Impact of Solar Parasol Shading on Automobile Temperatures

SUMMARY REPORT OF PRELIMINARY FINDINGS





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The Project

This study investigated the effects of PowerParasol® solar shade structures on the interior temperatures of vehicles in Phoenix during the summer. Tests compared vehicles parked in the sun to those parked under the shade structures, and were conducted on the ASU campus at Surface Parking Lot #59. Here, PowerParasol® solar shade structures occupy about 25% of the asphalt surface parking.

The interior air and surface temperatures of three pairs of identical-model cars (silver mid-size sedans, silver economy cars and white minivans, Figure 1) were monitored during simulated shopping trips, with one of each vehicle model parked in the sun and the other parked under a PowerParasol® solar shade structure. All six vehicles were 2014 models.

Each day for two weeks between June 25 and July 11, 2014, beginning at 9:00 a.m., the cars were parked for an hour to simulate a shopping trip. Then, the air conditioning was run to cool the car back down to the ambient air temperature or 85°F, whichever was cooler. The cycle was repeated throughout the day until 5:00 p.m.

The interior air and surface temperatures were recorded before and after each simulated shopping trip in order to monitor the initial and final temperatures, as well as to calculate the rate of temperature increase while parked and the rate of decrease during the cooling phase. The surfaces monitored included the i) steering wheel, ii) dashboard and iii) seat. An additional temperature sensor was mounted inside each vehicle to record the temperature every one minute to determine how quickly the vehicle heated or cooled.

Results

We compared the results for cars in the shade to those for cars in the sun. There was a *significant difference* in the surface temperatures of the dashboard, steering wheel and seat at the end of the simulated shopping trip. The averages for the vehicles in the sun were 156°F, 128°F and 123°F for the dashboard, steering wheel and seat, while the shaded vehicles reported 118°F, 107°F and 106°F, respectively (Table 1 and Figure 2). Extreme, or peak, values are shown in Table 2.

The variability among the three surfaces was expected, as the dashboard receives the most direct solar radiation and the seat receives the least.

Over the course of all simulated shopping trips, **the average air temperatures were 116°F for the vehicles in the sun and 101°F for the vehicles**

Figure 1 *- Exposure of vehicles shaded by a solar structure and of those that were not.*

in the shade after one hour. The peak value for the dashboard was 192°F in the sun and 172°F in the shade for the economy car, and 185°F in the sun and 159°F in the shade for the minivan.

Since the strength of solar radiation varies throughout the day, the earliest shopping trips resulted in the coolest internal temperatures, while the late afternoon trips had the highest temperatures, ranging from 91°F to 130°F for the averages.

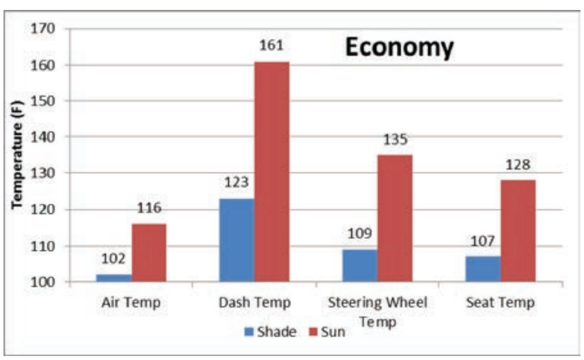
The interior vehicle temperatures after cooling by running the air conditioning were not significantly different, as the vehicles all cooled to nearly the same air temperature, by design. However, **the time required for the cooling varied considerably, because the temperature difference between the vehicle air temperatures after heating ranged from 130°F for a car in the sun to 91°F for a car in the shade.** In addition, the sedan had the most effective air conditioning, the minivan had the least effective and the economy car was in between. The ambient air temperatures outside the vehicle ranged from 85°F to 111°F over the course of the experiment.

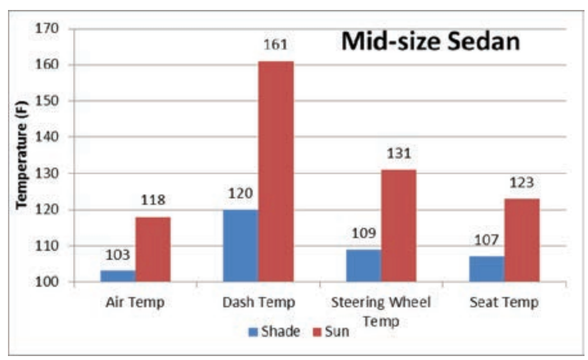
Cooler temperatures prevailed during the early morning, but – by 11:00 a.m. through the end of the afternoon – all vehicles in the sun experienced much higher temperatures. The peak values are shown in Table 2 and Figure 3.

