Road Traffic Noise Control: Analysis of the Ineffectiveness of Various Implementations

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Kyle John Kuennen

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

Introduction

According to the World Health Organization (2011), "At least one million healthy life years are lost every year from traffic related noise in the western part of Europe."(p.5) However, the problem of road traffic noise spans beyond just Europe. Around the world, the number of cars that are making their ways onto roads is increasing at a faster rate every year. The number of cars in use on the roads has increased by about 300 million between 2006 and 2015 (Carlier, 2021). What this means is that the side effects associated with these vehicles are also on the rise. While many people have general knowledge regarding the air pollution caused by vehicles, many may not think about the noise pollution produced. Many technologies that have been developed and are used in today's society produce noise. However, often times, many of these devices exceed what is considered a safe listening level. The loudness of noise that is generally deemed as safe for exposure of long periods of time is anything below 70dB ("Too Loud. Too Long.", 2019). However, according to Corbisier of the U.S. Department of Transportation (2003), cars and trucks average around 80 dB when listening from only fifty feet away which is above what is considered a safe listening level.

While trucks and cars produce unsafe noise levels, it is also important to note the scale that this noise impacts individuals in order to highlight the prevalence of the problem. For instance, roughly half of the U.S. population in 1981, about 100 million people, were reportedly exposed to levels of road traffic noise on a yearly basis (Hammer et al., 2013, p.1). Additionally, the negative impact that road traffic noise has on an individual's health also plays into the significance of the problem with studies showing that it can cause symptoms such as anxiety, hostility, sleep disturbance, headaches, and fatigue among others (Nazneen et al., 2020).

Thus, while it is clear that road traffic noise poses a problem, it is currently unclear what the best method for minimizing it is as well as why the current methods of doing so are not as effective. Many governments, have or are starting to implement stricter regulations and control measures regarding noise produced by road traffic in response to the disturbances and health worries associated with it. This includes the implementation of legal regulations and associated fines, the building of wall barriers along busy roads, and even traffic management techniques.

For this research paper, I study the sociotechnical system of road traffic noise and its control by looking at its impact on all actors involved. This process will be done through conducting literature review on current research surrounding this topic. The current methods for reducing road traffic noise and the way they are implemented are ineffective at reducing the negative impact of excess noise on individuals. Thus, to understand why this is the case, the framework of actor network theory (ANT) as described by Cressman (2009) and method of Pacey's triangle as detailed by Arnold Pacey (1983) will be used to further analyze this topic.

Problem Definition: The Impact of Road Traffic Noise and Approaches to Its Control

According to the Center for Environmental Excellence (2022), **"**Noise is defined as unwanted or excessive sound. Sound becomes unwanted when it interferes with normal activities, such as sleep, work, speech, or recreation."(n.p) Thus, when referring to road traffic noise, this is sound coming from vehicles such as cars, trucks or motorcycles that can not only be unwanted or excessive but also unsafe. As mentioned earlier, any noise above 70 dB is considered unsafe and there are three main factors that contribute to vehicles rising above this threshold: volume of traffic, speed of traffic, and the number of trucks or larger vehicles in the

traffic (Center for Environmental Excellence, 2022). All three, as shown in Figure 1, play an important role in how individuals both perceive and are affected by road traffic noise.

