Fall 2014

Noise Pollution? What's the solution?: Understanding Traffic Noise Pollution in Gettysburg, Pennsylvania

Andrew F. Kapp
Gettysburg College

Joseph M. Passmore
Gettysburg College

Anika H. Schneider
Gettysburg College

Noise Pollution? What's the solution?: Understanding Traffic Noise Pollution in Gettysburg, Pennsylvania

Abstract
Noise pollution can be damaging to a community by impacting its atmosphere as well as the health of its residents, local quality of life, and local economy. Our study sought to gain insight into the level of noise pollution in Gettysburg, both in-town and on the Gettysburg College campus, and how noise pollution may be affecting the local residents and students. We selected 9 sampling sites, 6 in-town and 3 on the college campus, and measured the noise pollution in dBA with portable sound meters three days a week and three times a day over a three week period. Our data showed no major trends in terms of time of day or day of the week, but there were clear differences in noise pollution levels between the different sites in that town sites were generally louder than on campus sites. Noise pollution in town was often louder than 70 dBA, the noise threshold that indicates possible hearing damage overtime set by the World Health Organization. Gettysburg has recently enacted a noise ordinance; our study suggests the Borough possibly could do more to mitigate traffic noise by repairing roads and manipulating road design.

Keywords
Noise Pollution, Gettysburg, Sound Decibels, Traffic, Traffic Noise

Disciplines
Environmental Education | Environmental Indicators and Impact Assessment | Environmental Sciences | Oil, Gas, and Energy

Comments
Environmental Studies Thesis

Noise Pollution? What's the Solution?: Understanding Traffic Noise Pollution in Gettysburg, Pennsylvania

Drew Kapp, Joseph Passmore, Anika Schneider

ES 400: The Automobile and the American Landscape

Department of Environmental Studies, Gettysburg College

December 20, 2014

Abstract:

Noise pollution can be damaging to a community by impacting its atmosphere as well as the health of its residents, local quality of life, and local economy. Our study sought to gain insight into the level of noise pollution in Gettysburg, both in-town and on the Gettysburg College campus, and how noise pollution may be affecting the local residents and students. We selected 9 sampling sites, 6 in-town and 3 on the college campus, and measured the noise pollution in dBA with portable sound meters three days a week and three times a day over a three week period. Our data showed no major trends in terms of time of day or day of the week, but there were clear differences in noise pollution levels between the different sites in that town sites were generally louder than on campus sites. Noise pollution in town was often louder than 70 dBA, the noise threshold that indicates possible hearing damage overtime set by the World Health Organization. Gettysburg has recently enacted a noise ordinance; our study suggests the Borough possibly could do more to mitigate traffic noise by repairing roads and manipulating road design.

Introduction:

Many studies in recent years have focused on the causes and effects of noise pollution, as noise pollution has come to be recognized as one of the major influences affecting urban quality of life. For instance, studies in Erzurum, Turkey, Yazd City, Iran, and Rourkela City, India, which are all major urban centers, have all identified traffic as being a major cause of noise pollution and studies such as that by Huang have measured significant differences in heart rate when individuals were exposed to the sound levels of heavy traffic (Ozer et al. 2014, Ehramoush et al. 2012, Goswami et al. 2013, and Huang et al. 2013). All of these studies measured noise levels at different sites within their study area in attempts to pinpoint noise levels and their causes by geographic location in order to propose proper mitigation for more affected areas. While many studies, such as the ones described, have been conducted on large urban areas, significantly fewer studies have been conducted regarding noise pollution in more suburban settings. Loud noises can also destroy small peaceful communities which may rely on their quaint atmospheres to stimulate their economy. Tractor-trailers, buses, motorcycles, trucks, even SUVs and sedans, can cause considerable amounts of noise pollution. Yet other factors also affect noise pollution, such as road design, open spaces, shape and physical position of buildings, and population distribution (Abbaspour et al. 2015). Noise also threatens educational atmospheres that institutions of higher learning aim to foster. While many studies have focused on noise sensitive locations such as parks and hospitals, there have been far less research on educational institutions, yet campuses are especially susceptible to negative impacts from traffic (Ozer et al. 2014). A study by Ataturk University determined that noise pollution makes it difficult to concentrate on lectures, assignments,

or studying (Ozer et al. 2014). Constant loud noises can have an impact on hearing ability. High noise levels can make it difficult to hold a conversation or sleep and it can also cause the much more serious health impacts of heart conditions and hypertension (Berglund et al. 1999). Additionally, studies have observed that stressors associated with noise pollution can have long term effects on mental health, which may be displayed as mood disorders (Tzivian et al. 2015).

The area for this study is the Borough of Gettysburg, Pennsylvania where about 7,600 residents reside. As mentioned previously, Gettysburg contains a walkable historic downtown as well as an adjoining college campus, Gettysburg College. Due to the town's unique characteristics, noise pollution could be particularly detrimental to quality of life. The local residents and students depend on a peaceful atmosphere to work, study, and sleep, while the economy of Gettysburg depends on a steady flow of tourists through the town to visit shops, go on ghost tours, and visit historic locations. The Borough of Gettysburg is a town of historic crossroads in both a metaphorical and literal sense. The town location lends itself to the fact the many major roads from surrounding towns meet at Gettysburg. This is still true today as many roads radiate from the town, and these roads provide access to surrounding urban areas such as Washington DC, Carlisle, Harrisburg, Frederick, York, Baltimore, and more. Gettysburg is also located along U.S. Route 30, which runs right through the middle of town.

Interestingly, previous to 2011, the Borough of Gettysburg did not have any noise enforcement laws. A noise ordinance in Gettysburg was proposed in 2008 due to a large amount of noise complaints. The noise ordinance has since been adopted in 2011. The Borough Council President stated that noise complaints are the "single biggest issue" he

hears about (Gettysburg Times 2010). The noise ordinance was modeled after Environmental Protection Agency guidelines and nearby Lancaster City's similar noise ordinance. The Gettysburg noise ordinance focuses on 17 noise disturbances such as rapid advance of throttle, racing of engine, squealing tires, standing vehicles, revving internal combustion engine, and others. (Gettysburg Code Ordinance: Chapter 6 2011). Due to these traffic noise disturbances and noise complaints, the goal of our study was to determine and compare noise levels in Gettysburg, both on Gettysburg College's campus and in the historic downtown of Gettysburg. The aim of determining noise levels at different sites was to help identify causes of noise pollution and to better understand how the noise level in that area may be affecting the residents in close proximity. By comparing noise levels we hoped to gain more insight into which areas were being more or less affected by noise pollution. Through understanding these differences we would be able to better identify what causes differences in noise levels at specific locations to better recommend effective mitigation techniques.

Methods:

In order to determine noise levels among different sections of Gettysburg, nine data collection sites were chosen. These sites were chosen with the goal of creating three approximate transects through the campus and town in order to detect any gradient like patterns in noise pollution levels. The data collection sites were also specifically chosen to represent different, yet representational, areas of Gettysburg. The nine data collection sites used were the Spring Ave. fork at the corner of West St. (Site 1), corner of Wall Alley and Baltimore St. (Site 2), Hanover St. fork at the corner of Liberty St. (Site 3), Lincoln Square (Site 4), intersection of Carlisle St. and E Water St. at the location of the

Ugly Mug (Site 5), corner of Lincoln Ave. and Carlisle St. (Site 6), corner of N Washington St. and W Lincoln Ave. (Site 7), corner of College Ave. and W Lincoln Ave. (Site 8), and the corner of Constitution Ave. and W Lincoln Ave. (Site 9). Data was collected over a three week time period starting the last week of October. The data was collected using a CEM digital sound level meter, model number D7-85A (Figure 1). For the three week study period data was recorded three days each week, Monday, Wednesday, and Sunday. For each of the days data was collected during three time intervals, at approximately 9-10 am, 12-1 pm, and 5-6 pm (Ozer et al. 2014). Each time data was collected, five recordings were taken for both the maximum and the minimum dBA. The noise meter would be allowed to run for a one minute time frame within which both the minimum and the maximum would be recorded. This was done five times in a row over the course of five minutes. Also, while recording dBA data the vehicle type which produced the observed maximum dBA was recorded and along with any other pertinent observations such weather conditions, vehicle age, and miscellaneous background noise.

In order to understand our many noise level recording we first analyzed our raw sound data to determine the noise levels by site. This was done by calculating a series of different averages. We define overall average as the average of every noise level ever recorded for a variable, such as overall average by site or by time of day. We define average absolute maximum as the highest and average absolute minimum as the lowest sound level recorded during each five-minute data collection period of that variable. For example, the overall average for Site 1 would be every noise level for Site 1 averaged together, while the overall average for 9:30 am would be the average of every noise level

recorded at 9:30 am. After we had determined the noise levels for our various variables by calculating averages, we created a series of figures, tables, and ran several ANOVA tests to compare our noise levels by our many variables.

