The 2025 MidMCM

Kayla Blyman, PhD,
Associate Professor and Chair of Mathematics at Saint Martin's University, MidMCM Director, and ICM Director

Amanda Provost,
Doctoral Candidate in Mathematics Education at Montclair State University

Thomas Roberts, PhD,
Associate Professor, Bowling Green State University

Congratulations to all the teams who participated in the fifth annual international Middle School/Level Mathematical Contest in Modeling (MidMCM). A total of 108 middle school/level teams, with up to four students each, representing 53 schools and 6 countries/regions, competed in MidMCM this year. The judges were impressed with the obvious time and effort that all teams put into their submissions. The MidMCM is an amazing and rewarding experience for students, advisors, schools, and judges around the world.

We applaud all participants. In the end, three teams rose to the top and were designated Outstanding Winners. The National Council of Teachers of Mathematics (NCTM) supported the designation of one of our MidMCM teams as the NCTM Award winner.

Outstanding Teams

- 16524 - Edu Plus Academy, Irvine, CA, USA, NCTM Award Winner
- 16895- Yali-Peicui School, Changsha, China
- 16970- Shanghai Pinghe School, Shanghai, China

The 2025 Contest

We are truly impressed by the amazing teamwork and creativity shown by participating students. The MidMCM problem, *Responsible and Interesting Zoos!*, challenged teams to develop models that could be used to design a scale model of a zoo, with an emphasis on wildlife conservation, scientific research, recreation, and education. The variety of approaches that teams took to the problem delighted judges.

Overview

While COMAP has offered international modeling contests for over 40 years, 2025 was only the fifth year in which MidMCM joined HiMCM as an annual fall contest. As mathematical modeling continues to expand in the school curriculum, participation in COMAP's modeling contests continues to increase.

MidMCM participants demonstrate strong mathematical modeling ability as is evident in the problem solutions and professional submissions we receive. Advisors and teachers deserve a lot of credit for their work with their students. As teachers and students engage in mathematical modeling at all levels, COMAP is happy and eager to assist your efforts.

Results

Table 1 shows the results of the 2025 Middle School/Level Mathematical Contest in Modeling (MidMCM).

In total, 372 students participated in the 2025 MidMCM. A wide range of schools competed, including teams from Australia, Canada, China, Peru, Singapore, and the United States of America. The 43 teams from the United States represented 13 states. Submissions included 65 foreign teams with China representing about 89% of those teams.

Our MidMCM participants are quite diverse. Of the 372 student participants this year, 142 (38%) self-identified as female and 230 (62%) self-identified as male. We hope that all students enjoyed their contest experience and continue to pursue further Science, Technology, Engineering, Arts, and Mathematics (STEAM) in their studies and beyond. We welcome all levels of middle school/level students to participate in the MidMCM. The only prerequisites for success in the contest are middle school/level mathematics skills and concepts and a desire to work on a team to solve a real-world problem.

Rules

Teams of up to four students all under the age of 14½ years old can schedule their own working time within the two week contest window. Our 25-page limit for papers results in well-written and well-organized solution papers. Teams must choose what information, modeling, and graphical support is necessary to present their full analysis of the problem within 25 pages.

Outstanding	%	Finalist	%	Meritorious	%	Honorable Mention	%	Successful Participant	%	Total
3	3%	5	5%	11	10%	27	25%	62	57%	108

Table 1: *2025 MidMCM Judging Results*

One important rule is that students may only use the members of their own team along with inanimate (non-living) sources to complete the contest problem. Students may not use their teachers or advisors, any chat rooms, electronic communication, or social media sources. Each year we have some teams that do not understand this rule. To be clear, contacting an expert in a field or an author of one of the referenced sources is a violation of this rule. Gathering data from persons outside of your team through the use of an interview or a survey or a questionnaire is a violation of this rule. Using solutions shared electronically by other teams or by organizations is a violation of this rule. Again, only the team members may contribute to the solution through their own knowledge and work, and by using inanimate resources (e.g. research articles, web sites, textbooks, journals, publications). Additionally, COMAP will never require that you purchase additional materials or information to be successful in the MidMCM. The materials and information provided by COMAP, along with your own team's knowledge, skills, and perhaps a bit of research using allowed references, is all that you need for success.

Artificial intelligence (AI) may be used to help teams in the competition. For example, using AI to conduct research on the topic or to edit grammar or to translate a paper to English are all acceptable uses of AI. All uses of AI must be reported. The report does not count toward the 25 page limit. A good report includes all AI prompts and the associated AI output. Submissions that heavily use AI are often unsuccessful. Submissions that heavily use AI with limited or no AI reports are often scored low or disqualified.

COMAP uses X (formerly known as Twitter) and Weibo to provide contest information to participants. Follow us @COMAPMath on X or COMAPCHINAOFFICIAL on Weibo for contest guidance and up to date contest information.

Judging

All contest submissions are electronic. This allows a high quality and diverse judging pool to simultaneously judge papers. In December 2025, we conducted our first round of contest judging with judges from the U.S. states of New Jersey, Ohio, and Washington. Each paper is read and scored by two preliminary judges. We thank these judges for their careful review of our MidMCM submissions.

All judging is blind with respect to any identifying information about the participants or their schools. Preliminary judges rank papers as Finalist, Meritorious, Honorable Mention, and Successful Participant. Judges sent all papers ranked as "Finalist" or "Meritorious" to Final Judging. This year, 19 papers went to Final Judging for a panel of three judges to consider. These 19 papers were the best submissions from the preliminary round. At final judging the judges decided which papers were designated as "meritorious," "finalist," and from those chose the "best of the best" as Outstanding papers. Three papers earned the Outstanding award with 5 more being designated as Finalists and 11 additional papers being designated as Meritorious. The multiple reviews for judging papers provides a good process for identifying the best submissions.

The Future MidMCM

COMAP's mission to improve mathematics education for students of all ages led to the first MidMCM in 2021. Mathematical modeling continues to grow at all school levels around the world, and we recognize that middle school/level students are modeling too. Therefore, the MidMCM will continue to occur concurrently with HiMCM in the fall each year so that middle school/level students have the opportunity to demonstrate their mathematics and modeling abilities. Please visit www.MidMCM.org for more details and the results of this contest each year.

The MidMCM allows students to mathematize their world as they use mathematics and quantitative reasoning to build models that represent, understand, and explain real world events. By participating in these contests, students look for and leverage patterns, apply critical thinking through iterative problem solving, and see how mathematics is connected to daily life. As students work through the problems, they gain confidence in their own mathematical abilities as they apply their mathematical knowledge in a collaborative effort to better understand real-world events. This also helps students realize mathematics is not just a subject in school, but it is relevant to daily life and can be a collaborative and creative endeavor.

Advisors and students often ask what level of mathematics is required, and what special programming or coding skills are needed for the contest. Our MidMCM problems require only middle school/level mathematics. As in all of our contests, each of our problems is accessible on multiple levels, with many teams making use of different levels of mathematics and technology tools. Students should apply the mathematics they understand and are able to explain in their solution analysis, as the ability to clearly communicate their methods and rationale is valued in final judging.

Advisors need only be motivators and facilitators to encourage students to be creative and imaginative. COMAP encourages all middle school STEAM faculty to get involved, encourage your students to be problem solvers, make STEAM relevant, and open the doors to future success. We want to partner with teachers as we continually strive to improve the contest and make it accessible and impactful to all students. We encourage teachers and team advisors to explore past problems with their students anytime throughout the year to prepare them for participating in the competition. All past COMAP competition problems can be accessed at mathmodels.org. Any school can enter, and each school can enter as many teams as it desires. MidMCM has no restrictions on the number of total schools or the numbers of total teams from any one school or overall.

More than just learning skills and operations, mathematics is both an art and a science. Through mathematical modeling, students learn to think critically, communicate effectively, and become confident, competent problem solvers. Success is not only about the procedural technique used, but the

Awards

Finalist
Meritorious
Honorable Mention
Successful Participant

After final judging, MidMCM papers receive a designation in one of the categories above. Depending upon the quality of the papers, the top 20-25% of submitted papers receive a designation of Meritorious or above, with approximately the top 1-2% designated as Outstanding.

2026 Contest Dates

Mark your calendars for the 6th annual MidMCM, and the 29th HiMCM, to be held November 4 - 17, 2026. Registration for the 2026 MidMCM and HiMCM will open in September. Student teams may work at any time during the contest window. At the team members' convenience, teams download and choose their problem, complete their modeling solution, and electronically submit their solution document by the deadline on November 17th. Again in 2026, one team for each problem will receive the NCTM award. Teams can learn more about COMAP's contests and registration at: **https://www.comap.org.**

MathModels.org Has Moved!

