to know each other better and to make the implementation easier, we strongly suggest to organize a teambuilding activity before starting with the realization of reallocation.

7.2.2. Realization

During the entire process of realization of the reallocation of capacity, the medical manager of the animal shelters is responsible. Like the realization of the parallel work processes, we have identified certain activities that have to be executed to make sure the implementation of the reallocation of capacity goes well.

Table 34 Realization activities for reallocating capacity

Activity	Goal	Responsible	Deadline
Translate demand to work hours	Finalize the expected demand	Medical manager	Second week month nine
Identify surplus and shortage per animal shelter	Finalize the expected demand	Medical manager	Second week month nine
Adjust staff planning	Realize the capacity reallocation	A vet technician with additional work hours for planning + Medical manager	Third week month nine
Interim evaluation	Tackle problems in time	Medical manager	Maximal 2 weeks after a staff member started at a different animal shelter

Translate demand to work hours
As preparation, the expected demand per animal shelter for the following year is determined. To get a better insight into where the shortages and surpluses lie within the organization, this demand needs to be translated into work hours per animal shelter. In the preferred situation, this activity has to be carried out before the second week of month nine, to make sure there is enough time left to adjust the staff planning before the next year. The medical manager is responsible that is activity is carried out, but it can be outsourced to another staff member.

Identify surplus and shortage per animal shelter
After the expected work hours per animal shelter are determined, the surpluses and shortages per quarter or week can be identified depending on the chosen time horizon. This activity can be performed together with translating the demand to work hours. Therefore, the responsible staff member and deadline will be the same. They are stated separately in the table, since it is important that the activities are performed in the mentioned order.

Adjust staff planning
The next step of the realization of this part of the implementation plan is to adjust the staff planning. In the current situation at the animal shelters we see that the vet technicians are best informed on the staff planning of both the veterinarians and vet technicians. Therefore, we propose to give one of the vet technicians the responsibility to oversee the scheduling of all staff members at the three animal shelters. To adjust the staffing levels at the animal shelters, the example of Section 6.1.1.3 can be followed. Here, the capacity is reallocated per quarter, but the same steps can be taken when reallocating capacity per month or week. Preferably, the staffing levels per animal shelter are determined for the entire upcoming year. Therefore, the deadline of this activity is in the preferred situation is the third week of month nine, so that every staff member knows before the Christmas break at which animal shelter he or she will work. When the choice is made to shift staff members between the animal shelters per week, the choice can also be made to determine staffing levels per half year.

Interim evaluation
It could be possible that staff members encounter some problems when they are reallocated to another animal shelter, for example the work methodologies are not yet that general as we would like. To tackle these problems in time, the medical manager has to perform an evaluation with staff members maximal two weeks after they have started working at a different animal shelter. This could be a short online meeting or a longer visit, depending on the experiences of the concerned staff member.

7.2.3. Evaluation

The evaluation of the implementation of reallocating capacity of staff members consists of two parts, which both need to take place when the reallocation has been used a year. This implementation can ask a lot of the staff members of the animal shelters, since it could for example mean that their travel time increases or they work with new colleagues in a different work environment. Therefore, it is important to organize a feedback session with all veterinarians and vet technicians working at the animal shelters. What were their experiences and where lie the improvement points for the next year?

The second part of the evaluation is to check whether comparable improvements are achieved as predicted in Section 6.1.1.3. When they are comparable, same methodologies can be used the following year. When they are not comparable, look at the forecast of the expected demand. When the forecast does not comply with the actual demand, another forecasting technique should be used and the realization steps as described have to be retaken.

7.3. Outsource cleaning activities

The last part of this implementation plan concerns mostly the vet technicians working at the animal shelters. Outsourcing the cleaning activities is a strategic change, but the choice can be made to start earlier with this implementation than the end of a calendar year. As can be seen in the implementation roadmap of Figure 29, we start immediately with implementing this part of the solution. We made this choice since the expected decrease in overtime for vet technicians due to this part of the solution is large.

7.3.1. Preparation

The preparation before the cleaning activities can be outsourced consist of two activities. The medical manager is responsible for both activities and they have to be carried out before the realization of this implementation can start.

In Section 6.1.2.1, two options for outsourcing cleaning activities are proposed. One option is to hire additional staff members through a cleaning company and the other option is to delegate the cleaning activities to animal caretakers or volunteers. Both options have their pros and cons, but they both provide the same improvements. Therefore it is up to the medical manager to make a choice between the two options. Per animal shelter, one staff member needs to assigned to perform the cleaning activities from now on. It is possible to employ one staff member for the animal shelters in A and B, since together they are opened five days in the week.

Furthermore, the medical manager has to ensure that every vet technician is on-board with the idea of outsourcing the cleaning activities, since they can have the feeling they lose a bit of control of the cleanliness of the OR and treatment areas.

7.3.2. Realization

After all the preparations have been made, the realization of outsourcing cleaning activities can start. In Table 35, the realization activities for outsourcing cleaning activities are listed, together with their goal, responsible, and deadline.

