Undergraduate Thesis Prospectus

# Optimization of a Formula SAE Vehicle Intake Manifold

(technical research project in Mechanical Engineering)

# Navigating the Road Ahead: The Paradigm Shift from Internal Combustion Engines to Electric Vehicles

(sociotechnical research project)

by

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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.

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## General Research Problem

*Is it worth optimizing internal combustion engines over switching to electric systems?*

One of the biggest problems our world faces in modern times is counteracting the effects we've made on the global ecosystem. Climate change has enacted a voice in society to motivate technological changes within companies and countries, to make an active effort in limiting their ecological impact. Increasing the efficiency of traditional internal combustion engines (ICE) can help to minimize the use of natural resources and limit pollution. The technical problem addressed in this report is focused on designing and manufacturing a more optimized intake system for the Virginia Motorsports formula one (F1) car, which has an internal combustion engine. However, while iterating on designs to create more efficient systems like this does have many benefits to consumers and the environment, is it the best use of resources with the current problems facing society?

These valuable human and environmental resources may be better used towards a new form of transportation as iterative methods will begin to plateau in efficiency before reaching an amount suitable for combating climate change and resource depletion. With pollution continually rising and alternative energy sources emerging, the transition from ICE to electric vehicles (EV) is being propelled forward. American physicist and philosopher Thomas Kuhn argued that science and technology has a paradigm which remains constant before going through a rapid shift. It is often described as when an important change in the normal actions or thoughts of society become replaced by a new and different way. I argue that we are currently in a paradigmatic shift from ICE to EM, and this shift has a multitude of factors both limiting and

aiding in the transition. By looking at this shift and drawing onto incites in the EV market growth we can determine whether innovations in the ICE industry are justified or simply slowing down a necessary shift humans need to make to create a greener future. To start we can look at the EV market and how there are many factors influencing its growth. Once we obtain an idea of the EV market growth, we can have a better understanding of when the paradigmatic shift will happen, and, in turn, when ICE are no longer needed, making their iterations obsolete.

Humans when faced with choosing between something foreign or familiar will almost always choose the familiar as it is instinctually the safer option. This is a huge limiting factor when looking at new technologies as consumers' willingness to change is very low. That aside, there are a plethora of genuine concerns about electric cars that turn away consumers. Aspects like infrastructure to support charging stations, reliability of the motor, longevity, and cost are just some of the limiting factors in this transition. Despite this, we still see a growth in the electric vehicle (EV) market, which is estimated to grow at a compound annual growth rate (CAGR) of 25.4% from 2022 to 2029 (Fortune Business Insights, 2022). Why is the EV market growing at such a high rate? Will innovations in the ICE industry just prolong the inevitable transition, or can it still a viable option in the future?

## Technical Research Problem

*How can the intake system of the Virginia Motorsports Formula 1 car be optimized?*

Before we can analyze the effect ICE has on the EV market, we need to understand how these innovations on traditional engines affect performance and efficiency. For the technical project, we looked at ways to improve the F1 car to improve its power and efficiency for

competitions. Formula SAE (FSAE) is a collegiate engineering competition organized by the Society of Automotive Engineers (SAE) to provide students with an opportunity to design and build an open cockpit, open wheel (Formula-1) style race car. The intake system to the engine was decided to be the best aspect of the engine to optimize. This system is responsible for supplying the engine with oxygen which is essential for the combustion process. First, you will need to understand the components of an intake system for an ICE and how they each in turn affect the engine's performance. The three components being analyzed in this project are the plenum, runners, and restrictor.