Powered by COMAP content, MathModels.org is a wonderful resource for students and teachers to make mathematical modeling a year-round activity. This site includes past competition problems, exemplar solution papers, and judges' commentaries that can provide guidance for teams preparing to compete. Teachers and students may use the materials found on this site to enrich their classes and help prepare students for mathematical and interdisciplinary modeling contests. We encourage you to visit MathModels.org and explore the resources available.

Problem Discussion

conceptual understanding in discovering the role of assumptions and model development in driving those techniques to a valid solution and conclusion. The ability to recognize problems, formulate a mathematical model, use technology, and to communicate and reflect on one's work are important skills to develop. Applying the mathematical principles and concepts that one learns is key to individual and societal future success.

Problem Discussion

We were once again extremely pleased with the submissions in the fifth annual MidMCM. The teams followed the guidance and submitted well-written and organized papers with appropriate mathematics, explanations, and diagrams.

Our MidMCM problem focused on middle school/level mathematics so that it is accessible to middle school/level students. Teams that were most successful clearly communicated their process of building a model and the outcomes from their model. This is often best done when teams use middle school/level mathematics content that they understand and can fully explain.

Creative approaches were also successful, as unique considerations of the problem illustrated diversity of thoughts and mathematics. Creativity was evident in assumptions, solutions, and in other recommendations to ensure the design of the zoo addressed the four primary purposes of conservation, research, education, and recreation. Making clear assumptions that are justified well are also important components of the strongest papers.

Papers are not as strong when teams attempt to use advanced tools and/or concepts found on the internet that they cannot fully explain. In particular, many teams this year chose to use the Analytic Hierarchy Process. None of the teams that did so provided an explanation of this technique that made the submission rise to the level of Meritorious or above.

The specific problem discussion below describes how teams addressed the requirements of the Responsible and Interesting Zoos! problem. Following this section, we provide judges' comments about the solutions and presentations by breaking down the various parts of a submission. To view the complete problem statement, visit:

www.comap.org/mathmodels or
www.midmcm.org

Problem C: Responsible and Interesting Zoos!

Teams were asked to consider how to design a zoo on a 1 square kilometer plot of land for the Council Obsessed with Maximizing Animal Prosperity (COMAP). Teams choose locations all over the world to design their zoo, many identifying locations that did not have an existing zoo.

We asked MidMCM teams to consider the four primary purposes of a zoo: (1) wildlife conservation, (2) scientific research, (3) education, and (4) recreation. To help scaffold this problem for the middle school/level, the MidMCM problem asked participating teams to identify how a zoo could contribute to each of the four purposes, and considerations about what a zoo would need for animals, employees, and visitors. In addition to the technical report, we asked teams to provide several smaller 1-2 page documents to ensure they addressed the needs of these groups more clearly.

Teams were asked to create a model based on these considerations and provide a scale model map of their zoo. Based on their research, teams defined relevant variables for use in their model. Many teams had multi-part models that took into account different components of designing a zoo, such as choosing the animals and allocating

space, and addressing the needs of employees and visitors. This information was helpful to create a 2-page visitor's guide to optimize their zoo experience.

Teams were also asked to create a 2-page memo for animal welfare groups to address the safety, health, and happiness of the animals in the zoo and to extend their model by considering other collections of animals. Finally, teams were asked to write a 1-page letter to convince COMAP on why their zoo design should be chosen and how their model addressed the four purposes of a zoo. Strong papers provided clear explanations of their models and presented the results of their models.

Judges saw many interesting papers in the fifth MidMCM. Teams presented a range of methodologies, from simple and straightforward to more complex, to respond to the requirements of this problem. Some teams had creative solutions, considering the ways they grouped animals, different geometric layouts, and by the names they chose for their models and zoos.

It seemed teams had fun developing their solutions and the judges were happy to see their creativity shining through.

Judges' Discussion

In this section we provide comments from the judges about the submissions received this year. We start with an overall perspective and then address each required section of the submission. Excerpts from top rated papers (Meritorious and above) are provided at the end to serve as exemplars. Full versions of the Outstanding papers are available at:

www.comap.org/mathmodels.

Overall

It is imperative that participants follow the contest rules posted on the website. The papers should be no more than 25 pages (the AI Use Report does not count towards the page limit) and use at least 12-point font. Within the 25 pages,

Judges' Discussion

participants should include the introduction/executive summary, the solution that addresses all parts of the problem, provides a resource list, and include any appendices. Papers should be organized, focused, well written, and free from any school or student identifying information (including in the body of the document and the file name). The process of developing, testing, and revising the model should be clearly explained. Although background research may be helpful to developing the model, this information should only be briefly addressed in the paper. We strongly encourage all participants to use spelling and grammar checkers before submitting a paper. This is often one of the areas where AI can be used effectively. However, this use of AI must also be declared on the AI Use Report. Participants from outside of the United States of America should ensure that all symbols in tables and graphs are in English.

Papers considered for Finalist and Outstanding typically use clearly defined headings that illustrate the organization of paper, being sure to address each part of the problem. They initially summarize the problem. These papers then preview their paper with an organized Table of Contents. Assumptions with justifications are clearly stated. They then explain the development of their model and its solutions, apply their model, and support the results mathematically. The very best papers communicate clearly, include a sensitivity analysis, address the model's strengths and limitations, and finally, state their conclusions. Papers that communicate clearly using non-technical language are more accessible for judges from a variety of backgrounds and areas of expertise.

Executive Summary

As the first page, or cover sheet, the Executive Summary provides a first impression of your paper. It should clearly and concisely communicate a synopsis of the paper, your modeling and analysis process, and your solution. Thorough, well-written descriptions of the problem and process are common. It is also important to include your actual results and recommendations. The Executive Summary should summarize the entire contents of the paper. Although typically written last, spend time on this important part of your submission. Team 16970 presented a good example of such a summary (Example 1).

Introduction/Background

Following the Executive Summary and Table of Contents, teams should provide some brief background, restate the problem, and perhaps provide a preview of the solution. Teams should not simply repeat what was in the summary. Most teams this year used the Introduction to discuss their considerations related to the four purposes of the zoo, the needs of the animals, employees, and visitors, such as that done by Team 16895 (Example 2). In addition, Team 16740 laid out a good research plan for their paper in their problem restatement subsection of their introduction (Example 3).

Assumptions with Justifications

Good models make necessary assumptions to help simplify the modeling process. These are sometimes called simplifying assumptions. A common mistake judges see is teams that make assumptions that are not needed nor relevant to developing their model. Good and relevant assumptions are difficult to identify and articulately state. You should include a short justification to show each assumption is reasonable and explain why it is necessary for the construction of the model. Team 17329 offered 11 assumptions with justification for each (Example 4). The assumptions

were clearly stated and thoroughly justified. They were relevant to the model the team developed. While this team was thorough with their assumptions, the judges remind teams that it may not always be possible to dedicate three pages to assumptions and justifications. The judges encourage teams to be discerning in their choices of assumptions.

Definition and Use of Variables

Most mathematical models include several (and sometimes many) variables that teams must define for the reader. Oftentimes teams present a separate section with a list of variables that includes the variable symbol, a short description of the variable, and the units of the variable. Using best practices, teams should focus on a manageable set of variables when modeling. Variables with descriptive subscripts can help with readability (e.g., Aanimals to represent the total area of animal exhibits). However, moving forward, we would like to recommend that teams incorporate these variable definitions into the sections where they are constructing their models. By incorporating the variable definitions where they are being used in the construction of the models, it assists the reader in following the logic of your process and demonstrates your understanding of the relationship between variables in your model. For instance, Team 16787 provided a basic set of notation in a list, but further defined their variables with descriptive subscripts and explanations in the context of explaining their model creation (Example 5). We find this helps teams more clearly communicate their construction and application of their models.

Mathematical Model

The development of the mathematical model is the most important part of your submission. There is always more than one appropriate solution method to our MidMCM problems and so teams should address the problem with the mathematics they know and understand. Papers should explain the development of the mathematical model(s) and/or algorithm(s) and define the relationships between variables in a logical manner. Teams should take the reader on a journey describing their thought process and steps. Better teams will explain why they choose their model and how they plan to use or modify it to fit this problem. Judges are more impressed with a well thought out (and perhaps simple) model than with a very complex model that a team struggles to apply or explain clearly. To impress the judges, focus on applying sound principles to your model that you understand. Judges do value creativity and thinking "outside of the box" in your modeling process but be sure to balance creativity with your level of expertise and modeling experience. So, be creative and have fun.

