Team Control Number

11791

Problem Chosen

C

2021

HiMCM/MidMCM

Summary Sheet

(Your team's summary should be included as the first page of your electronic submission.)
Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

This paper thus seeks to find a design for the dog park. Firstly, we analyzed a public survey of dog owners and many dog park design guidelines to gain a fundamental understanding of dog parks. Then, we pick the location and layout of the dog park based on factors such as scalability, a public survey on the dog park's functional division, and minimizing the effect of dogs' unpitched sound on neighbors. Additionally, we use Poisson distribution formula to analyze Google Maps data from other dog parks around the United States to estimate the maximum capacity of the park. Finally, we use these facts to calculate the quantity and cost of amenities such as benches, dog waste bags, and so on.

Our project's goal is to design a dog park for the town of Middleville. Firstly, we need to consider the features that we want to include in our design. After that, the design, size, materials, and fund required to construct and maintain our dog park must be evaluated. Following our park's planning, a sketch is created along with a BOM chart (a chart that includes the facility's and material's names and their costs). Furthermore, we need to make some adjustments to our plan to make it scalable . Finally, we need to write the Middleville director of Parks and Recreation a letter that contains descriptions of the park as well as information about its scalability.

One of the most significant advantage of our design is its scalability. The barriers between different parts of the park can be easily removed and placed. This gives the park ability to easily cope with changes such as increase in dog number or the degrade in dog owner’ s enthusiasm in training dogs. The second benefit of our dog park design is its practicality. Every part of the park is connected to the paths in the rhomboid, so with doors open on these paths, the dog owners can come to any part of the park directly without getting through the whole park inconveniently. The last advantage that we have is our concern about the safety of the park. We used the double door design in our park. A double door looks like a double security door but with space between the two doors. While a dog owner and his or her’ s dog want to get into the park, they need to close the first door before open the second door to get inside. This type of design can prevent dogs from snicking out of the park while someone enters.

1 Letter to the Middleville Director of Parks & Recreation

Dear Director:
We understand you are interested in building a dog park in the Middleville's Town and the nature of your request was to find a plan that is scalable and scientific.

Here is a brief summary of the steps that we took to answer your questions. Firstly, We studied the design of other dog parks as well as considerations like public input, scalability, and noise reduction to determine the park's location and shape. Then, using data from the Google Maps to modeling the patterns of visitors volume, we simulated the park's maximum capacity and hours of operation. We discovered that there would be roughly 40 dogs and 17 people in our park in the busiest hours, and that the park will be open from 6:00 a.m. to 10:00 p.m. Finally, we used these statistics to prepare the park's facilities and ensure that there are enough to go around even during busy hours.

Now, we will show you our plan in detail, and list the peculiarities and cost of the plan for your reference. Our dog park is designed as an irregular shape pinches between two sides of the lane, part of the existing path to the skateboard park and a road that connects two paths to the skateboard park. The blue area is the parks revenue area. This section includes an 80-square-meter store that sells pet-related items. The green area is a 2950 square meters main playing area of the dog park. In the shade of the two trees, 4 benches are placed, and there are two groups of 2 small dog entertaining facilities. This area is equally well-organized, with four trash cans in separate corners and a flushing tank. The bright yellow region is reserved for small dog s & old dog owners area.This 900 square meters area includes 2 small dog playing installations, four benches, a trash can and a flushing tank. The sum of the cost of fencing, construction and facilities of our dog park is about 62591.4 dollars.

We hope that you find the flexibility and efficacy of our model compelling, and adopt it for future application.

Thank you for contacting us to create this model for you.

Team,
11791

Contents

2 Introduction

Dog is the most popular pet in the USA. According to national pet owners survey, about 63 percents of pet in the United States is dog.(American Pet Products Association's 2019-2020 National Pet Owners Survey). In 2018, there were already 89.7 million dogs in the USA alone, and the number had increased about 19.7 million from 2012 (Pets by the Numbers. The Humane Society of the United States. www.animalsheltering.org). At the same time, about 48.5 percents of American family had at least one dog, the number has increased about 16.9 percents since 2012. Also in 2018, another survey showed that an average American family had about 1.49 dogs.....

Because of the dramatic increase in the amount of dog ownership, the demand for dog park has a significant increase. From 2010 to 2015 the amount of dog parks had only increased for less than 100 (Center for City Park Excellence, The Trust for Public Land). But mean while, from 2012 to 2018, the amount of dogs had increased for about 19.7 million. The increase in the amount of dog park is far behind the significant increase in the amount of dogs.

Dog parks are typically defined very broadly. The American Kennel Club (AKC) states that a dog park is, a public park, typically fenced, where people and their dogs can play together.The National Recreation and Park Association (NRPA) defines a dog park as,a contained public area where dog owners may allow their dogs to run off-leash.Also variably referred to as bark parksandoff-leash areas. Generally speaking, Dog park is a type of communal facility that has a similar purpose as human playground. A dog park is used for dogs to exercise, play and rest. A dog park can also be a social place for dog owners.

The Middleville, is a medium sized town located in the United States. The town has approximately dogs, but there isnt a single dog parks in the town. Due to the increasing demand for a dog exercising and neighborhood socializing area, The Town of Middleville Director of Parks & Recreation has asked us to build a dog park. This paper thus seeks an opinion of how to build the dog park. The data about dog population in towns, descriptions of other famous dog parks and dog owners public survey are analyzed. Further more, we choose the location and shape of the park while calculate the cost of equipment and facilities that are needed.

