Problem Chosen	2025 MCM/ICM Summary Sheet	Team Control Number
B		2527063

In this report, we explore how differential mathematical models can represent the relationship between complex variables within tourism, focusing on the cruise industry's impact on Juneau, Alaska. Over the past decade, the influx of tourists arriving on cruise ships has significantly increased the city's carbon footprint, threatening the natural attractions necessary to sustaining its tourism industry. While tourism is essential for Juneau's economy—providing jobs and revenue for local businesses and government—the negative effects of over-tourism are becoming increasingly evident.

Our primary goal is to use differential equation models to create a framework for sustainable tourism. Sustainable tourism addresses economic, environmental, and social concerns to balance growth and preservation. Specifically, we analyzed how to reduce carbon dioxide emissions from tourism while maintaining sufficient revenue to support the local economy and combat climate change's effects on Juneau's natural environment. Key variables in our model include daily carbon dioxide emissions from cruise ship tourists, average tourist spending, the city's maximum tourist capacity, the growth rate of tourism, and its loss rate.

To stop the tourism's environmental impact, we identified the need to reduce carbon dioxide emissions by 60% while respecting Juneau's self-imposed daily cap of 16,000 tourists. We chose this percentage because it is the aim of most destinations that are successfully practicing sustainable tourism. Using these constraints, we developed a revenue function to optimize the city's revenue based on tourist numbers and their spending habits. Additionally, we incorporated more complex variables, such as the growth and loss rates of tourism, into a system of differential equations. This system combines logistic growth and linear functions to model the relationship between factors that attract tourists, such as popular attractions and businesses, and those that deter them, such as stricter environmental policies and increased costs to visit the city.

The model demonstrates that while tourism growth increases revenue, it also heightens the risk of overcrowding and environmental degradation. To address these challenges, we recommend leveraging the additional revenue generated by the optimized model to invest in eco-friendly infrastructure and diversify Juneau's attractions beyond the Mendenhall Glacier. By reducing reliance on this rapidly melting natural landmark, the city can shift focus to other attractions with lower carbon footprints, ultimately decreasing emissions and promoting a more sustainable tourism model.

Our findings indicate that balancing revenue and sustainability involves strategic measures, such as moderately increasing prices to boost income without deterring visitors and using these funds to support eco-friendly transportation and activities. By decreasing the carbon footprint per tourist, Juneau can accommodate more visitors while preserving its environment. This approach not only increases revenue but also enables the city to invest in sustainable infrastructure and expand its capacity for tourism without harming the natural beauty that draws visitors to Alaska.

When implementing this model to other destinations, factors may differ such as changing the maximum of tourists allowed in the city, the rate at which tourism grows, and the rate at which tourism is lost. Whether attractions are natural also can alter the model because there might be less focus on carbon dioxide emissions if the attraction is man made and is not affected by carbon dioxide emissions.

In conclusion, we propose that Juneau implement policies and initiatives to better support sustainable tourism, ensuring the city's economic growth aligns with environmental preservation and long-term viability. These changes can serve as a guide for other destinations seeking to protect the environmental while being a flourishing economy.

Contents

1 Introduction

In the modern era, the impacts of tourism have contributed significantly to an increased carbon footprint, attributing to numerous hidden costs among its popular destinations, and leading to strain on its infrastructures. Specifically, cruise ships—and the influx of tourists they generate—can cause substantial waste for their port cities. In addition, cruise ships place heavy demand on water supplies, and in themselves produce large amounts of carbon dioxide emissions. As cruises often center on excursions and locations with a vivid ecosystem, many of these destinations have faced profound environmental impacts to their region.