A data a summary table was created. This summary data table contains the overall minimum and maximum value of all samples, the average of all absolute minimums for each 5-minute testing period, the average of all absolute maximums for each 5-minute testing period, and the overall average of the minimums and maximums for all testing periods. The standard deviation was calculated for the overall average and the average of the absolute minimums and absolute maximums (Ozer et al. 2014). Our clustered bar graphs compared the averages between day collected, time collected, and site collected. These comparisons allowed us to determine whether there were any underlying patterns as to which times or sites were louder or quieter. Graphs were also made to find out whether specific times of day at specific sites were louder or quieter. For instance, we compared the average for each of the three data collection times by site to determine whether some sites tended to be louder in the morning than others or if some may be louder in the evenings. We also compared average maximums and minimums to different variables in order to find out whether some sites or times had significant peaks of loud noises or extended periods of relative silence that are associated with particular variables.

In order to better understand variation in noise levels at each site a map was created. This map displayed the 9 data collection sites and their average absolute maximums and average absolute minimums. Graduated symbols were used to allow viewers to visually compare differences in maximum and minimum noise levels from site

to site and to compare differences between each site. Additionally, in order to visualize the data collected on vehicle types we created a bar graph showing the frequency at which each vehicle type was associated with the maximum sound levels produced within each five minute recording period. A scatter plot was also constructed to show the frequency at which each car type was associated with the top maximums produced within each five minute recording period and the average of those top maximums per each car type.

Results:

The overall average of our collected sound values was 62.19 dBA with a standard deviation of 4.49. Our sound data also had an average absolute minimum of 49.16 dBA over our 5 minute testing periods with a standard deviation of 9.71 and an average absolute maximum of 78.46 dBA and a standard deviation of 5.86 (Table 1). The highest recorded noise in our study was 99.6 dBA, which was a sound value produced by a passing Semi Truck (Table 2). While there were substantial differences between the minimum and maximum sound values we observed, our data indicates that noise levels do not seem to vary much or follow patterns temporally, but spatial patterns were observed. Our data analysis revealed that time of day did not have much influence on traffic noise pollution, as much as different sites did. In comparing average noise levels of each time of day to site collected we saw a statistically significant difference (P=0.00) (Figure 2), but when comparing average noise levels of each time of day (P=0.246, 0.485, 0.228) (Figure 3) and maximum average noise values to day of week no significant relationship was found (P=0.304, 0.352, 0.396) (Figure 4). This indicates that noise levels in fact changed by site and not by time of day. By looking at the overall average and the

average maximums, there is no apparent pattern as to what time of the day is the loudest (Figure 5). For instance, in Figure 6 average maximums are compared for all three time periods by site, but there is no one time period that is consistently quieter or louder. Each time of day has the loudest average maximum and overall average for one of the sites (Figure 2 & 6). While Figure 6 does not reveal patterns of noise levels between noise each time of day, it does display differences in noise levels by site with those sites on campus being significantly less loud than in town sites (P=0.00). There appeared to be no substantial trend in time of week either, as each day of the week had little variation in noise levels over the three times of day we tested and noise levels look almost identical despite day of week (Figure 7).

However, while neither time of day nor day of week had much influence on noise levels, when analyzing the noise levels spatially, by site location, differences in noise levels were present (Figure 8). There was a clear difference in the noise levels at different sites, with the in-town sites, sites 1-6, having a higher average and average maximum compared to sites 7-9, which were located on-campus (Figure 8). The differences between the overall average, average maximum, and average minimum at each site are statistically significant (P=0.00) (Figure 9).The three sites on campus had smaller average absolute maximums (Table 3). For the absolute maximums there was a 18.8 dBA range in the average absolute maximum noise levels (Table 3) and a range of 20.7 dBA for the absolute maximum (Table 4). Between Site 7, which had the highest noise level readings on campus, and Site 2, which had the next highest noise level readings, there was a 10.8 dBA difference in the average absolute maximum (Table 3).

Interestingly, the minimum noise level values do not vary as much as the maximum values, which can be seen in the map (Figure 8). The range for absolute minimum was 14.5 dBA (Table 4) and the range for average absolute minimum was 7.3 dBA (Table 3). Also of note, the sites on campus, which had much quieter maximums, had equivalent minimums or even louder minimums in comparison to the in-town sites (Figure 8). For example, Site 7, an on campus site, actually had the highest absolute minimum of any site 48.1 dBA (Table 4). Site 9, also an on campus site, had the lowest absolute min of 33.6 dBA (Table 4). Site 9 also had the least variation in noise levels being overall the quietest site (Figure 8). When looking at the average of the absolute minimums, the three on campus sites had the first, second, and fifth highest absolute minimums (Table 4). Therefore, while the maximums of the on campus sites were lower than the other sites, the minimums did not follow suit and were not proportionately lower in comparison to the maximums (Figure 8). However, the sound values on campus were still significantly lower than in town (P=0.00) (Figure 9).

Additionally, we examined the frequency at which max sound values were associated with each of the fourteen vehicle types we identified for our study and compared that data with the frequency at which top maxes were associated with each car type. In doing so we revealed some interesting relationships between maximum sound values and vehicle types (Figure 10). We found that Sedans were most often associated with maximum sound level, followed by SUV’s and Pickup Trucks. These were the most frequently observed vehicle types on the road, so if a louder vehicle type, such as motorcycle, did not occur during a one minute recording period it was more than likely that one of these vehicle types (Sedans especially) would be associated with the

maximum sound value for that one minute recording period (Figure 10). What was also of note was that the fourth most frequent category to be associated with maximums was the None/Misc category. This category was used if no vehicle types were observed during a one minute recording period or if the vehicle type associated with the maximums did not match the description of any of the other vehicle types we identified for our study (Figure 10). You can see that there is a downward trend in the occurrence of this category over the course of the three week study (Figure 10).

When we went back and selected the top maximums produced during each five minute recording period and their associated car types we revealed some interesting trends. Sports Cars and Emergency Vehicles for instance, were among the least associated with top maximum as well as average maximum sound values, but the top maximum sound values they were associated with averaged out to be the highest of all 14 vehicle types (Figure 11). Also of importance was that a third of the maximums associated with Sports Cars (5 out of 15) were top maximums and almost all of the maximums associated with Emergency Vehicles (13 out of 16) were top maximums.

The three old vehicle types (Old Sedan, Old Pickup Trucks and Old SUV’s) were associated with top maximums that were very similar to one another. You can see in Figure 11 that they are clustered together, with Old Pickup Trucks having a slightly higher average top maximum value and Old Sedans being slightly more frequently associated with top maximum values.

The vehicle type that was the second most associated with top maximum values was Semi Trucks, all 32 of which averaged out to be 84.47 dBA (Figure 11). This is interesting since any sound levels above 70 dBA are considered detrimental to human

health and so Semi Trucks consistently produced sound levels that were well above that. Pickup Trucks proved to be the vehicle type that was most frequently associated with top maximum values with 47 top maxes averaging out to be 77.9 dBa (Figure 11). This is interesting because Pickup Trucks were overall the third most frequently associated with maximum sound values. So one of the most frequent vehicle types we observed is also frequently producing the most top maximum sound values. In short, Pickup Trucks were the most effective producers of maximum sound values out of the 14 vehicle types.

Discussion:

Site by Site Noise Pollution Analysis

The majority of our results were due to the unique spatial attributes of each site. For example, because of its traffic patterns Site 9 had the lowest overall sound level readings and therefore was the quietest site (Figure 8). Site 9 is located at the end of two streets where there is little destination for traffic. The most likely reason for traffic at this intersection would be college students or faculty look for parking in Constitution Lot or along the street. This traffic likely travels at slow speeds, resulting in lower maximums and consistently low minimums. Additionally, when arriving at Site 9, traffic must turn and cannot go straight through the intersection, which resulted in lower peak maximums. Even while being a remote location, Site 9 still had some fairly loud peak noises reaching the high 70s, which is well above the World Health Organization, or WHO, recommended value of 55 dBA (Table 5). This is likely because Site 9 still receives some heavyweight traffic as it is on the route for the Freedom Transit and it was observed that there is a decent amount of traffic for college facilities passing through this site.