Several of the shaded vehicles reported high surface and air temperatures a few times as a result of the gaps in the PowerParasol® solar shade where the sun shines through. These extremes are shown in Table 2 and Figure 3 and are generally due to the heating of

Vehicle Temperature	Economy Car *Shade/Sun* (°F)	Mid-size Sedan *Shade/ Sun* (°F)	Minivan *Shade/Sun* (°F)
Air Temperature	102/126	103/118	101/114
Dashboard Temperature	123/161	120/161	113/152
Steering Wheel Temperature	109/135	109/131	106/124
Seat Temperature	107/128	107/123	105/120

Table 1 *- Average air and surface temperatures.*





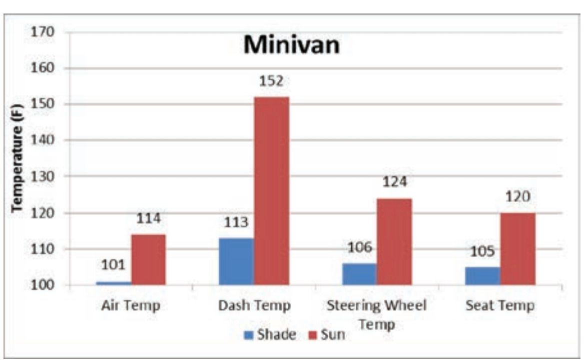


Figure 2 *– Average air and surface temperatures for the shaded and sun-exposed vehicles*

the dashboard when the solar radiation reaches the vehicle. The highest sedan air temperature in the shade was 122°F because the vehicle was facing south and the large gap in solar panels allowed the sun to heat the dashboard (surface temperature 169°F), which then heated the air inside the vehicle. The average air temperature of the shaded sedan was 103°F. The average dashboard temperature in the shaded vehicles ranged from 113°F to 123°F, though extremes were occasionally much higher (Table 2).

All vehicles were moved into the sun for the cooling phase of the cycle to simulate the cooling that would occur when a shopping trip concluded and the vehicle drove away. **The average cooling rates for the vehicles varied from 1.8°F/minute for the mid-size sedan in the sun to 1.2°F/minute for the minivan in the sun** (Figure 4). The slower cooling rate for the minivan was likely due to the larger air volume of the vehicle. The heating rates in the sun averaged from 0.60°F/minute for the minivan to 0.75°F/minute for the economy car, again likely due to the relative air volumes in the vehicles.