Table 35 Realization activities for outsourcing cleaning activities

Activity	Goal	Responsible	Deadline
Overview cleaning activities	Make sure all the cleaning activities are properly elaborated	Two vet technicians	Second week month one
Job shadowing 1	Get familiar with the cleaning activities	Vet technicians and new staff members	End month one
Job shadowing 2	Provide additional feedback where needed	Vet technicians and new staff members	Second week month two
Trial period	Get familiar with the new division of work processes	Vet technicians and new staff members	First week month three
Evaluation	Identify possible bottlenecks and/or improvement points	Vet technicians and new staff members	Second week month three

Overview cleaning activities
There already exists an overview of the cleaning activities that need to take place every day at the end of the day at the animal shelters. Also the quarterly and yearly cleaning activities are included in this overview. To make sure this overview is complete and up to date, it is the responsibility of two vet technicians to check this overview and make the necessary changes. Preferably, these two vet technicians both currently work at another veterinary team. The deadline of this activity is the second week of month one, since after this date the new staff members will start with the job shadowing.

Job shadowing 1
To prevent miscommunication between any staff member, two job shadowing activities need to take place. During the first job shadowing, the new staff members shadow the vet technicians during their cleaning activities. The activities are performed with and according to the overview. During this shadowing, the new staff members receive the overview of cleaning activities. This job shadowing activity will take place over the course of one week, where the new staff member shadows at least two days.

Job shadowing 2
The second job shadowing is comparable to the previous job shadowing, but the roles are reversed. The new staff member will perform the cleaning activities according to the overview while the vet technician is still present for potential questions or remarks. This activity will again take place over the course of one week, where the new staff member at least cleans on two days.

Trial period
After the two job shadowing activities, the trial period starts. Over the course of a month, the new staff members take over all cleaning activities from the vet technicians. During this period both staff members can learn how to co-operate.

Evaluation
After the trial period of a month, a meeting is planned with all staff members involved to evaluate the past month and bring up possible bottlenecks and/or improvement points. This evaluation needs to take place before the general evaluation, therefore the deadline of this activity is the second week of month three.

7.3.3. Evaluation

Like for the other parts of the implementation plan, we want to plan a general evaluation to check whether comparable improvements have been achieved as stated in Section 6.1.2.1. To be able to make a good analysis, the implementation of outsourcing the cleaning activities can be evaluated minimal half a year after the new staff members have started working.

Furthermore, when the cleaning activities have been outsourced another evaluation has to be made on the parallelizing of the work processes. The implementation of both components take place partially in parallel. Therefore, the realization steps of parallelizing work processes need to be retaken after the implementation and evaluation of outsourcing the cleaning activities. When realization steps of the parallelization of work processes have not yet been executed they will follow after this part of the implementation plan.

7.4. Conclusion

This chapter discussed the implementation of the three selected improvements ideas, which together form the solution of this research to be more in control to be able to handle the expected demand. The implementation plan entails all activities that need to be taken as preparation, realization, and evaluation. A responsible is assigned to every activity, together with a deadline. Figure 29 showed the implementation roadmap of our solution. When the execution of the implementation plan starts in April 2023, and all activities are carried out according to the set deadlines, it is expected that the animal shelters can work with parallel work processes from the beginning of the year 2024. Furthermore, the capacity reallocation choices need to be made at the end of 2023, together with outsourcing the cleaning activities. Therefore, the animal shelters can be able to handle their expected demand in a better way from the beginning of 2024.

8. Conclusions and recommendations

This last chapter finalizes the research. First the main conclusions are presented in Section 8.1. Then Section 8.2 discusses the results, which is followed by the recommendations in Section 8.3.

8.1. Conclusion

The Dutch animal protection has various animal shelters all over the country, where this research focused on the shelters located in A, B, and C. At these shelters, veterinarians, vet technicians, and animal caretakers treat animals, shelter them, and find them a new forever home. During the care process, veterinarians and vet technicians experience a high workload. Because of this it happens often that staff members have to work in overtime, or certain work activities are shifted to the next workday. Therefore, the objective of this research was to suggest improvements to decrease the gap between supply and demand. Hereby, the following research question was formulated:

How can the animal shelters in A, B, and C be in control as much as possible of how to deploy staff members to be able to meet the demand?

Together with the management of the animal shelters, a desired situation was drafted. In the desired situation, the selected animal shelters integrate their staff planning and standardize their work methodologies, with the goal that the veterinarians and vet technicians can work independently of each other.

To show the current performance of the used staff scheduling and work methodologies, a forecasting method was developed to forecast the expected demand. The expected demand of the year 2023 per week per animal shelter was forecasted based on data of the previous three years. For this, the double exponential smoothing method and Holt-Winter model were used. Overtime is defined as the main key performance indicator, since this was the main problem arising on the work floor. The probability of overtime is considered to be acceptable when it is below the threshold of 30%. Table 36 shows the current probability of working in overtime, together with the expectation and standard deviation, per staff member and per animal shelter. Analyzing the performance of the current block schedule, the conclusion can be drawn that in many weeks the expected amount of work does not comply with the available work hours.