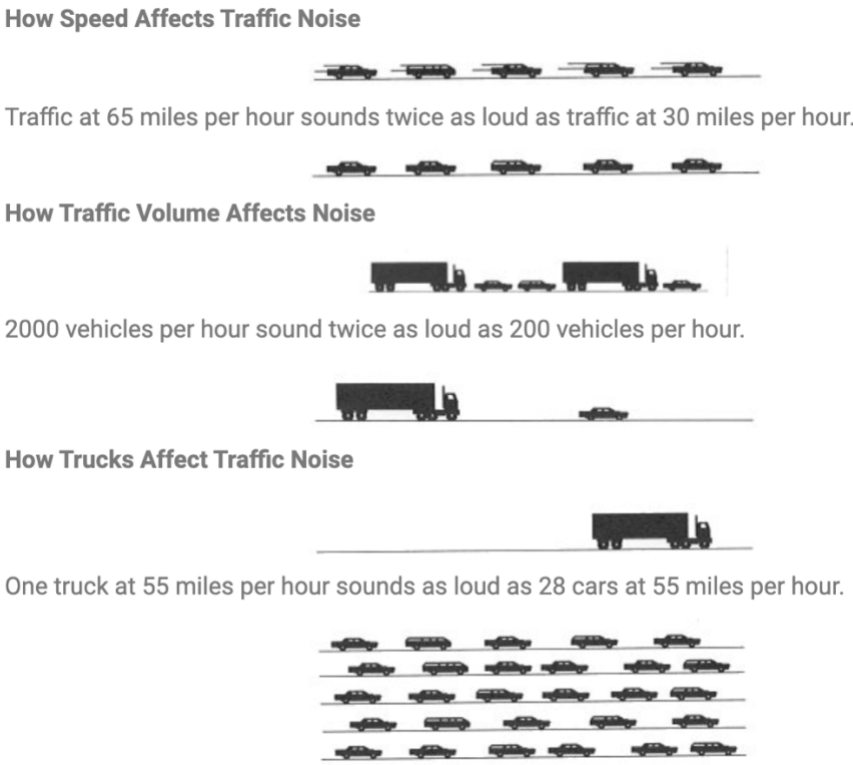

Figure 1: Factors Involved in Excess Road Traffic Noise. The visual depiction of the three different factors that results in unsafe noise levels from road traffic. (Center for Environmental Excellence, 2022, n.p.).

As previously mentioned, road traffic noise affects a large number of people around the world. In the United States, during the early 2000s, the U.S. Census Bureau (2009) asked individuals across 38 metropolitan areas questions regarding road traffic noise with 29% saying they felt the impact of it. Across the globe in the European Union, as seen in Figure 2, over 70 million people are affected by high noise levels from road traffic in urban areas alone and additional 32 million outside of urban areas (European Environment Agency, 2019). Additionally, the number of people road traffic noise affects is greater by a large margin when compared to other contributors such as railroads, airports, and industry. While it is evident that

road traffic noise is a prevalent problem affecting a lot of people worldwide, it is also important to highlight the significant impacts it has on individuals' health and well-being. According to Munzel et al. (2020), "Traffic noise has been classified as the second worst environmental stressor affecting human health, exceeded only by air pollution." (p.310)

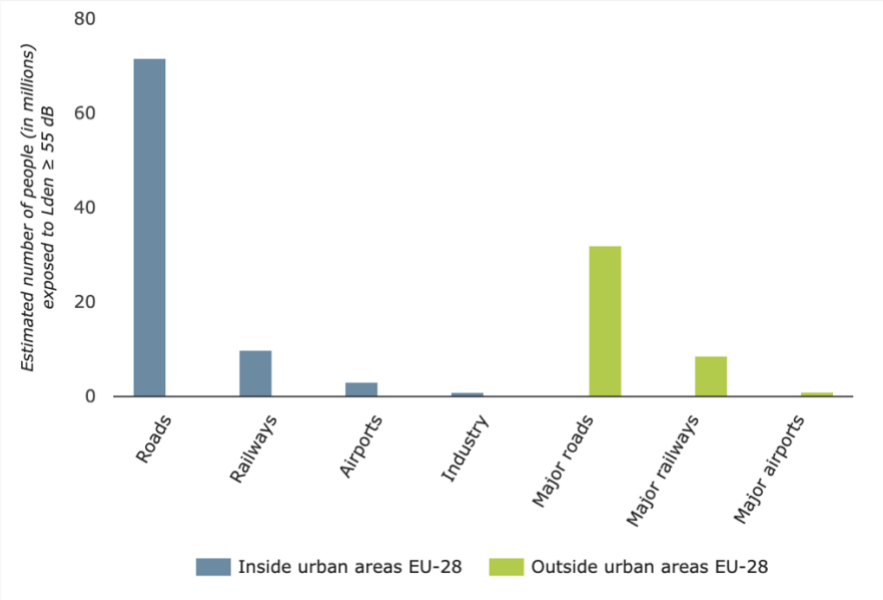

Figure 2: Number of EU Residents Exposed to Excess Noise. The visual depiction of the number of people (in millions) in the European Union exposed to high levels of noise, including that caused by road traffic (European Environment Agency, 2019).