2.1 Problem Restatement

Our project's goal is to design a dog park for the town of Middleville. Firstly, we need to consider the features that we want to include in our design. After that, the design, size, materials, and fund required to construct and maintain our dog park must be evaluated. Following our park's planning, a sketch is created along with a BOM chart (a chart that includes the facility's and material's names and their costs). Furthermore, we need to make some adjustments to our plan to make it scalable . Finally, we need to write the MiddleVille director of Parks and Recreation a letter that contains descriptions of the park as well as information about its scalability.

- Preparation: This section will include designs for the park's shape and size. It also needs to include ia plan for the materials and features you want to include or use, as well as an estimate of the cost to maintain. This section should conclude with a clear final report on the design.
- Designing: A BOM chart should be included (The type of list that includes the number of materials and the cost of it as well). A sketch of the park should also be included in this section. All of the appliances, walkways, ground materials, and other amenities you created should be included in the sketch. Finally, this project should be scalable in order to accommodate future adjustments.

- Sharing: This section includes a letter to the Middleville Director of parks & recreation describing the project in three ways: features, scalability, and the dog park's location.

3 Assumptions

1. **Location of Middleville**
   Assumption: We assume that Middleville is a town located in the United States.
   Justification: Our visitor volume data were collected from 127 dog parks in the United States.

2. **Category of Park**
   Assumption: We assume our dog park is a neighborhood (small) type of park and serves up to a 2-mile radius.
   Justification: According to the standards of the *Salt Lake County Off-Leash Dog Park Master Plan Level of Service Standards (2008)*
   , our dog park with an area of less than 1 acre falls under the category of neighborhood (small) dog parks.

3. **Uniqueness of Park**
   Assumption: We assume that Middleville is the only dog park in this town.
   Justification: Generally speaking, there is often one or none dog parks in a medium sized town, and there is no signs or data about the another dog park of the town in the paper.

4. **Source of Fund**
   Assumption: We assume that our park building program is supported by the government, and the government will give us abundant capital to use.
   Justification: The project is given by the government to us and want us to design the dog park for them, so the government should to give us capital to complete our plan.

5. **Neglectable Seasonaility**
   Assumption: We dont include season as a factor that affects the amount of people come to the park.
   Justification: Our information source, the Google Map, doesnt include season as a factor. Instead, it uses the weekday strategy to calculate the average amount of people come to the park.

6. **Neglectable Age Factor**
   Assumption: We dont include the age of the dog owner as a factor that affects visitors' behaviors, including when they choose to visit the park and how long they stay during each visit.
   Justification: Without any demographic data of visitors to dog parks available, it is not manageable to include age as a factor in our model.

7. **One Household, One Person**
   Assumption: We assume that only one person will be responsible for taking dogs to our park for every household.
   Justification: Dog-waking is usually the responsibility of one family member.

8. **Separated Areas**
   Assumption: We assume that big dogs should have their owns area while small and medium sized dogs share another area separated from the big-dog area.
   Justification: In the United States, the number of big dogs is nearly the same with the sum of the number of small dogs and the number of medium sized dogs (Dog Ownership in the United States) in the country, and according to public surveys, most of the dog owners are agree with the opinion of separate dog areas.

9. **Univariate Model**
   Assumption: We assume that the number of visitors coming to our dog park is only affected by the area of our dog park.
   Justification: It is too complicated to quantify the impact of other factors such as the environment of dog parks on visitor volumes.

4 Variable Definitions

A table of variables used in the study is given below.

Notation	Definition
t	time
C	Circumfence of the dog park, in feet
A	Area of the dog park, in acres
SSE	Sum of Squared errors
λ	Poisson parameter of the Visitor Volume Model
A_p	Area of the pet market at Paw Hub
r_t	Monthly leasing fee of the pet market at Paw Hub
P_t	Number of premium members of Boomerang Dog Park
F	a Fixed annual premium membership fee of Boomerang Dog Park
W_t	Hourly usage of water by each water fountain
N_f	Number of water fountains
T_f	Active hours of water fountains
C_f	Price of water per gallon
P	Power of each light bulb
N_l	Number of light bulbs
T_l	Active hours of light bulbs
C_l	Price of electricity

Table 1: Notations

5 Model Description

5.1 Data Collection

Google Maps provides visitor volume data of dog parks via the Places Application Programming Interface(API). The hourly total number of visitors to a dog park is collected from 00:00 to 24:00, Monday through Sunday, to produce historical average numbers of visitors for each hour in a day and each weekday in a week. We first conducted an exhaustive search, using a Python program to collect unique place identification numbers of 1,058 dog parks across the United States from Google Maps Places API service. Since it is both time-consuming and expensive to collect visitor volume data for all dog parks, we randomly sampled 200 dog parks and collected their "open and close time" as well as "popular hours" data. After a data preprocessing procedure, including removing invalid data and imputing means for missing values, we have a sample size of 127 dog parks' visitor volume data for further analysis.

5.2 Data Analysis

We firstly observe the weekly total numbers of visitors of the 127 dog parks in the U.S. follow a normal distribution. While the most popular dog park receives 7,087 visitors per week on average, the least visited dog park only hosts 695 people per week as shown in Figure 1. Although the visitor volume of a dog park is governed by complicated factors including its area, environment,

location, etc., without detailed data we assume the size of a dog park is the only component affecting its visitor volume.