Specifically, we see the effects of these hidden costs in Juneau, Alaska, where current daily foot traffic is up to $20,000$ visitors per day during its tourist season. In 2023, the city of Juneau saw nearly 1.7 million passengers and $36,000$ crew members from over 700 cruise ships. This brought in over $375 million dollars in revenue for the city with only a population of $30,000$ [2]. It is noted that tourism plays a vital role in Juneau's economy by creating jobs for the residents, supporting local businesses, and contributing money for infrastructure development; however, the recent surge in tourism, especially in the last two years, has caused overcrowding in the city due to the limit of people the city can hold. The local community is feeling this impact, as costs of housing and supply are driving up, and the city's ability to accommodate the large numbers of visitors dwindles. Furthermore, Juneau's carbon footprint has grown significantly in response. As one of the most unfortunate side effects to this overcrowding and rise in carbon dioxide emissions, one of Juneau's largest attractions—the Mendenhall Glacier—has been shrinking in size since 2007, and as much as 8 football fields[10]. With the quickly receding loss of this natural wonder, many residents are concerned about the decline in tourism revenue and how this loss of funds will affect the city's economy long term[10].

To address these challenges that the city faces in relation to tourism, the local government has enacted steps in an attempt to control the lasting effects of carbon dioxide emissions on the region. These actions include limiting how many tourists come by cruise ship at a time, increasing the costs of for tourists, such as the implementation of hotel taxes and visitor fees, and using the money from these raised taxes towards the preservation of the environment. Further, to combat the negative effects of tourism, including the rise in carbon dioxide emissions, Juneau must implement a model for sustainable tourism that maximizes the revenue generated from tourism, while minimizing the carbon dioxide emissions and overcrowding of tourists. Ultimately, the model must culminate in the growth of tourism interest among aspects of Juneau culture that expand upon the Mendenhall Glacier and the reliance of the cruise industry.

2 Background

For our purposes, we take the definition of sustainable tourism to be a concept that encapsulates economic, social, and environmental issues as well as the effort to improve tourists experience while addressing the needs of the country being visited [5].

In addition, we will often reference the presence of carbon dioxide emissions in the cruise industry from varying sources. In general, we define carbon dioxide emissions as the emission of the chemical carbon dioxide from the burning or consumption of solid, liquid, and gas fuels [6]. In this context, carbon dioxide emissions can come from things like cruise ships, waste, and public transportation. In one article we analyzed from the Friends of the Earth, a non-profit organization concerned with influencing policy and action towards a cut in carbon dioxide emissions, new data revealed that a single person on a seven-day cruise ship from Seattle to Alaska, including all of the standard amenities, will have a carbon footprint that is 8 times higher per day than an average individual visiting Seattle by land (and participating in land activities), on the high end of the carbon footprint scale (i.e., lodging at high end hotels, participating in an average to high amount of activities at some of Seattle's most popular locations, and electing to take private transportation rather than public)[7]. In addition, we found that while some cruise ships have changed to use shore power when docked, the majority of them have not tried to reduce their emissions. Further, until cruise companies implement more sustainable strategies, popular tourist cities like Juneau are forced to help themselves. On account of this, Juneau was able to get the nation's four largest cruise lines to schedule ships to contain no more than $16,000$ standard beds in Juneau per day, and no more than $12,000$ on Saturdays, coming down from their peak amount of almost $21,000$ passengers per day[8].

Concerning our model, one aspect utilizes a logistic growth equation. In general, a logistic growth model uses differential equations to model population growth while taking environmental limits into account. Here, we elected to use a logistic growth model instead of exponential because it allows us to consider the maximum population size, or carrying capacity, that the environment can sustain. The model is given by:

$$\tfrac{dP}{dt} = rP(1 - \tfrac{P}{K}),$$

where P is the population at time t, r is the proportionality constant or growth rate, and K is the carrying capacity [9]. Later, we will adjust this for our context.

For our model, we elected to consider the maximum amount of tourists (T_{max}) as our constraint. This constraint is expressed two different ways: in the first part of our model, it is calculated directly in proportion to a 60% decrease in carbon dioxide emissions, and in the second part, as the maximum amount of passengers allowed per day starting in 2026 as determined by the city of Juneau, at 16,000 (or 12,000 for Saturdays) [8]. Further, our model depicts how the growth rate of tourism and the mitigation/loss rate of tourism impacts the optimization of revenue.