Additional research was done in Fulton County Georgia in which the focus was analyzing how many people's well-being were impacted by road traffic noise, specifically regarding annoyance and sleep disturbance (Kim et al. 2012). The study concluded that the people that were affected the most were those living near major state roads and highways. It was also concluded by the researchers that roughly 9.5% of the studied population would be at risk of being highly annoyed during the daytime and around 2.3% would be at risk of having high levels of sleep disturbance. (p.355) While these percentages may seem low, it must be noted that they correspond to roughly 110,000 people and 20,000 people respectively. The researchers also point out that among the measured data across the whole Georgia county, the noise levels in busy

urban areas such as Atlanta was above average in causing daytime annoyance and sleep disturbance.

Additionally, in 2011, a study was done in the Zanjan province of Iran during which the intensity of road traffic noise was measured and reviewed (Javaherian et al., 2018). The researchers placed seventeen noise sensors in different locations across the city measuring noise data for fifteen hours a day for ten days. The researchers when analyzing the data made sure to account for any errors such as background noise that could have been picked up by the sensors. On average, across the seventeen sensors the noise intensity level was above 70dB throughout the whole day with it reaching peak values of around 76 dB. These, sound levels that were measured are above the recommended safe noise level of 70dB. Prolonged exposure to noises above this safe level can lead to both auditory problems, such as hearing loss, and non-auditory problems such as hypertension, cardiovascular disease, decreased cognitive performance, and sleep disturbance (Basner et al. 2014). Thus, in two different areas of the world, Fulton County Georgia and Zanjan Iran, and in two different cultures, there is evidence that individuals, especially in busy urban areas, are commonly exposed to road traffic noise at volumes that negatively impact their health and well-being.

It is clear that road traffic noise has an aspect of magnitude in that it affects a large number of people while also being a significant problem in and of itself in that it affects the health and well-being of individuals. Thus, many countries around the world have made attempts to reduce the impact of road traffic noise on individuals whether that's through legal regulations or other means. In the United States for instance, the Noise Control Act of 1972 was put into effect (Center for Environmental Excellence, 2022). This piece of legislation gave the Environmental Protection Agency (EPA) complete control over the regulation of major

contributors to excess noise, including road traffic noise. Similarly, the European Commission (n.d.) has put into effect the Environmental Noise Directive which is the main piece of legislation in Europe that focuses on not only identifying noise pollution levels, but also acting on them accordingly.

Despite these pieces of legislation put in place for limiting road traffic noise, it is unclear why there is still continued negative impacts on a large scale even roughly fifty years after they were put in place. Through these pieces of legislation and other means, countries have been starting to implement measures to control road traffic noise. However, it is unknown why these attempts at controlling this problem have ultimately been ineffective with many individuals still being affected yearly.

There are many control measures that have been implemented for the reason to try and reduce road traffic noise. The first of which involves regulating the vehicles themselves and that amount of noise they are able to produce. In the United States, motor vehicles are to be designed, built, and equipped to not produce noise levels in excess of 80 dB which is a standard that has not been updated since it was implemented back in 1988 (Center for Environmental Excellence, 2022). It also must be noted that the relationship between decibels and perceived loudness is not linear. Thus, when comparing the base decibel value of 70dB for safe listening, anything at 80dB is perceived to be twice as loud. The relationship between decibels and perceived loudness can be seen in Figure 3, but generally as the dB value increases by 10 then the perceived loudness doubles (Center for Environmental Excellence, 2022). Moreover, the 80 dB standard put in place not only affects the car manufacturers themselves, but also individuals wishing to modify their vehicles. In many U.S. states, it is illegal to modify the exhaust system in a way that will amplify

the noise level coming from the vehicle more than what was admitted by the original exhaust system and muffler.

