2022

Calculating outdoor summer tourism savings in Los Angeles resulting from Smart Surfaces adoption

ALEXANDER REID

1. Abstract

The purpose of this report is to estimate the expected loss of revenue that climate change-driven increases in summer temperatures will have on U.S cities. This is determined for Los Angeles using attendance data from the LA Zoo and weather information from Visual Crossing, a free weather database. Our analysis projects that increased temperatures due to climate change would cut outdoor tourism revenue in Los Angeles by about 10%. By adopting Smart Surfaces (reflective, green, and porous surfaces, solar PV, and trees) city-wide, Los Angeles can reduce average city temperatures up to 2°C and provide a net present value (NPV) of $830 million over the next thirty years despite rising global temperatures.

2. Introduction

2.1 The effects of climate change on US cities

More and more cities are becoming intolerably hot in the summer, and in the coming years, are increasingly at risk of becoming unlivable due to more extreme summer temperatures. This is in large part because most cities are covered with dark, heat-absorbing, impervious surfaces, such as asphalt parking lots and dark roofs, resulting in higher peak temperatures, higher energy bills, worsened flooding, and increased air pollution. Summers are now commonly 5°C hotter in cities than the surrounding countryside, an effect referred to as the urban heat island (Xu et al., 2020). The impact is usually even worse in lower-income neighborhoods, which generally have even fewer trees and less reflective surfaces, with temperatures often 5.5°C hotter than wealthy neighborhoods with more trees.

Climate change is making cities even hotter. Under current projections, many cities will experience a tripling of extremely hot summer days by 2050 (Xu et al., 2020). A National Academy of Sciences report warns that the mean human-experienced temperature will rise by an estimated 7°C by 2070. These projected increases in extreme heat pose significant threats to urban public health and local economies.

2.2 Climate change as it relates to summer tourism

In the United States, tourism, which makes up about 3% of the national GDP, is most common in the summer due to school holidays and families traveling (Osborne, 2022, p. 1) despite rising temperatures. According to an international survey of 66 national tourism and meteorological organizations, 81% of respondents felt weather and climate were major determinants of tourism in their country with some arguing that climate is the most dominant factor affecting international tourism (Scott and Lemieux, 2010, p. 147). For last-minute domestic tourism, nearterm forecasts have been found to be the most important factor in determining destination (Scott and Lemieux, 2010, p. 167).

Because tourism is highly influenced by weather, climate change-driven increases in summer temperatures will significantly impact the economies of major tourism destinations in the United States. The Secretary General of the United Nations World Tourism Council, Francesco Frangialli (2005), said that “with many tourism activities heavily dependent on the climate…accurate weather information and forecasting of extreme climatic events are becoming ever more important for tourism business.” As seen in beach resorts in Greece, when climates are no longer suitable for certain tourism markets (i.e. a city becomes uncomfortably hot in the summer), tourism operators are forced to close seasonally. Figure 1 demonstrates how cities that previously ranked “Ideal” or “Good” on the U.S. Tourism Climate Index are moving towards “Unfavorable” due to climate change.

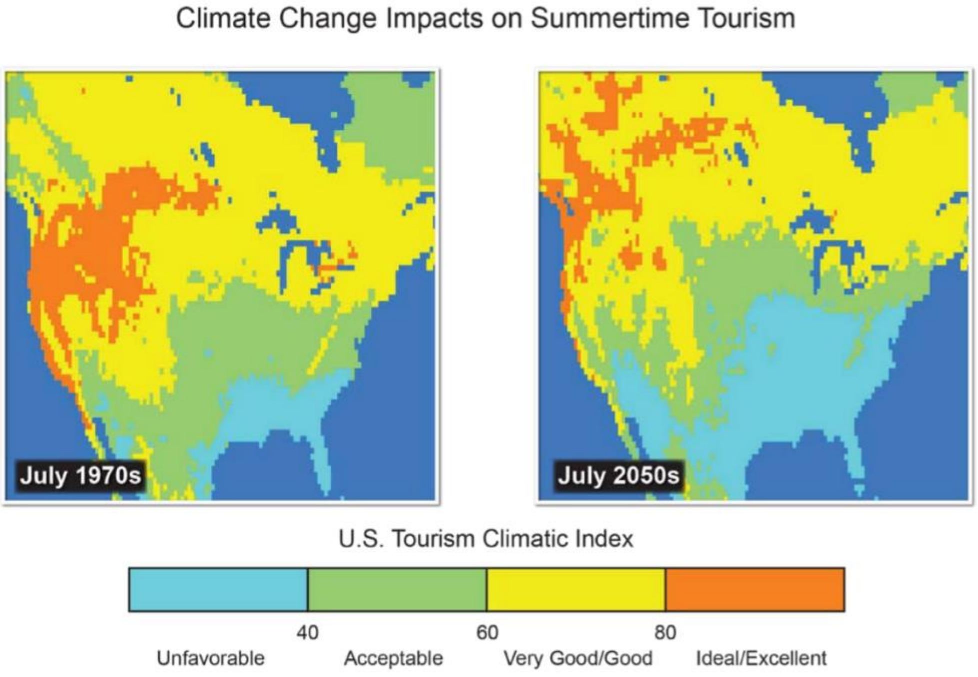


Figure 1: Climate Change Impacts on Summertime Tourism (Kats and Jarrell, 2021, p. 20)

According to a survey completed by Dr. Daniel Scott (2010), a professor of Geography and Environmental Management at the University of Waterloo, in North America, Europe, and New Zealand, tourists expressed concern that temperatures above 31°C in urban areas were “unacceptably hot”, which is depicted in figure 2. In the same survey, Dr. Scott found that on a scale of 1-7 (with 7 being most important), “comfortable temperature” was the most important factor to tourists with a mean score of 5.98.