Table 36 Current performance of the used staff scheduling and work methodologies

	Veterinarian			**Vet technician**		
	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.55	1.8	2.4	0.72	2.7	2.7
B	0.17	0.6	1.8	0.60	1.8	2.2
C	0.64	2.4	2.7	0.81	3.8	3.3

To make sure that the animal shelters will be more in control of handling their demand, thirteen improvement ideas have been proposed. These improvement ideas have been placed in the hierarchical framework of planning and control with the levels strategic, tactical, offline operational, and online operational. Together with the management of the animal shelters, the choice has been made to develop an implementation plan for three of the thirteen proposed improvement ideas. The first improvement idea is to reallocate capacity differently over the animal shelters per quarter, since it is expected that some animal shelters will have a surplus of capacity during a quarter where another animal shelters has a shortage of capacity. In that way, they can co-operate to both be able to handle their demand. The second improvement idea is to outsource the cleaning activities of the vet technicians. Since these activities are relatively simple and mostly are performed in overtime, this improvement idea has the potential to lower the probability and expectation of the overtime of the vet technicians. The last improvement idea is to parallelize the work processes of the veterinarians and vet technicians, to improve the efficiency of the work methodologies and make it possible that

the staff members can work as separate teams. Table 37 shows the expected improvements per improvement idea.

Table 37 Improvements in probability, expectation and standard deviation of overtime per improvement idea

	Veterinarian			Vet technician		
Capacity reallocation	Probability	E(X) [h]	SD(X) [h]	Probability	E(X) [h]	SD(X) [h]
A	0.55 → **0.45**	1.8 → 1.4	2.4 → 2.3	0.72	2.7	2.7
B	0.17	0.6	1.8	0.60	1.8	2.2
C	0.64 → **0.58**	2.4 → 2.2	2.7 → 2.7	0.81	3.8	3.3
Outsource cleaning						
A	0.55	1.8	2.4	0.72 → **0.45**	2.7 → 1.7	2.7 → 2.5
B	0.17	0.6	1.8	0.60 → **0.36**	1.8 → 1.0	2.2 → 1.8
C	0.64	2.4	2.7	0.81 → **0.58**	3.8 → 2.6	3.3 → 3.0
Parallelize processes						
A	0.55 → **0.30**	1.8 → 1.0	2.4 → 1.9	0.72 → **0.62**	2.7 → 2.0	2.7 → 2.4
B	0.17 → **0.15**	0.6 → 0.5	1.8 → 1.4	0.60 → **0.43**	1.8 → 1.2	2.2 → 1.8
C	0.64 → **0.55**	2.4 → 1.9	2.7 → 2.5	0.81 → **0.74**	3.8 → 3.2	3.3 → 3.1

During the development of the implementation plan it was discovered that the improvement ideas relate to each other. Therefore, the three improvement ideas are combined and presented as one solution. The PDCA-cycle was used during the development of the implementation plan. Every part consists of preparation, realization, and evaluation activities which all correspond to a phase of the PDCA-cycle. When all defined steps are followed, the expected improvements of Table 37 can be achieved before the beginning of 2024. Since the solution shows a decrease for the probability, expectation, and standard deviation of the overtime for almost every staff member and animal shelter, we can conclude that the animal shelters will be more in control of handling their expected demand.

8.2. Discussion

This section discusses the performed research. First, we will treat some general discussion points. These are followed by the assumptions and the application of the research. This section ends with the adjustments proposed to our research with our hindsight knowledge.

8.2.1. General discussion points

In Chapter 7 the implementation plan of three improvement ideas has been elaborated. Before, in Chapter 6, the expected improvements in probability, expectation, and standard deviation of overtime of the same improvement ideas is determined. Every improvement idea shows its own improvement for overtime probability for veterinarians, vet technicians, or both. When all three improvement ideas are implemented, it cannot be guaranteed that they will provide the same improvements as when they are implemented solely. Since some improvement ideas affect the same staff members, the outcomes are dependent on each other. If the order of the implementation plan of Chapter 7 is followed, the absolute improvements that are expected for the probability of working overtime for parallelizing work processes will probably be lower since already some improvements have been made by implementing the capacity reallocation and outsourcing cleaning activities.

This research concluded with an implementation plan to narrow the gap between expected demand and supply at the animal shelters. Whether the expected improvements can be achieved is largely depending on the changeability and change readiness of the animal shelters. Section 2.6 already touched upon change management in organizations briefly. The changeability of an organization has to do with the potential adaptation of a system. Only when all elements of a system are included,

a change can be successful (Büttner & Müller, 2018; de Heer et al., 2018). Where changeability mostly has to do with the organization itself, change readiness focusses employees. Staff members play a critical role in change implementation, since they can offer a lot of resistance. Susanto defines seven aspects of change readiness: perception toward change efforts, vision for change, mutual trust and respect, change initiatives, management support, acceptance, and how the organization manages the change process (Susanto, 2008). Many studies conclude that staff members, and their willingness of cooperation, have the biggest influence on whether the change implementation will be successful (Armenakis & Harris, 2002; Smith, 2005; Susanto, 2008). Therefore, the success of the implementation mentioned in Chapter 7 depends on the changeability and change readiness of the organization at the animal shelters.