Figure 3: Decibel vs Perceived Loudness. The visual depiction of the exponential relationship between the increase in decibels from a base value versus the perceived relative loudness by an individual (Koehler, 2021).

Outside of legal regulations, there are other methods for reducing the noise levels from road traffic that have been implemented. One of the most common is through the design and construction of noise barriers, especially along busy roads. These have been known to reduce road traffic noise by around seven to ten decibels, roughly half the perceived loudness (Center for Environmental Excellence, 2022). However, there are drawbacks such as its cost, ineffectiveness where openings are required, and obstruction of sunlight and breezes. Noise compatible planning is another method that has been used which involves planning land development projects in a way that results in the impact of road traffic noise being minimized such as through the zoning of residential areas away from busy roads and highways (Center for Environmental Excellence, 2022). Other methods that have been looked at to reduce road traffic noise include traffic management techniques, creation of buffer zones along busy roads, and vegetative planting which act as natural noise barriers.

Even with the implementation of legislation and a combination of control measures, road traffic noise is still a significant problem impacting millions of people. Thus, the current implementations of these control measures which have been around for half a century are largely ineffective at reducing the problem. In turn, I will further analyze the potential reasons for these insufficiencies through the use of actor network theory and the method of Pacey's triangle.

Methods of Analyzing Road Traffic Noise Control: Actor Network Theory and Pacey's Triangle

Actor network theory (ANT) is a framework for analyzing sociotechnical systems that was first detailed by three main contributors: Michel Callon, Bruno Latour, and John Law. Cressman (2009) later summarizes and expands upon the work done by these writers in his work, "A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation." The main concept of actor network theory centers around the idea that every sociotechnical system is made up of both human and non-human "actors". Actors in this case referring to anything that plays a role in a sociotechnical system whether through acting on other actors or similarly being acted upon. However, it is not the actors themselves that fully make up this framework, but instead the focus is with regard to the relationships between them. These relationships form a structural "network", connecting all the actors together like a web. Cressman (2009) summarizes this concept by stating, "ANT attempts to 'open the black box' of science and technology by tracing the complex relationships that exist between governments, technologies, knowledge, texts, money and people." (p.3)

Cressman (2009) expands upon the framework of actor network theory by highlighting three main concepts: black boxes/punctualization, heterogeneous engineering, and translation.

The first of which, black boxes and punctualization, is an important concept in simplifying the complexity of a structural network. A black box refers to the idea that an actor is viewed as a whole instead of further analyzing the relationships within it. Punctualization refers to the idea of linking together these "black boxes" to then form a network. For instance, if someone were to look at the system of an airport one might consider actors to involve the pilots, the terminals, air traffic control, and the airplanes. However, an individual could then look at the relationships within the system of the airplane such as the cockpit, passengers, wings, and engine. Furthermore, the engine could then be looked into through the relationships between the compressor, combustor, and the turbine. This process could continue and would add unneeded complexity to the analysis of the system. Instead, it would be beneficial to "black box" the airport in order to analyze the larger system as a whole instead of all the individual actors within as depicted in Figure 4.