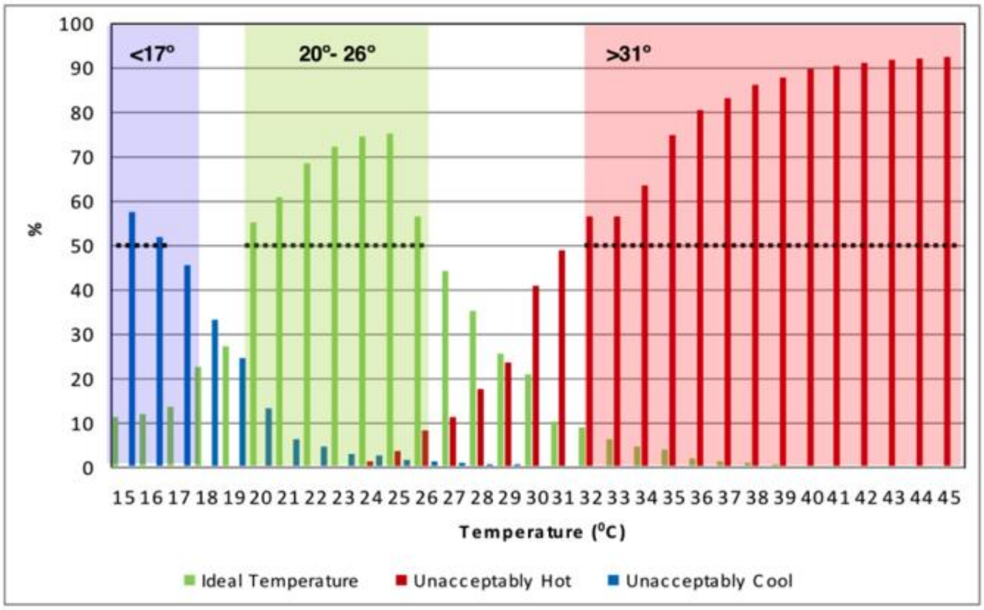


Figure 22. Tourist rating of temperatures for urban holidays (Source: Rutty and Scott [101])

Figure 2: Tourist Rating of Temperatures for Urban Holidays (Scott and Lemieux, 2010, p. 173)

2.3 Smart Surfaces as a solution to cool cities

To avoid losing significant summer tourism revenue, cities must make themselves cooler and mitigate the effects of climate change. The only strategy available that cost-effectively cools cities while mitigating climate change and addressing environmental justice is the adoption of Smart Surfaces, a strategy referring to the integrated deployment of reflective, porous, and green surfaces (such as cool or green roofs or reflective parking lots), trees, and solar photovoltaic panels. It is therefore important to understand the potential and cost-effectiveness of Smart Surfaces for cooling cities and mitigating climate change.

The Smart Surfaces Coalition is composed of leading health, planning, architecture, city policy, energy, affordable housing, and other organizations dedicated to supporting expanded adoption of Smart Surfaces globally. Prior studies of potential city-wide Smart Surfaces adoption by El Paso, Philadelphia, Baltimore, and Washington DC demonstrate Smart Surfaces are a cost-effective, city-wide strategy to address climate change mitigation while also improving equity and creating jobs.

2.4 Los Angeles County and the LA Zoo

This report specifically considers the city of Los Angeles, a very popular summer tourism destination with many attractions and a hot, dry climate. Figure 3 demonstrates the high degree of vulnerability in many neighborhoods in Los Angeles County. A ULCA report predicted average annual maximum temperatures to be around 2.2-2.7°C higher by 2050 and 2.7-4.4°C higher by 2100 (Hall, Berg, and Reich, 2018, p. 6). Given that the baseline temperatures for this study were from 1981-2000 and that RCP 8.5, the most aggressive climate change projection scenario, was used, this report assumes that the average annual maximum temperature increases will be around 1.5°C.

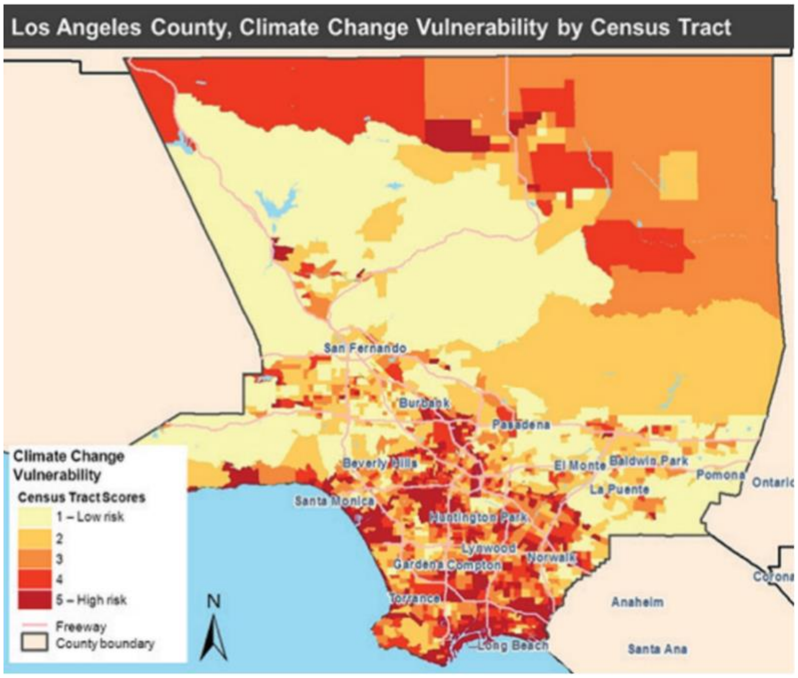


Figure 3: Climate Change Vulnerability by Census Tract for Los Angeles County (Hall, Berg, and Reich, 2018, p. 30)