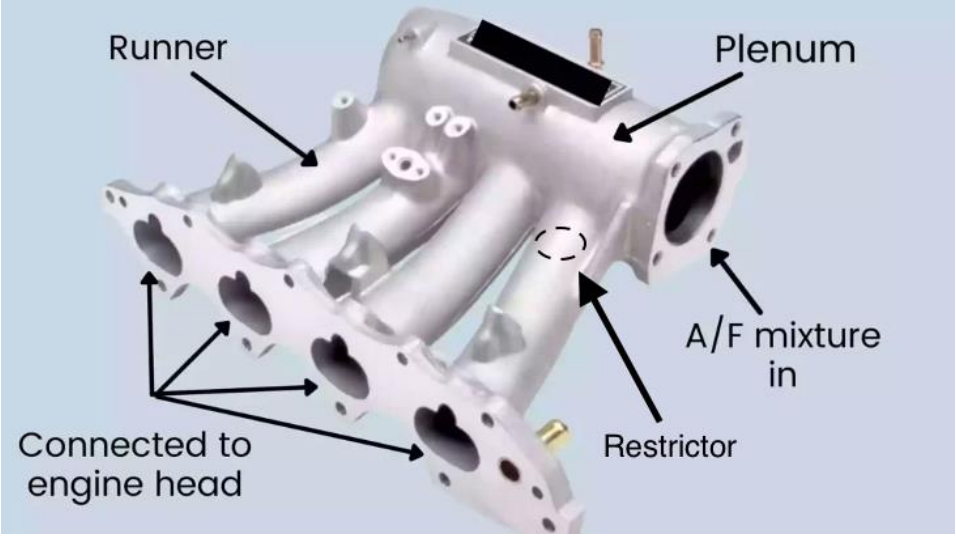


**Figure 1**: Intake Manifold Diagram

In an internal combustion engine, the air gas mixture passes through the plenum before going through the restrictors, as depicted in Figure 1. These restrictors are nested internally at the head of each runner. Once through the restrictor the mixture travels through the intake runners which feeds the fuel into the intake valve. Now that we know the process, what purpose do each of these parts serve? The plenum chamber is a volume that draws in air to run the engine

efficiently. This air is then mixed with fuel before continuing its flow into the restrictor. The restrictor acts as its name implies, slowing the airflow into the engine and in turn reducing the speed and horsepower generated. This is mainly done for safety reasons and regulations in the competition. Once the flow passes through the restrictor it enters the intake runners. There is one intake runner per piston, and they serve to create a more laminar flow regime. Creating a laminar flow helps increase the flow rate and efficiency by layering the flow into parallel layers, reducing mixing and turbulence.

To optimize this system there is one aspect of fluid dynamics that needs to be addressed, before understanding how to maximize the torque to fuel ratio. This flow is occurring at high speeds and pressures. The opening and closing of the intake valve sends an oscillating pressure wave through the intake system as flow gets cut off. If you can time the pressure wave to come down the runners at the same time the intake valve opens, you can utilize this increased pressure to force extra air-gas mixture into the piston. This in turn generates more power and increases the efficiency of the motor. To do this the shape, size, material, and surface of each component must be fine-tuned to create the most laminar flow possible. Our team will be utilizing computational fluid dynamics (CFD) software in conjunction with computer aided design (CAD) software to create an intake system that utilizes geometric and fluid dynamic principles to create a more effective flow regime into the engine. As a team we will first create a basic design for each part, restrictor, plenum, and runners. With the preliminary design we can then use these software's to change variables such as shape and material and find a design that optimizes our engines intake. These software's allow us to continually and refine on our design until reaching a system that will create the most efficient flow regime possible. Other aspects like temperature and durability were taken into consideration when designing as well. For these aspects the team will use finite

element analysis (FEA) software once the parts and system have been finalized in their design. This allows us to look at how and when the parts may fail under extreme temperatures, and prolonged vibrational stresses. After all these computations and fine tunings are completed, how much of a difference will it make if society is leaning away from internal combustion engines?

## STS Research Problem

*How are governmental and societal factors influencing the paradigmatic shift from internal combustion engines to electric motors within the United States?*

Society and consumer choice has begun to accept EV's as a viable source of transportation. This shift is still in its beginning stages as combustion engines still dominate the automotive sector. The rate of this shift is largely influenced by societal perception and technological innovations in EV's, as well as the infrastructure to support them. To analyze this rate at which EV's are being chosen over their ICE counterparts, we will need to look at case studies and journals that have analyzed the implications each aspect has on the growth rate of the EV market. Once we have an idea of the EV market, we can better answer the question of whether or not iterating on ICE is justified.

If we look at when electric vehicles were first introduced, we see that consumers didn't care all that much. However, this isn't uncommon for a technology to be accepted widely years after its introduction. For example, it wasn't until the late 1940's that a majority of US citizens owned cars despite cars having been available for decades. The introduction of EV's has been similarly slow until recent years. It wasn't until the infrastructure was put in place to support these vehicles that people started to see them as a viable option. At the same time charging

stations were being built the engineering behind the vehicles only got better, allowing the cars to have increased battery range. In 2011 there were less than 1,000 charging stations for plug in vehicles. Now there are more than 48,000 charging stations in the US (evadoption, 2022). At the same time the battery range of an EV, on average, went from 78.5 miles in 2011 to 200 plus miles in 2022 (Billington, 2022). This technological advancement and supporting infrastructure was the exact response to many of the consumers biggest concerns. Consumers mainly expressed concerns in battery life, longevity of the car, charging stations, and repair costs. Later we will look at how exactly the electric market is improving its technologies to create new consumers and grow their market. However, even with the technology now providing a viable form of transportation, we still don't see electric cars dominating the market. Why is that?