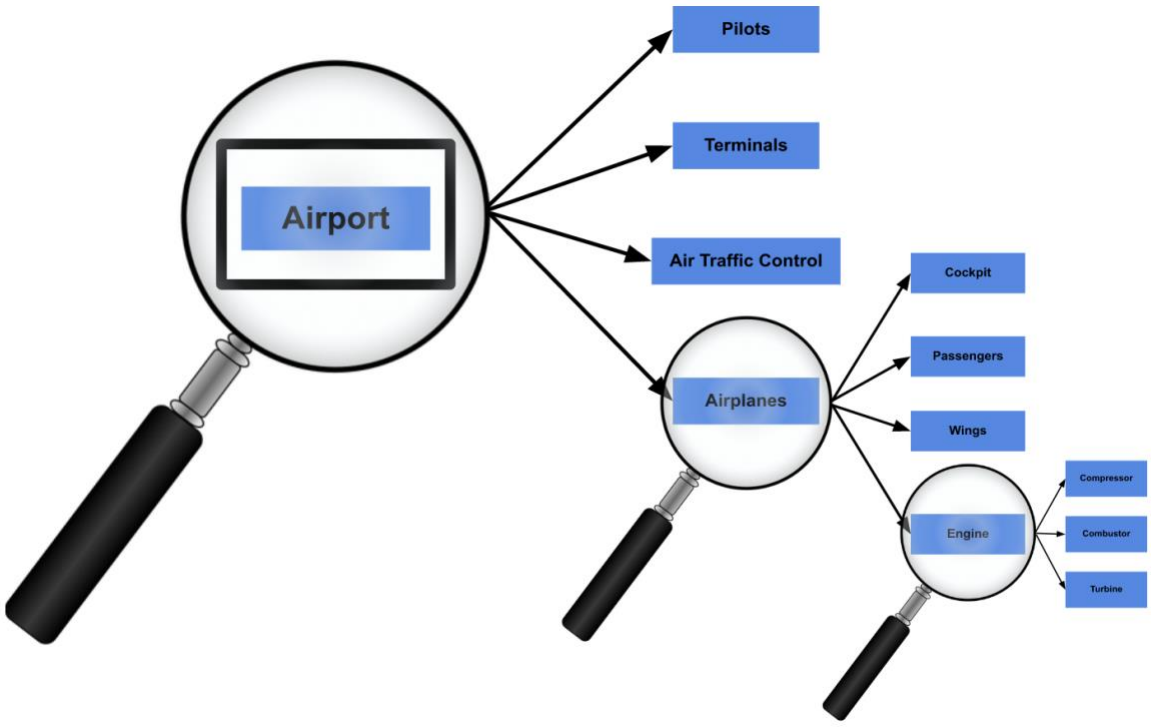

Figure 4: Example of Black Box Concept. The visual depiction of the concept of black boxes applied to the sociotechnical system of an airport. (Created by Author)

Another fundamental concept of actor network theory as highlighted by Cressman (2009) is the concept of heterogenous engineering. This refers to the idea that it is important to understand both the social aspects (economical, political, and cultural) and non-social aspects (technical and scientific) especially when going through the process of engineering a system. However, this concept can also be used when trying to analyze a system. Cressman (2009) compares this to another common framework, social construction of technology (SCOT), which mainly focuses on just the social aspect whereas "ANT seeks a symmetrical account of the social and the non-social." (p.8) The last concept he discusses is the idea of translation and is related to the previous concept of heterogenous engineering. While the latter concept focuses on identifying that there are social and non-social aspects of systems, translation is a "concept that bridges the gap between the varied aspects." (Cressman, 2009, p.9) In essence, how the social and non-social aspects of a system relate and connect with each other should be considered.

While actor network theory serves as the overarching framework, Pacey's triangle as detailed by Arnold Pacey (1983) will be used as the main method to analyze the actors. With actor network theory, as previously discussed, it is important to identify actors of appropriate complexity, "black boxed", as well as looking at the relationships between social and non-social aspects. This fits perfectly with the method of Pacey's triangle, as depicted in Figure 5, in that actors are grouped by three separate aspects: technical, organizational, and cultural. These three aspects can be categorized with technical representing the non-social aspect and organizational as well as cultural representing the social aspects of a system. The relationships and connection between the actors in these different groups are then analyzed. Ultimately, the Pacey's triangle methodology presents a more refined version of actor network theory for analyzing sociotechnical systems with many of the concepts overlapping.