3 Model

In developing our model, we decided it was important to gain a better understanding of the total carbon dioxide emissions by the cruise industry in Juneau, Alaska in order to develop a tangible goal for lowered emissions, while simultaneously maximizing revenue and limiting the amount of tourists per year. In doing this, we determined that a goal of 60% lowered emissions by the cruise industry would be tangible, based on the Global Destination Sustainability Movement's top 40 list of sustainable tourism destinations around the world having a sustainability goal of 60% lowered emissions [1].

Thus, we were able to establish the first equation in our model:

$$E_{new} = E_{old} * 0.4$$

Where E_{new} represents the new carbon dioxide emissions goal and E_{old} represents the original status of carbon dioxide emissions. Multiplying the original carbon dioxide emissions by 0.40 reflects a 60% reduction in emission totals.

Further, we can establish a maximum tourist capacity, given a constant amount of tourist emissions per year/cruise season and assuming no other confounding factors, such as carrying capacity of cruise ships relative to the amount of cruise ship passengers. Thus, we can find that the maximum amount of tourists allowed by our new carbon dioxide emissions goal of E_{new} is given by:

$$T_{max} = \frac{E_{new}}{E_{passenger}},$$

where $E_{passenger}$ is the carbon emitted per day per passenger, and T_{max} is the maximum amount of tourists.

In establishing our maximum revenue achieved from our carbon dioxide emissions goals and maximum tourists, we yield the equation

$$R_{max} \leq T_{max} * S(T),$$

where $S(T)$ represents the total spending of tourists per year, and R_{max} is the maximum revenue achieved per year.

While this model so far minimizes emissions and limits the amount of tourists based on these limited emissions, the model hasn't necessarily accounted for optimized revenue, which is an important aspect concerning sustainable tourism, especially given that the tourism industry alone accounts for $375 million dollars in additional revenue for Juneau per year, and 11% of Juneau's total labor income[2].

Thus, to account for optimized revenue, we must first expand upon our model such that we can account for positive and negative fluctuation impacts on the growth of tourism, including a system of differential equations with a logistic growth function and a first-order linear equation. If we want to focus on reducing the carbon dioxide emissions by 60%, we can use the earlier T_{max} found, which represents the maximum amount of tourists that we can have in the city at a given time t, using the emission values per person and the total carbon dioxide emissions. However, if we choose to maximize the amount of tourists by utilizing the capacity Juneau will implement next year (16,000 for Sunday to Friday, 12,000 for Saturday) we can use T_{max} = 16,000 or T_{max} = 12,000. Based on this constraint, we can create two differential equations to represent the change in tourists over time and the change in revenue over time. The first differential equation is given by

$$\frac{dT}{dt} = rT(1 - \frac{T}{T_{max}}) - mT,$$

where $\frac{dT}{dt}$ represents the change in number of tourists over time t, r represents the growth rate of tourism as influenced by factors such as increased attractions, T is the amount of tourists at time t, and m is the loss rate of tourists that can be attributed to things such as limitations of environmental policies, decreased interest due to increased price of items in the area, or increased cost of excursions, resulting in a smaller availability of resources. While r and m are somewhat abstract numbers in this model, they represent the complex factors that are necessary to consider when addressing how to maximize revenue while protecting the environment. Overall, this equation uses a logistics growth model to represent the increase in tourists coming to the city, while also using a linear factor as the amount of tourist interest to mitigate because of things that the city is doing to mitigate the amount of tourists coming to Juneau at once. This equation is used in the second differential equation to represent how the amount of tourists change over time.