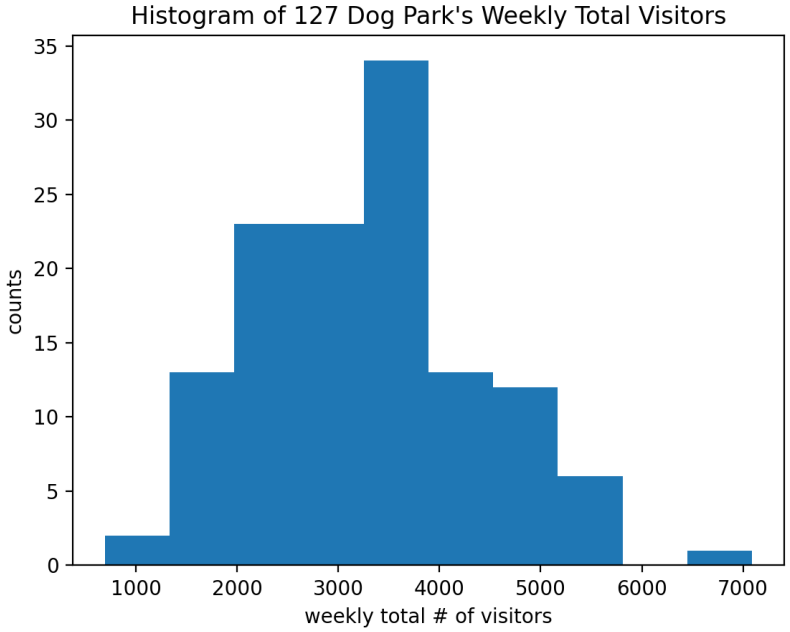

Figure 1: Histogram of 127 Dog Park's Weekly Total Visitors

Combining hourly numbers of visitors in each weekday and averaging across the data of 127 dog parks, we are not surprised to see an obvious increase of visitor volume during weekends. As the daily visitor volume in Monday through Friday fluctuates around 400 people, it increases by 50% to about 600 people on Saturday and Sunday.

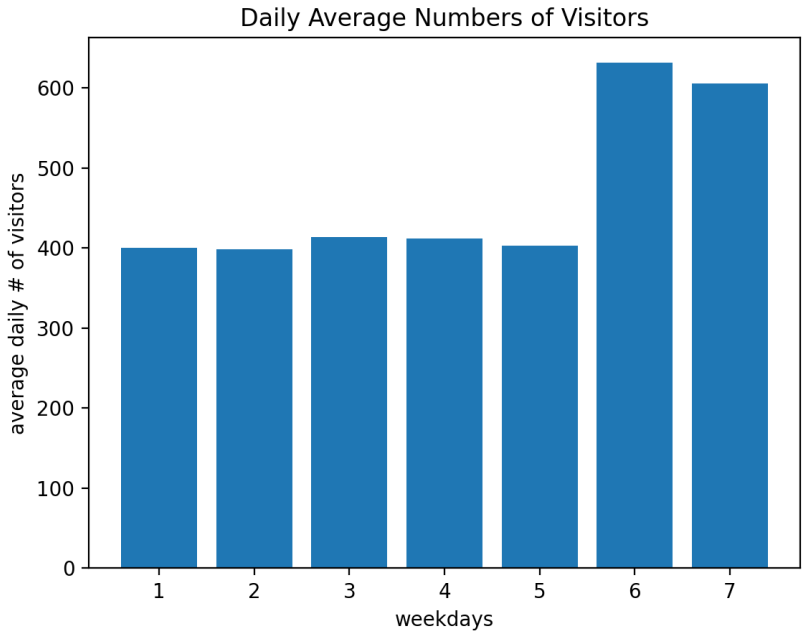

Figure 2: Daily Average Numbers of Visitors to Dog Parks

On top of the visitor volume data per weekday, we take a step further to examine data on an hourly scale. Regardless of weekdays, we integrate the hourly numbers of visitors during 23 one-hour time slots between 00:00 and 24:00. It is easy to see the most active hours of dog parks are from 6 A.M. to 10 P.M., and the analysis of data from the 127 dog parks also supports this idea, that the modes of opening and closing hours coincide with 6 A.M. and 10 P.M. What's more, the distribution of average number of visitors over the time axis appears to have two peaks, one around 11 A.M. and another around 5 P.M. We plan to follow the pattern of the most of dog parks and also operate our dog park from 6 A.M. to 10 P.M., Monday through Sunday.

