Sustainable and Affordable Strategies to Reduce Traffic Emissions in Urban Areas

Muhammad Ali and Majid Ali Khan

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Muhammad Ali[1] and Majid Ali Khan[2]

[1] Nürtingen-Geislingen University(HfWU), Germany
engr.mohammadalikhan@gmail.com
[2] Technische Universität Chemnitz, Germany
majidalikhn@gmail.com

Abstract. Due to rising global temperature, mobility sector is witnessing a transition phase. It is essential to cut tailpipe emissions significantly to reduce rising global temperature and avoid changing climate patterns. In response to climate change, innovations in automotive sector, sustainable mobility solutions and increased public awareness for global warming is needed. While significant progress has been made in reducing greenhouse gas emissions, the transportation industry remained largely unchanged. Europe aims to achieve carbon neutrality by 2050, necessitating a major shift in traditional transportation practices. Conventional means of transport burning fossil fuel in urban areas are major contributors to emissions, posing environmental and health risks. Emerging technological advancements in automotive sector offer a promising way to improve urban environments, in line with Europe's Green Deal and Paris Agreement. This study aims to suggest techniques to create more sustainable and liveable cities through affordable mobility innovations. The research explores the potential of integrating modern vehicle technologies with existing road infrastructure to reduce transport emissions.

Keywords: Sustainable Mobility, Liveable cities, Traffic flow, Tailpipe emissions, Urban traffic congestion, Minimizing urban emissions

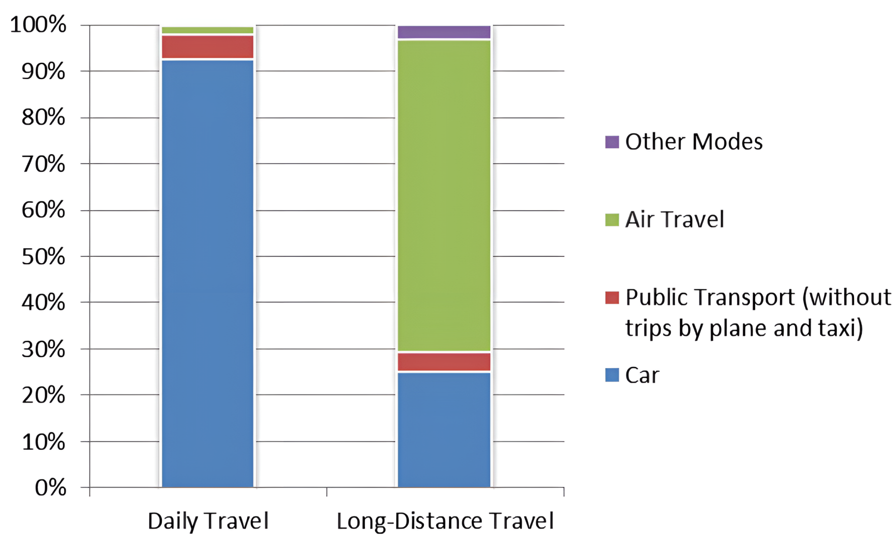
1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) reports and various scientific researches, substantive efforts are needed to mitigate global warming. The landmark Paris Agreement provides a structured framework for the international community to curtail Green House Gases (GHGs), targeting a 2°C limit, and a more ambitious goal to minimize these GHGs to 1.5°C above pre-industrial levels. The ongoing debate on carbon neutrality and pollutant emissions reduction by 2050 though, looks challenging considering the Paris Agreement, as previously set objectives are not being met, narrowing down the window to tackle the factors, as Sven unfolded [1].

Research shows that about one-third of the global energy consumption is attributed to the world's transport sector, contributing to the production of approximately 95% of direct tailpipe matter particles through the consumption of fossil fuels [2]. Moreover, it also contributes as the primary sector responsible for the emission of major greenhouse gases, significantly worsening the existing situation of global warming [3][4].

Europe is committed to reduce the harmful gases about 50% till 2030 compare to 1990 levels and become the first carbon neutral continent till 2050. This ambitious goal is only possible by its political will and following the objectives of European Green Deal and Paris Agreement, as experts say. [5][6]. However, automotive sector with many technological inventions for example, vehicle auto start-stop feature, tyre pressure monitoring sensor, cylinder deactivation technology and transition to electrify the mobility sector to make the transport sustainable, look unsuccessful comparing with other categories responsible for the GHG emissions.