The second equation that focuses on how revenue is changed over time is

$$\frac{dR}{dt} = S(t) \cdot \frac{dT}{dt} = S(t) \cdot [rT(1 - \frac{T}{T_{max}}) - mT],$$

where $\frac{dR}{dt}$ is the change in revenue over time t, and $S(t)$ is the amount of spending per tourist at time t. This is the equation that we want to maximize so that the city can make the most money possible while still respecting the constrained limit of tourists, either due to carbon dioxide emissions reduction goals, or the set maximum of 12,000-16,000 they have implemented. Thus, in order to optimize the change in revenue over time to be at its maximum, we need to focus on optimizing three different variables, $S(t)$, r, and m. Optimizing $S(t)$ would increase the amount each tourist is spending; however, we need to be cautious to not make this number too high. Making this number larger has a direct impact on m, which is the rate at which people are not choosing to come to Juneau. Making $S(t)$ larger in turn makes the rate of loss larger, causing the change in tourists over time to be smaller or even negative due to m's negative effect on $\frac{dT}{dt}$. We also need to be cautious about r, since increasing this variable too much will increase the amount of tourists, leading to more carbon dioxide emissions and overcrowding, thus affecting the tourist attractions in nature, causing r to decrease as well due to less attractions for the city.

To find what R_{max} is with this new model, we make the assumption that we want to stabilize the amount of tourists coming into and out of the city at a given time, so we set $\frac{dT}{dt}$ to 0. Thus, the differential equation is

$$\frac{dT}{dt} = rT(1 - \frac{T}{T_{max}}) - mT = 0$$
$$T[r(1 - \frac{T}{T_{max}}) - m] = 0$$
$$T = 0 \text{ or } r(1 - \frac{T}{T_{max}}) - m = 0,$$

If $T = 0$, it is the trivial solution, so $r(1 - \frac{T}{T_{max}}) - m = 0$. If this is the case, then

$$r(1 - \frac{T}{T_{max}}) - m = 0$$
$$r(1 - \frac{T}{T_{max}}) = m$$
$$1 - \frac{T}{T_{max}} = \frac{m}{r}$$
$$-\frac{T}{T_{max}} = \frac{m}{r} - 1$$
$$-\frac{T}{T_{max}} = \frac{m}{r} - 1$$

Thus, $T = T_{max}(1 - \frac{m}{r})$. Using this equality to find the maximum revenue that the city can make given the constraint, we create the equation where R_{max} is the maximum amount of revenue the city can make based on 4 different variables.

$$\begin{aligned} R_{max} &= S \cdot T \\ &= S \cdot T_{max}(1 - \frac{m}{r}) \end{aligned}$$

Each of these variables can affect whether the city is making more money than they are now bringing in through tourism. This equation is used for the sensitivity analysis in section 5 to better understand how changing variables can alter the maximum revenue the city makes.

4 Expenditures from Additional Revenue

In maximizing our revenue, it is often important to make some expenses up front to increase the potential for revenue long term. Since our team recognizes the concern of what the melting of the

Mendenhall Glacier might do to Juneau's tourism industry, we suggest additional revenue and energy be invested in other existing tourist attractions, which will enhance the culture of Juneau and spread out the tourism industry in general. Specifically, the additional expenditures on tourist attractions should be funneled toward attractions that keep tourists on land, such as increased availability to hiking trails and campgrounds. In one article written by the Friends of the Earth—a non-profit organization that promotes policies and action to cut carbon dioxide emissions—new data was found that in Seattle, as stated earlier, tourists who vacationed on land versus on Alaskan cruises had a carbon footprint that was about 8 times less compared to those on a cruise. These calculations considered the high end of a carbon footprint trail, where the numbers accounted for the average American diet, staying in a high end hotel, and embarking on multiple activities around Seattle, including private versus public transportation. Not only would these measures lessen the potential carbon footprint per tourist, but certain marketing techniques could be developed to promote on land tourist activities, which paired with the development of decreased availability of cruises for tourists (with the 2026 reduced passenger protocol) could ultimately encourage tourists to venture into other parts of Juneau, and experience the destination more broadly. Further, this has potential to help increase growth in tourism interest. On account of our model, these measures would help to increase the value of r, thus increasing the value of R_{max}, while the potential for m decreases.