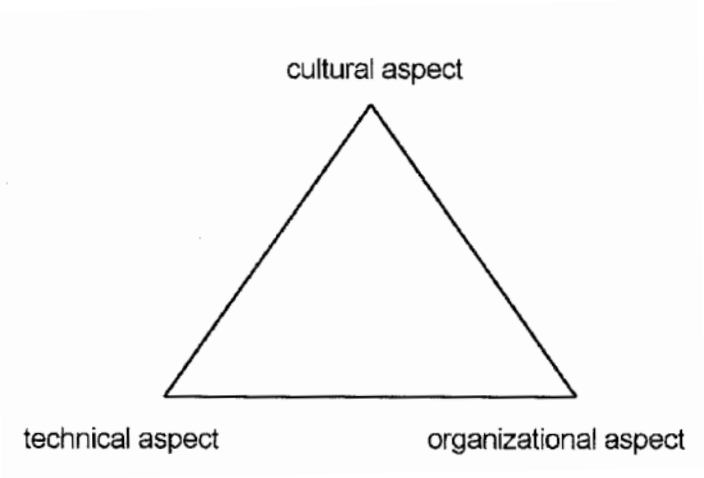

Figure 5: Pacey's Triangle. The visual depiction of the relationship between the Technical, Cultural, and Organizational aspects of a sociotechnical system (Neeley, p. 42, adapted from Pacey's Culture of Technology).

The first step of applying Pacey's triangle methodology to the sociotechnical system of road traffic noise and its control involves first identifying actors of appropriate complexity meaning that the actors selected are not too specific and/or broad to ensure the most effective analysis. The next step involves categorizing the actors into the three main groups: technical, organizational, and cultural (Neeley, n.d.). The technical aspect includes the tangible objects, techniques, and processes for applying knowledge related to road traffic noise control, one example being wall barriers. The organizational aspect is made up of the related institutions and groups who interact within the sociotechnical system of road traffic noise control such as vehicle manufacturers. The cultural aspect refers the public's beliefs and attitudes with regard to the system of road traffic noise control, for instance, the lifestyle surrounding the modification of vehicles. The last step for applying the methodology of Pacey's triangle involves analyzing the relationships between the different categorized actors and the effects they have upon each other.

The negative impact of road traffic noise has been attempted to be reduced by countries through many different methods for around half a century; however, these efforts have ultimately

been ineffective. Through actor network theory and Pacey's triangle as well as the steps previously outlined, the societal impact can be further looked at through the study of the social factors and their relationship with the non-social factors. With road traffic noise control taking up many different forms, it is essential to consider both factors, so that insight might be gained regarding the effectiveness of past implementations as well as potential problems associated with these methods of control.

Results of Road Traffic Noise Control Analysis: Reviewing Its Technical, Organizational, and Cultural Aspects

As previously mentioned, there are many different methods for reducing road traffic noise. However, to tighten the scope of the analysis when reviewing the effectiveness of these implementations, the three most common utilized methods have been reviewed: legal regulations on vehicles, wall barriers, and traffic management.

Vehicle noise regulations are categorized as organizational within Pacey's triangle with government agencies such as the Environmental Protection Agency and the European Commission managing them. However, it is important to analyze the relationship between the regulations and other institutions that fall under the organizational category. One such institution to consider is the vehicle manufacturers. Major vehicle manufacturers, such as Chevrolet and Ford among others, are going to be against further regulation. These large corporations would have to spend large amount of workforce hours and money researching and designing ways to make their vehicles quieter. As of 2016, it cost the automotive industry between 3.3-4.2 billion dollars yearly to meet regulations of all types that were put in place (Schroeder et al., 2016).

Another institution that should be highlighted with regard to vehicle noise regulations is that of enforcement agencies, such as local and state police officers. There have been regulations put in place that not only limit automotive manufacturers but also the owners of the vehicles if a set noise level is exceeded, especially at night, whether that from the engine, speaker system, or honking. However, while the regulations are in place, the negative impacts of excessive noise won't be reduced if they are not enforced. This lack of enforcement could occur for many reasons but one such reason might be due to the technical aspect of a lack of noise measuring technology being used by law enforcement. One of the first countries to implement this type of technology is France. In Paris, noise sensors have recently been put in place that detect the noise coming from automobiles and if too loud take a picture of the license plate and fine the respective party (Bubola, 2022). However, the article by Bubola also discusses backlash among certain social groups such as motorcycle enthusiasts when the sensors were implemented.