8.2.2. Assumptions

Throughout this research some assumptions needed to be made. These assumptions have an influence on the values obtained during our analysis, but they do not alter our main conclusion. We still expect that the proposed solution will lead to a decrease of the gap between the expected demand and supply at the animal shelters, although the assumptions do not match the actual situation completely. This section discusses the assumptions and their effect on the outcome of this research.

The input data for the forecasting model of the animal shelter in C needed to be assumed based on the input data of the other two shelters. When the actual performed procedures for this animal shelter during the years 2019 until 2022 is known, the performance of the current block schedule probably would be different. Then, also the expected improvements after the implementation of the improvement ideas will be different. This difference can both be positive and negative, depending on whether the current assumed performed procedures during the years 2019 until 2022 was an under- or overestimation.

Another assumption that has influence on the values of the outcome is the duration of neutralizations. For the performance of the current block schedule, durations per procedure have been drawn from a distribution. To draw a random duration from a distribution, a mean and standard deviation are needed. To obtain these values per procedure, observations have taken place. The durations of castrations on dogs and cats differ a lot. The same holds for sterilizations. However, in this research one mean and one standard deviation per procedure have been determined. The analysis of the performed procedures shows that they are not divided equally over the animal species. On average, 73% of the castrations are performed on cats, compared to 10% on dogs. The differences by the sterilizations is even bigger, here the distribution is 91% on cats and 7% on dogs. The remainder of the neutralizations is performed on other animal species. Since the duration of neutralizations performed on cats is shorter compared to dogs, the expected OR time per animal shelter could be an overestimation.

An additional note needs to be made on the durations in combination with the expected overtime per staff member. As mentioned, an average has been made of all procedures. The overtime probabilities mentioned in this research are determined per kind of staff member. The expected overtime per week is equally distributed over the workdays of veterinarians and vet technicians per week. In other words, overtime is divided equally. It is also assumed that every veterinarian can perform the same amount of procedures in a day. Only, the situation on the work floor shows something different. Both veterinary teams consist of a veterinarian that performs procedures faster compared to the other. This has been taken into account partially since an average of the durations has been taken. It still can have influence on the value of outcome since the biggest part of the procedures in C are performed by the 'faster veterinarian'. In A and B this ratio is the other way around. Therefore, the actual expectation of veterinary overtime hours in C probably lies lower and of A and B higher.

As mentioned in Section 5.1.5., the output of our forecasting model is dependent on the input. Therefore a sensitivity analysis was performed. We used both increases and decreases in the input values. The outcomes of the sensitivity analysis showed that the forecast model was most affected

when the naïve forecasting method was used. During the analysis of the performance of the current block schedule and with the calculation of improvement ideas, still the original forecast was used. During these analyzes, the sensitivity analysis was not taken into account. Therefore, the remainder of our conclusions is also dependent on the input. When the actual demand of the animal shelters differs strongly from our forecast, then the values of the outcome will be different.

8.2.3. Application of research

This research focused on integrating the work processes and organization of three animal shelters located in A, B, and C. These three animal shelters lie in a close proximity of each other. Therefore, a collaboration makes sense. Analyzing the placement of other animal shelters, other groups consisting of three or four animal shelters can be indicated for a possible collaboration. When these animal shelters experience similar gap between their expected demand and supply, the findings of this research can be applicated to another group of animal shelters of the AP.

Looking for a wider application of this research we look at regular veterinarian practices. Comparing their work processes with the ones from the animal shelters, these organizations execute the same procedures in their ORs and during their consultation hours. As already mentioned in Section 6.1.1.1, the division of expected demand over the year is the opposite compared to the expected demand at the animal shelters. Although the peaks in demand lie in different months for regular veterinarian practices, the findings of this research can still be used to narrow the gap between expected demand and supply or to realize a collaboration between practices.

The general methods used in this research are also applicable to other research fields outside animal care. When an organization wants to realize a collaboration between locations, integrate work processes or decrease the gap between expected demand and supply, the general steps of this research can be used. The general steps consist of forecasting demand, identifying surpluses and shortages, and proposing improvement ideas to use the surpluses and decrease the shortages.

8.2.4. Adjustments with hindsight knowledge

After we have conducted this research, we can propose adjustments we would have made afterwards. We would have performed the selection of improvement ideas for which an implementation plan is developed differently. Now the opinion of the AP weights more compared to the possible reduction of the overtime probability. If we were to conduct this study again, we would test the improvement ideas to predetermined criteria. Every improvement idea will get a score between one and five per criteria. Then an implementation plan will be drawn up for the improvement ideas that score the highest across all criteria.