In addition to investing in land-based attractions, a significant portion of the increased revenue should be directed towards the development of eco-friendly infrastructure that reduces the environmental impact of tourism, which can allow more tourists to enter Juneau at a time. One of the most effective strategies is to allocate funds toward the implementation of renewable energy sources, such as wind and solar power, to reduce Juneau's dependence on fossil fuels. By doing so, the city can mitigate the carbon dioxide emissions connected with energy consumption, which is crucial for the long-term sustainability of tourism. Furthermore, investing in electric-powered public transportation options, such as electric buses or shuttles, could offer a cleaner, more efficient way for tourists to travel between various attractions. This aligns with the goal of reducing environmental degradation while simultaneously improving the visitor experience.

Moreover, the revenue could also be used to implement waste reduction initiatives, such as recycling and composting programs, to manage the additional waste generated by tourists. By encouraging responsible waste disposal, Juneau can create a culture of sustainability. These efforts could enhance the city's appeal as an eco-conscious destination. By reinvesting tourism revenue into these sustainability-focused projects, Juneau can create a more balanced and long-term tourism model that benefits both the local economy and the environment.

5 Sensitivity Analysis

The table below is our sensitivity analysis of the key parameters in our model. We chose to focus on r (growth rate of tourism), m (loss rate of interest), $S(t)$ (tourist spending), and $E_{passenger}$ (emissions per passenger) and their influence on T_{Max} (maximum tourist capacity) and R_{Max} (maximum revenue) because of the stabilization of $T(t)$ explained above.

From Table 1, we can see that T_{Max} is influenced primarily by $E_{passenger}$ where emissions per passenger and maximum tourist capacity have a direct correlation. Alternatively, R_{Max} is influenced by all parameters. Growth rate and spending per tourist have a direct correlation with maximum revenue, while loss rate and emissions per passenger have an indirect correlation with maximum

Parameter Outcomes			
Parameter		T_{Max}	R_{Max}
r	Increase	Neutral	Increase
	Decrease	Neutral	Decrease
m	Increase	Neutral	Decrease
	Decrease	Neutral	Increase
$S(t)$	Increase	Neutral	Increase
	Decrease	Neutral	Decrease
$E_{passenger}$	Increase	Decrease	Decrease
	Decrease	Increase	Increase

Table 1: Sensitivity of Parameters on Maximum Tourist Capacity and Revenue

revenue decreasing. The relationships between these parameters demonstrates the complexity of the different factors playing into this problem.

The following table describes the behavior of some variables in our model. Similarly, we chose to focus our table on r, m, $S(t)$, $E_{passenger}$, T_{Max}, and R_{Max}. The table describes the current structure of the variables in Juneau and four other outcomes according to our model.

Model Outcomes						
Scenario	r	m	$S(t)$	$E_{passenger}$	T_{Max}	R_{Max}
Current Structure	Increase	Increase	Increase	Neutral	Decrease	Neutral
Unrealistic, Ideal	Increase	Decrease	Increase	Decrease	Increase	Increase
Realistic,More Revenue	Increase	Decrease	Increase	Increase	Decrease	Increase
Realistic,Less Emissions	Decrease	Increase	Decrease	Decrease	Increase	Neutral
Worst Case	Decrease	Increase	Decrease	Increase	Decrease	Decrease

Table 2: Different Scenario Outcomes of the Model

In the Current Structure, Juneau is trying to balance the economic benefits of tourism with the environmental costs of emissions and overcrowding. Note that Juneau has an increase in both growth rate and loss rate that work to offset each other, but there is still a rise of tourist spending in the city. Maximum tourist capacity decreases due to there being no significant change in emissions per passenger, as Juneau creates more carbon reduction plans for tourists. Revenue still remains neutral as tourists are still spending enough money to offset the reduced capacity.