All Outstanding teams developed models that impressed the judges. Team 16524 used a simplistic approach with many considerations. Example 6 presents a few of their model formulations. While the model would need to be revised, the simplified approach led to a mathematical model that satisfactorily addressed the problem. Team 16970 also impressed the judges with their explanation of the initial map, revisions, and the final map they developed for this problem (Example 7). This approach allowed the judges to understand the team's process and how they made revisions as the larger model was refined. Team 16740 included a clear map and visitor's guide that demonstrated the team's ability to communicate the outcomes of the model in non-technical ways (Example 8).

There are many ways to model and analyze the MidMCM problem. This year we saw a variety of appropriate, as well as creative, models. Many times, a picture is worth a thousand words! The use of tables, graphs, and images is often helpful to show your modeling process. Team 17560 had a very clear visual of a labeled map with an easy to use scale (Example 9). Similarly, Team 16828 determined exactly where they would build the zoo and provided an overview of the zoo layout over an existing map (Example 10). They also impressed the judges with the Visitor's Guide that included suggested routes and attraction times, demonstrating attention to detail with the recreation and education components of the problem.

The Letter

The purpose of the letter is to show the judges that regardless of the complexity of your mathematics or analysis, you can convey your work and solution in common terms. Often, the recipients and consumers of mathematical modeling and research are not as technically astute as the mathematicians and scientists doing the work. In writing the letter, teams must translate their hard work into a shorter descriptive format. This increases the likelihood your audience will understand and consider your solution and recommendations.

Like the executive summary, the letter briefly describes the problem and background, your model or process, and your results and any recommendations. Some teams include visuals in their letter. These graphics can assist the team in presenting their process and the reader in understanding the model and results. Team 16895 provides a clear and well written letter explaining how their zoo model addresses the areas of conservation, research, education, and recreation (Example 11).

Strengths and Limitations

As teams only have a short time to develop their solutions, they should be critical of the approaches and mathematics they used in their solution. Teams should identify strengths and limitations of their work. Is your solution reasonable? Under

what conditions will it perform best and where will it not? Additionally, teams should address how changes might impact their solution. Was there a critical assumption made that if changed would significantly change the solution? Would changing the values of any constants or multipliers (coefficients) significantly impact your results? Teams should validate their models, even if by numerical example or intuition. Team 16524 provided a good example of reflecting on the model's strengths and limitations (Example 12).

Sensitivity Analysis

Few teams included a sensitivity analysis – an exploration of the impact of an assumption by changing it in some way. Example 13 shows Team 16895's sensitivity analysis for their model where they explored the impact of changing the value of their variables for animal conservation and visitor population and explained how the results of the changes in the model would impact their design. For instance, focusing more on conservation would suggest more reptiles than large mammals and more children and elderly visitors would require more visitor amenities.

Reflection in a Two Page Memo

The purpose of the reflection part of this problem, which was to write a 2-page memo to an animal advocacy group, was to have teams think about the adaptability of their model. Teams were asked to consider how their zoo model provided for the safety, health, and happiness of the animals. Example 14 is from Team 17329 who does a good job of explaining how their Paw Print Index (PPI) model addressed the needs of a zoo.

Conclusion

A clear conclusion and answers to the specific scenario questions are key components to an Outstanding paper. Attention to detail and proofreading your paper prior to final submission are vital as the judges look for excellence in your submission. Teams should take the time to read the entire paper to ensure they have followed a logical sequence and flow that tells a story from start to end. Example 15 show's Team 16828's concluding paragraph in which they explain their research, decision-making, and adjustments in the modeling process. They also acknowledge limitations in a reflective sentence. This layout captures Team 16828's experience with this problem while also reminding judges of the big picture steps they took in completing the modeling problem. Few teams included a conclusion like this, but several included a conclusion that was a meaningful reflection on their work, complete with ideas for the future.

Citations and References

Citations are very important within the paper, as well as either a reference list or bibliography page at the end. Teams that use existing models should cite their source(s) within the paper at the point they present the model and include a reference citation at the end of the paper. For example, judges noticed many teams cited specific standards to inform their model, such as the International Union for the Conservation of Nature's (IUCN) Red List Criteria. All data, figures, graphs, and tables that come from outside sources require documentation at the point in the paper where they appear and included in the reference list at the end. Lack of documentation will result in a lower designation.

Judges have noticed many teams using Wikipedia as a source. While Wikipedia can be a great tool for learning about something rather quickly, it is not an academic source and as such should not be trusted as a sole source. Teams should look for and use more authoritative – ideally primary sources – whenever possible.

Use of AI Tools Report

Teams are required to include a declaration of how they use AI tools as part of their process. Teams have used AI tools for multiple purposes including to quickly collect data sets from online sources, examine coding libraries to better understand how code can be used, and to generate potential strategies to be used. Teams should also include the full prompts and outputs from all AI tools used in their solution. A summary of prompts and outputs is not sufficient. The only exception to this is when AI is used for translation and grammar editing. Example 16 is from Team 16828 who used AI tools to conduct research for their model and included specific prompts and outputs in their Use of AI Tools Report.

Final Thoughts

The submissions for the fifth year of the MidMCM impressed judges and left them excited for the future of the contest. We truly enjoy reading all solution papers. We hope all participating students also enjoyed the experience and improved their mathematics, modeling, teamwork, and communication skills in the process. We encourage students of all levels to compete in future MidMCM competitions. To be successful, read the comments and guidance provided in this article, see the TIPS article on the COMAP website, and visit www.comap.org/mathmodels to review previous problems.

Follow us @COMAPMath on Twitter or COMAPCHINAOFFICIAL on Weibo for information about all COMAP contests.

List of Examples

1. Executive Summary (Team 16970) Shanghai Pinghe School, China

2. Introduction/Background (Team 16895) Yali-Peicui School, China

3. Introduction/Background (Team 16740) Shanghai Starriver Bilingual School, China

4. Assumptions/Justifications (Team 17329) RJ Grey JH, Massachusetts

5. Definition of Variables (Team 16787) Shanghai Starriver Bilingual School, China

6. Model Development (Team 16524) Edu Plus Academy, California

7. Model Development (Team 16970) Shanghai Pinghe School, China

8. Model Development (Team 16740) Shanghai Starriver Bilingual School, China

9. Model Development (Team 17560) McDougle Middle School, North Carolina

10. Model Development (Team 16828) Rye Country Day School, New York

11. Letter (Team 16895) Yali-Peicui School, China

12. Strengths and Limitations (Team 16524) Edu Plus Academy, California

13. Sensitivity Analysis (Team 16895) Yali-Peicui School, China

14. Reflection in 2 page memo (Team 17392) Nantong Stalford International School, China

15. Conclusion (Team 16828) Rye Country Day School, New York

16. AI Usage Report (Team 16828) Rye Country Day School, New York

Team Control Number

16970

Problem Chosen

C

2025

HiMCM/MidMCM

Summary Sheet

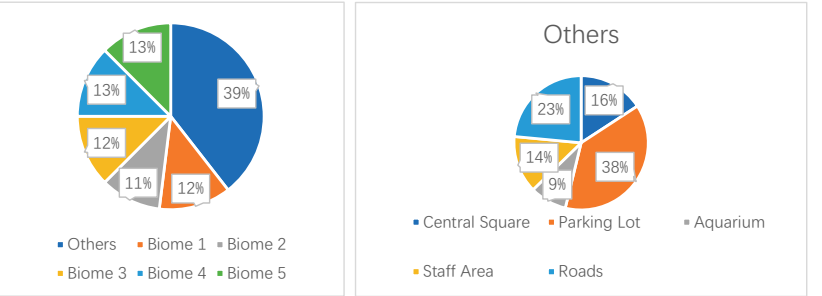
We were asked by the Council Obsessed with Maximizing Animal Prosperity (COMAP) to design a zoo with 1 square kilometer area. Our zoo, *Veridian Ark*, fulfills four primary purposes, which are wildlife conservation, scientific research, education, and recreation. The zoo mainly exhibits animals in five different biomes (tropical rainforest, savanna, desert / arid, temperate grassland, prairie, and boreal forest / taiga).