When traveling down Lincoln Ave. toward Carlisle St. traffic volume would increase at times due to varying traffic patterns. For example, the traffic flow at Site 8 would pick up when cars randomly commuted into Gettysburg by cutting through the battlefields via College Ave. The College Union Building and dining hall (Servo) located at the corner of this site also made it a popular destination for cars. Observations also revealed that the dining hall would receive several delivery trucks in the mornings, which directly affected noise maximums. Sites 7 and 8 had subsequently greater noise level readings (Figure 8). These two sites, in comparison to Sites 8 and 9, were four way stops that facilitated high traffic flows. Although Site 6 borders campus as well this site was located on a major intersection with traffic lights and turn lanes resulting in heavy traffic flow and louder noise readings. Site 6's average absolute maximum was 84.3 dBA, which is well over the recommended maximum value of 55 dBA and potentially high detrimental as both college owned and private residential buildings are located on all four corners of the intersection (Table 3).

While the on campus sites had smaller maximum values they did not have smaller minimum values (Table 3). Overall there was far less variation in the minimum values (Table 4). This is likely because although there were certain peaks for loud noises (maximums) and during the time in between loud noises there seemed to be a certain baseline for how quiet it could get. This makes sense because in an outdoor environment it is unlikely that there will be dips down in sound to a level approaching complete silence. Sites 7 and 8, on campus sites, actually had slightly louder average minimums along with Site 4. For sites 7 and 8, this is potentially because they are located right outside of the College's dining hall and gym so both sites would see a lot of foot traffic

and the noise meters likely picked up noises from people’s conversations and other aspects of noise from student life. Site 4 is the location of a major highway intersection and is also the main traffic circle in town. This makes this site unique because the other sites all had either traffic lights or stop signs. The presence of a traffic circle could be the reason this site’s average minimums were not as low as the other sites, despite its high volume of traffic. While traffic would come to a complete stop at traffic lights or stop signs, a traffic circle allows for a constant flow of traffic potentially explaining why the minimums did not dip down quite as far, yet the average absolute maximums were actually lower than less traveled sites with traffic lights such as site 5 or 6 (Table 4 & Figure 8).

There were noticeable spikes of a few dBA in traffic noise at Site 5 when cars would travel quickly over a certain section of the road. This section of road was noticeably uneven and contained a major pothole (Figure 12). The velocity of these cars mixed with the uneven road tended to force the cars to quickly dip into the pothole and bounce out, creating a notable noise. This could be one possible reason that Site 5 had the highest recorded absolute maximum traffic noise level of 99.6 dBA. There were also additional, less extreme examples of poor road maintenance or design, at some of the other sites. The proper maintenance and design of roads seems to have a noticeable effect on traffic noise pollution.

Both Site 1 and 3 have similar spatial attributes in that they both have traffic lights, are forks that converge on the portion of Route 30 leading in and out of the center of Gettysburg, and are both a similar distance from the center traffic circle. For this reason, they are exposed to very similar traffic patterns and have almost identical overall

maximum and minimum sound levels during all three weeks of our sound data collection. Site 2, on the other hand, had slightly lower overall maximum and minimum sound levels despite being a similar distance from the center as Sites 1 and 3. One likely reason for this is that there were no traffic lights present at this site, so there was no stop-and-go traffic that would lead cars to produce the louder sounds associated with braking and accelerating. Also, Baltimore St. leads to the larger southern portion of the Gettysburg battlefields which, during the summertime, would likely lead to more traffic passing through this point due to tourism. However, since our recordings took place during October and November, which are less popular months for tourism of the Gettysburg battlefields, we saw no real evidence of this type of traffic at Site 2.

Automobile Type Breakdown

Figure 10 shows that over the course of our study Sedans were the most consistent car type observed, followed by SUV's and Pickup Trucks (Figure 10). Our data also shows that over the course of our three weeks of data collection the number of each vehicle type observed at each site remain relatively the same except for motorcycles. (Figure 10) Motorcycles go from 3% of the total during week one, to 1% of the total during week two and then disappear from the total completely during week three (Figure 10). This has a significant effect on our results because motorcycles produced some of the largest maximum sound levels during our study. We assume that this decline and eventual absence of motorcycles in Gettysburg was due to the increase in cold and rainy weather conditions during the early weeks of November. This type of weather is obviously unfavorable for bikers since their vehicles provide minimal protection from the elements.

A unique category in Figure 11 is the None/Misc. category. This category means that at the time of a recording either no cars were observed, the car type that produced the maximum sound level was unknown or the source of the maximum sound level was something outside of the categories we developed for automotive vehicles types. The pie charts show that this category decrease in size from 13%, to 7%, to a mere 5%. This may demonstrate that as we became more experienced at collecting sound data were able to better identify car types. It may also mean that there was an increase in the volume of traffic passing through Gettysburg over the course of our three week study.

Noise Pollution Community Impacts

As a point of reference, the National Institute of Safety and Health recommends limiting an employee to an 8 hour exposure of 85 dBA to avoid hearing loss, and states that exposure of 100 dBA or more should be limited to only 15 minutes per day to avoid hearing loss (OSHA 2014). The World Health Organization states that sound levels higher than 50 to 55 dBA would be considered annoying by a majority of the adult population and inadvisable. It also suggests that levels of 65 dBA or higher make normal conversation more difficult and levels of 35 dBA or higher makes it more difficult to comprehend complex speech activities, such as talking on the phone, listening to a foreign language, or understanding an academic lecture (Berglund et al. 1999).

Overall, Gettysburg's noise pollution fair rather poorly in comparison to guidelines set by the World Health Organization. Our overall average noise level was 62.19 dBA, with an average sound maximum over a 5 minute period being 78.46 dBA. This means that as a whole, Gettysburg is often above the WHO's threshold for "annoyance" caused by noise pollution, which is set at 55 dBA (Table 5). The borough

proper of Gettysburg, which would include Sites 1 through 6, fares much worse in comparison to WHO guidelines than the roads within Gettysburg College, which would include sites 7 to 9. Gettysburg proper has an average traffic noise value of 64.4 dB and an average noise maximum of 83.7 dBA. Even the average minimum within Gettysburg barely passes WHO standards at 48.2 dBA. This means that pretty consistently, pedestrians in Gettysburg would find traffic noise “annoying” and have a more difficult time having conversations. For Gettysburg, which relies on its historic feel and charming atmosphere to bring in tourism, this could have serious financial implications. Traffic noise could drive away potential tourism, which would cost residents and Gettysburg revenue.

Our noise level recordings were closely aligned with the levels measured by other noise pollution studies. For example from measuring 12 sites around Ataturk University and the surrounding area in Erzurum, Turkey the average noise level calculated was 62.7 dBA (Ozer et al. 2014). A study of Yazd City, Iran calculated 74.3 dB A as the mean level of maximum noise level, also similar to Gettysburg (Ehrampoush et al. 2012). Additionally a study in Rourkela City, India measured that noise levels ranged from 68.5 to 120.3 dBA during the day time (Goswami et al. 2013). Our average noise level was very close to Ataturk University’s and the vast majority of our noise levels fall within the range of Rourkela City’s. It is concerning that Gettysburg's noise levels align so closely with those of other studies because both Erzurum and Rourkela are much more urban areas in comparison to Gettysburg. While Gettysburg has a population of 7,620, Erzurum, Rourkela, and Yazd have populations of 367,250, 210,412, and 330,000 respectively. There are a variety of factors that could explain these results such as population density,

traffic infrastructure, and prevalence of automobiles, but it is still concerning for Gettysburg which depends on its quaintness and historic feel to thrive economically.

The traffic noise in the Gettysburg Borough could also contribute to a more hostile social atmosphere in town, as traffic makes communication outside more difficult, and psychological research has shown that higher levels of ambient noise may reduce the helping tendencies of individuals (Berglund et al. 1999; Geller & Malia 1981). Furthermore, the WHO recommends that noise levels be under 30 dBA in order to not disturb the sleep of residents. It is possible that residents who live near to these busier roads may have noise pollution levels over 30 dBA within their homes. The average sound value in the evening was 61.9 dBA and the average 5-minute maximum was 78.5 dBA. Disturbing the sleep of residents could pose a variety of health, social, and economic risks to the community (Berglund et al. 1999). For example, residents who get less sleep will be more likely to get ill or more likely to get in car accidents. The Borough should also be careful in future land use plans and road design. The EPA has stated that traffic noise levels that are consistently over 70 dBA can cause damage to hearing over time. In-town, levels are only on average 5.6 dBA lower than that, and peak over this limit often according to our data, typically a few times each minute. Any project in-town that increased traffic and noise further could damage the hearing of residents over time (EPA 1974).

The roads in Gettysburg College only barely surpass the 55 dBA guidelines, with an average traffic noise of 57.9 dBA and a maximum of only 68 dBa. This means according to the WHO, any impacts on campus residents and communication is likely minimal. The WHO also recommends that classrooms be kept under 35 dBA so students

are not disturbed or distracted, (Berglund et al. 1999). Research has indicated that the exterior of normal buildings near a road typically decrease traffic noise by about 20-25 dBA, which means some campus building close to the road may occasionally reach levels significantly higher than 35 dBA, but such levels would likely not be consistent (Fidell et al. 2013).