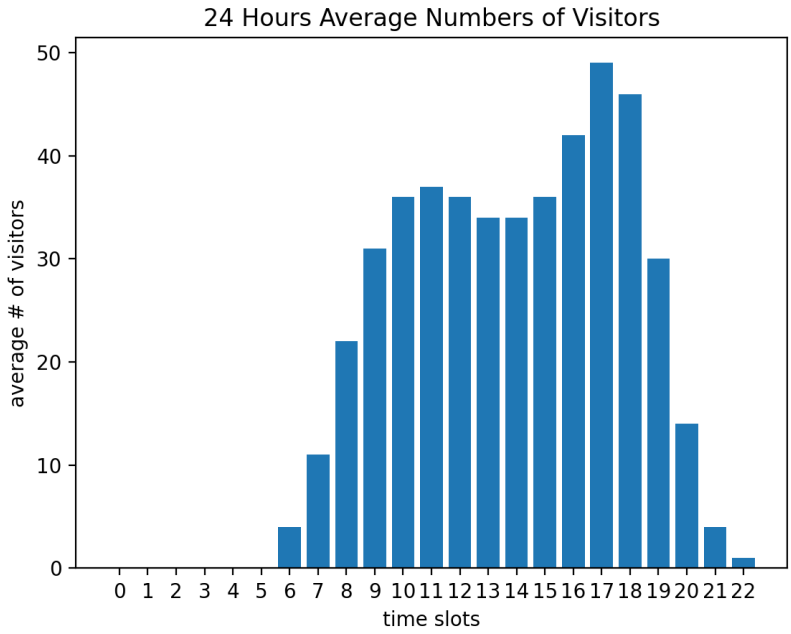

Figure 3: 24 Hours Average Numbers of Visitors to Dog Parks

5.3 Visitor Volume Model

In this section, we try to estimate the number of visitors to our park per hour with a Visitor Volume Model, so that we can accordingly design and plan for our park settings. Since the outcome of an individual's visiting behavior is a binary variable ("to come" or "not to come", it is a question), the number of visitors during a one-hour period should follow the Poisson Distribution, the mathematical expression of which is given as,

$$p(x) = \frac{\lambda^x e^{-\lambda}}{x!} \tag{1}$$

where $p(x)$ denotes the probability of x visitors coming per hour and λ is the Poisson paramter as well as the mean.

5.3.1 Calculate the Poisson Parameter λ

Since we do not have detailed information such as area or running budget of the 127 dog parks in the U.S., following our assumption of area being the only explanatory variable for visitor volume, we decided to adopt a clustering algorithm, K-means, and derive the Poisson parameter λ from the centers of clusters. K-means is one of the unsupervised algorithms in the field of machine learning

based on the sum of squares criterion (SSQ), which performs the classification task by optimizing the sum of squared errors (SSE) of k partitioned groups of the investigated sample. The mathematical expression of SSE is given by:

$$SSE = \sum_{i=1}^{k} \sum_{p \in C_i} (p - m_i)^2 \tag{2}$$

where k denotes the number of clusters, C the set of samples in a cluster, and m_i the center point of a cluster.

Implementing the K-means algorithm to the weekly total visitor volume data of the 127 dog parks yields three centers of clusters, 2,139 for small-size dog parks, 3,397 for medium-size dog parks, and 4,866 for large-size ones. Therefore, it is safe to assume that about 2,139 visitors will come to our dog park every week. Dividing that number by 7 days per week and 24 hours per day, we then have 12.73 average number of visitors per hour, which is the desired Poisson parameter λ.

5.3.2 Model Result and Key Takeaways

Next, we investigate the cumulative distribution function of $X \sim Poisson(12.73)$ and find out its 99% confidence interval to be [5,23]. In other words, we are 99% certain that at most 23 and at least 5 residents will visit our dog park simultaneously in a one-hour period.
This interval of estimated visitor volume, when combined with our "one household, one person" assumption and data from *2017-2018 APPA Survey* that on average every household keeps 1.49 dogs, translates to an interval of estimated number of dogs, [8,35] (rounded up), specifying that we are 99% certain that at most 35 and at least 8 dogs will play around our dog park simultaneously in a one-hour period.
This estimation will be the basis of and guideline for our design and planning for the dog park.

6 Design and Planning

6.1 Philosophy of Design

1. Serve Local Community
2. Meet Diversified Demands
3. Use Space Wisely
4. Sustainableable Design

6.2 Introducing to you...Boomerang Dog Park!

In accordance with the philosophy of design listed above, we present our conceptual sketch of the dog park to you. Since its contours resemble with the shape of a boomerang, we have decided to call it Boomerang Dog Park.