In our designing process, we first chose 30 common species for each of the 5 biomes. Next, we designed an evaluation model in Excel that aim for choosing species which have the highest scores of the combination of the four main purposes. Then, we input these species with relatively high rankings (mostly the highest 20 in overall score) into a Python program to get a more accurate selection of species. Finally, we designed the map of *Veridian Ark*, and gave each species a fixed area based on their size and scarcity.

Although the five biomes are the most essential part in our zoo, we also need to include:

- an aquarium
- a central square containing a lake with an in-lake restaurant
- a parking lot
- staff area

The purpose of the aquarium is to increase the biodiversity, and the rest of the designs focuses on cultivating *recreation*, which further increases *visitor's experience*. The figure below showcases the percentages of different sections in the zoo.



Example 1.

1 Introduction

1.1 Problem background

In today's world, biodiversity is facing unprecedented challenges. Habitat loss, climate change, and human disturbances have placed many species in a highly vulnerable position. Modern zoos are no longer merely places for viewing animals; instead, they have become integrated platforms for wildlife conservation, scientific research, education, and recreation.

This project, commissioned by the **Council Obsessed with Maximizing Animal Prosperity (*COMAP*)**, aims to design a 1-square-kilometer wildlife-friendly zoo. The goal of the park is not only to provide animals with a safe and suitable habitat, but also to support scientific research, educational activities, and enjoyable visitor experiences. The problem requires us to consider the needs of three groups—animals, employees and visitors—and to optimize layout, facility placement, and visitor routes accordingly.

Specifically, the animal section must ensure animal health and activity; the employees section must ensure safety and work efficiency; and the visitor section must provide a rich, meaningful, and safe experience. Existing research indicates that high-quality modern zoos, which operate under the four missions of "conservation + education + research + recreation" perform significantly better than traditional zoos that function only as exhibition spaces.

Through the design of this project, we aim not only to propose a mathematically rigorous optimization model, but also to present a responsible and engaging paradigm for zoo planning in terms of spatial layout and visitor experience. By balancing animal welfare, staff safety, and visitor learning, our design seeks to integrate both conservation and entertainment into a unified and meaningful approach.

1.2 Restatement of problem

1.2.1 Four Major Objectives: Conservation, Research, Education, and Recreation

The mission of modern zoos is commonly summarized into four core objectives: wildlife conservation, scientific research, public education, and recreation:

Conservation: To provide animals with an environment suitable for living, breeding, and restoring endangered populations.

Scientific Research: To support biological and ecological studies by offering observation spaces, behavioral research opportunities, and reliable platforms for data collection related to animal welfare and ecosystem science.

Education: To communicate knowledge of wildlife protection, biodiversity, and ecological systems to the public—especially students—so that visitors not only observe animals but also gain meaningful learning experiences.

Example 2.

1.2 Problem Restatement

COMAP has approached our team at MidMCM to help them develop the best zoological park possible on a 1-square-kilometer plot of land that serve all of the following functions: **wildlife conservation**, **scientific research**, **educational purposes**, and **recreation**. The zoo should promote the conservation of wildlife through propagation of selected endangered species. It should encourage research through transparent breeding processes and observations of animal behavioral patterns. The zoo should demonstrate behavioral and physical adaptations of animals, inspiring understanding of ecological systems and building public awareness, as well as providing necessary protection and sanctuary. Lastly, it should provide children and families with opportunities to enjoy interactive, hands-on enjoyment during their visit while ensuring their safety and convenience. The model represents an effort to achieve a harmonious balance by creating naturalistic exhibits of animals while addressing needs for visitor services, such as increasing convenience via providing parking capacity and employee safety. However, we need to ensure that our model is not too complex as the provided resources are not unlimited.

First, we have to do specific research on the animals we wish to keep in our zoo, including their lifestyle, needs, and habitats to ensure appropriate enclosure, health, and happiness. We also need to figure out the amenities, such as efficient and collaborative workspaces, and safety measures for assumed numbers of employees and visitors. Then, we need to lay out our zoo design on a clearly labeled map. Next, we have to present our zoo on a 2-page tourist guide handed to visitors promising a maximized visiting experience. After creating our zoo model, we need to apply it for another compilation of different a nimals. Finally, we were required to write a letter to COMAP regarding highlights of our design and an explanation of how it fulfills all requested purposes.

Example 3.

2. Problem Assumptions & Justifications

To get ourselves prepared for the zoological park design, we collected data of around 50 zoos in the US that are located in different cities, with acreage ranging from 30 to above 250. We found that large cities are usually inclined to have zoos with bigger acreage, which usually have more animals. For example, big metro areas such as New York City and Chicago have zoos with areas above 200 acres, annual visitor numbers of more than 2 million. There are zoos in regional major cities with acreage of around 100 to 150, and host animal populations well over ten thousand, such as San Diego Zoo and Omaha's Henry Doorly Zoo. This indicates that the area of 1 kilometer by 1 kilometer (around 250 acres) should have no issue at all in having a very large animal population and diversity. [1-6]

Figure 1 on top of the next page demonstrates a clear correlation between the data of zoo size, in terms of the area, versus the nearby population in the great metropolis. Therefore, large-sized zoos, with bigger acreage, tend to support a broader population and better serve the four primary purposes—wildlife conservation, scientific research, education, and recreation.

There are large zoos in places with less population, such as Wichita, Kansas, and small zoos in population-dense areas like Chicago, IL. According to what we found from the collected zoo data across the US, the zoo we are about to design (on the 1 km^2 land) should be a zoo with an ample area of 250 acres, located in a metropolitan region with a large population as potential visitors. [7-9]

Example 4.

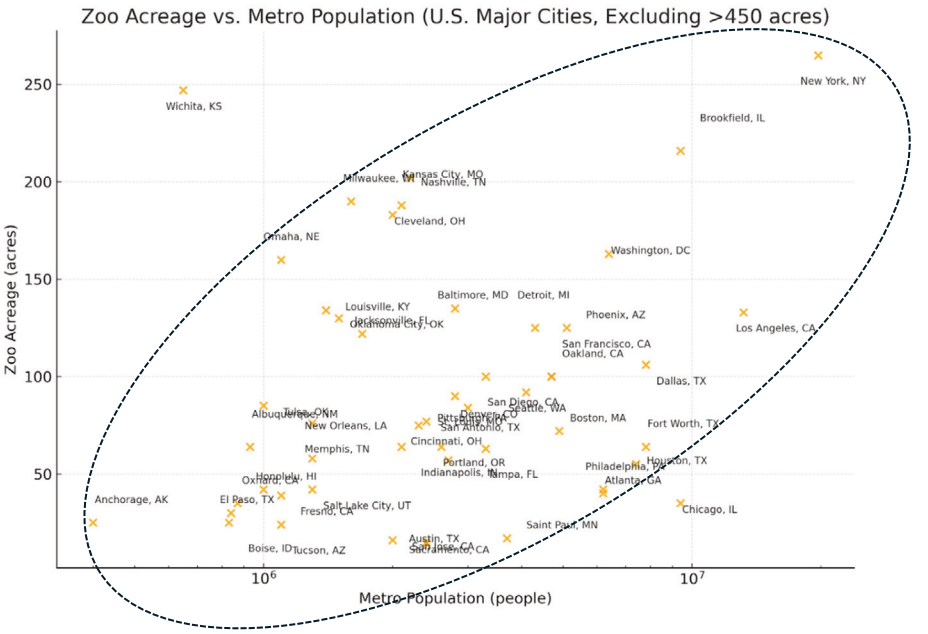


Figure 1: Data on zoo acreage vs the metropolitan population and its correlation

Among all the 50+ zoos we have surveyed, we carefully analyzed the locations, size, and number of visitors annually, safety and amenity facilities available, educational programs provided, food and entertainment, we have arrived at the following observations. [7, 10-13]

Observations:

- Big zoos usually have research/medical centers
- They group animals based on categories like enclosed and wide-open spaces
- Notice that large-acreage zoos are in large population metropolitan areas
- Large zoos have more than one entrance
- Large zoos have millions of visitors
- Zoos contain multiple cafeterias spread in the park to serve large numbers of visitors
- Entertaining facilities are always popular

Based on the aforementioned observations, we will carry out the modeling process with the **Assumptions** below:

1) ASSUMPTION

We assume that the city our zoo is located in is a metropolitan area with a large population, and that we have potential visitors on the order of millions per year.

Example 4.

JUSTIFICATION

Based on the data collected in the previous section about the public data of zoos in the country, we notice that zoos with an acreage similar to ours (about 250 acres) usually tend to be located in major cities with large populations, such as New York City or Chicago. The data also shows that these zoos have millions of visitors per year.