Fig. 1: CO2 emissions proportion by transport mode



(a) Reference: Proportions of daily travel and long-distance travel(Reichert, A,et al,. 2016)

Despite 22.5% reduction in Europe's overall greenhouse gas (GHG) emissions between 1990 and 2018, there was an alarming surge of over 23% in total emissions from the transportation sector. The predominant contributor to this rise was transport emissions specifically the road-dominant sector, which increased roughly 27% during the mentioned period, constituting approximately 95% of the entire spectrum of transport emissions by the year 2018. The proportion of emissions attributed to road transport witnessed a rise, climbing from just under 13% in 1990 to nearly 21% by 2018, as researchers unfolded [7][8].

Furthermore, mega cities play a substantial role in economic development and contribute up to 60% of global GDP, according to the UN's 11th sustainable development goal "Sustainable Cities and Communities". Notably, with the economic progress, the mega cities are also responsible for 70% global GHG emissions, and the fundamental reason is rapid urbanization. [9][10].

According to UN's estimates, over 80% of European citizens will reside in the cities around the year 2050. The growing urban population of Germany is already evident, where between the years 2008 to 2016, mega cities of Frankfurt and Munich experienced a notable growth of 7%, as Mark describes [11]. The IPCC in its 2018 report declared that mobility is the major sector liable for 28% of the globe's final energy demand and 23% of its energy-related GHG emissions. The least diverse energy end-use sector, which accounted for 65% of the world's oil final energy demand and 92% of which was made up of oil products [12].

These statistics point to significant obstacles to de-carbonization. The major challenge lies in transitioning to sustainable and smart cities, a shift deemed very difficult without sustainable transportation, as noted by experts. This wider move towards "environmentally friendly cities" or "green urbanization" is currently influencing the global stage [13]. Sven describes that the effects of rising temperatures, traffic congestion, pollution, health inequalities, and limited access to these facilities are major concerns for authorities. He recognized that the current transportation status quo is not just unsustainable but also a major contributor to greenhouse gas emissions, a barrier to transform cities and make them more liveable [14].

Rapid urbanization is the reason for the increase in motorized vehicles; studies claim that by the year 2030, the number of vehicles will reach about two billion. Compared to suburbs, cities contribute higher greenhouse gases per kilometre. The total number of journeys taken and the distance travelled are aspects in determining an individual's carbon footprint. The more frequent the travel in propelled modes, the greater the tailpipe emissions produced. [15].

The discussion shows road transport a major contributor to GHGs at the local level and to urban air pollution, leading to various illnesses among neighbouring residents. Implementing new and advanced vehicle technologies is crucial to improve air quality, bridge them with road infrastructure and participate actively to minimize the carbon emissions from internal combustion engines (ICEs). This study focuses on the role of vehicle's engine auto start-stop feature and its potential to improve air quality. The paper also examines the benefits of combining different approaches, vehicle technology, road infrastructure and drivers active participation, to reduce urban traffic pollution.

2 Literature Review

2.1 Vehicle Auto Start-Stop Technology

Huff, S, et al states that by letting the auto start-stop feature engaged, the technology reduces CO2 emissions, it has financial benefits too, according to the start-stop intervals because of increased fuel efficiency in busy cities where the idling is commonly observed [16]. In their research Thitipatanapong, S., et and Gaines, L., et al say that this system is an economical way to minimize energy losses when a car is idling, which is important in cities with increasing traffic and it is proved by previous studies that traffic congestion and small stops consume 50 percent extra fuel, while instantly producing toxic emissions [17] [18].

Due to the potential benefits, some manufacturers have put start-stop systems in their vehicles from, BOSCH, Valero, and Denso. Comparing the feature to cars without the start-stop function, the installation of this system saves about 12% on fuel. Zhu, T, et al and Asekar, A.K found that in traffic with significant congestion, the start-stop technology can save about 8% on fuel, according to test results and figures released recently by BOSCH, a well-known manufacturer of auto start-stop systems. Zhu, T, et al and Asekar, A.K. in their findings observed that significant congestion results in even larger fuel efficiency and financial discounts [19] [20].

Karrouchi, M, et al and Santos, N.D.S.A, et al in their study argued that total fuel consumption is up to 10% by vehicle when its engine is at idle and an effective start-stop system has the potential to reduce fuel consumption by 7% to 9%, respectively [21] [22]. Huff, S, et al and Kropiwnicki, J. and Kneba explain the Start-Stop system's operation that it depends on the motor being turned off when the car is moving or motionless and not obtaining power from its engine. When the driver plans to move forward or act accordingly, the vehicle's engine is started. Reduced tailpipe pollutants and improved fuel efficiency are due to the vehicle equipped with auto start-stop feature [16] [23].