8.3. Recommendations

The last section of this chapter will describe some recommendations for the animal shelters.

At the beginning of this research, to goal was to develop a new scheduling method for the animal shelters and deploy their staff members more efficiently. We also wanted to look at the block schedule and make adjustments per half year or per quarter. After we analyzed the performance of the current block schedule, we made the conclusion that at this point in the research at the animal shelters, making adjustments to the block schedule and deployment of staff members are not suitable. Therefore, some research questions and deliverables of this research changed. After the solution of this research is implemented, the expected demand and supply should lie closer to each other and the probability of working overtime should be lower. When this is the case, we would recommend the animal shelters to carry out our original research goal. This will correspond to the Act part of the PDCA-cycle, where the process is improved, and the planning is made for the next cycle with a better baseline. We believe that when the available work hours match the expected work hours per week, the development of smart methods for staff scheduling and block schedule layout will lead to more efficient use of the supply of the animal shelters. Then also the improved staff scheduling method and a prototype can be delivered.

The solution of this research consisted of three improvement ideas. In the remainder of Chapter 7, additional improvement ideas are proposed. Some of these ideas proved to be unsuitable in practice, but other improvement ideas are still suitable for implementation. The current solution lowers the probability of working overtime, but for some staff members at some animal shelters not entirely below the threshold of 30%. Therefore, we would recommend the animal shelters to have a look at the other improvement ideas and find other improvements to make sure that the probability of working overtime falls below the threshold.

Section 8.2 mentioned that changeability and change readiness have a large impact on the chance of succeeding of the implementation of the proposed solution. Therefore, we would like to recommend the animal shelters to pay a lot of attention to these concepts during the implementation. The importance of change readiness is shortly mentioned in Section 7.3.1, but both concepts should be included in all steps of carrying out the implementation plan.

This research focused on the work methodologies of veterinarians and vet technicians. These staff members mostly work in the OR- and treatment rooms. Another part of the animal shelter consists of the kennels, where the animals are sheltered and further treated. Here, the care of animals is mostly taken over by animal caretakers and volunteers. We recommend conducting additional research on the staff schedules of these staff members. Comparable capacity planning methods can be applied here to increase the efficiency of the entire animal shelter.

In Chapter 5 of this research, a forecast model has been developed to determine the expected demand for the coming year. A sensitivity analysis has been performed, but we recommend the animal protection to perform an additional analysis to map the variability in demand. When an organization maps the variability of their demand, better insights can be provided into the staffing levels that are needed per week.

During the development of the problem context, we encountered some behavioral issues. Since the animal protection is a NGO, they make use of the employability of volunteers. Although these volunteers will always be there for the organization, their reliability and responsibility are lower compared to paid employees. Therefore, addressing their errors is more complicated. Also as mentioned in the discussion, there is a difference in the execution of procedures between staff members. In this research, these behavioral aspects of the organization are intentionally left out. We recommend the management of the animal shelters to take a look into the behavioral issues within their organization since these have a large influence on their efficiency.

A part of the solution of this research was to reallocate capacity between animal shelters. Hereby the two veterinary teams will become one since staff members can be allocated to all three animal shelters. To stimulate the cooperation, we would recommend the animal shelters to organize multidisciplinary consultations, where complicated cases can be discussed. During these meetings, staff members can learn from each other and keep up with the newest methodologies and procedures.

Finally, we advise the animal shelters to make agreements on the administration of the medical procedures. In the current database, many different categories are used for one procedure. To create a better overview of the performed medical procedures, this research made a distinction between five main medical procedures. When agreements would be made about the administration of procedures, the determination of expected demand would become easier. And therefore also the expected work hours per week.

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Appendix A Systematic literature review

This systematic literature was carried out to answer the following research question composed in Section 1.6:

What is already known about staff scheduling in the field of shelter medicine?

The first step of a systematic literature review is to compose keywords. The following combination of keywords were drawn up and will be used:

- Animal shelter OR veterinarian OR shelter medicine
- Planning OR staff scheduling
- Capacity OR staff

Different combinations of these keywords are made and used as search terms in the databases Scopus and PubMed. The results can be found below. The found sources were judged on their title and abstract. Only the search terms which yield applicable sources are listed.

Scopus

- TITLE-ABS-KEY (shelter AND medicine) AND (staff OR scheduling) (108 hits)
- TITLE-ABS-KEY (staff AND scheduling) AND (veterinary AND care) (17 hits)
- TITLE-ABS-KEY (staff AND scheduling) AND (animal AND shelter) (2 hits)
- TITLE-ABS-KEY (animal AND shelter) AND capacity (426 hits)
- TITLE-ABS-KEY (animal AND shelter) AND (capacity OR staff) (743 hits)

PubMed

- (staff AND scheduling) AND (veterinary AND care) (9 hits)
- (animal AND shelter) AND capacity (121 hits)

During this systematic review it became clear that most literature in shelter medicine are focused on outbreaks and or infections within animal shelters, or about infrastructure. The sources found with this systematic review that could help answer the research question are the following:

1. (Powell et al., 2021)
2. (Laderman-Jones et al., 2016)
3. (Hayes et al., 2020)
4. (S. Hobson et al., 2021)
5. (White, 2019)
6. (Karsten et al., 2017)
7. (Hurley, 2022)
8. (Weiss et al., 2015)

Appendix B.1 Values of updating parameters

Table 38 Values of the updating parameters per medical procedure

Medical procedure	α	β	γ
A, other surgeries	0.55	0.53	0.1
B, other surgeries	0.55	0.53	0.1
C, in-house	0.3	0.53	0.1
Other procedures	0.19	0.53	0.1

Appendix B.2 Forecast per week

Location A

Table 39 Forecast per week per (medical) procedure for the animal shelter located in A

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Castration	3	4	5	10	12	5	3	6	5	7	6
Sterilization	2	3	1	21	6	10	11	11	9	7	7
Other surgeries	0	0	0	0	0	1	3	0	0	0	0
X-ray	1	1	1	4	1	1	1	1	1	1	1
Dental remediation	1	1	1	1	1	1	1	1	1	1	1
Appointments	3	30	32	32	15	21	9	40	2	73	17
In-house	3	55	58	56	62	33	35	33	32	32	48
Neutralizations	0	0	0	0	0	0	0	0	0	0	0
Arrivals	0	10	16	11	7	1	17	6	12	8	12
Week	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Castration	2	7	7	2	2	3	3	5	5	5	2
Sterilization	6	8	4	7	3	5	3	8	6	5	3
Other surgeries	0	0	0	0	0	0	0	0	0	0	0
X-ray	1	1	1	1	1	1	1	1	1	1	1
Dental remediation	1	1	1	1	1	1	1	1	1	1	1
Appointments	32	27	7	2	13	9	18	11	18	5	2
In-house	39	61	39	44	34	20	38	68	52	36	39
Neutralizations	0	0	1	1	1	4	1	0	0	1	0
Arrivals	14	8	7	5	21	19	7	14	21	26	19

Week	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Castration	5	4	8	2	5	4	1	0	0	2	2
Sterilization	4	4	4	5	5	6	1	2	3	4	10
Other surgeries	0	0	0	0	0	0	0	0	0	1	1
X-ray	1	2	1	2	1	1	1	1	1	1	1
Dental remediation	1	1	1	1	1	1	1	0	0	0	0
Appointments	3	10	10	2	3	11	0	2	6	18	44
In-house	39	33	63	32	71	59	10	17	6	53	46
Neutralizations	0	0	1	1	1	1	0	0	0	0	0
Arrivals	18	10	11	15	21	8	19	22	21	23	18
Week	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
Castration	3	2	8	5	12	3	10	9	8	13	6
Sterilization	6	7	6	8	8	7	6	5	6	7	4
Other surgeries	0	0	0	0	1	0	0	2	1	0	0
X-ray	1	1	1	1	1	1	1	1	1	1	1
Dental remediation	0	0	0	0	0	1	1	1	1	1	1
Appointments	22	23	34	17	40	25	22	11	25	40	27
In-house	40	36	60	22	27	41	20	52	37	59	37
Neutralizations	0	0	1	0	0	1	1	1	0	0	0
Arrivals	13	11	17	19	26	19	17	18	13	18	10

Week	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**		
Castration	11	7	8	17	6	6	9	2	4		
Sterilization	10	3	9	12	8	7	10	4	4		
Other surgeries	0	0	0	0	3	4	2	1	6		
X-ray	1	1	2	2	1	1	1	1	1		
Dental remediation	1	1	1	1	1	1	1	1	1		
Appointments	36	23	33	50	14	25	15	9	9		
In-house	55	51	36	34	30	34	16	36	39		
Neutralizations	0	0	0	0	0	0	0	0	0		
Arrivals	14	29	19	13	8	6	12	16	5		

Location B

Table 40 Forecast per week per (medical) procedure for the animal shelter located in B

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Castration	0	3	0	0	4	2	1	4	9	7	4
Sterilization	2	6	2	14	5	10	4	0	0	1	2
Other surgeries	0	0	0	0	1	1	1	1	1	1	1
X-ray	0	1	0	1	0	3	0	0	0	1	1
Dental remediation	0	0	0	0	0	0	1	0	0	0	0
Appointments	0	61	30	53	33	20	40	28	22	67	22
In-house	0	37	41	47	49	30	50	30	37	47	63
Neutralizations	0	0	0	0	0	0	0	0	0	0	0
Arrivals	3	14	15	9	9	7	7	15	12	8	4
Week	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Castration	4	4	4	3	2	0	0	2	2	1	3
Sterilization	0	0	1	1	1	1	1	5	0	0	1
Other surgeries	3	2	1	0	0	0	0	0	1	1	1
X-ray	0	0	0	0	0	0	1	0	0	0	1
Dental remediation	0	0	0	0	0	0	0	0	0	0	0
Appointments	9	23	4	9	0	0	9	33	22	7	5
In-house	41	32	36	32	30	42	33	54	41	36	38
Neutralizations	0	0	0	0	0	0	0	0	0	0	0
Arrivals	8	14	12	10	6	10	23	15	28	12	9