We have analyzed data and applied our model to six zoos in the country, with the one most similar in size to our zoo being Bronx Zoo. This zoo is the one we will be comparing our zoo to, and we want the population size in the areas around our zoo to be similar to the population of the Bronx. In addition, our data shows that zoos of this size would normally have more than one entry, for the convenience of visitors coming from different directions, so we assume that our zoo will have three.[14]

2) ASSUMPTION

We assume that money and available resources are not concerns, and that all prices for our spending could be covered and provided within reason.

JUSTIFICATION

The goal of our model is not to create a zoo that optimizes revenue or has a minimal budget, but one that generates the best product and is the most effective. Therefore, money earned is not a priority for this process, and we assume that it is not of any concern and that we have access to all necessary resources within a reasonable scale.

3) ASSUMPTION

We assume that given the 1 square kilometer plot of land, the zoo shape is a square with a side length of 1 kilometer.

JUSTIFICATION

The specific shape of a zoo should be determined by land availability and neighborhood geography, which is hard to control or change once the city location is chosen. However, the specific shape of the zoo does not have a significant impact on the design and where certain units are placed, since 1 km^2 of area is ample for a zoo. Once the units and their relative positions are determined through the modeling process, the square design could be transformed into another shape if needed. A different shape of a zoo would not affect the result of the optimization.

4) ASSUMPTION

We assume that only the size and the location of each unit, or separate functional space inside of the whole 1 km by 1 km area, will be optimized and kept track of.

JUSTIFICATION

We only care about how large each unit is and where it is because those are the aspects that will affect the outcome of our model, which is seeing how popular and effective a zoo with

Example 4.

certain factors will be. Since we only take size and location into consideration, things like terrain or shape of units are to be ignored and will not affect the result of the model.

5) ASSUMPTION

We assume that all animal species can be categorized into three groups with different traits. The first group consists of animals called territorial animals that require much more space and are usually lower in number, such as tigers or elephants. The second group, called non-territorial animals, has animals that require a fenced-in space and cohabitate in larger groups, and the third group consists of animals that are considered indoor animals, or those that require an enclosed space due to size or climate.

JUSTIFICATION

We categorize all animal species into three groups because these groups have vastly different space requirements and densities of animals, which will be important later on and affect the way we calculate the result of our model. However, there is no need to individually calculate all animal species because the size and location of each group of animals is what we're focusing on and optimizing, and the specific species of animals of the same group will not affect the outcome.

6) ASSUMPTION

We assume that the area of the path visitors use and the area of the buffer between units is small enough to be counted or included in the area of the unit itself.

JUSTIFICATION

We assume this because the area of the units is extremely large in comparison to the path the visitors will use and the buffer area between units to separate different animals that cannot cohabitate. Since the area of the path and buffer zone do not add up to much, they can be counted into the unit area without much effect on the outcome.

7) ASSUMPTION

We assume that all designs of zoos are drawn on grids with 40-meter-by-40-meter blocks, where each unit consists of a number of these blocks and each block is part of only one unit and serves a single purpose within it.

JUSTIFICATION

We assume this because it would greatly simplify the process of finding the areas of the units by changing all the irregular curves into figures made of squares. Based on the data we collected from the list of existing zoos, we know that the smallest unit we plan on, including in our design, a café, is typically larger than 40 meters by 40 meters. This means that we can effectively find the areas of each of our units using this grid. In addition, we are able to do this because the small gaps between the shape of the real unit and the shape we create using squares is small enough to be ignored, especially since that area already includes a buffer zone area and a path area (see assumption #6).

Example 4.

8) ASSUMPTION

We assume that units with any entertaining facilities included are beneficial and should be included.

JUSTIFICATION

We assume that anything added, like a playground for young children, a petting zoo, an interactive area, a cinema, etc., will be beneficial and will be included because this would be helpful for recreation, and the six benchmark zoos that we have analyzed and tested our model on all include facilities like these.

9) ASSUMPTION

We assume that the research spaces will be located far from the entrance of the zoo, or wherever visitors would not typically go, and we assume that the visitors would not want to see those spaces.

JUSTIFICATION

We assume this because visitors would not be able to enter these spaces, and to enhance their educational and recreational experience, the research center spaces should be kept somewhere that visitors typically would not go.

10) ASSUMPTION

We assume that the workspace for employees is accounted for inside the region of animals and visitors.

JUSTIFICATION

We assume that employee workspaces, such as spaces for employees that take care of animals or those that maintain things for visitors—like cafés, shops, and entertainment facilities—will be included within the animal and visitor spaces because they serve the same function and are small enough that this wouldn't affect the outcome of the model.

11) ASSUMPTION

We assume that more parking lot space is beneficial, that a parking spot will only hold one car per day, having an average of four visitors per car, and with three times as much space in the whole parking lot (unit area) as the total area of actual parking spaces.

JUSTIFICATION

We assume these things to help us create the model efficiently, as having one car per day per parking spot will simplify the problem, and assuming the whole lot is three times the area of the actual parking spaces accounts for driveways and aisles in the parking lot. This will be further explained in the modeling process on why such an assumption is reasonable.

Example 4.

Notation:

A	Area
N	Number
P	Perimeter
θ	Angle
$\bar{x}$	Average needed space of animal
F	Fencing height
H	Animal jumping height
M	cost

Below is a detailed analysis of the distribution of animals:

Let: $\theta = the\ angle\ of\ each\ sector$; $A_{central\ tower}$ includes the area of the central tower and the 5m wide passway surrounding it. Then:

$$A_{outer\ road} = A_{zoo} - A_{central\ tower} - A_{all\ sectors} = 3.14 \times 10^2 = 314\ m^2$$

$$\theta_{sector} = \frac{360°}{3} = 120°$$

$$A_{sector} = \frac{A_{zoo} - A_{outer\ road} - A_{central\ tower}}{N_{sector}} = \frac{1000 \times 1000 - 314 - \pi(100+5)^2}{3} \approx 321{,}689\ m^2$$

Each sector includes a 449m long by 5m wide passway.

We assume that each group of animals has an even distribution of land. In mammals, there are four groups of animals: Bengal Tigers, Giant Pandas, Raccoons and Red Pandas, Meerkats and Wallabies and Armadillos. Thus, each group has a total area of

$$A_{land\ animal\ group} = \frac{A_{land\ animal\ sector} - A_{passway}}{N_{land\ animal\ group}} = \frac{321{,}689 - 449 \times 5}{4} = 79{,}861 m^2$$

$$\theta_{tiger} = \theta_{giant\ panda} = \theta_{raccoon\ and\ red\ panda} = \theta_{meerkat,wallaby,and\ armadillo}\ \frac{120°}{4} = 30°$$

Example 5.

5 Model 1: Animal Welfare Scoring

5.1 Motivation

Animal welfare is the foundation of any responsible zoo. The "Five Domains" model is widely used in zoo science: Nutrition (N), Environment (E), Health (H), Behaviour (B), and Mental State (M). Each domain can be rated from very poor to excellent based on observation and veterinary records.

5.2 Variables and Formula

For each species s, we define:

- $x_{s,N}, x_{s,E}, x_{s,H}, x_{s,B}, x_{s,M}$: scores in each domain (0 to 5),
- w_N, w_E, w_H, w_B, w_M: weights for each domain,
- W_s: overall welfare index.

We compute

$$W_s = w_N x_{s,N} + w_E x_{s,E} + w_H x_{s,H} + w_B x_{s,B} + w_M x_{s,M}.$$

Assumption 1 (Equal importance). We start with equal weights:

$$w_N = w_E = w_H = w_B = w_M = \frac{1}{5}.$$

Design targets. For every key species s we require

$$W_s \geq 4.0 \quad \text{and} \quad x_{s,D} \geq 3.0 \text{ for all domains } D.$$

This means no domain can be worse than "good" and the average should be at least "very good".

Example 6.

6 Model 2: Space, Cohabitation, and Buffers

6.1 Motivation

Animals need enough space to move, explore, and avoid conflicts. Different species also have different cohabitation rules: some can share enclosures, while others must be separated. Finally, predator and prey zones should not be immediately adjacent without buffers.

We build a area model to check that each zone has enough room for its planned animals and that we respect cohabitation and buffer constraints.

6.2 Variables

Let

- Z be the set of zones: Safari, Aquatic, Desert, Arctic, Jungle.
- A_z be the total area of zone z in m^2.
- S_z be the set of species in zone z.
- For each species $s \in S_z$:
  - a_s: minimum area per individual (m^2),
  - n_s: planned number of individuals.