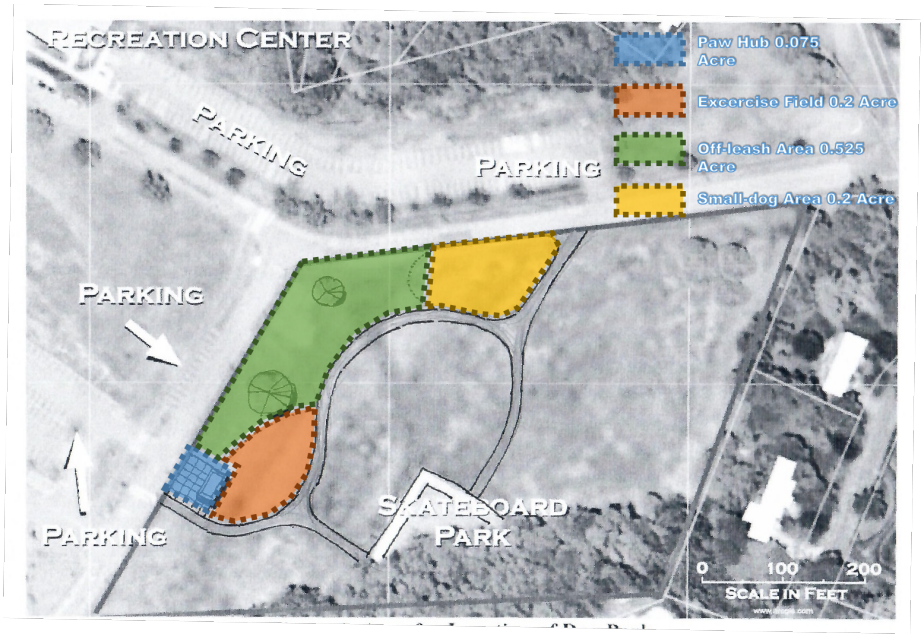

Figure 4: Boomerang Dog Park Sketch

In order to take advantages of the existing facilities, we determined to place the Boomerang Dog Park as close to the parking lots as possible and as centered between two existing roads as possible. This design not only ensures easy routes from either side of the parking lots, but also utilize two trees as natural shades as well as creating a buffer area between the dog park and the skateboard park. Besides the two roads that currently enclose our Boomerang Dog Park, we plan to construct a third road along with the inner side of the Boomerang Dog Park to connect two exisitng roads. While this third road creates a buffer area which can be used as a relaxing public space for picnics or simply lying down on the grass, it also adds extra motion lines to the park and provides accessibility for wheelchair users.
As specified in Figure 4, the Boomerang Dog Park is mainly consisted of 4 functional areas:

1. Off-Leash Area 0.525 Acre
   The Off-Leash Area is the main area of the Boomerang Dog Park. With a longest diagonal of about 340 feet, it allows large dogs to run freely and

unleash their energies. 6 entertainment facilities, 1 flushing tank, and 4 bag dispensers are planned for this area to meet the need of dogs.

2. Small Dog Area 0.2 Acre
   The Small Dog Area is designed to be a place where dogs of smaller size can play with other dogs safely. Separated from the main off-leash area with chain link fences, the Small Dog Area keeps large-size dogs and potential hazards away. 2 entertainment facilities, 1 flushing tank, and 1 bag dispenser are placed within this area.

3. Exercise Field 0.2 Acre
   The Excercise Field is designed to meet some dog owners' need of professional training. 5 professional training facilities, 1 flushing tank, and 1 bag dispenser are placed within this area.

4. Paw Hub 0.075 Acre
   Paw Hub provides a space for the Management Office (0.005 acre or 217.8 squared feet) of the Boomerang Dog Park and a pet market which retails necessities for both dogs and their owners. Power distribution and water supply systems of the Boomerang Dog Park are also integrated at Paw Hub.

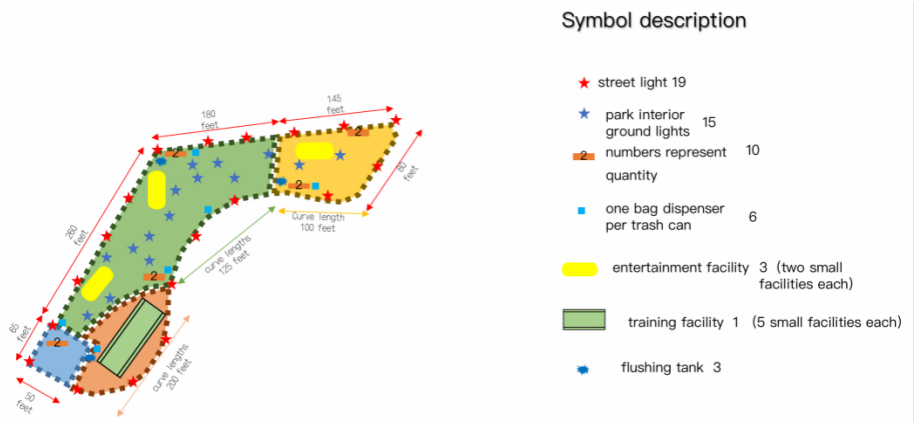

Figure 5: Boomerang Dog Park Design

6.3 Bill of Materials

bill of material				
item number	item number	amount needed	cost per item	total cost
18	dog slide	2	156.25	312.5
17	obstacle climb shelf	2	50	100
16	broken bridge	3	15.625	46.875
15	four stage platform	2	156.25	312.5
14	single plank bridge	2	156.25	312.5
13	jump through hoops	5	15.625	78.125
12	drinking fountains	3	80	240
11	dog passage	5	10.9375	54.6875
10	fences(120cm width ,160cm height)	390	28	10920
9	streetlight(3lm)	19	59	1121
8	bag dispenser	6	22	132
7	Lawnlamp (15lm)	15	56	840
6	bench (50.4-in W x 35-in L)	10	112	1120
5	trash can 13.5gallon	6	17	102
4	poop bags	6	0.6	3.6
3	water pipes	341	1.5	511.5
2	Double door	4	1662	6648
1	wooden gate	2	28	56
0	Grassground	50000	0.75	37500
	Total cost of materials	59294		

Figure 6: Boomerang Dog Park Bill of Materials

6.4 Rules and Regulations

- Dogs are required to wear a collar with current license and rabies tags.
- Large dogs are not allowed to enter the Small-Dog Area. Small dogs are not required but recommended to play within the Small-Dog Area.
- Maximum 2 dogs per owner/handler per visit.
- No female dogs in heat allowed in dog park.
- No puppies under 4 months allowed in dog park.
- Aggressive dogs are not allowed and any dogs exhibiting aggression must be removed by owner immediately.
- Dog leash laws apply up to dog park fenced boundaries.
- Dog leash to be removed inside double gate; dogs shall not wear leashes inside the dog park for their own safety.
- Dog owners are responsible for cleaning up their dogs' waste before leave.

- Social distancing rule applies to the Boomerang Dog Park during speical periods.