Week	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Castration	2	1	0	0	0	0	0	1	2	1	3
Sterilization	1	2	3	2	2	0	0	0	1	0	0
Other surgeries	0	0	0	0	0	0	1	1	1	1	1
X-ray	1	0	1	1	1	0	0	0	0	0	1
Dental remediation	0	0	0	0	0	0	0	0	0	0	0
Appointments	7	15	30	20	17	10	10	30	18	10	41
In-house	37	12	45	52	66	7	11	5	9	6	16
Neutralizations	0	0	0	0	0	0	0	0	0	2	1
Arrivals	27	20	35	19	24	28	22	23	26	23	31
Week	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
Castration	2	4	6	8	8	3	6	9	4	10	9
Sterilization	1	1	3	11	8	3	5	12	3	8	5
Other surgeries	1	1	1	1	0	0	0	0	0	0	1
X-ray	1	0	0	0	0	1	0	0	0	0	0
Dental remediation	0	0	0	0	0	0	0	0	0	0	0
Appointments	27	33	33	22	10	14	18	25	20	22	15
In-house	10	8	3	3	5	5	6	9	4	6	4
Neutralizations	1	0	0	0	0	0	0	0	0	0	0
Arrivals	20	22	20	17	29	18	23	25	16	9	22

Week	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**		
Castration	6	16	15	11	5	13	2	0	0		
Sterilization	4	24	11	13	7	9	3	4	5		
Other surgeries	1	1	1	1	1	2	1	0	3		
X-ray	0	0	0	0	0	0	0	0	0		
Dental remediation	0	0	0	0	0	0	0	0	0		
Appointments	72	23	22	27	0	18	27	18	7		
In-house	8	8	10	17	11	12	16	14	12		
Neutralizations	0	0	0	0	0	0	0	0	0		
Arrivals	20	13	9	11	10	7	7	4	1		

Location C

Table 41 Forecast per week per (medical) procedure for the animal shelter located in C

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Castration	0	6	0	0	6	4	3	13	41	33	20
Sterilization	1	11	5	56	24	52	21	0	0	0	-2
Other surgeries	0	0	0	2	1	4	3	0	3	0	3
X-ray	0	3	0	4	0	8	0	0	0	3	4
Dental remediation	0	1	0	0	0	0	3	0	0	0	0
Appointments	0	12	21	11	5	6	6	9	3	6	9
In-house	5	16	25	48	25	39	39	25	23	41	98
Neutralizations	0	0	1	1	2	0	0	0	0	0	0
Arrivals	13	17	18	30	24	12	23	24	13	43	14
Week	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Castration	20	19	21	13	8	0	0	0	0	0	0
Sterilization	0	0	0	2	5	5	5	29	0	0	0
Other surgeries	8	0	0	0	0	0	2	1	3	0	0
X-ray	0	0	0	0	3	0	3	0	0	0	5
Dental remediation	2	0	0	2	0	1	0	1	0	0	0
Appointments	11	3	6	6	3	3	17	6	2	5	2
In-house	46	31	46	11	38	22	41	27	21	10	19
Neutralizations	0	4	3	3	10	9	3	3	2	16	2
Arrivals	29	21	28	33	27	12	30	30	24	38	43

Week	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Castration	0	2	0	0	1	0	0	1	4	4	14
Sterilization	0	0	0	0	2	0	0	0	3	0	0
Other surgeries	1	0	0	0	0	0	1	0	0	1	0
X-ray	5	1	3	4	3	0	0	0	0	0	3
Dental remediation	0	0	0	0	0	0	0	0	0	0	0
Appointments	5	5	5	11	14	17	14	18	11	18	23
In-house	10	16	14	19	17	32	49	34	46	21	38
Neutralizations	6	10	22	11	7	12	5	4	7	19	9
Arrivals	48	41	37	27	59	76	55	46	31	39	33
Week	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
Castration	9	22	38	49	49	14	31	36	13	27	16
Sterilization	0	6	16	73	62	18	37	77	13	39	20
Other surgeries	0	3	0	1	1	0	1	2	0	0	1
X-ray	4	0	0	0	1	3	1	0	0	0	1
Dental remediation	0	0	0	0	0	1	0	0	0	0	1
Appointments	21	21	18	20	23	23	18	26	24	12	17
In-house	21	14	11	24	28	29	44	69	30	46	39
Neutralizations	5	1	5	1	3	7	12	6	2	3	0
Arrivals	42	48	50	36	38	48	32	25	37	33	23

Week	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**		
Castration	8	24	23	17	8	26	3	0	0		
Sterilization	14	81	31	33	16	16	4	2	4		
Other surgeries	3	0	2	3	5	5	1	1	3		
X-ray	1	1	1	0	0	0	0	1	1		
Dental remediation	0	0	0	2	0	1	1	0	0		
Appointments	15	20	14	11	11	17	12	8	11		
In-house	56	38	17	21	12	6	9	11	8		
Neutralizations	0	1	1	2	0	0	0	0	0		
Arrivals	36	20	18	31	22	18	17	10	9		