  The total required animal area in zone z is

$$R_z = \sum_{s \in S_z} a_s n_s.$$

We require

$$R_z \leq 0.7 A_z$$

so that at least 30% of the zone area remains for vegetation, pools, backstage areas, and visitor paths.

Example 6.

7 Model 3: Visitor Flow and Educational Experience

7.1 Motivation

A good zoo should be fun but also educational. Visitors should be able to see most of the zoo in a reasonable amount of time and encounter many opportunities to learn.

Our visitor-flow model checks that the walking distances and dwell times are reasonable and defines an education–recreation score.

7.2 Walking Distance and Time

The outer circumference of the site is

$$L_{\text{outer}} = 2\pi r \approx 2\pi \times 564 \approx 3{,}544 \text{ m}.$$

The main visitor path is slightly inside the fence, so we approximate the loop length as $L \approx 3{,}300$ m.

Assuming an average walking speed $v = 1.5$ m/s, the walking time for one loop is

$$T_{\text{walk}} = \frac{L}{v} \approx \frac{3{,}300}{1.5} \approx 2{,}200 \text{ s} \approx 37 \text{ min}.$$

Example 6.

So far, our map looks like this:

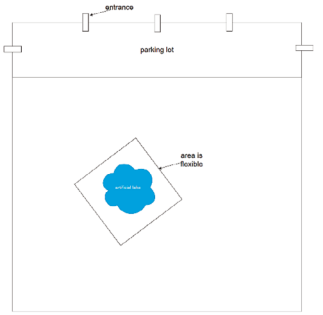


Figure 2.3.1 First Draft of Map

We made sure that the parking lot occupies an entire edge of the biggest square, so that visitors' cars can come in from every direction, and it won't impact much on the shapes of other areas.

Then, we used the rest space to design the place and shape of the five biomes and the aquarium:

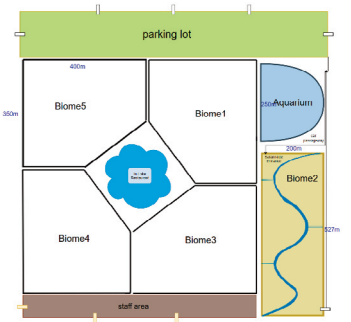


Figure 2.3.2 Second Draft of Map

In this design, **biome 1**, **biome 3**, **biome 4**, and **biome 5** all have areas of 125,000m^2, and **biome 2**, used for safari rides, has an area of 105,400m^2.

The aquarium is designed with an arc-shaped edge, so that there will be enough space for safari cars to pass. Therefore, it makes the area of the aquarium a little less than 50,000m^2.

There is also a huge area left for the staff (about 54,576m^2), so that they can rest and hold major meetings there.

Example 7.

At last, we designed the interior appearance of the five biomes, shown in **Figure 2.3.3**.



Figure 2.3.3 Third Draft of Map

Example 7.


Asia
Entrance
Interaction Tickets
River
Pands Observation Deck
lake
Fire-infared alarm devices
double fence
Working room
Restroom
Medical room
Routes
Oceania
Koala
Kangaroo
Echidna
Emu
River
Kakapo
Entrance
Restroom
Working Room
Medical room
Europe
European Brown Bear
Spanish Lynx
Red Deer
Laboratory
Wild Boar
Entrance
Exit
Fence-infared Alarm devices
Restroom
Working room
Tool room
Double fence
Polar Region
Snowy Owl
Polar Bears
performance center
Walrus
Seal
Reindeer
Entrance
River
Muskox
Medical & tools room
Restroom
Double fence
Working room
Alarm system
America
Parrots
Cougar
Jaguar
Bald Eagle
Pronghorn
Butterfly
American Bison
Gray Wolf
River
Fence—infared Alarm devices
Double fence
Restroom
Working room
Medical room
Tool room
AQUARIAM
The warm ocean
Lukewarm ocean
The cold ocean
The frozen ocean
Animal Performance Center
entrance
Exit
Shop
Africa
Double fence
Restroom
White Rhinoceros
Alarm System
Medical room
African elephant
Hippopotamus
Entrance
Working Room
Regulation room
Shop
River
Guide Map

Example 8.



Dear COMAP,

Thank you for choosing to work with MidMCM Zoological Park Consultants. We are confident our design best fulfills the standards by balancing wildlife conservation, scientific research, education, and recreation. Our design balances animal, employee, and visitor well-being with the zoo's core purposes, all within a practical, real-world framework.

Our design is based on extensive research into animal behavior, diets, spatial needs, and interspecies interactions. This is shown from specific enclosures that ensure safety by separating incompatible species and providing special care for vulnerable animals. We ensure animal safety by separating species based on predator-prey dynamics and climate. Special care is provided for vulnerable animals, while habitat enrichment and meticulous daily attention promote their overall well-being. Trained staff meticulously track animal health and behavior, while enriched habitats—featuring climbing frames, caves, and pools—simulate natural foraging and hiding activities to promote well-being.

We promise the safety and well-being for the zoo's employees and visitors via installing multiple amenities. The cafeteria and dormitory make life convenient for employees. They are protected with dedicated amenities, personal protective equipment, and medical facilities, while workrooms are situated away from exhibits to minimize direct contact. For everyone's security, double fences are installed around ferocious animals, and trained employees are always ready to guide visitors safely. For our visitors, we considered for vulnerable groups, setting up barrier-free access, sightseeing buses and rest areas for the elderly and children. Externally, four parking lots on each of the entrances mitigates traffic impact and increases convenience.

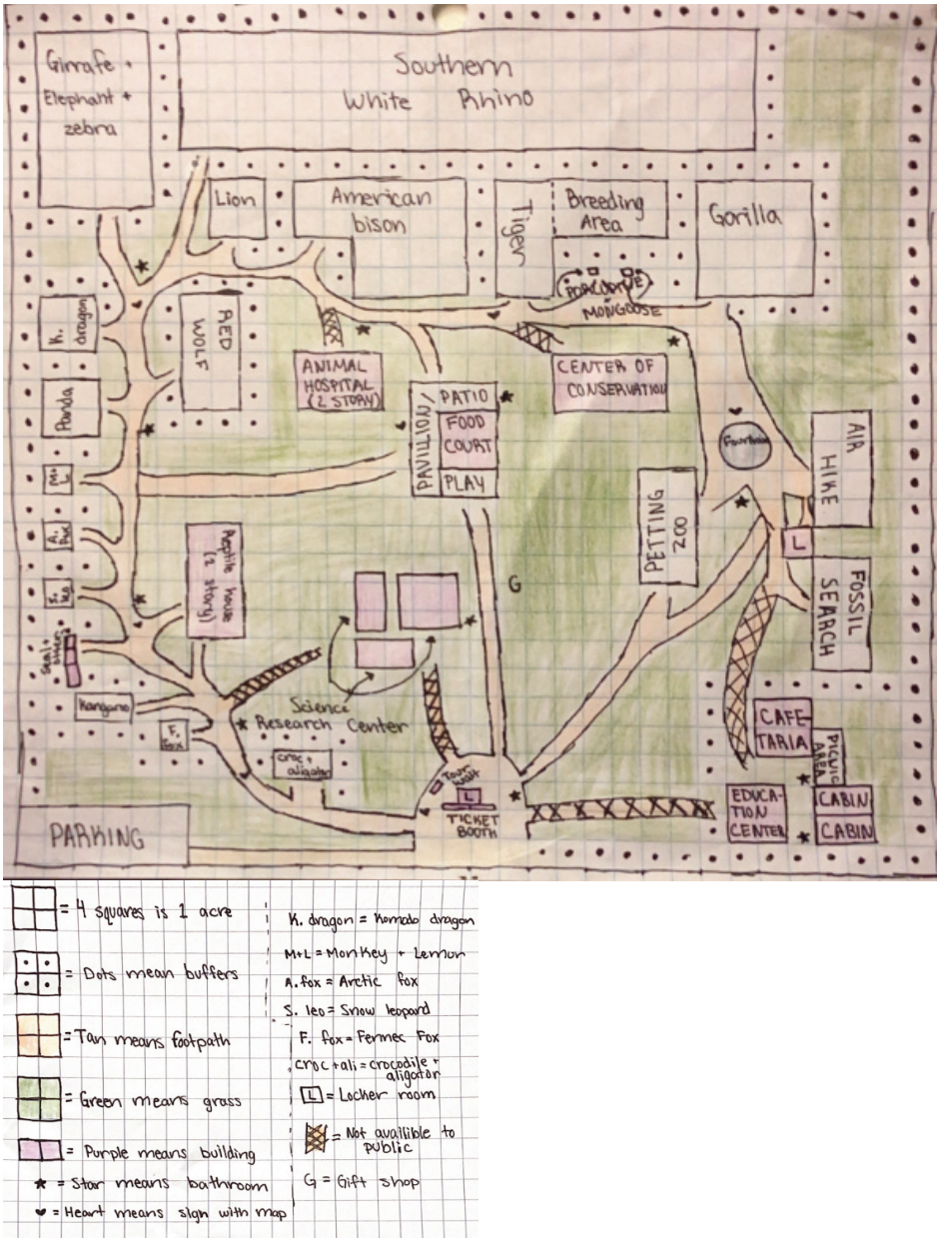
Our model is not only friendly to the parties above, but is proficient in embodying all four primary functions. The zoo functions as a dedicated wildlife conservation site, actively protecting endangered species to help revive global biodiversity. Our design supports scientific research through transparent breeding rooms and laboratories, while the naturalistic habitats themselves generate veritable animal behaviors for study. The zoo is organized by continental regions, a layout that naturally teaches visitors about the native habitats of the animals. Interactive centers are located in almost each continental zone. The zoo also provides recreational refreshment through aquarium shows, feeding interactions, and conveniently located shops and restaurants.