In 2018[1], Los Angeles welcomed approximately 50 million tourists and $23.9 billion in direct visitor spending (Tourism Economics, 2018, p. 1). A few major outdoor tourism attractions in Los Angeles include two Major League Baseball teams, the Disneyland Amusement Park, and the LA Zoo. The LA Zoo generated an annual revenue of $22 million in 2018-2019, and an independent study found that Disneyland Resort annually generates $5.7 billion for the Southern California economy including more than $370 million in local and state tax revenue (Disney, 2015, p. 1). While not all of this revenue will be impacted from the extreme heat in

---

[1] Using data from 2018 and 2019 to avoid influence from COVID-19

the summer, this report estimates that the entire industry brings in approximately $500 million in the months of June-October that will be affected by extreme heat.

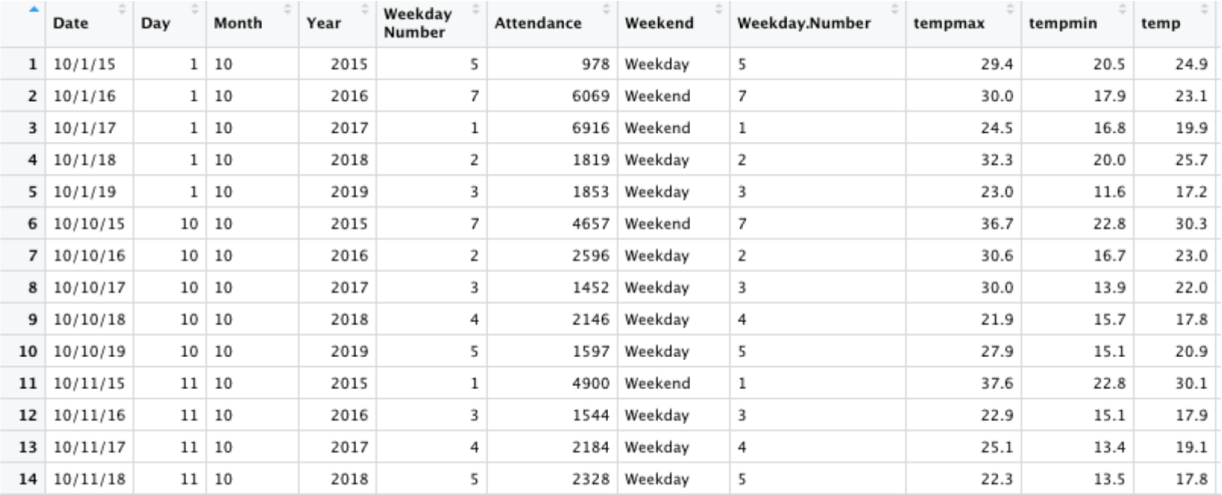
Evidently, Los Angeles is heavily dependent on its outdoor tourism industry. This report analyzes how climate change-driven increases in summer temperatures will affect this industry over the next 30 years if no action is taken, as well as how deploying Smart Surfaces city-wide can enable industry growth despite rising global temperatures.

3. Methods

3.1 Data

This report uses a proxy variable to isolate the effects of climate change-driven increases in extreme heat on the outdoor summer tourism industry in Los Angeles. The LA Zoo provided data on daily attendance from 2015-2019 for the months of June, July, August, September, and October since these have historically been the hottest months in Los Angeles. Daily attendance for the LA Zoo proved to be a valuable proxy variable because, in most cases, we found a decision to visit a zoo is typically made the day of, with specific consideration to daily weather and maximum daily temperatures.

First, we acquired daily weather data from Visual Crossing, a free weather data database, to correlate the daily attendance values with the weather. This included maximum, minimum, and average temperature, humidity, etc. Table 1 demonstrates how the datasets were bound together in R Studio by date and were used to determine the relationship between outdoor summer tourism and daily maximum temperature.



	Date	Day	Month	Year	Weekday Number	Attendance	Weekend	Weekday.Number	tempmax	tempmin	temp
1	10/1/15	1	10	2015	5	978	Weekday	5	29.4	20.5	24.9
2	10/1/16	1	10	2016	7	6069	Weekend	7	30.0	17.9	23.1
3	10/1/17	1	10	2017	1	6916	Weekend	1	24.5	16.8	19.9
4	10/1/18	1	10	2018	2	1819	Weekday	2	32.3	20.0	25.7
5	10/1/19	1	10	2019	3	1853	Weekday	3	23.0	11.6	17.2
6	10/10/15	10	10	2015	7	4657	Weekend	7	36.7	22.8	30.3
7	10/10/16	10	10	2016	2	2596	Weekday	2	30.6	16.7	23.0
8	10/10/17	10	10	2017	3	1452	Weekday	3	30.0	13.9	22.0
9	10/10/18	10	10	2018	4	2146	Weekday	4	21.9	15.7	17.8
10	10/10/19	10	10	2019	5	1597	Weekday	5	27.9	15.1	20.9
11	10/11/15	11	10	2015	1	4900	Weekend	1	37.6	22.8	30.1
12	10/11/16	11	10	2016	3	1544	Weekday	3	22.9	15.1	17.9
13	10/11/17	11	10	2017	4	2184	Weekday	4	25.1	13.4	19.1
14	10/11/18	11	10	2018	5	2328	Weekday	5	22.3	13.5	17.8

Table 1: Bound Attendance and Weather Data

3.2 Proving temperature is a valid predictor variable of attendance

Then, we constructed a simple linear regression model in R Studio predicting daily attendance values by maximum daily temperature to prove that maximum daily temperature was indeed a valid predictor variable of daily attendance. The model's output provided a t-statistic of -6.268. The subsequent p-value of this variable was less than $2*10^{-16}$, and since the coefficient between daily maximum temperature and daily attendance is not zero, there is strong evidence that there is a relationship between the two variables.