The Unrealistic/Ideal scenario reflects a perfect balance as growth rate and tourist spending increases while loss rate and emissions per passenger decreases. This causes an increase in both maximum tourist capacity and revenue. Although this is a perfect situation where Juneau is able to reduce emissions while also increasing tourist numbers and spending, it is highly unlikely as implementing widespread green transportation and eco-tourism practices is extremely difficult.

The Realistic, More Revenue scenario shows Juneau increasing growth rates and tourist spending while also decreasing loss rates. But in order to do this, emissions per passenger would still increase which would decrease maximum tourist capacity. But because tourists are spending more money, overall revenue increases. Although this scenario would be very beneficial for Juneau's economy, it does not remedy the environmental issues that directly effect tourist attractions like the Mendenhall Glacier.

Alternatively, the Realistic, Less Emissions scenario demonstrates the trade-off of economic stability and reducing carbon dioxide emissions. This is done by decreasing growth rates and tourist spending while increasing loss rates. Maximum tourist capacity increases because emissions per passenger decreases. Overall revenue stays neutral.

To show the different hypothetical scenarios the model is capable of, we included a Worst Case situation where overcrowding and emissions continue to rise while the environment also continues to degrade. This situation has a decrease in growth rates and tourist spending with an increase in loss rates and emissions per passenger. This results in a decrease in both maximum tourist capacity and revenue.

6 Other Destinations

On account of other destinations struggling with over-tourism that may be able to utilize our model, there wouldn't need to be too much of an abstraction from our optimizations, constraints, or variables for considered.

However, carbon dioxide emissions goals can be adapted in priority with a new destination's goals for carbon dioxide emissions reduction, resulting in a different value of T_{max}. For example, in the case of Juneau, we had prior knowledge that the city would be implementing a cap in tourist cruise passengers per day by 12,000-16,000, which gave us one possible limit on the tourism constraint, and we also suggested a carbon reduction goal of 60%, which gave us another (given T_{max} was calculated in proportion to an adapted carbon dioxide emissions goal). Suppose instead that a new destination opted to begin with a 40% carbon dioxide emissions reduction. Then the equation for calculating T_{max} from this goal would adapt as follows:

$$E_{new} = E_{old} * 0.6.$$

Further, the rates of r, m, and $S(t)$ will adapt depending on the environment of the destination, interests, and expenditures of tourists. Similarly, the original values of existing carbon dioxide emissions levels E_{old} will adjust according to the current destination levels. While in most cases over-tourism leads to exceeding rates of carbon dioxide emissions, there may be occurrences where destinations are less concerned with carbon dioxide emissions, in which case the rate of carbon dioxide emissions would not play a factor. In turn, they may choose to increase costs to tourists, which may increase the rate of m and lower the rate of r.

For destinations aiming to promote their attractions and increase the number of tourists, the constraint T_{max} would not initially apply since the focus is not meant to limit the number of visitors. Thus, the focus would instead be on optimizing the term $1 - \frac{m}{r}$, which determines the growth potential of the tourist population. By minimizing the ratio $\frac{m}{r}$, the destination can maximize $T(t)$, which then increases revenue because more people are spending money at one time.

In the short term, increasing r—which is the growth rate of tourists—can occur through offering discounts, introducing new attractions, and leveraging social media to rapidly raise awareness of the destination. The rapid increase of interest in tourists through these methods not only builds the destination's reputation as a place to travel to, but it also attracts more visitors in the future through word of mouth.

Once the destination becomes established as a tourist attraction, the focus can shift to maximizing long-term revenue by reducing m, which is the loss rate of tourists. Strategies to lower m include implementing loyalty programs, offering discounted memberships to attractions, and creating incentives for repeat visits. Additionally, once the flow of tourists has stabilized, the destination can gradually increase the cost of experiences, which then raises the average spending per person (S), and ensures a steady amount of income into the city over time. This additional revenue can be used for other things such as maintaining the infrastructure of the destination. This dynamic approach aligns with the differential model, where finding ways to increase r and decrease m over time allows for sustainable growth and maximization of revenue.