6.5 Construction Budget Model

- Gates
  We set 6 gates in total, two of them were right next to the road, two of them are set in the two edges of our park in case anyone comes from the skateboard park. One of the gate were set right on one side of the shop for those who want to buy somethings when they leave our park. The two gates inside of our park were for the separation between sections, its mainly for dogs that might run into the other section rather than for human. And to be an addition, the gate that separates the big dog section and the training section would be locked, cause you need to pay to get inside and train, also not to let those who are training to get interrupted. An additional design we decided to use for the gate doors is that we wanted to use a special kind of door in for the four entrance, the double door, where theres two door joined together. The benefit of this kind of door is to not let the dog run away by it self.

  Cost:
  Cost per one double door = $1662
  Total double door needed = 6
  Total cost of double door = $9972
  Cost per gate = $28
  Total gates needed = 2
  Total cost of gates = $56

- Water Pipes
  According to the water supply net designed by the US government, we knew the fact that theres pipe under every roads, and because our dog park is right next to the connection of the two roads, we decided to estimate the total length of the pipe were going to use using the perimeter of our dog park. We chose to use the perimeter of our dog park because we dont have the ability to calculate the route of the pipes, and also, by taking the perimeter of our dog park, the total length of our pipe would definitely be enough.

  These blue lines on the road are those routes where there should already have pipes berried by the government of US, the green line are where the routes the pipes would go inside the dog park and these green dots are the places that needed water.

Figure 7: Supposed Public Water Pipes

Cost:
Cost per one pipe = $1.5
The length per one pipe = 1 meter
Length of pipes needed = perimeter of our dog parks = 1540 feet = 341 meter
Total pipes needed = 341 / 1 = 341 pipes
Total cost of pipes = 341 * 1.5 = $11.5

- Street Lights & Small Lawn lamps
  We first calculated the light coverage for both kind of the light sources, and we then fill the surrounding ways by the bigger street light and fill then inside of our park with the smaller lawn lamps: The radius of the light of our lawn lamp is about 2 meter; The radius of the light of our street lights is about 5 meter.
  For an addition, we decided that we don't need to have the full amount of light coverage over the whole park, so many parts of the inside park could be lighted by the street lights out of the fence, which saves a lot use of small lawn lamps. And we're also not going to set any kind of light sources in the training section, because we dont think anyone would want to train their dogs in the later afternoon or in the morning when theres no sun light.

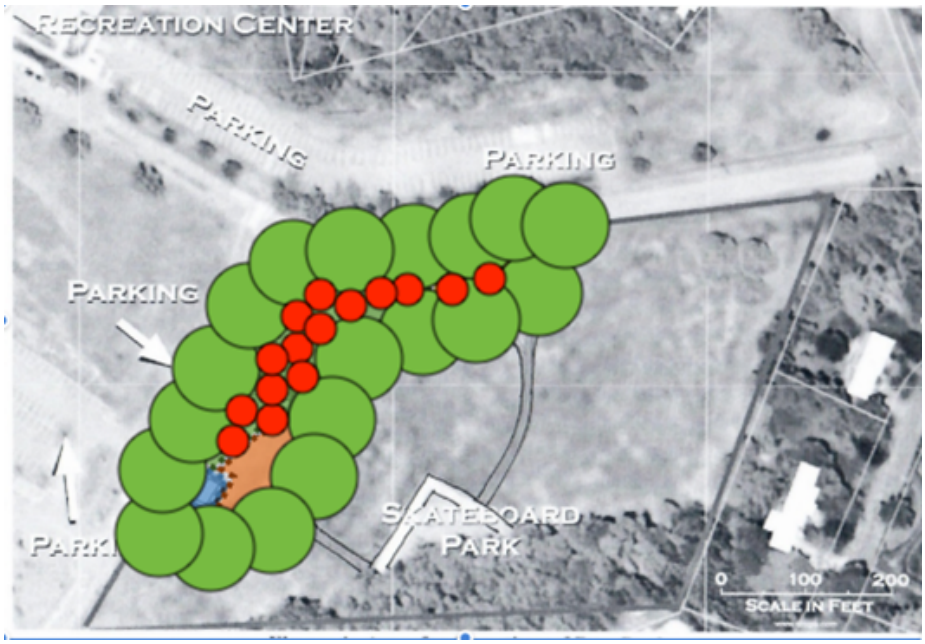

Figure 8: Light Design

Cost:
The cost per lawn lamp = $56
Number of lawn lamp needed = 15
The cost per one street light = $59
Number of street light needed = 19
The total cost of the lawn lamps = 15 * 56 = $840
The total cost of the street light = 59 * 19 = $1121
The red dot is the lawn lamps and the green dot is the street light, and the size of the dots shows irradiation range.

- Benches
  According to the essay called the Master Plan(which is basically an essay about the summary of all the dog parks in the city called Clovis), we decided to put all of our benches in a shaded area in some way, no matter if the shade is created by trees or sheds. Because theres already two trees in the part of our park for the bigger dogs, so we could put the benches under the trees right away. But for the part for the smaller dogs, there isnt any shaded area created by tree, so we need to add a shed in the corner of the park to create a shaded area for us to put benches. The reason we decide not to put any benches inside the training section, because we dont believe that anyone would want to sit down and train their dogs.
  The costs:
  Benches:

Cost per bench = $112
Amount used = 8
Total cost of benches = 112 * 8 = $896
Shed:
Cost per shed = $341
Amount used = 1
Total cost = 1 * 341 = $341

Figure 9: Bench Design

The green dots are the benches and the purple dot is the shed.