Why are our model the best? Our zoo design comprehensively considers for all three parties from physical safety to spiritual happiness while completely adhering to the requirements of designing the zoo to serve four purposes. Our design is not overly complex but straightforward and comprehensive, taking vulnerable animals and tourist groups into account. We are proud to claim that we had established the best zoological park within limited resources on this 1 square-kilometer of land.

Thank you again for working with the MidMCM Consultant Group. We hope you can consider our zoo model for planning.

Sincerely,
Team 16740

Example 8.



(Legend and scale included)

Example 9.


1 inch = 695 ft
GONDOLA (the path is the blue line)
Gift shop
Farmhouse
Service Entrance
Visitor info center
Paths
Restroom
Fillers/buffers
African Desert
Employee lounges
Water Refill
First Aid
Parking
Photo Booths
East Riverside Dr
Faro Dr
The Patten East
Zookeeper Hut
electrical utilities
Iron Workers Union Local 482
Zoey
Grove Place
Riverside Villas
Dollar General
service entrance
Delmy's Pupus
Football field
North America
Research, conservation, and care building-- employees only
Wild Asia
Australia
Vet Clinic Quarantine facility
Terrarium
Petting Zoo Farm
African Savanna
Natural Hole
Attwater Prairie Chicken
Congo Rainforest
Grove Blvd
Homey 2BR Suite Close to Downtown w Fast Wifi
Office of the Attorney General
E Oltorf St
Alvin Devane Blvd
South American
Parking lot
Texas Institute for Electronics
Canoe river
Montopolis Dr

Example 10.

7. Visitor's Guide

When families visit Austin, Texas, they expect to make memories that last lifetimes. They hope to reminisce about this trip and grin and remember the moments filled with laughter and smiles. The Winloa Zoo, which is where you or you and your family are, is designed to fulfill this. We have countless programs made to create memories, educate people of all ages, and ensure our animals flourish. So, what experiences will you partake in, as a visitor, that will change your perspective about this zoo and enhance your trip to Austin, and how can you maximize your recreational and educational experience at Winloa Zoo? Here's our guide to a perfect day!

Some rules that we would like you to maintain just to ensure everyone's safety.

1. Please do not touch or feed the animals unless instructed to do so.
2. Do not tease the animals in the exhibits.
3. Respect and listen to our employees and staff – they just want to keep you safe!

*The zoo is open Mondays through Saturdays from 8:00 AM to 7:00 PM, and on Tuesdays and Thursdays it closes at 9:00 for extended access to the nocturnal exhibits.
Fun activities at the Winloa Zoo.

Horse Back Riding Times (Farmhouse):
Mondays through Saturdays from 9:00 AM to 9:15 AM

Seal Feeding times (Polar Extreme):s
Mondays and Saturdays from 9:30 AM to 10:00 AM
Fridays from 3:00 PM to 3:30 PM

Bird Watching Times (Great North American Mixed Aviary):
Saturdays from 10:45 AM to 11:00 AM

Feeding giraffes times (Amazing Africa):
Saturdays and Wednesdays from 2:45 PM to 3:00 PM

Bathing elephants times (Amazing Africa):
Saturdays and Tuesdays from 3:10 PM to 3:30 PM

Example 10.

Suggested Main Lot Itinerary:

South America → Australia → Asia → North America → Great Plains Gondola → Lunch at South Lot guest services restaurant/food truck area → African Savanna Gondola → Congo Rainforest → Desert → Madagascar

From the South Lot, the suggested crowd flow is as follows:

Great Plains Gondola → North America → Asia → Australia → South America → Lunch at Main lot guest services cafeteria → Madagascar → Desert → Congo Rainforest → African Savanna Gondola
From the North Lot, which has minimal visitor parking, the suggested crowd flow is as follows:
Asia → Australia → South America → Madagascar → Desert → Congo Rainforest → African Savanna Gondola → Great Plains Gondola → North America

These are only some of the great things one can take part in at the Winloa Zoo. A popular favorite is the gondola in some exhibits, which creates an aerial view of the Great Plains and Africa (exhibit names). However, the Winloa Zoo does not only exist for recreational purposes; there are also numerous educational programs and activities available.

1. The Goodall Theater (Named after Jane Goodall, and will include screenings of her work with the chimpanzees)
    a. Screening Times
        i. Every day from 6:15 PM to 7:00 PM - screens different educational videos and teaches the viewers about The Winloa Zoo and how we contribute to wildlife conservation and scientific research.
2. The Petting Zoo
    a. Children
        i. Aimed to educate children about animal life
            1. Egg process with chickens
            2. Goats making milk
            3. Horses and farriers' jobs
3. Exhibits in general and diverse species
    a. Teaches people in general about the large number of animals there are in the world and their natural habitat

Example 10.

9 One-Page Letter

Dear COMAP Committee,

We are writing to share why we believe our zoo design is a great choice for your project. When planning our zoo, we focused on the four main purposes of modern zoos: **conservation, education, research, and recreation**. Our design was made to support all four goals in a clear and balanced way.

First, our zoo strongly supports **animal conservation**. We selected species based on two scientific ideas: **how endangered the animal is, and how long it can live in captivity**. This helped us choose animals that truly need protection and that can stay healthy in the zoo for many years. That is why our final list includes important endangered animals like orangutans, rhinoceroses, elephants, tigers, and polar bears.

Second, our design helps **education**. We placed the Education Center in the middle of the zoo so everyone can reach it easily. Along the walking path, visitors will find learning signs and displays that explain each animal's lifestyle and why the species is important. Students, families, and young children can all learn something new as they explore.

Third, our zoo supports **research**. Because we chose species with real conservation value and followed official zoo design standards, researchers will have safe, organized habitats where they can study animal behavior, health, and conservation needs.

Finally, our zoo gives visitors a great **recreational experience**. The visitor path is designed as a smooth loop with good walking distances, resting spots, and clear signs. Visitors start with big herbivores, then move to primates, reptiles, big cats, and finally bears near the exit. This order keeps the experience fun and interesting. In the middle of the loop, people can relax in the dining area and children can play in the kids' zone.

In conclusion, our zoo design protects animals, teaches visitors, supports research, and makes the trip enjoyable for everyone. We believe our design fits COMAP's goals and would be a strong and responsible choice.

Thank you for reading our letter.

Sincerely,
Team 16895

Example 11.

9 Sensitivity Analysis and Limitations

Our models are assumption-dependent. Key sensitivities:

Visitor Numbers: If attendance increases from 6,000 to 8,000, Model 3 would adjust dwell times to check if visits stay under 5 hours. May need additional tram stops.

Zone Areas: Reducing Safari by 25% would require Model 2 recomputation. Might need smaller herds to stay under 70% limit.