Public health research has also been conducted on how traffic noise pollution can impact the health of residents. Researchers have determined that average noise values greater than 60 dBA can increase a person’s risk of heart disease and hypertension. This is likely due to an increase in the levels of stress and annoyance of individuals, which increases heart rate, blood pressure, and stress hormones. Hypertension can lead to increases in the risk of an individual’s chances for other complications, such a stroke or heart attack. Gettysburg proper does have an average sound level higher than 60 dBA, so traffic noise pollution is likely having an impact on public health within the Borough. These health complications can harm Gettysburg residents’ quality of life, or even be fatal. Medical treatment for the health impacts of traffic noise in Gettysburg could be significant, which may be hurting the area economically as well. Gettysburg College does not have average noise pollution over 60 dBA, so they possibly are exempt from these effects according to these specific studies (Bodin et al. 2009). Yet even when noise levels are not consistently high there can still be health effects, even among young healthy adults. A 2013 study that measured changes in cardiac autonomic function of 19-32 year olds, with a mean age of 24.4 years, after having them sit by bus stops for short periods of time (Huang et al. 2013). The study attributed these changes to the heart’s ability to

adapt to changing circumstances and unpredictable stimulus meaning periodic unpredictable loud noises can severely detrimental to one's health (Huang et al. 2013).

Mitigation in Gettysburg

The Borough of Gettysburg has already taken measures to regulate noise pollution with the passing of the 2011 Noise Ordinance. But to mitigate the negative effects of noise pollution more should be done because unfortunately noise is fleeting and the ordinance is mostly a complaint based ordinance. Although the Noise Ordinance is a good place to start for the Borough, it has received criticism. Most of the criticism surrounds the ambiguity in how noise levels will be enforced as the code currently "relies on the judgment of the officer" and "does not distinguish different noise ordinances in different zones" (Gettysburg Times 2011). Currently, there are two different methods for noise ordinances and noise control in Pennsylvania, and the preferred method is not the approach that Gettysburg took (Gettysburg Times 2011). The preferred method uses precise decibel levels and enforces through the use of noise measurement, and the Borough of Gettysburg does not have time for police training or the money to purchase the instruments needed (Gettysburg Times 2010).

Instead of relying on either complaints or strict enforcement of noise levels, we propose a series of strategies which could both reduce actual noise levels and more properly diffuse noise to improve quality of life. Rather than simply putting restrictions on noise levels, the Borough should try to control the variables that aggregate noise pollution. In the case of this study, the variable contributing to noise pollution is traffic. Therefore, instead of enforcing noise levels, the Borough should adopt stricter traffic enforcement laws which will be easier to enforce. For instance, one strategy could be

restrictions on number and type of vehicles that are allowed in certain areas. Similarly to our study, a study by Zhou measured that heavy vehicles such as trucks and busses have sound levels of 89-92 dBA (Zhou et al. 2014). Policies could be enacted so that these types of vehicles are limited to where they can travel. Such policies could include preventing tour busses from cutting through residential areas, and traffic of large tractor trailers could be diverted from the center of town. In regards to educational facilities, one study suggested that vehicles should be diverted to large autoparks not in close proximity to educational areas (Ozer et al. 2014). If certain parking spots, such as the roadside parking near campus buildings, was moved further from some of the main campus buildings, traffic would then be less heavy around sensitive educational areas. This technique could also be applied to the town by reducing parking within downtown Gettysburg, deterring cars from entering the area, thereby decreasing noise pollution in the area. Additionally, stricter speed enforcement laws could be put in place. Noise can be reduced by 2 dBA if speed is reduced by 10 Km/h or 6.2 mi/h (Zhou et al. 2014). This could be done by either lowering the speed limit or by using other techniques, such as narrowing roads, so that drivers feel less safe and therefore drive slower (Speck 2012). The Borough could reassess speed limits, and perhaps lower local speed limits to 15 mph to limit noise pollution.

Working with proactive regulation techniques, the Borough could implement complementing reactive strategies to help negate the effects of noise pollution. For instance, several studies have measured the potential that different types of asphalt have in mitigating noise pollution. One study measures a 3 dBA difference in noise pollution between different types of asphalt (Petrescu and Borza 2013). This difference has to do

with the variation in porosity of asphalt. Asphalt with a high porosity of 15-25% had actually been accounted for a reduction of noise pollution by 8 dBA (Zhou et al. 2014). This could be useful within the Borough of Gettysburg. for instance when roads were re-paved asphalt with a higher porosity could be implement. One example of this would be at Site 4 (Servo) , several different types of asphalt occur at this site as areas of road here are fixed and resurfaced a consistent type of noise reducing asphalt could be implemented. It could also invest in better materials for infrastructure, which could help mitigate noise pollution. Properly maintaining roads and repairing road potholes is also another way the Borough could reduce noise pollution, as the pothole identified in Site 5 in one factor that increased noise pollution in the area (Figure 12).

Another technique that is growing in popularity is the creation of green belts or planted buffer zones alongside the edge of roads (Ozer et al. 2014). Green spaces with a strategic combination of coniferous and broad leaved tree species may be able to reduce noise levels by 10 to 15 dBA (Ozer et al. 2014). A reduction of 10 to 15 dBA would be enough to bring many areas of Gettysburg below the recommended 55 dBA. Another study also measured that a green belt of more than 10 meters in width has the potential to reduce traffic noise by 4-5 dBA (Zhou et al. 2014). One type of tree specifically, the *Acer pseudoplatamus* or Sycamore Maple, is known to reduce noise pollution by 10-12 dBA (Ozer et al. 2014). Strips of planted buffer zones could therefore be potentially better than constructed sound barriers, which typically reduce noise pollution by more than 10 dBA (Zhou et al. 2014). But if there is not space for a green belt of trees, which are optimal both aesthetically and environmentally, constructed sound barriers can be valuable for areas especially sensitive to noise pollution such as highways.

These strategies to reduce noise pollution should be examined in any further noise pollution study of Gettysburg. Our study focused solely on automobile noise, site location, and temporal patterns, and we did not measure or conduct significant analysis on other factors that may have influenced our noise readings. Our data could have also easily been influenced by other factors such as differences in asphalt or the presence of large trees. Additionally, the size and layout of the surrounding buildings of the data sites were not analyzed and this could have easily influenced our readings by capturing and reflecting noise waves. Our readings could have been more conclusive with higher quality instruments, as more expensive sound meters can be set up and constantly record noise levels at a site. This would have allowed us to collect noise levels 24 hours a day and 7 days of week. This could reveal interesting trends that we were not able to identify, as we were constrained by our schedule and only able to sample three times a day and three days a week. Our study could also be improved by expanding the study period over a longer period of time. We only analyzed noise pollution over a three week period, but a study conducted over a year could identify seasonal trends. For example, motorcycle would likely have a larger impact on noise pollution in the spring and summer months when the weather is nicer, and our study was in late fall. Further studies could also be very useful in assisting the Borough in creating a more effective plan to combat noise pollution.

Conclusion:

Our study determined that as you approach the center of Gettysburg campus traffic noise pollution levels drop noticeably. However as you approach the outskirts of campus, especially the southern portion closest to the center of Gettysburg, sound levels

increase. For this reason, we would predict that Gettysburg College housing and academic buildings located nearest to the center of Gettysburg would be most affected by noise pollution. We would also predict that tourist destinations in the center of town may suffer due to excessive noise, and that residents near the center of town may suffer longer term health impacts from noise pollution. We also observed that variations in road and traffic characteristics such as the presence of traffic lights or potholes affected the occurrence of certain sound level at each data recording sites. Our study determined that preventative mitigation measures, such as green buffers, proper road maintenance, reduced speed limits, and careful traffic flow planning would be most effective in reducing noise pollution. In general, we have found that the Borough of Gettysburg consistently has higher than recommended levels of noise pollution and that steps should be taken to mitigate these levels in order to reduce the overall impact of noise pollution on the community.

The Noise Ordinance for the Borough of Gettysburg is a complaint based ordinance. While we cannot speak to the effectiveness of this ordinance, we feel that additional mitigative steps should be taken. Since noise is fleeting mitigation based on complaints would be quite difficult as it is hard to enforce noise levels after the incidence has occurred. For this reason we suggest more proactive mitigation techniques that would help reduce noise levels rather than react to existing noise levels. These techniques can be as simple as increasing the number of trees. For example in our in town sites such as Site 2 people's bedroom windows are a mere few feet from the road, if a curtain of trees were planted in front of their windows they would be shielded from some of the noise pollution. Additionally, simple road care such as repairing potholes could reduce high

peaks of loud noise. Such an example would be the pothole in the middle of the intersection of Site 5.