3.3 Isolating relationship between temperature and attendance

Zoo attendance can fluctuate based on a variety of factors, such as day of the week and the month. These internal trends need to be accounted for and removed to isolate the relationship between daily maximum temperature and daily attendance. The interaction term between weekday and month also needs to be taken into consideration since a Saturday in June is different than a Saturday in September with regards to visitation. Figures 4 and 5 show that attendance on the weekends was higher than on weekdays (most likely due to work and school schedules), but both had a negative relationship with maximum daily temperature after the maximum point, approximately 25°C.

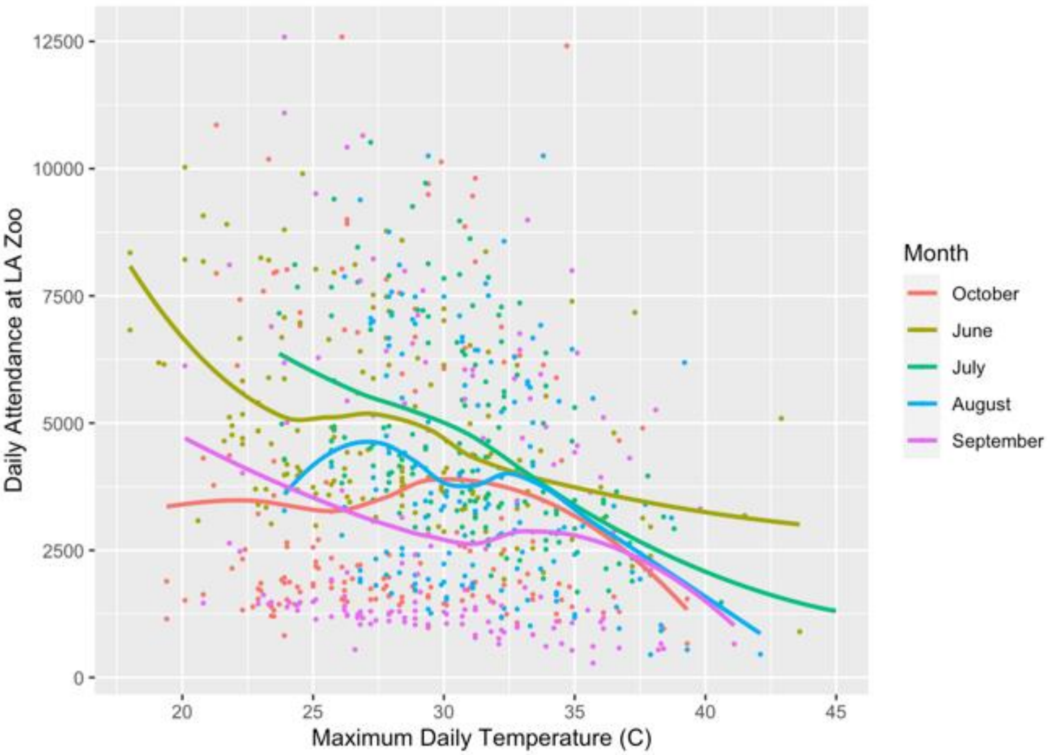


Figure 4: Attendendance by Maximum Daily Temperature Organized by Month

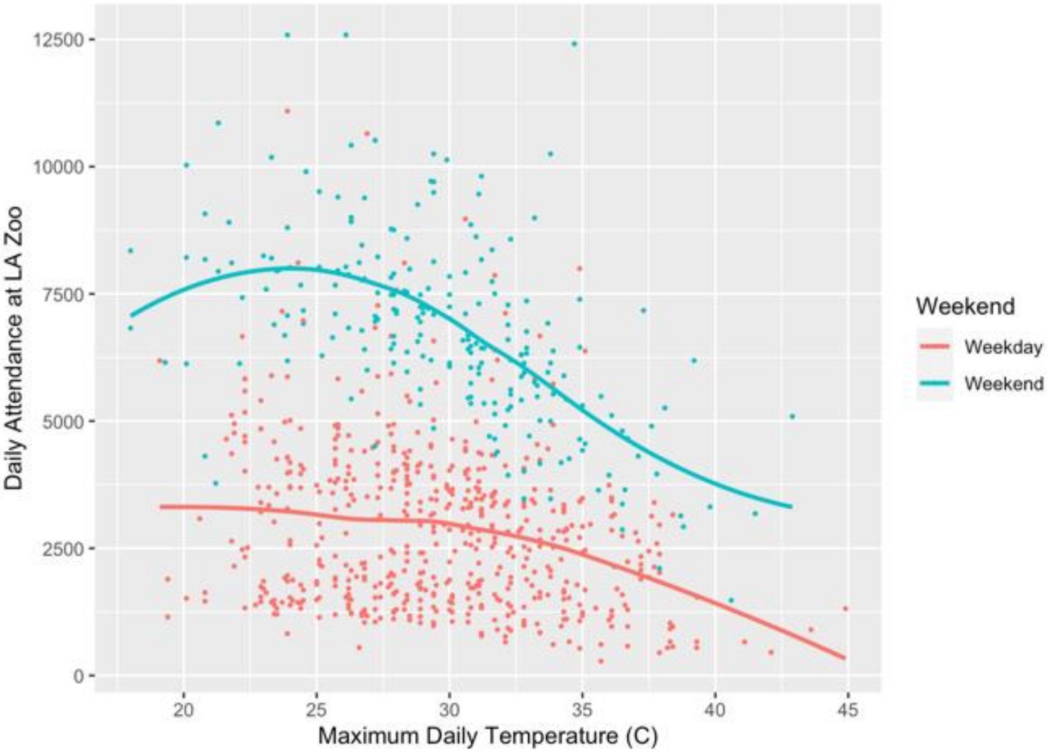


Figure 5 Attendendance by Maximum Daily Temperature Organized by Weekend

3.4 Building the model to identify exact relationship between temperature and attendance

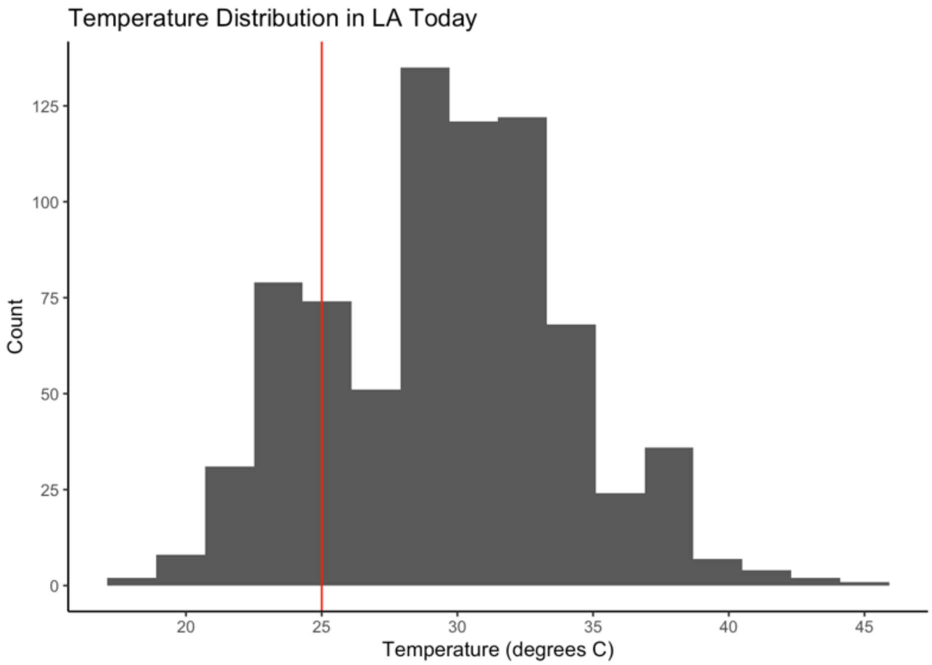
After proving that daily maximum temperature was a valid indicator of daily attendance and accounting for the confounding variables of weekday and month, we built a model in R Studio using daily maximum temperature, day