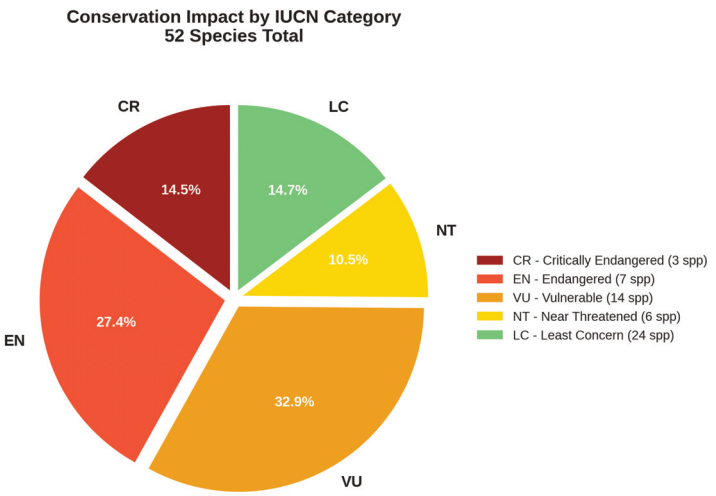


Figure 6: Conservation impact by IUCN category. The majority of conservation effort is directed toward Vulnerable (VU), Endangered (EN), and Critically Endangered (CR) species.

Welfare Weights: If Mental State weight doubles to 0.4 (others 0.15), Model 1 shows which species need more enrichment investment.

Conservation Priorities: Increasing program priority p_s for local Texas species would shift bar and pie charts in Model 4.

Limitations: (1) Welfare/space values are simplified guidelines, not species-specific standards. (2) Visitor-flow doesn't simulate crowded weekends. (3) Conservation index uses IUCN categories, not real population dynamics.

Example 12.

4.2 Sensitivity Analysis

Sensitivity analysis is used to test how much our results change when we adjust or remove an assumption.

Test 1: Changing the weight of conservation value

In our priority model, we set the weight of conservation value to 0.7 and lifespan to 0.3. We tested what happens if both weights are changed to 0.5 and 0.5.

Result:

Some long-living but less endangered animals became ranked higher. For example:

- Brown bear and black bear moved up several places.
- Rhinoceros and orangutan stayed high but slightly shifted.
- Iguana dropped because its lifespan is short.

This test shows that our original choice of weights really pushes the zoo toward **strong conservation**. If a future zoo wanted more focus on entertainment or stable "famous animals," it might choose a more balanced weighting like 0.5/0.5. Our work makes it clear how the **mission of the zoo** (protection vs. entertainment) directly changes which animals should be selected.

Test 2: Considering Protection Efficiency

If we calculate *conservation efficiency*, which means how much conservation value a species provides per unit of area, we define the function:

$$E_i = \frac{PS_i}{Area_{min_i}}$$

Here,

- E_i is the conservation efficiency of species i,
- PS_i is the species' priority score, and
- $Area_{min_i}$ is the minimum enclosure area required for that species.

Result:

- Reptiles and small turtles rank extremely high because they require very little land but still provide conservation value.
- Large mammals rank very low because they take up a lot of land.

If the zoo's goal were **maximum conservation value per square meter**, the zoo would choose many reptiles and birds, not big mammals. However, for real zoos, conservation must be balanced with education, research, and recreation—where large

Example 13.

mammals play an important role. This test shows that **different goals lead to very different optimal species lists**.

Test 3: Changing the Visitor Walking-Distance Requirement

In our design, we assume that the best walking distance for one route segment is **400–800 meters**, with the most comfortable distance around **500 meters**. This is based on zoo reports and our fitted satisfaction curve.

Now we test what happens if the zoo wants to mainly serve **very young children or elderly visitors**, and changes the target segment length to **200–400 meters**.

Result:

To keep each segment shorter, the zoo would need:

- More small rest and service nodes,
- More path branches or shortcuts,
- Exhibits and service buildings placed closer together.

This would increase construction and maintenance costs, and some land might need to be moved away from animal enclosures to service and path areas.

This test shows that **visitor experience is very sensitive to the walking-distance assumption**. If the target group changes (for example, from teenagers to elderly visitors), the route design must be adjusted, and the balance between animal space and visitor space may also change. Our model gives a clear baseline for "normal" visitors, but future planners can adapt it for other groups by changing this assumption.

Example 13.

To: The Local Emergency Planning Committee
From: Team 17392
Date: November 14, 2025
Subject: Proposal for a Dynamic, Data-Driven Evacuation Sweep Strategy

---

Dear Committee Members,

Emergency "sweep" operations face environmental volatility that static plans cannot efficiently handle. Based on our modeling of the 2025 HiMCM problem, we propose shifting from rigid command chains to a responsive strategy titled "Bid for Safety." We submit the following recommendations to transition your operations into a dynamic Cyber-Physical System.

Our core proposal is an **Auction-Based Task Allocation System**. Instead of preassigning rooms, this digital framework treats rescue tasks as goods in a marketplace. Responders' devices automatically "bid" on nearby rooms based on proximity and capability. The team that can clear a room fastest wins the assignment. This mechanism ensures **system redundancy**: if a team is delayed by debris, their unfinished tasks are instantly re-released to the market for others to claim, guaranteeing no room is left behind.

To implement this effectively, we prioritize three actionable strategies:

- **Dynamic Load Balancing:** Do not distribute teams evenly by headcount. Instead, balance by **Workload Weight**. Before entry, estimate the difficulty of each sector based on layout complexity and victim probability. Distributing teams based on these predicted costs prevents bottlenecks where some units are overwhelmed while others are idle.
- **Sensor-to-Soldier Connectivity (CPS):** Link building automation systems directly to responder tablets. If a smoke sensor detects high heat, the system should instantly increase the "cost" of that path in the digital model. The auction algorithm will automatically reroute teams around the danger zone without requiring human intervention.
- **Strategic Saturation Control:** More responders do not always equal faster rescues. Our simulations reveal that exceeding a saturation point (e.g., 7 teams for a standard 100-room office floor) causes specific "Strategic Interference" due to hallway congestion. We recommend identifying these thresholds to keep deployments lean and efficient.

By adhering to these data-driven strategies, you can significantly minimize mission makespan while maximizing the safety of your personnel.

Sincerely,

Team 17392

Example 14.

10. Concluding Paragraph

After two full weeks of work, Team #16828 feels confident that we have finalized our zoo project and developed a strong model of what a well-functioning zoological institution should look like. We began by researching the Bronx Zoo and the San Diego Zoo, which was an excellent starting point that provided solid, reliable, and accurate information for our project. As we moved forward, we analyzed potential locations for our zoo and ultimately decided on Austin, Texas, as the best option, with both a favorable climate and large audience for our new establishment. This was a well-thought-out portion of our project and one that we commend ourselves for. Soon after, we realized that our designs needed a stronger mathematical foundation, resulting in the making of formulas and an extremely high-effort modeled table with area. Despite the long and sometimes strenuous process, we created a detailed and well-supported model of all our exhibits, backed up by hours of research and fulfilling the requests of conservation, education, and recreation with unique programs like the SSP program, the gondola, and the Farmhouse. Reflecting on this competition, we acknowledge that our time management could have been significantly improved, our project could have been slightly more accurate, and we could have dived deeper into the mathematical aspects of the zoo institution, but overall Team #16828 believes that we did a good job and are proud of our work.

Example 15.

1. Open AI Chat GPT (Nov 14, Chat GPT 5 Version) Query : How many black bears and foxes can you keep together in a zoo exhibit? Output : **ChatGPT said:**

You can't keep black bears and foxes together safely in the same zoo exhibit.
Here's why:

1. Black bears are dangerous to foxes

- Black bears are much larger (200–600 lbs) and can easily injure or kill a fox, even if not intentionally.
- Bears are dominant omnivores; foxes are small carnivores. That creates a **predator–prey** or **dominant–subordinate** relationship.

2. Very different needs

- **Feeding:** Bears need large, calorie-dense diets; foxes need small frequent meals. Bears could steal all the food.
- **Enrichment:** Bears destroy enrichment objects; foxes need smaller, delicate ones.
- **Space & habitat:** Bears need large climbing/foraging areas; foxes need places to hide. Bears could block access to shelters.

3. Exhibit design conflicts

- You'd have to build escape routes for foxes (tunnels, small dens).
- But anything a fox can escape into, a bear can destroy.

4. Ethical & AZA standards

Accredited zoos (AZA) **do not house large carnivores with small carnivores** in mixed exhibits due to welfare and safety.

So the real answer:

0 foxes + any number of black bears in the *same* exhibit.
They must be kept in **separate enclosures**.

If you want, I can tell you:

- What species *can* be mixed with black bears
- What foxes *can* be mixed with
- Or help you design a safe mixed-species exhibit.

Example 16.