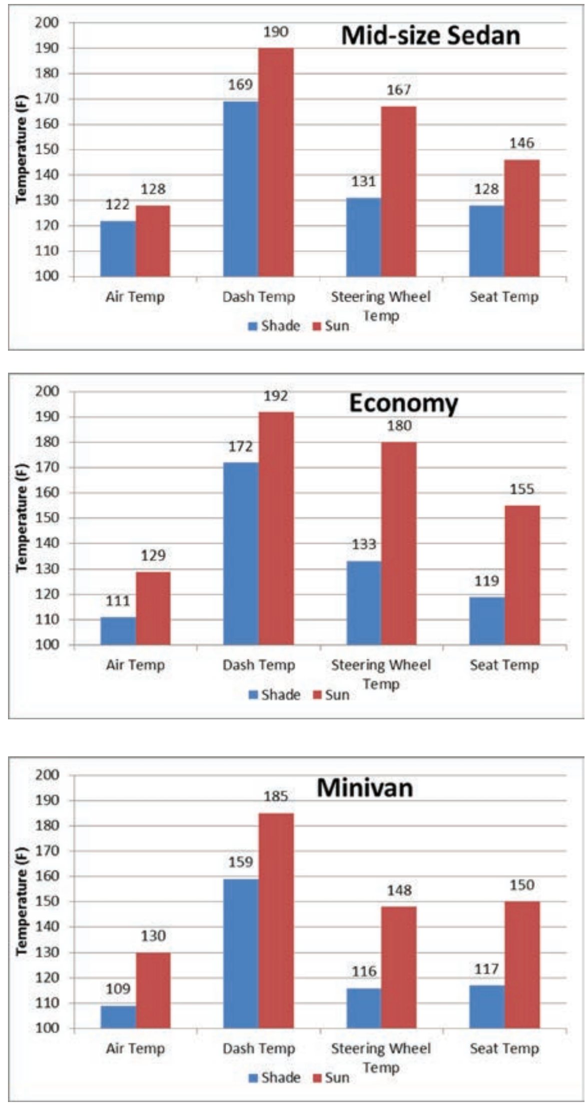


Figure 3 *– Extreme (peak) air and surface temperatures.*

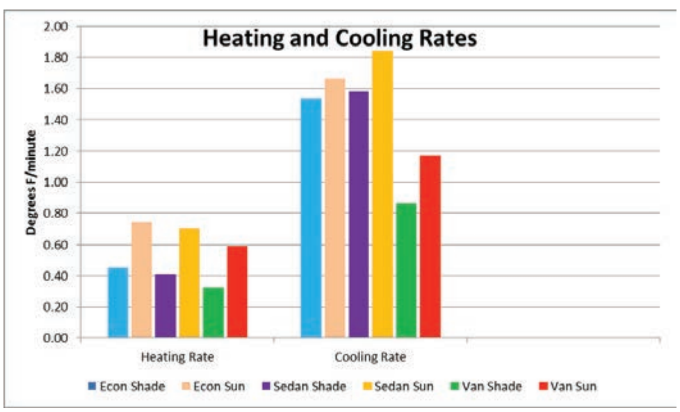


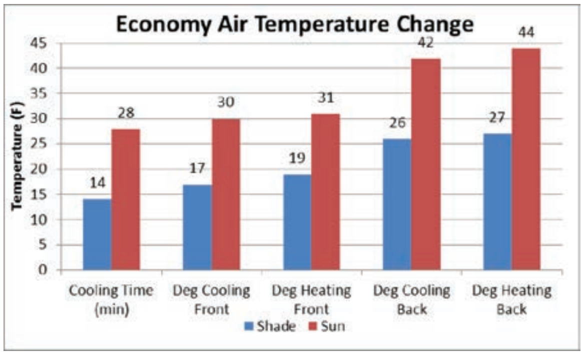
Figure 4 *– Average heating and cooling rates of vehicles*

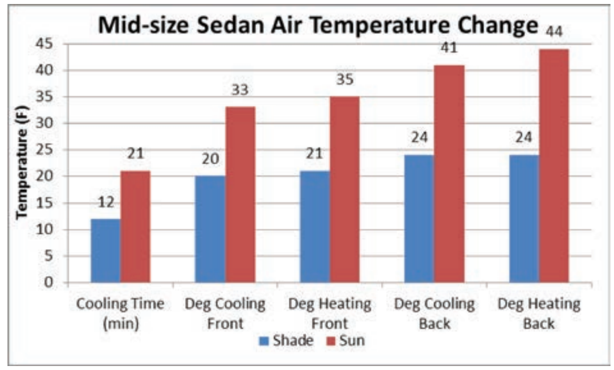
Vehicle Temperature	Economy Car *Shade/Sun* (°F)	Mid-size Sedan *Shade/Sun* (°F)	Minivan *Shade/Sun* (°F)
Air Temperature	111/129	122/128	109/130
Dashboard Temperature	172/192	169/190	159/185
Steering Wheel Temperature	133/180	131/167	116/148
Seat Temperature	119/155	128/146	117/150

Table 2 *– Extreme (peak) air and surface temperatures (Temperatures show peak values)*

Vehicle Temperature	Economy Car *Shade/Sun* (°F)	Mid-size Sedan *Shade/Sun* (°F)	Minivan *Shade/Sun* (°F)
Dashboard temperatures after one shopping trip cycle	68/76	74/72	77/76
Dashboard temperature after last daily cycle	126/145	138/161	144/162