of the week, month, and the interaction term of weekday and month to predict daily attendance. Because daily attendance only shows a negative relationship after 25°C, the lower bound of the range of uncomfortable heat, the model isolates days above this turning point to solely look at the negative relationship. The residuals of the model were random and closely followed a normal distribution. It was therefore determined that the model was valid and provided a well-founded estimate of by how much daily attendance changed as a result of an increase of 1.5°C in daily maximum temperature. The model estimated daily attendance to decrease by about 160 visitors or $3,200 in revenue for each increase of 1°C in daily maximum temperature after 25°C.

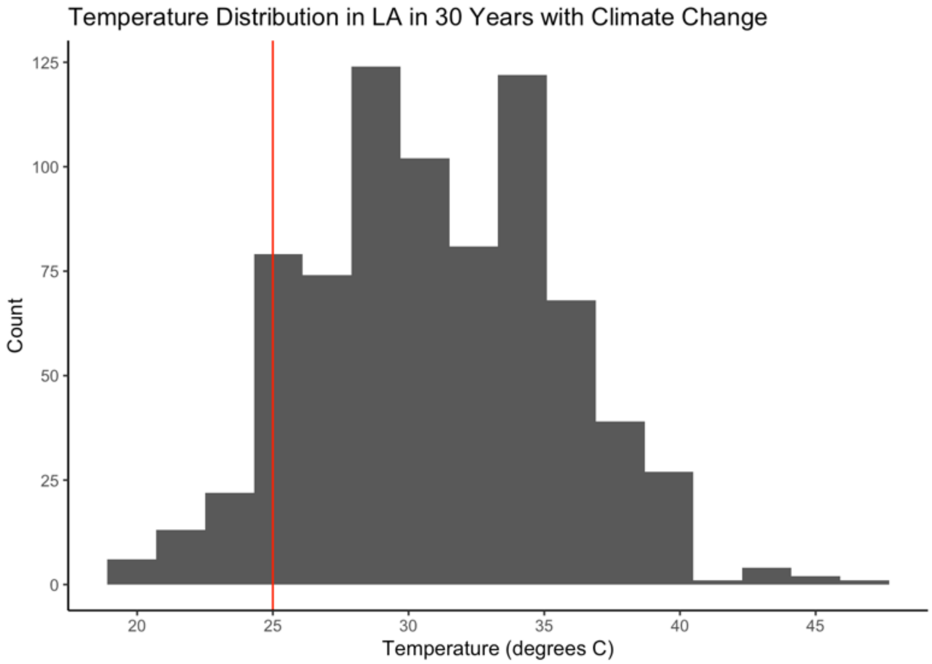
4 Analysis

4.1 Assumptions

We accounted for a few assumptions in the analysis. The first, which has already been discussed, is that outdoor tourism in the summer is correlated with maximum daily temperatures; this was proven using a t-test in R Studio. Moreover, there is a negative relationship between outdoor summer tourism and maximum daily temperature when temperatures are greater than 25°C. Therefore, there will be no effect on daily visitation for maximum daily temperatures less than 25°C in the analysis.