Appendix C Sensitivity analysis

Table 42 Results sensitivity analysis -10% and 10%

	-10%				10%			
A	effect	min	max	no effect	effect	min	max	no effect
Castration	38	50%	100%	15	15	100%	133%	38
Sterilization	31	75%	100%	22	11	100%	133%	42
Other surgeries	0	100%	100%	53	7	100%	200%	46
X-ray	0	100%	100%	53	16	100%	200%	37
Dental remediation	0	100%	100%	53	7	100%	200%	46
Appointments	43	80%	100%	10	38	100%	114%	15
In-house	51	90%	100%	2	53	110%	133%	0
Neutralizations	0	100%	100%	53	4	100%	200%	49
Arrivals	40	90%	100%	13	52	110%	200%	1
B	effect	min	max	no effect	effect	min	max	no effect
Castration	12	50%	100%	41	19	100%	150%	34
Sterilization	9	67%	100%	44	18	100%	150%	35
Other surgeries	0	100%	100%	53	10	100%	200%	43
X-ray	0	100%	100%	53	14	133%	200%	39
Dental remediation	0	100%	100%	53	1	200%	200%	52
Appointments	48	75%	100%	5	45	100%	120%	8
In-house	36	90%	100%	17	52	110%	133%	1
Neutralizations	0	100%	100%	53	1	100%	150%	52
Arrivals	37	90%	100%	16	53	110%	200%	0
C	effect	min	max	no effect	effect	min	max	no effect
Castration	34	0%	100%	19	28	0%	200%	25
Sterilization	23	50%	100%	30	24	100%	150%	29
Other surgeries	0	100%	100%	53	27	113%	200%	26
X-ray	0	100%	100%	53	24	113%	200%	29
Dental remediation	0	100%	100%	53	11	133%	200%	42
Appointments	33	88%	100%	20	45	100%	133%	8
In-house	50	80%	100%	3	52	100%	122%	1
Neutralizations	3	80%	100%	50	29	100%	200%	24
Arrivals	52	90%	100%	1	53	110%	117%	0

Table 43 Results sensitivity analysis 20% and 30%

	20%				30%			
A	effect	min	max	no effect	effect	min	max	no effect
Castration	26	100%	133%	27	35	100%	200%	18
Sterilization	30	100%	133%	23	43	100%	200%	10
Other surgeries	7	100%	200%	46	7	100%	200%	46
X-ray	16	100%	200%	37	16	100%	200%	37
Dental remediation	7	100%	200%	46	7	100%	200%	46
Appointments	46	100%	133%	7	47	100%	136%	6
In-house	53	120%	133%	0	53	130%	135%	0
Neutralizations	4	100%	200%	49	4	100%	200%	49
Arrivals	52	120%	200%	1	52	130%	200%	1
B	effect	min	max	no effect	effect	min	max	no effect
Castration	28	100%	200%	25	29	100%	200%	24
Sterilization	21	100%	200%	32	24	100%	200%	29
Other surgeries	10	100%	200%	43	10	100%	200%	43
X-ray	14	133%	200%	39	14	133%	200%	39
Dental remediation	1	200%	200%	52	1	200%	200%	52
Appointments	48	100%	122%	5	49	121%	140%	4
In-house	52	120%	133%	1	52	130%	150%	1
Neutralizations	1	100%	150%	52	1	100%	150%	52
Arrivals	53	120%	200%	0	53	130%	200%	0
C	effect	min	max	no effect	effect	min	max	no effect
Castration	31	100%	200%	22	33	0%	136%	20
Sterilization	27	100%	150%	26	32	100%	150%	21
Other surgeries	27	120%	200%	26	27	133%	200%	26
X-ray	24	120%	200%	29	24	133%	200%	29
Dental remediation	11	133%	200%	42	11	133%	200%	42
Appointments	50	100%	133%	3	50	100%	133%	3
In-house	52	100%	133%	1	53	117%	144%	0
Neutralizations	30	100%	200%	23	31	100%	200%	22
Arrivals	53	120%	125%	0	53	130%	136%	0

Appendix D R code, log-normal distribution

```r
#set seed value
set.seed(555)

#initialize the values for the mean (m) and st.dev. (s)
m <- 1881
s <- 1008

#identify location and shape parameter, print for check and draw n random values
location <- log(m^2/sqrt(s^2+m^2))
shape <- sqrt(log(1+(s^2/m^2)))
print(paste("location:", location))
print(paste("shape:", shape))
draws <- rlnorm(n=6500, location, shape)

#check for mean and st.dev.
mean(draws)
sd(draws)

#write obtained values to excel sheet
data <- as.data.frame(draws)
library(writexl)
write_xlsx(data, "C://")
```

Figure 30 R code, log-normal distribution