Works Cited:

Abbaspour, M., E. Karimi, P. Nassiri, M. R. Monazzam, L. Taghavi. 2015. Hierarchal Assessment of Noise Pollution in Urban Areas- A Case Study. Transportation research Part D: Transportation and Environment 34: 95-103.

Berglund, B., T. Lindvall, & D. Schwela. 1999. Guidelines for Community Noise. World Health Organization, London, UK.

Bodin, T., M. Albin, J. Ardö, E. Stroh, P. Östergren, & J. Björk. 2009. Road Traffic Noise and Hypertension: Results from a Cross-sectional Public Health Survey in Southern Sweden. Environmental Health 8(38).

Borough, Gettysburg. 2013. Conduct. Code Ordinances. 3rd ed. Vol. 1. Borough of Gettysburg

Ehrampoush, M. H., G. H. Halvani, A. Barkhordari, M. Zare. 2012. Noise Pollution in Urban Environments: a Study in Yazd City, Iran. Polish Journal of Environmental Studies 21(4): 1095-1100.

Environmental Protection Agency. 1974. EPA Identifies Noise Levels Affecting Health and Welfare. <http://www2.epa.gov/aboutepa/epa-identifies-noise-levels-affecting-health-and-welfare> Accessed December 2, 2014.

Fidell, S., M. Sneddon, & R. Harrison. 2013. Relative contributions of highway and neighborhood sources to outdoor and indoor residential sound levels. Noise Control Engineering Journal 61(2): 205-218.

Geller, D. M., & G. P. Malia. 1981. The Effects of Noise on Helping Behavior Reconsidered. Basic & Applied Social Psychology 2(1):11-25

Goswami, S., B. Kumar Swain, & S. Kumar Panda. 2013. Assessment, Analysis and Appraisal of Road Traffic Noise Pollution in Rourkela City, India. Journal of Environmental Biology 34(5): 891-895.

Huang, J., F. Deng, S. Wu, H. Lu, & X. Guo. 2013. The Impacts of Short-Term Exposure to Noise and Traffic-Related Air Pollution on Heart Rate Variability in Young Healthy Adults. Journal of Exposure Science and Environmental Epidemiology 23(5): 559-564.

Occupational Health and Safety Administration. 2014. Occupational Noise Exposure. <https://www.osha.gov/SLTC/noisehearingconservation/#loud> Accessed October 19, 2014.

Ozer, S., M. Zengin, & H. Yilmaz. 2014. Determination of the Noise Pollution on University (Education) Campuses: a Case study of Ataturk University. Ekoloji Dergisi 23(90): 49-54.

Pitzer, Scot. "Gettysburg PA Ordinance Lacks Support." *Gettysburg Times* 8 June 2010. Gettysburg Times. Web. 1 Nov. 2014. <http://www.thedailydecibel.com/2010/06/gettysburg-pa-ordinance-lacks-support.html>.

Petrescu, V., S. Borza. 2013. Research on Noise Pollution in Densely Populated Urban Areas. Environmental Engineering and Management Journal 12(2): 409-415.

Speck, Jeff. *Walkable City: How Downtown Can save America, One Step at a Time*. New York: Farrar, Straus and Giroux, 2012. Print.

Stull, Sara. "Borough Council Meeting Minutes, July 8th 2013." *Borough of Gettysburg: Historical Cross Roads*. Gettysburg Borough Secretary, 8 July 2013. Web. 1 Nov. 2014. <http://www.gettysburg-pa.gov/minutes/borough_council/2013/070813.htm>.

Tzivian, L., A. Winkler, M. Dlugaj, T. Schikowski, M. Vossoughi, K. Fuks, G. Weinmayr, & B. Hoffmann. Effect of Long-Term Outdoor Air Pollution and Noise on Cognitive and Psychological Functions in Adults. International Journal of Hygiene and Environmental Health 218(1): 1-11.

Zhou, J. Q. Jiang, X. Zhang. 2014. Monitoring and Evaluation Study on Traffic Noise of College Road. Nature Environment and Pollution Technology 13(2): 309-314.

Table 1: Summary statistics for all sound level data collected.

Overall Max (dBA)	99.6		
Average Absolute Max (dBA)	78.46	Standard Deviation of Min	5.86
Overall Average (dBA)	62.19	Standard Deviation of Average	4.49
Average Absolute Min (dBA)	49.16	Standard Deviation of Max	9.71

Table 2: Location of each data collection site.

Site #	**Site Location**
1	Spring Ave fork at the corner of West St
2	Corner of Wall Alley and Baltimore St
3	Hanover St. fork at the corner of Liberty St.
4	Lincoln Square
5	Carlisle St and E Water St at the location of the Ugly Mug
6	Corner of Lincoln Ave and Carlisle St
7	Corner of N Washington St and W Lincoln Ave
8	Corner of College Ave and W Lincoln Ave
9	Corner of Constitution Ave and W Lincoln Ave

Table 3: Average of absolute maximums and minimums for each five minute data collection period by site.

Site	Average Absolute Maximum	Average Absolute Minimum
1	83.7	50
2	81.3	48.1
3	84.4	48.5
4	84.1	51.7
5	84.3	45.5
6	84.3	46.4
7	70.5	52.4
8	67.9	51.8
9	65.6	49.1

Table 4: Absolute maximum recorded over entire data collection period for each site.

Site	Absolute Maximum	Absolute Minimum
1	98.4	44.2
2	87.2	44.2
3	96.2	41.4
4	92.7	21.9 (38.9)*
5	99.6	20.3 (36.2)*
6	96	16 (38.1)*
7	85.4	48.1
8	80.2	47.2
9	78.9	33.6

*Indicates likely sound meter error in absolute minimum, next lowest minimum is given in parentheses

Table 5: Reference noise levels and World Health Organization noise level standards.

Sound Level dBA	Cause/Impact	Environment
60	Normal Conversation	Indoors
85	Busy Traffic	Urban setting
50-55	Annoyance	Outdoor living areas
30	Sleep disturbance	Bedrooms
35	Disturbance of communication	School classrooms
70	Hearing impairment	Industrial, commercial, and traffic areas

Figure 1. Sound level meter used for noise data collection.

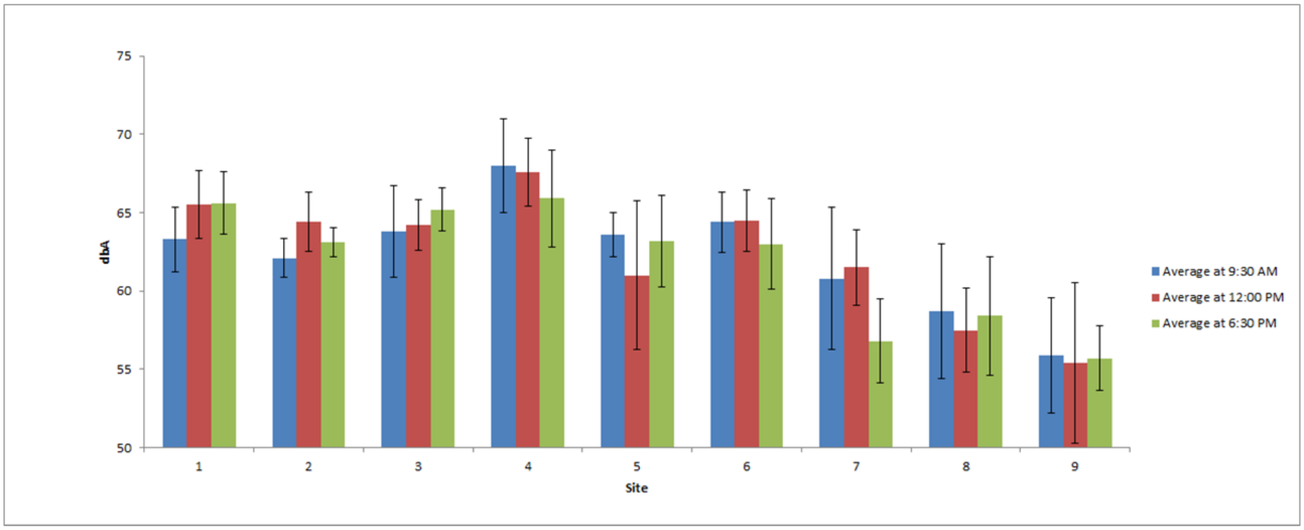


Figure 2: Comparison of overall sound level averages by time of day and site. Standard error bars displayed. An ANOVA revealed all three values were statistically significant when compared by site with a P-value of 0.000 for all three.