This is where societal perception and human psychology begins to play a role. Looking at an experiment conducted in 2019 we can better answer the question of; why sales of PEVs (plug-in electric vehicles) are still lower than traditional combustion engines despite government, environmental, and practical incentives. The study was conducted whereby a sample set of people rated their likelihood of buying a PEV before and after driving in one for a short time. To sum the results, test subjects were far more likely to buy a PEV in the future after just a short 3-5 min car ride in them (Roberson & Helveston, 2020). My perspective on this is that consumers don't want change but once interacting, and directly experiencing the unfamiliar, even for a short duration, will be much more accepting of that change as it is now familiar to them in some basic sense. Sources like this give a perspective that consumers are not yet ready for a shift to EV's and that iterative design on ICE is still viable for the foreseeable future. However, we will need to analyze more studies later in the report before jumping to that conclusion. The studies we will focus on are aimed at determining how electric car knowledge influences consumers car choice

and if this is a significant problem hindering the shift. We will also investigate broader studies about human behavior when faced with unfamiliar stimuli to further our understanding. For now, keep in mind that people are habitual creatures and until shown an alternative directly will often stick with what is familiar. The EV industry will need to convince consumers to leave the familiar and shift to the unknown if they ever want to make ICE a technology of the past.

While societal perceptions may serve to limit this market's growth, it is also one of the largest supporting factors. People care about the environment, and in turn care about their individual impact. Fossil fuels are no longer seen as a lasting source of energy and technologies that limit pollution are quickly becoming preferred. Currently passenger vehicles account for 16.4% of all carbon emissions in the US (Reynolds, 2021). With such a large portion of pollution coming from the automotive industry it's no wonder people are beginning to choose electric vehicles. There are misconceptions that they produce the same amount of emissions, and skeptics of EV's often refer to them as 'coal burners'. This has been disproved, and later we will investigate the truth behind EV emissions in scientific journals to determine and quantify their environmental impacts.

Another limiting factor in this shift from ICE to EV is affordability and social groups. Currently, these vehicles are seen more as a luxury or status symbol rather than an option for the masses. This price gap is why the first automobiles were not owned by the majority of citizens until the 1940's. It wasn't until the industry introduced the assembly line and made cars more affordable, that consumers started to purchase them on a wide scale. According to experts, it is expected that electric vehicles will cost the same as their ICE counterparts by 2025 (Scruggs, 2022). This is extremely important as it is estimated that less than 15% of US drivers can afford EV's (Welch, 2022), and that the average income of an EV owner is $100,000 (EV Consumer

Behavior 2021). This creates a social group that EV's are targeted towards. This will need to be addressed as this paradigmatic shift to electric vehicles can only happen if the whole of society accepts it, not just the privileged. One thing for sure is that the cost of EV's will need to decrease before we can see them outsell their ICE counterparts. To determine how EV's are addressing the social gap in their market more sources will be analyzed later to determine if this is simply a pricing issue, or a problem built through cultural perceptions.

It is not just consumers looking towards investing in EV's but also governments. The world is switching to a greener future, and governments often provide incentives for renewable energy sources, and similarly, eco-friendly technologies. In this paper we will be looking at how the US has been attempting to aid consumers in transition to EV's and what they plan to do moving forward. For example, currently the US Federal Tax Credit incentivizes citizens by giving them up to $7,500 on new plug-in electric vehicles (Gold, 2022). These incentives offered by the government are in an effort to reduce the total carbon emissions of the country and move society in a better direction for the sake of our planet's ecosystem.

## Conclusion

The aim of this paper is to answer if iterating on traditional engines and increasing the efficiencies is worth it when the world is shifting towards an all-electric future. The most important aspect when determining 'if iterating is worth it' is to look at the rate of this shift. Hypothetically let's say the EV market doesn't become widely accepted for another 30 years. If this is to be the case, then iterating on ICE engines is absolutely worth the resources as it still aiding in putting society towards a more efficient future. On the other hand, if EV's can emerge within the next 5 years, are new ICE vehicles just slowing an inevitable switch and hindering in

the reduction of pollutants? As you can see the growth of the EV market and consumer perspective is critical in understanding the validity of iteration on ICE. To analyze this growth rate, we will be looking into research on how societal factors and technological innovation in EV market. The growth rate of the EV market is a great indicator of the shift rate form ICE to EV and can help us determine when ICE vehicles may need to stop production. The technical report serves as an example of the complexity that goes into increasing the efficiency of an internal combustion engine, and just how much all these design changes make on actual power output.

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