7 Conclusion

While many destinations are suffering the hidden negatives of over-tourism such as increased carbon footprint and overcrowding, Juneau, Alaska is especially concerned with the impacts of the cruise line industry on climate change in its area. Specifically, one of their main attractions, the Mendenhall Glacier, has shown significant reduction in mass since 2007, declining at the size of almost 8 football fields [10]. Despite this, the tourism industry has shown significant positives for Juneau, including the additional revenue to the city and increased amount of jobs. Thus, a sustainable tourism model was created for Juneau in order to maximize its revenue from tourism, while limiting the amount of visitors, and decreasing the overall amount of carbon dioxide emissions. To do this, we utilized a system of differential and linear equations, including a logistic growth model. Additionally, suggestions were made on where to focus additional revenue, promoting interest in diverse areas of Juneau, increasing interest in attractions outside of the glacier, and promoting a cut on carbon dioxide emissions. Finally, our model was shown to adapt to other destinations, including locations looking to promote tourism with fewer tourists.

8 Memo to the Tourist Council

To: Tourist Council of Juneau
From: Problem B Team 2527063
Date: 26 January 2025
Subject: Predictions, Effects, and Advice on Optimizing Sustainable Tourism

On account of the need for a sustainable tourism model for the city of Juneau, our project team has worked to develop a model which will maximize revenue, while constraining the amount of tourists to address overcrowding, and acknowledge the need for lower carbon dioxide emissions. This is done through a system of differential equations, consisting of a logistic growth model and linear equations, which can be optimized to invoke the largest potential for revenue given a limited number of tourists. The model addresses concerns of the effects on tourism interest due to the disappearance of the Mendenhall Glacier over time, as it includes variables r and m representing the rate of growth in tourism interest and the rate of tourism interest decline, respectively. Further, the model factors in the spending of tourists, which can vary year to year as prices rise or fall.

To address overcrowding, our model includes the limitation of tourists (specifically from the cruise line industry) in two versions: 1) it limits the number of tourists proportional to lowered carbon dioxide emissions goals, and 2) it limits the number of tourists based on the new cruise passenger constraints outlined by the City of Juneau for the year 2026 (between 12,000-16,000 depending on the day).

To address the need for lowering carbon dioxide emissions, our model limits the amount of tourists in proportion to the goal of carbon dioxide emissions reduction. Further, we suggest ways to limit carbon dioxide emissions by funneling additional revenue towards marketing and increasing the availability of in land based attractions, such as hiking trails and campgrounds. We predict that this change will lower carbon dioxide emissions as we have found data that shows that on land tourists can emit 8 times less carbon dioxide than cruise passengers[7]. Furthermore, this structure feeds back into our model to increase revenue as the interest of tourists r increases with the introduction of, increased marketing of, and increased availability of hiking trails and camp grounds.

Another effective strategy to tackle the rising carbon dioxide emissions in Juneau is to implement and promote eco-friendly modes of transportation and sustainable waste management practices to minimize the environmental footprint left by tourists. To achieve this, we recommend that the city prioritize investments in renewable energy sources such as wind power and solar panels. By transitioning to these clean energy alternatives, Juneau can significantly reduce its reliance on fossil fuels.

Additionally, a key area for improvement lies in the transportation infrastructure. Investing in electric-powered public transportation systems, such as electric buses or shuttles, would help reduce the carbon footprint generated by tourists commuting between various attractions. By providing clean transportation options, the city can ensure that visitors have access to sustainable travel choices while simultaneously decreasing air pollution and traffic congestion.

Moreover, the city could implement waste reduction initiatives, such as encouraging recycling and composting among tourists, providing easily accessible disposal bins, and partnering with local businesses to promote sustainable packaging. Together, these steps can help create a more environmentally responsible tourism industry in Juneau, safeguarding its natural resources and ensuring a sustainable future for generations to come.

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