The second assumption is that the weather distribution will remain constant over the next thirty years. To determine the distribution of temperatures in Los Angeles over the summer, we found the proportions for each daily maximum temperature for the five years of data and applied those proportions to the projections. This is shown in Figure 6 along with projected temperature distributions for Los Angeles if no action to cool the city is taken and if Smart Surfaces are deployed city-wide. The vertical red line is at 25°C, representing the lower boundary of uncomfortable heat.


Temperature Distribution in LA Today


Temperature Distribution in LA in 30 Years with Climate Change

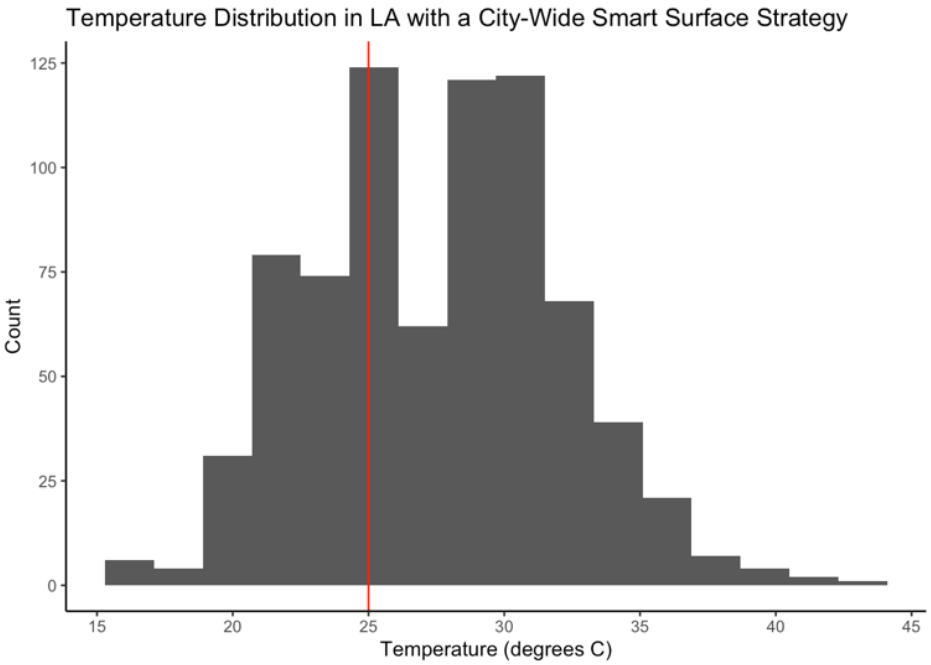


Figure 6: Temperature Distributions of Los Angeles Under Different Scenarios

The third assumption is that Los Angeles will warm by 1.5°C over the next thirty years linearly year-to-year, which we view as a conservative estimate. The UCLA report estimates that average annual maximum temperatures are projected to be around 2.2–2.7°C higher by 2050. These estimates were made considering RCP 8.5 with a baseline from 1991-2000, which is a high projection for the effects climate change.

The analysis assumes that by adopting Smart Surfaces city-wide, discussed in section 2.3, Los Angeles will have the cooling effects of decreasing daily maximum temperatures by 2°C across the city linearly year-to-year.

The final assumption is that half of the total annual revenue for the outdoor tourism industry is brought in during the summer season. Based on the revenue data provided by the LA Zoo, the revenue brought in between June-October totals roughly $6.5 million. When compared to the LA Zoo’s annual report, this represents approximately half of the total annual admissions revenue. Therefore, we can assume that about half of revenues for the outdoor tourism industry are brought in during the months of June-October.

4.2 Analysis of the Effects of Climate Change on LA Zoo Attendance and Revenue

The LA Zoo is in danger of losing visitors due to the effects of climate change-driven increases in summer temperatures. Using R Studio, we predicted that the LA Zoo will lose about 160 visitors per day per degree C above 25°C which is equivalent to a loss of about $3,200 or a 4.7% loss in attendance and revenue per degree C above 25°C.

Given that the average ticket price for the LA Zoo is $20, this decline in visitation translates to a mean daily loss of $16,000 ($2,500,000 per summer season) in Year 1 and eventually a mean daily loss of $20,000 ($3,000,000 per summer season) in Year 30 between June-October. To isolate the effect of climate change, we compared these losses to the baseline losses if there was no increase in temperatures. If there is an increase in 1.5°C in daily maximum temperature, we expect a loss in summertime revenue of 0.3% in Year 1 and 10% in Year 30 solely due to the effects of climate change. Figure 7 shows how this translates to a cumulative loss of summertime revenue of approximately $10,000,000 by 2052.

If these cash flow losses are discounted to the present using a conservative 3% interest rate, it equates to a net present loss of about $5,500,000.