There is also the cultural aspect with regard to the trying to regulate the vehicles themselves that should be considered. One example is the culture surrounding the modification of cars. Many people enjoy changing their vehicle in ways that make them louder than what was produced by the manufacturer especially through the modification of the exhaust system and muffler. These changes are often difficult enforce with many people continuing to them despite regulations put in place. Another example would be the motorcycle culture that exists not only as a form of transportation but as a social community. Motorcycles, in the United States, adhere to same 80dB noise limit as other vehicles; however, there is still the ability to modify the exhaust system. In a study of 2003 to 2007 model motorcycles in southern California by the California Air Resources Board, 85% of them had some form of exhaust modification ("Motorcycles",

n.d.). Thus, despite the regulations that are put in place, the culture surrounding the modification of vehicles is active and should be considered when trying to reduce road traffic noise.

Wall barriers are the second method of road traffic noise to be reviewed control and can be categorized as a technical aspect. As mentioned previously, there are technical limitations associated with the design of wall barriers. For instance, they are ineffective when opening is required in the wall for things such side streets (Center for Environmental Excellence, 2022). However, other limitations include that for effective sound blocking to occur, the noise barriers have to be both long enough and tall enough to block the view to the road. These factors, along with the type of material used in construction, add to the cost of the noise barriers. Thus, this correlates to the relationship of noise barriers with the institution of government agencies categorized as an organizational aspect. With the expensiveness and economic requirements associated with large sections of these walls, this may lead to government agencies choosing to implement this technology at a much smaller scale and at a slower pace than what could be done.

With regard to the third method of traffic management, this form of road traffic noise control fits into the organizational category. There are two aspects of which the relationship with traffic management can be analyzed. The first of which is the organizational aspect of urban planning. This refers to the process of planning out a dense environment such as a city and taking into account many factors. One such factor is that of road traffic. Cities often times face heavy traffic problems and it important to plan the roadways as well as methods of public transportation accordingly. In cities where traffic management was not taken into account as effectively during its planning leads to many residents being exposed to road traffic noise throughout the day. A cultural aspect of which the relationship can be reviewed is that of driving culture. In the United States especially, driving a vehicle is a main source of transportation. This

not only adds to road traffic noise, but as more and more cars join the road each year it makes it hard to effectively manage traffic. This issue is especially prevalent in large cities in which driving is commonly used. While other methods are available such as public transportation and walking, dense cities such as New York City often face heavy traffic. Thus, it is evident that traffic management techniques should be taken into account to reduce road traffic noise; however, the effectiveness of traffic management techniques would be difficult in cities that have been already designed and constructed without the issue of road traffic noise in mind.

For all three methods of road traffic noise control, actors have been identified and sorted into the three categories relating to Pacey's triangle. The final step is to analyze the relationships between these actors as seen in Figure 6.