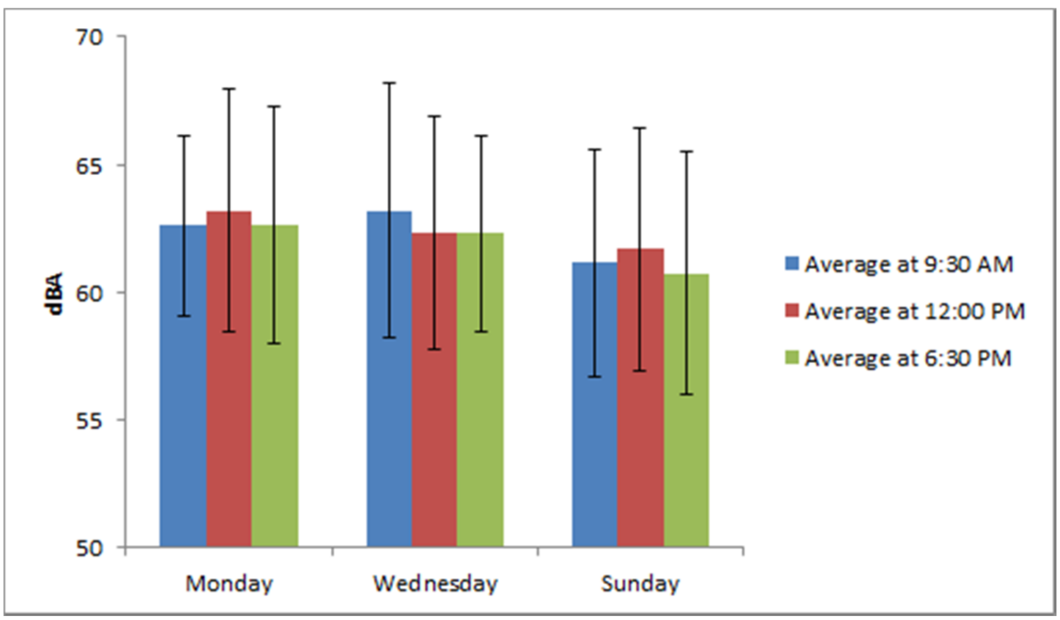


Figure 3: Comparisons of combined data for all sites of overall averages by day of week and time of day. Standard error bars displayed. No statistical significance was calculated with respective P-values being 0.246, 0.485, 0.228.

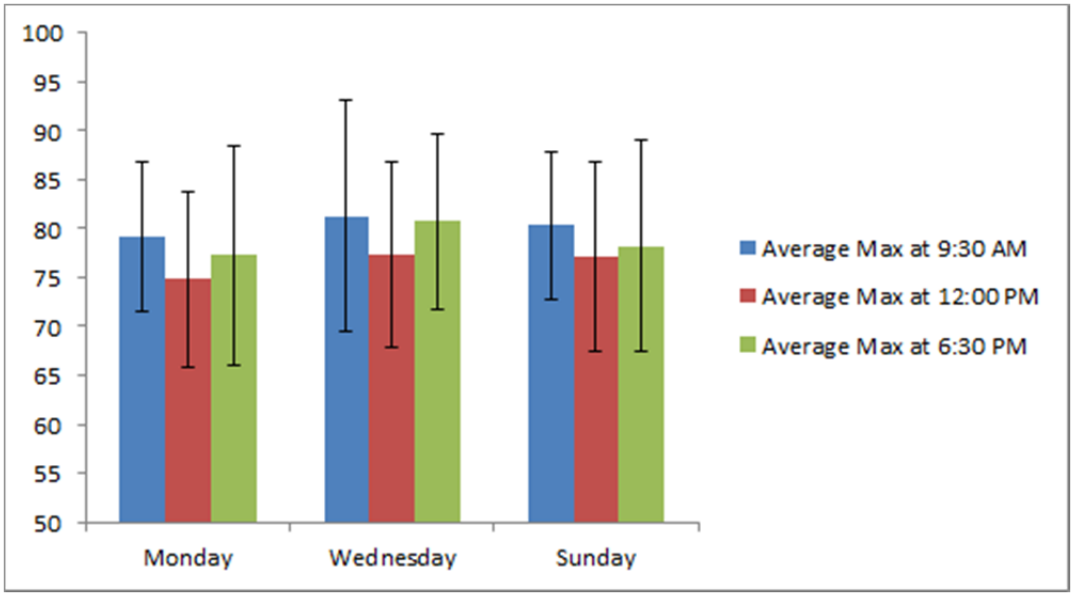


Figure 4: Comparison of the average of the absolute maximum sound values for by time of day and day of week. Standard error bars displayed. No significance was found with the P-values being 0.304, 0.352, and 0.396 in respective order.

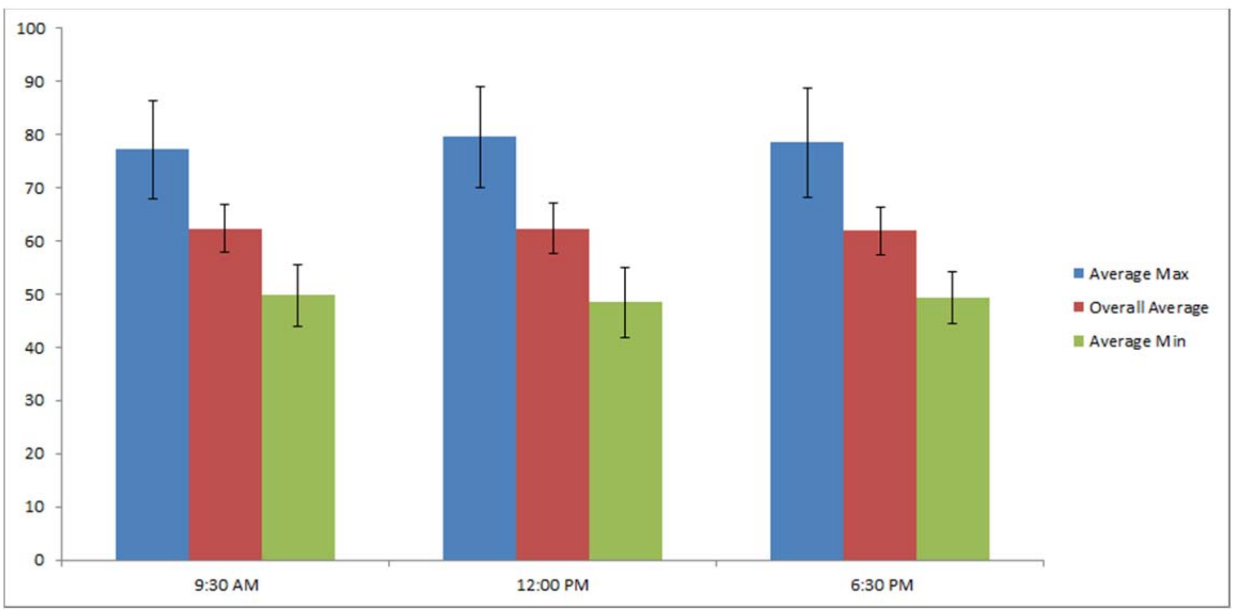


Figure 5: Comparison of the three data collection time periods for sites' combined average absolute maximum, overall average, and average absolute minimum. Standard error bars are displayed. A one way ANOVA test revealed that the average maximum and overall average were significantly different by time of day with P-values of 0.039 and 0.044 respectively. The average minimum was not significant with a P-value of 0.406.