- Fence Cost per one fence =$28
  perimeter = 409 meter + 23 meter = 432 meter
  length per fence = 1.2 meter
  Total fences needed = 432 / 1.2 = 360 fences
  Total cost of fences = 28 * 360 = $10080

- Bag Dispenser
  The bag dispenser is for the dog owner to collect their pets dung, so we set a trash can near each bag dispenser. Theres going to be some texts on each of the bag dispensers to remind the dog owners to remember to

collect the waste from their pet dogs.
Cost:
The cost per one bag dispenser = $22
Number needed = 6
The total cost of the street light = 22 * 6 = $132

Figure 10: Trash Can Design

The blue dot represents a bag dispenser with a garbage can.

- Building Construction
  According to the source Private industry employer costs for employee we found out that for each workers we used, we need to pay them a price of 32.24 dollar in the South and 40.62 dollar in the Northeast. We dont have the actual location of our dog park so we decide to take the average cost between the Northeast and the South.
  Average cost = (32.24 + 40.62) / 2 = $36.43 per hour
  Because there dont have too much things for the worker to do, so we assume that all the work should be done by 3 workers in 20 hours (most of the time were used for building the pipes). Total cost for building the park = 36.43 * 20 * 3 = $2185.8

6.6 Maintenance Budget Model

6.6.1 Revenue Model

Upon the onset of the Boomerang Dog Park's operation, its annual revenue is comprised of two major sources: leasing fees of the pet market at the Paw Hub and premium membership fees. Premium members of the Boomerang Dog Park are benefited from a discount rate at the pet market negotiated with the business owner. Furthermore, the Boomerang Dog Park will hire a dog training expert to offer lessons exclusively for premium members twice a month. The monthly leasing fee increases at a long-term inflation rate, and the premium membership fee is fixed unless adjusted by a community hearing. The annual revenue model can be described as,

$$R(t) = 12 \cdot A_p \cdot r_t + P_t \cdot F \tag{3}$$

where A_p denotes the area of the pet market at Paw Hub, r_t the monthly leasing fee per squared feet increasing at a long term inflation rate of 2%, P_t the number of premium members increasing at a long term population growth rate of 0.5%, and F a fixed premium membership fee.

6.6.2 Cost Model

We provide a breakdown analysis of the annual maintenance cost of the Boomerang Dog Park. Costs mainly come from:

- Water and Electricity Usage
  The cost of water and electricity usage is generated from the flushing tanks and lighting devices. We assume the business owner of the pet market will pay his or her own bills for utilities. The cost of water and electricity usage is then modeled as,

  $$Costof Utilities = W_t \cdot N_f \cdot T_f \cdot C_f + P \cdot N_l \cdot T_l \cdot C_l \tag{4}$$

  Definitions of notations can be found in Table 1. Note that the first term of (4) follows the rule of exponential growth at the rate of long-term population growth rate and the second term always remains unchanged.

- Operating Expenditure
  The operation of Boomerang Dog Park involves two positions: two full-time park managers working in shifts and a part-time dog coach giving training lessons to premium members twice a month. With an exponentially growing hourly rate factor S_i, the operating expenditure model is given as:

  $$Costof Expenditures = \sum_{i=1}^{3} S_i \cdot T_i \tag{5}$$

  where S_i denotes hourly rates of three employees and T_i their working hours.

- Bag Costs
  The Boomerang Dog Park is supposed to provide free trash bags for visitors. Costs incurred by the consumption of trash bags are constrained by both the number of dogs and the unit price of trash bags, which can be expressed in the form:

$$CostofBags = C_b * N_b \tag{6}$$

- Repairs and Replacement
  In this study, we only consider the repair and replacement of light bulbs as they are the most vulnerable parts of park assets. Firstly, we try to find out the expected time $E(T)$ of the first light bulb to burn out and set that period of time as Boomerang Dog Park's period of preventive maintenancean. As we notice the average lifetime of a LED bulb is 10 years, the event could be desribed as,

$$\min[T_1, T_2...T_{N_l}] \sim exponential(\sum_{i=1}^{N_l} \lambda_i) \tag{7}$$

  Since the number of light bulbs N_l is fixed and known, we subsitute $N_l = 34$ into (7) and acquire:

$$\min[T_1, T_2...T_{34}] \sim exponential(\sum_{i=1}^{34} \lambda_i) = exponential(\frac{34}{10}) \tag{8}$$

  and the expected value $E(T)$ is simply $\frac{1}{\sum_{i=1}^{34} \lambda_i} = 0.294$ year.
  Secondly, we are interested in another question: How many light bulbs need to be changed in every preventive maintenancean? We realize that the status of each light bulb are indepent identically distributed (i.i.d.) exponential variables, and the number of light bulbs mulfunctioning follows a binomial distribution, giving the probability of more than k light bulbs working normally as:

$$Pr(X > k) = 1 - \sum_{i=0}^{k} \binom{N_l}{i} p^i \cdot (1-p)^{N_l - i} \tag{9}$$

  and p is given by $Pr(T_i > 0.294) = 0.971, T_i \sim exponential(\lambda = \frac{1}{10})$.
  Subsitute $p = 0.971$ and $N_l = 34$ into (9) and solve the cumulative density function of $Binomial(n = 34, p = 0.971)$for the 99th quantile, i.e., the k value, we finally find out that more than 30 out of 34 light bulbs are expected to work normally in preventive maintenancean conducted every $\frac{10}{34}$ years and at most 4 bulbs need to be replaced each time.
  Next, we use the data of average hourly rate of electrical technicians and average selling price of a LED light bulb to calcualte the total cost of light

bulb repairs and replacement in a 10-year period:

$$\begin{aligned} TotalCost &= \frac{10}{\frac{10}{34}} \cdot 4 \cdot \$5 + \frac{10}{\frac{10}{34}} \cdot \$25 \\ &= \$2,380 \\ AnnualCost &= \frac{\$2,380}{10} = \$238 \end{aligned} \tag{10}$$