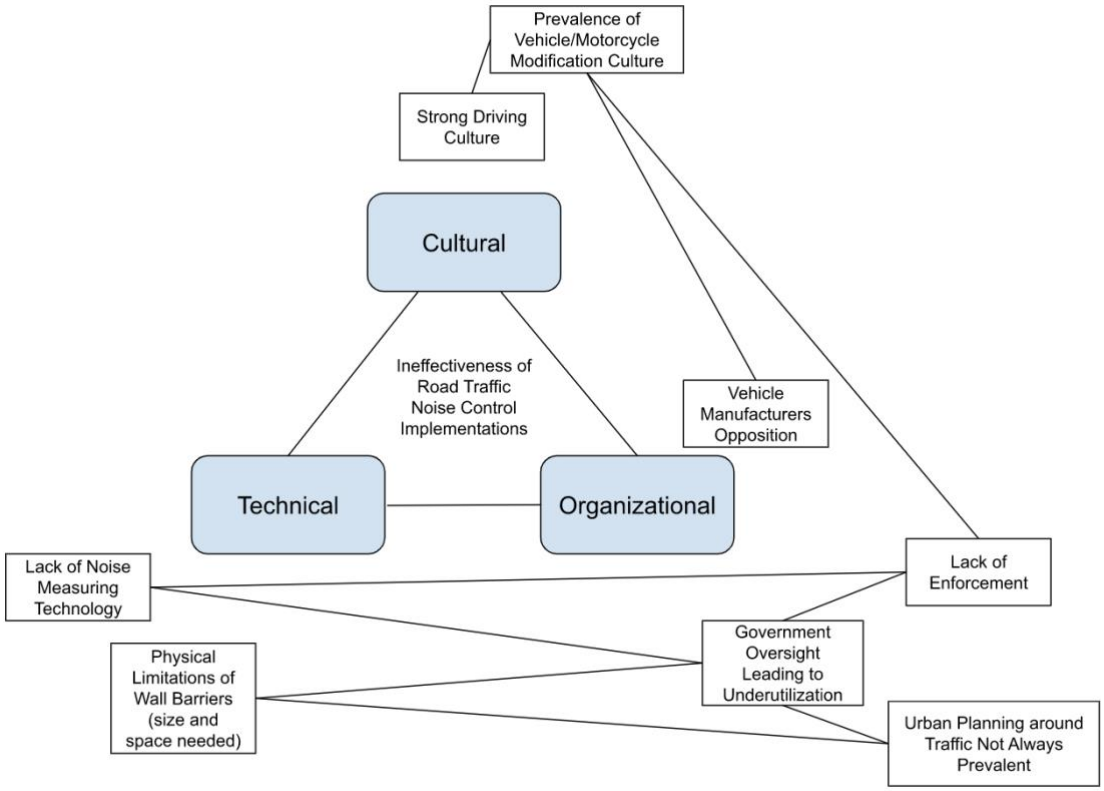

Figure 6: Pacey's Triangle Analysis. The visual depiction of implementing Pacey's triangle in the analyzation of the sociotechnical system of road traffic noise (Created by Author).

Upon analysis of the relationships between the actors involved within the sociotechnical system of road traffic noise it is evident that the actors within the organizational category are the most influential. The organizational actors impact both actors in the technical and cultural categories. However, government oversight regarding road traffic noise control plays the most significant role. These results seem valid as road traffic noise control such a wall barriers are public works that are funded and built by the government. Lack of law enforcement also plays a significant role which also makes sense because control methods such as legal regulations can be put in place but if there is no enforcement, they are essentially ineffective.

Ultimately, the analyzation of road traffic noise and its control indicate that the non-technical factors such as organizational and to a lesser extent cultural have a much stronger influence in what causes their ineffectiveness than the technical factors do. This result is significant as much of the research regarding road traffic noise control focuses mostly on the technical limitations. However, it is important to shift focus on to why specifically the government is underutilizing road traffic noise control implementations as well as why there seems to be a lack of enforcement surrounding the issue. Additionally, with regard to urban planning, future cities need to be designed with road traffic noise in mind as they are the places where the problem is most prevalent.

Actor network theory and Pacey's triangle provided me the ability to draw conclusions regarding the sociotechnical system of road traffic noise control using the method discussed in the previous section. This process was done by identifying the actors, sorting them into the appropriate categories based of Pacey's triangle, and then finally analyzing the relationships.

Conclusion

In this research paper, the Pacey's triangle methodology along with the broader actor network theory framework provided a sufficient structure to analyze the sociotechnical system of road traffic noise and its control. There was a larger non-technical impact versus technical impact especially with regard to the role the organizational actors played. This result as well as the relationships among the whole system further highlighted potential reasons that could have led to the ineffectiveness regarding current measures of controlling road traffic noise. It is clear that these measures alone are not the reason for the continued health and well-being issues associated with excessive road traffic noise, but it is also the interactions with other actors when placed in a larger network that contribute. Limitations from this analysis include not taking into account other forms of road traffic noise control outside of the three selected. Additionally, with Pacey's triangle being a more refined model for application of actor network theory, certain actors belonging to other categories, such as political or environmental, were not considered which could have led to greater insight.

Figuring out what the most effective way to reduce road traffic noise for future implementations of control is beyond the scope of this paper. However, by reviewing the problems of past implementations and recognizing the influence of organizational actors, then a more informed method of approach can be reached.

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