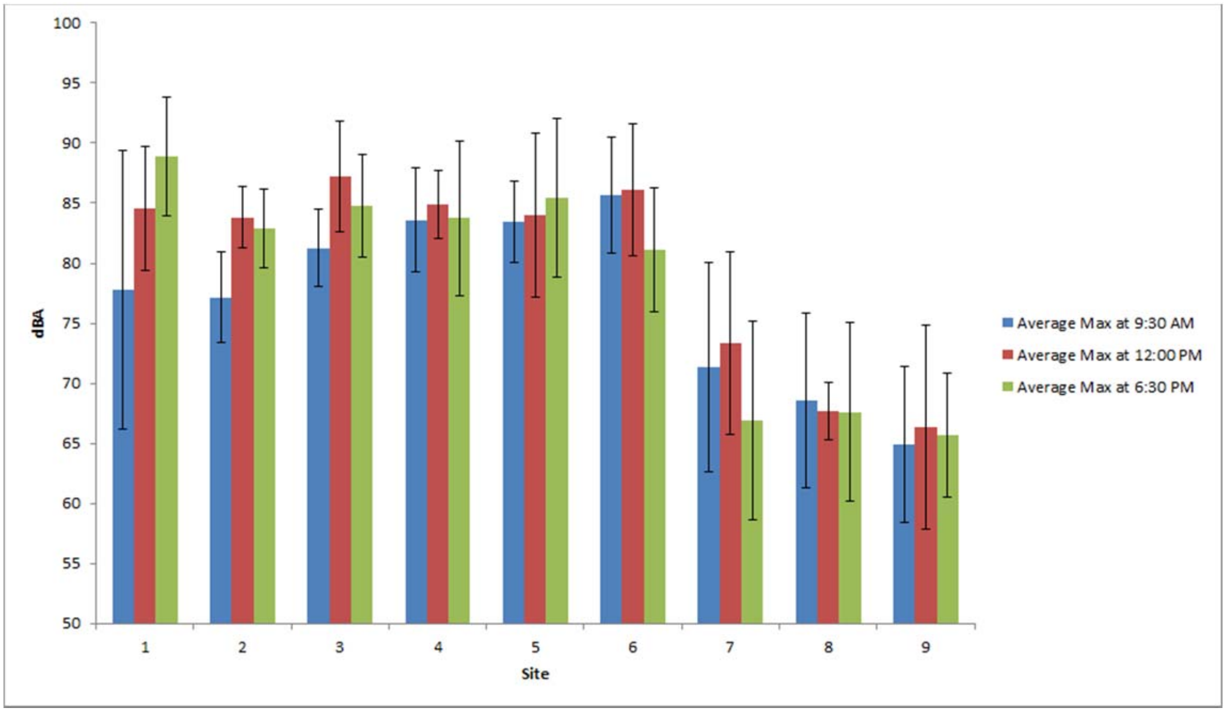


Figure 6: Comparison of average absolute maximums for each time of day sound level data was collected. Standard error bars displayed. An ANOVA revealed all three values were statistically significant when compared by site with a P-value of 0.000 for all three.

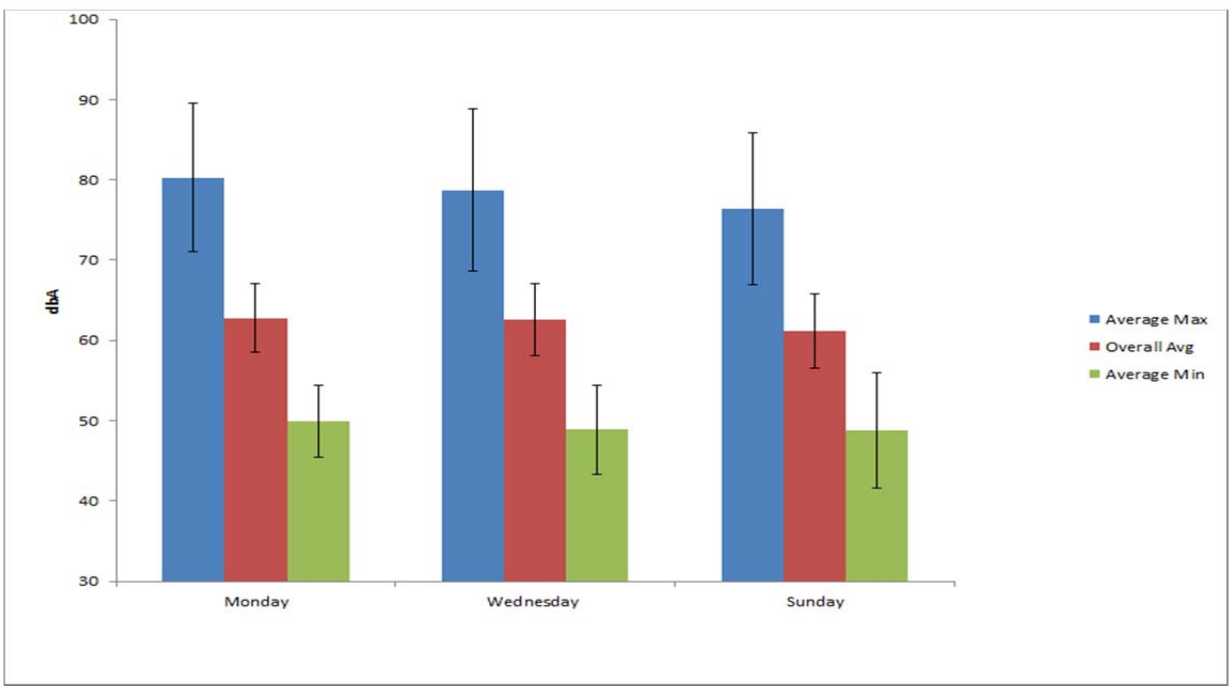


Figure 7: Comparison of the three data collection by weekday for sites' combined average absolute maximum, overall average, and average absolute minimum. Standard error bars are displayed. A one way ANOVA test revealed that the average max, overall average, and average minimum were not significantly different by day of week with P-values of 0.309, 0.325, and 0.407 respectively.

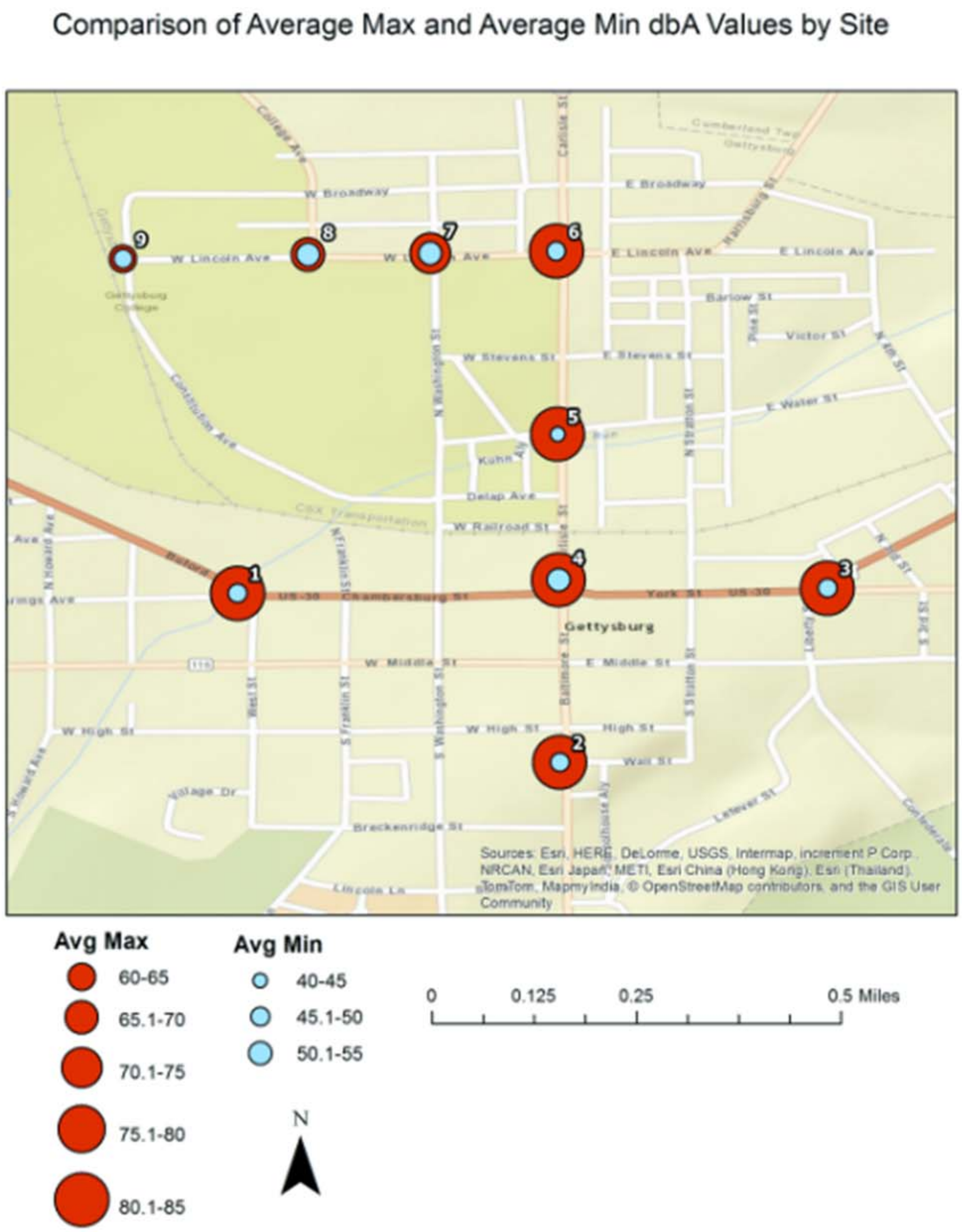


Figure 8: Map displaying the average absolute maximums and minimums for each data collection site using graduated symbols. Exact sound levels can be seen in Table 3.