6.6.3 10-Year Budget Forecasting

Year	Revenue	Cost	Balance
2023	139788	175011	(35223)
2024	141607	176854	(35247)
2025	143457	178729	(35272)
2026	145340	180637	(35297)
2027	147255	182579	(35324)
2028	149204	184555	(35351)
2029	151186	186567	(35381)
2030	153203	188614	(35411)
2031	155256	190698	(35442)
2032	157344	190698	(35476)

Table 2: 10-Year Budget Forecasting

6.7 Response to Policy Changes

- Cost increasing
  If the cost increases, our first consideration is to increase create income project.For example,pet dog beauty treatment,service centerand so on. We can also add some manual services, such as park navigator,dog trainer and gardner.Create income projects can not only make our park more diverse, but also reduce the cost of maintenance. After the cost increases, we can also beautify the park and add some green plants to the park.After all the above, we can also consider the publicity of the park and how to make our park more famous and have better reputation.

- Cost decreasing
  If we have less cost, we can delete the yellow area which is the reserving place for the small dogs. And we can also decrease some facility, such as the tent ,dog slide and dog passage. And the training area can have less facilities. If the limitation is samll, we don't need to build the dog necssity shop. We can make it into a grass land. Moreover we can change the facilities in the park. We can choose the cheaper devices for the dog park. Which can decrease the cost of the park. For example, we can buy the cheapest artificial grass, the cheapest fences. On the other hand, we

can extend the time to finish the building of this park. So that we can hire less workers.

- Area increasing
  We can add a rest area under the round footpath to give dog owners a better experience, or we can be more bold , expand a dog swimming pool. And we consider that the dog owners will be boring in th edog park, so we can add a service center for people who come to the dog park. There's some snack shop provided in this center. It will be convenient for the guest. Also, we can think about building a large dog training place. More dog can get trained here. It can be a training place for the professional dog training company.

- Area decreasing
  We can give up the yellow area which is the small dogs' area. It's not necessary for this dog park. But all kinds of dogs can only play in the green area. The another idea is that we can give up the dog necessity shop. It will be convenient for dog owners to buy some thing for their dogs. But it's not the most important thin gin this park. Or we can discard the orange area. And the training area. It's a special place for the people to train their dogs. But the green area can also provide enough area and equipment for most people to have dog drill. So we can choose one of these three places to save the area of this dog prak.

7 Analysis

7.1 Strengths

- Our modeling have different areas for different dogs. We have big dog area and small dog area. So its safe for both big dogs and small dogs. Also we provide some amusement area and training devices for dogs. The training area is free for people to train their dogs. There are 5 training projects in this area.

- Our layout is also very reasonable.

1. We use the existing footpath of the park to lead people from the public parking in the north and west to the park. Add a footpath so the existing footpath of the park to form a circular footpath system
2. The dog park has an area of 43000 square feet, including 'pet heart'pet store and pet medical care, pet training ground and pet public activity ground. Reserve 9800 square feet of small dog activity space.
3. Pet activity areas are separated by fence. You can set the fence to separate the two areas or You can cancel the fence and put the two areas together

4. We can set many entrances and exits along the footpath

- We choose a good location for this dog park. Its next to the parking area. So the dog owner can park their cars easily. Since the parking area is adjacent to the dog park, they dont need to walk for a long time to get to the park. And in consideration of the dog owners will feel boring in the dog park. The dog park is near the recreation center. After the owners bring their dogs to this dog park, they can go to the reaction center to have fun.

- Around the dog park, we have 19 big lights which provide enough light for the road. And 15 small lights are set inside the dog park. It illuminate the whole park. There are fences around the park. They are 1.6 meters high. It can prevent the dogs jump out the park.

- We set 6 trash bin in the park. We consider that the dogs waste is difficult to deal. We provide the bag dispenser for every guest who get into the park. People can use it to clean the dogs waste. There are extra bags beside the trash bin after you use the bag dispenser.

- In our dog park we design three flushing tank which the dog can take shower there. Its really convenient for dog owners.

- Our feature is our creating income projects, which can reduce our later maintenance cost . In case of insufficient funds, creating income projects can also be delete.The creating income projects are pet shops and pet medical care, which can provide dog owners with daily necessities and other services, or emergency measures like first aid in the park.

- In addition, we have a very interesting design. We call it double door. We use a fence to enclose a small space for the first door, and then open the second door at the fence. After entering the first door, we close it. And then open the second door. The main purpose of this is to prevent dogs in the park from running out.

7.2 Weaknesses

- We want dogs to have more kinds of entertainment, so we setting up a lot of entertainment facilities, will increase part of the cost, and the increase of facilities will lead to a lack of space.

- In the underground pipe network, we did not calculate and modeling the arrangement and connection of pipelines. The underground pipe network requires a lot of information resources and calculation, which requires more time.