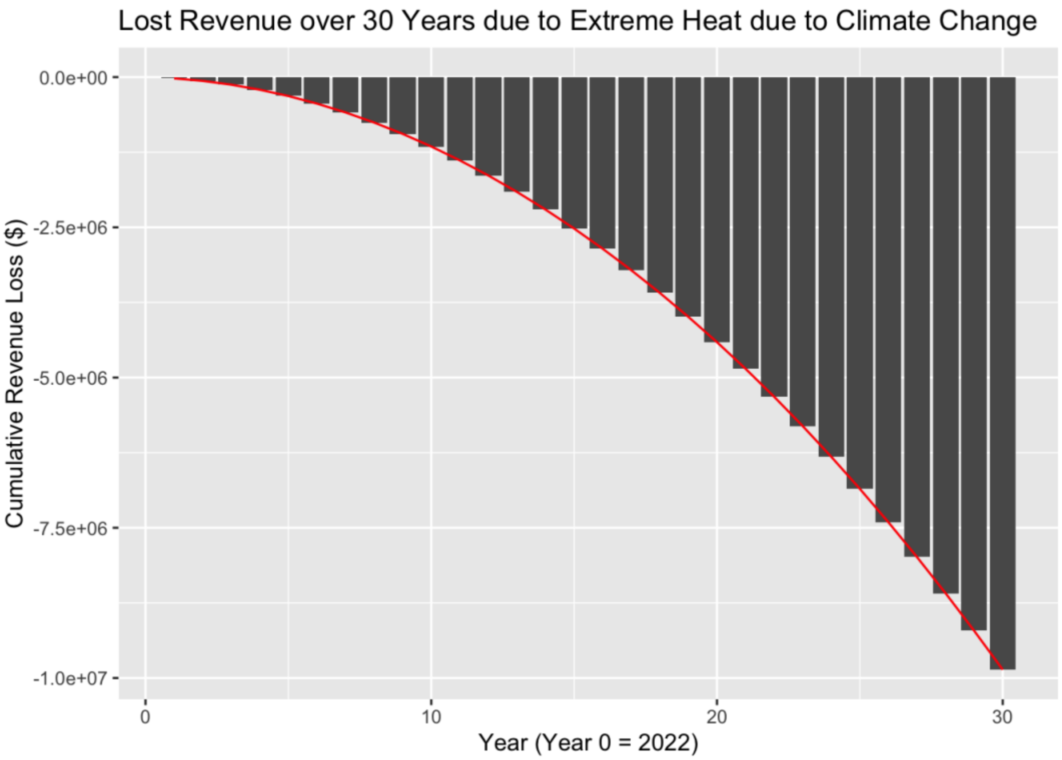


Figure 7: Cumulative Lost Revenue over 30 Years due to Temperature Increases

4.2 Analysis of the Effects of a Smart Surfaces Solution on LA Zoo Attendance and Revenue

We conducted a similar analysis to visualize the effects that adopting Smart Surfaces has on the LA Zoo's summertime attendance and revenue. Rather than an increase in 1.5°C in daily maximum temperature, by adopting Smart Surfaces city-wide, Los Angeles could decrease daily maximum temperature by 2°C. In Year 1, we would expect a loss of about 800 visitors per day in June-October due to extreme heat, but by Year 30 this could increase to roughly 550 visitors per day.

We isolated the effects of Smart Surfaces by comparing attendance data from the LA Zoo to the control values of no change in temperature. In Year 1, we expect a revenue increase of 0.3%, and by Year 30, we expect a summertime revenue increase of 9.1%. These percentage increases would eventually lead to cumulative revenue savings of ~ $12,000,000 by 2052 (Figure 8). If the cash flows are discounted at the same 3% interest rate as above, the NPV of adopting a Smart Surface strategy is about $7,000,000.

The combination of avoided attendance loss and projected increases in revenue from Smart Surfaces provide a combined NPV over 30 years of $12,500,000 for the LA Zoo alone.