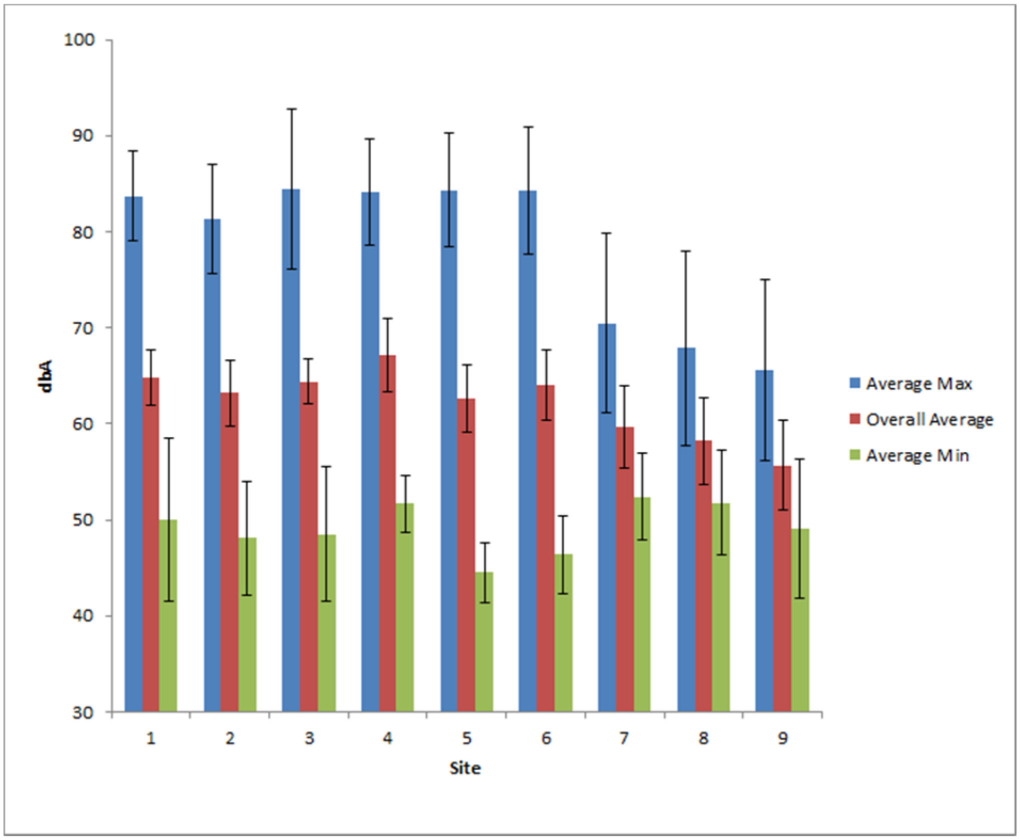
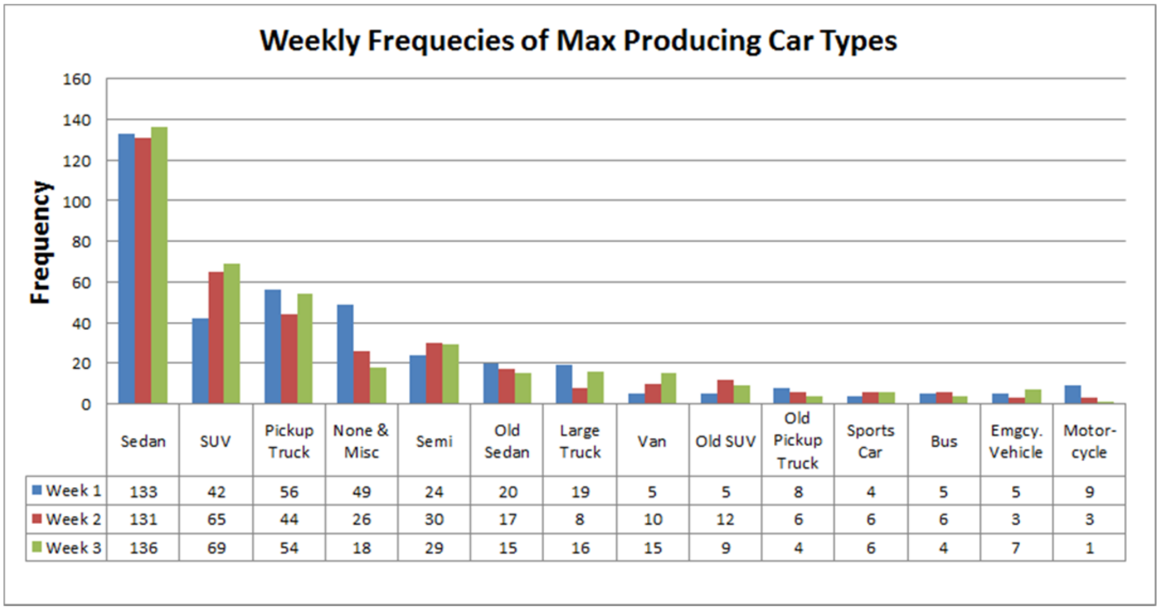


Figure 9: Average of absolute maximums and minimums and overall average for all data collected for each data collection site. Standard error bars displayed. An ANOVA revealed all three values were statistically significant when compared by site with a P-value of 0.000 for all three.



	Sedan	SUV	Pickup Truck	None & Misc	Semi	Old Sedan	Large Truck	Van	Old SUV	Old Pickup Truck	Sports Car	Bus	Emgcy. Vehicle	Motor-cycle
Week 1	133	42	56	49	24	20	19	5	5	8	4	5	5	9
Week 2	131	65	44	26	30	17	8	10	12	6	6	6	3	3
Week 3	136	69	54	18	29	15	16	15	9	4	6	4	7	1

Figure 10: Totals of each car type observed over the course of the entire study and each of the three weeks.

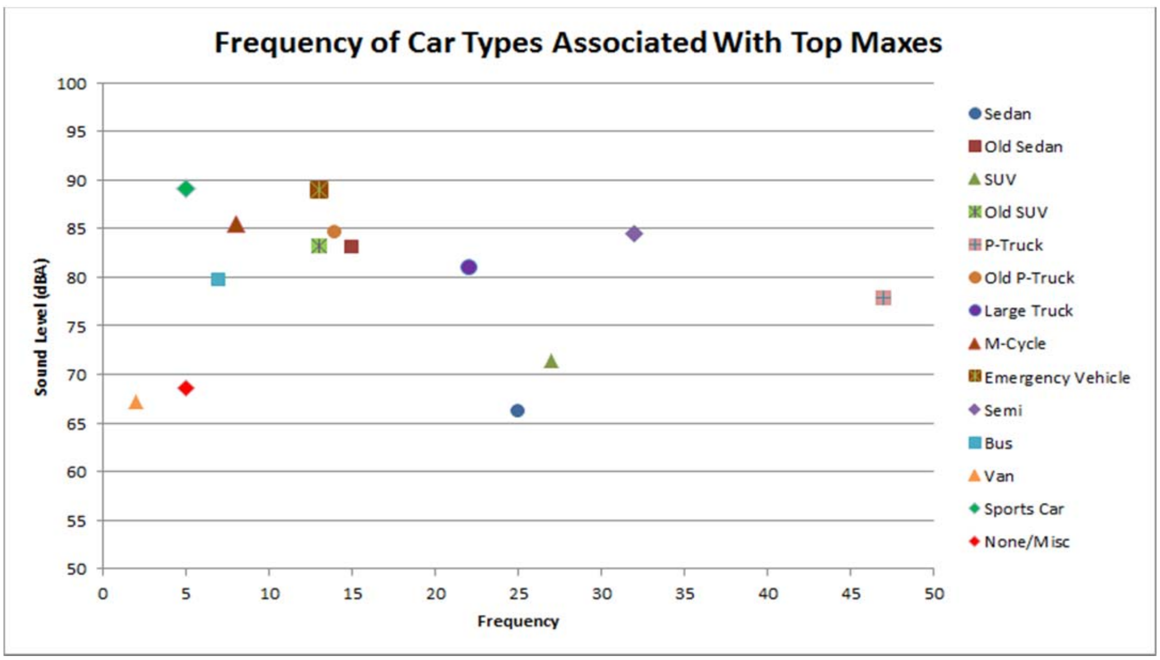


Figure 11: Displays the frequency at which each car type is associated with the top maxes produced during each five minute recording session.

Figure 12: Photo of road near Site 5 showing a major pothole that had an impact on site noise pollution.