Table 3 *– Residual heat in dashboard*





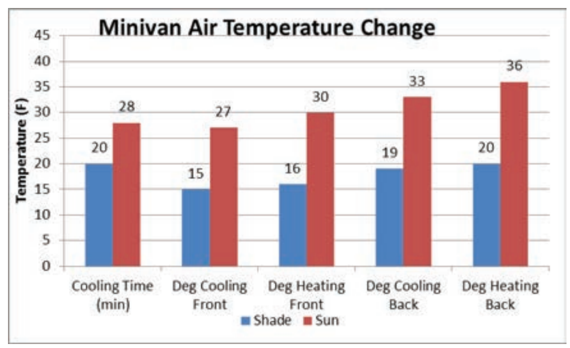


Figure 5 *– Average cooling time and temperature changes.*

Figure 5 shows **the average cooling times for the vehicles, with the shaded vehicles cooling almost twice as fast as the sun-exposed vehicles, except the minivan.** The shaded minivan required an average of 20 minutes to cool, while the sunny minivan required 28 minutes. The cooling temperatures were measured in the front seat, but in the sedans, the air temperature in the back, behind the front seat, exceeded the air temperatures in the front by about 10°F. In the minivan, the temperature difference from front seat to back was only about 4°F to 6°F. This is likely due to the fact that the cooling system in the sedan and economy car only pushes cool air out from the front dashboard, while the minivan also has cooling vents in the rear.

Even though the sun-exposed and shaded cars had similar air temperatures after the cooling phase, **the air conditioning phase did not bring them all back to the same cool condition.** This is because not all surfaces cooled to the ambient air temperatures due to the extended time required to cool the dashboard and steering wheel – surfaces that store heat. For example, the average dashboard temperature after cooling was 106°F for the shaded vehicles and 117°F for the vehicles in the sun. Consequently, although this was much cooler than the peak surface temperatures, the heat was not completely dissipated; it accumulated and contributed to subsequent heating in the succeeding shopping trips.

Table 3 shows the dashboard temperatures after the first trip of the day when the sun is low in the sky and no heat has accumulated, as well as the highest dashboard temperature after the last trip of the day when the heat has accumulated. This heat load that builds through the day means the air conditioning in a normal vehicle must continue to run long after the air is cooled, just to keep up with the heat being released into the car from the hot dashboard. The high values for the shaded cars were due to gaps between some of the solar panels that allowed the sun to reach the windshield of the vehicles. Nevertheless, the accumulated high dashboard

temperatures in the shaded cars were significantly lower than the surface temperatures in the sun-exposed cars.

The temperature changes within the vehicles were also examined at shorter time intervals. The one-minute air temperature data recorded inside the vehicles indicated the rapid temperature increase at the beginning of the shopping trip, followed by a slower rate as the air became warmer. The initial rate of increase differed throughout the day, and varied slightly by vehicle mostly due to interior air volume. The van had the slowest warming rate, followed by the sedan, and the economy vehicle had the highest heating rate.

The rate of heating also depends on the sun's angle. In the morning before 10 a.m. and in the afternoon after 4 p.m., the low angle of the sun causes the air inside the car to heat slower than between 10 a.m. and 4 p.m. when the sun is higher in the sky. For example, in the first 15 minutes, the sedan air temperature increased by 15°F in the early morning and by 17°F in the late afternoon, but the heating in the middle of the day was between 19°F and 21°F. The economy car heated even quicker, with the temperature rising 22°F in the first 15 minutes, then 12°F in the 15 minutes around noon.

As the day progresses, the initial air temperature inside the car increases due to the storage of heat within it, as indicated by the surface temperatures of the dashboard, steering wheel and seats. So, an air temperature that increases from 87°F at 9:30 a.m. to 100°F by 9:45 a.m., and to 109°F by 10:00 a.m., can rise from 103°F to 123°F at 2:00 p.m. in 15 minutes, and up to 136°F in another 15 minutes.

Conclusions

The PowerParasol® solar shade structures provided enough shade to keep the air temperature of the vehicles within 15°F to 18°F of the ambient outside air temperature in most cases. However, whenever the sunlight reaches a vehicle window, the interior solar heating of the surfaces will quickly raise the interior air temperature. **The results show the PowerParasol® solar shade structures can effectively reduce the interior air temperatures, but more importantly, can reduce the interior surface temperatures.**

Vehicles in this study faced either south or north, but predominantly south, so the windshield received the majority of the solar radiation at midday. This should represent the worst case scenario, as the largest surface area with the greatest heat gain is typically the dashboard, with the rear deck being the second largest surface to heat. Although orientation of parking spaces relative to the sun's path is important, its impacts could not be explored in this study. However, south-facing windshields do represent the maximum heating orientation for the majority of sunlight hours.

Acknowledgments

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