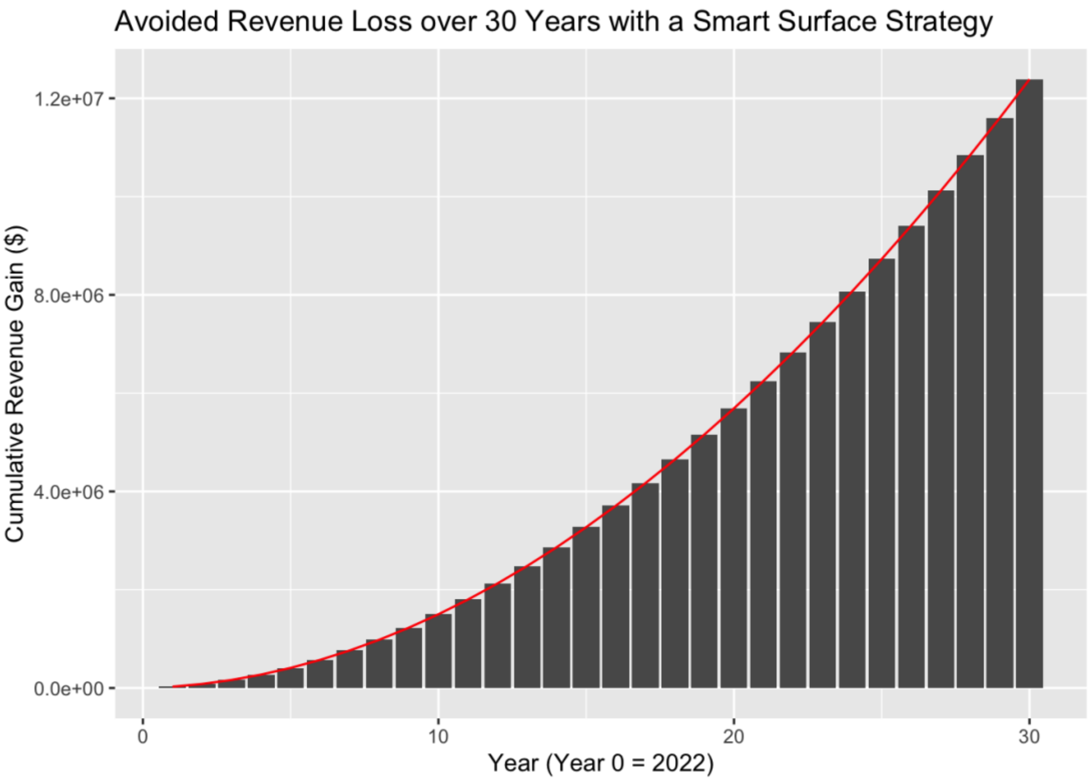


Figure 8: Cumulative Gained Revenue over 30 Years due to Temperature Reduction

5 Conclusion

5.1 Future Research Needed

Although these estimates are based on fundamental assumptions and modeling techniques, to provide a better estimate of the true impact on the outdoor summer tourism industry, more research is needed. For one, the evaluation of the annual revenue brought in from outdoor tourism was well-founded but far from exact, so it would be beneficial to find a more exact measure for the industry's revenue. Moreover, it would be necessary in further research to find data from different sources outside of the LA Zoo. Unfortunately, we were unable to get into contact with many amusement parks, baseball organizations, and other outdoor tourism companies. Thus, in the future, finding those attendance/revenue statistics, conducting a similar analysis, and comparing the results to the ones found in this study would bolster the evidence that this industry is affected by heat.

5.2 Applications to the Los Angeles Outdoor Tourism Industry

Assuming the outdoor tourism industry in Los Angeles brings in an estimated $500 million in revenue between June-October and using the projections from the LA Zoo analysis, if no actions are taken to mitigate climate change and reduce surging temperatures, the outdoor tourism industry in Los Angeles would lose ~$425 million NPV through 2052. This would result in an expected 10% decrease in revenues between June-October relative to today's value. By adopting Smart Surfaces city-wide, Los Angeles could offset and avoid these losses.

By adopting Smart Surfaces city-wide, Los Angeles would reduce peak summer temperatures and avoid expected losses in outdoor tourism revenue. The projected increase of tourism revenue to result from adopting Smart Surface would result in an NPV of ~ $405 million over thirty years and a 19% increase in revenues between June-October relative to business-as-usual.

The combination of avoided tourism revenue losses and projected increases in revenue from Smart Surfaces provide an estimated NPV over 30 years of $830 million.

6 Acknowledgements

I would like to first thank the Los Angeles Zoo and specifically Dr. Cathleen Cox for providing the data necessary for this study. Dr. Cox is the Director of Research at Los Angeles Zoo & Botanical Garden and was extremely helpful in the creation and writing of this report.

Secondly, I would like to thank you Dr. Daniel Scott and Chris Riehl for their support in this project and providing research materials to better understand the tourism industry and all aspects of the effects of climate change on this industry. Dr. Scott is a Professor, University Research Chair and Director, and Master of the Climate Change Program at the University of Waterloo, and Chris Riehl is the former President of the Baltimore Tourism Association.

References

Disney. (2015). Disneyland Resort Generates $5.7 Billion for Southern California Economy [web log]. Retrieved May 20, 2022, from https://publicaffairs.disneyland.com/disneyland-resort-generates-5-7-billion-for-southern-california-economy-2/.

Hall, Alex, Neil Berg, Katharine Reich. (University of California, Los Angeles). 2018. Los Angeles Summary Report. California's Fourth Climate Change Assessment. Publication number: SUM-CCCA4-2018-007.

Kats, G., & Jarrell, R. (2021). Cooling Cities, Slowing Climate Change and Enhancing Equity: Costs and Benefits of Smart Surfaces Adoption for Baltimore. Smart Surfaces Coalition.

Osborne, S. (2022, February 1). *U.S. travel and Tourism Satellite Account for 1999–2020*. U.S. Travel and Tourism Satellite Account for 1999–2022, Survey of Current Business, February 2022. Retrieved June 1, 2022, from https://apps.bea.gov/scb/2022/02-february/0222-travel-tourism-satellite-account.htm

Sands, S., Kats, G., & Davison, K. (2021). *The Value of Cooling: Quantifying the Ambient Temperature Impacts of Smart Surfaces on Electricity Demand*. Smart Surfaces Coalition. Retrieved May 20, 2022, from https://smartsurfacescoalition.org/s/Valuing-Cooling.pdf

Scott, D., & Lemieux, C. (2010). Weather and Climate Information for Tourism. *Procedia Environmental Sciences*, pp. 147–183.

Words by LA Tourism. (2019, May 8). *Tourism generated record $36.6 billion boost to Los Angeles economy in 2018*. Discover Los Angeles. Retrieved May 30, 2022, from https://www.discoverlosangeles.com/tourism-generated-record-366-billion-boost-to-los-angeles-economy-in-2018

Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J.-C., & Scheffer, M. (2020). Future of the human climate niche. *Proceedings of the National Academy of Sciences*, *117*(21), 11350–11355. https://doi.org/10.1073/pnas.1910114117