When gasoline is burned, it produces toxic gasses and CO2, and for every gallon of gasoline burned, it produces 8,887 grams of CO2. To make it easier to understand, let us convert grams into metric tons. An easier way to do this is by multiplying by a very small number, which is 10 to the power of minus 3, written as 10^{-3}. So, $8,887$ grams is the same as 8.887×10^{-3} metric tons. So, in a simpler form, it means that for every gallon of gasoline burned, it produces about 8.887 kilograms of CO2 emissions [24]. These calculations highlight the significant contribution of CO2 gasses from the combustion of gasoline from ICEs. Emphasizing initiatives towards sustainability, technology has the potential to play an important role in achieving the aims outlined in the European

Green Deal (EGD) and the Sustainable Development Goals (SDGs) set by the United Nations, paving the way for a better future.

2.2 Traffic Signals with Countdown Timer

One of the many significant solutions to reduce GHGs in local areas is to turn off the vehicle engines during waiting in busy traffic or at signalized crossroads according to the duration, remaining. Jou, R.C.et al in their research expressed that to lower the emissions from idling of vehicles, some of the states have prohibited the idling of the engines, and motorists have to turn the vehicles off during stops at intersections and traffic congestion, for example, this duration in different European states lays from 10 seconds to 3 minutes [25].

Kim, M and Kim, H.K in their findings observed that in account to keep the drivers well informed about the remaining red signal time, countdown timers can play significant role to reduce the CO2 emissions at busy urban areas [26]. Krukowicz, T, et al explained that the countdown timers are some kind of digital clocks, showing the duration of changing the red, green, or yellow signal at urban intersections and crossroads. The purpose of countdown signals is to keep the drivers well informed in their decisions, whether to brake or pass the junction, according to the time duration shown on the countdown timer [27]. Yan, W. et al., Islam, M. R. et al., and Islam, M. R. highlighted in their study that previous research has predominantly concentrated on analysing traffic flow and reducing red signal violations. They emphasized the significance of incorporating countdown timers at intersections for safety purposes [28] [29] [30]. Goel, A. and Kumar, P. referenced that frequent stop-and-go at intersections and busy traffic situations create extra delays, acceleration fluctuations, increased fuel consumption, exceeded emissions, and environmental degradation in local urban areas [31]. Goel, A., and Kumar unfolded in their research that because of acceleration and slow downing practices, particularly at heavy traffic locations, CO2 emissions are increased because of higher load of engine and road frictions [32].

Studies have demonstrated that traffic signals equipped with countdown timer possess the potential to positively influence driver's behavior in busy traffic scenarios, alleviating anxiety and facilitating decision-making for future journeys. Another significant contributor to air pollution resulting from traffic is the occurrence of sudden stops and rapid accelerations at intersections. When drivers approach a junction and encounter changing the signal to red, it might be challenging to react promptly, often leading to abrupt stops. These sudden braking actions increase tire friction, consequently releasing pollutants into the environment and posing significant health risks, due to a lack of information about changing the duration of traffic signals. Additionally, drivers may attempt to rush through intersections before the signal changes to red, accelerating their vehicles to pass promptly and further contributing to air pollution. This behavior encourages the emission of pollutants, compounding the environmental impact and again opposing the state policies to minimize the tailpipe emissions [27].

2.3 The Proposed Approach

The approach suggested in this paper not only strengthens the results of existing studies, but also emphasizes the importance of active driver participation and their behavior towards climate change in the traffic congestion. As the strategies to reduce overall carbon footprint, by curtailing the tailpipe emissions needed to improve urban environment without studying the behavior of drivers will be difficult.

3 Methodology

3.1 Online Survey

This study is comprised of an online survey based on carefully developed questionnaire. Online survey made it fast and inexpensive to reach out to participants and collect primary data directly, it reduced the overall response time (from distribution to submission) and made it possible to avoid inconsistencies caused by an indirect data collection or paper based survey. The target group consisted of drivers between 18 to 55 years of age, with diverse driving experience. The survey avoided asking questions that could potentially lead to any social profiling, stereotyping, racial, ethnic, or gender bias [33] [34] [35] [36].

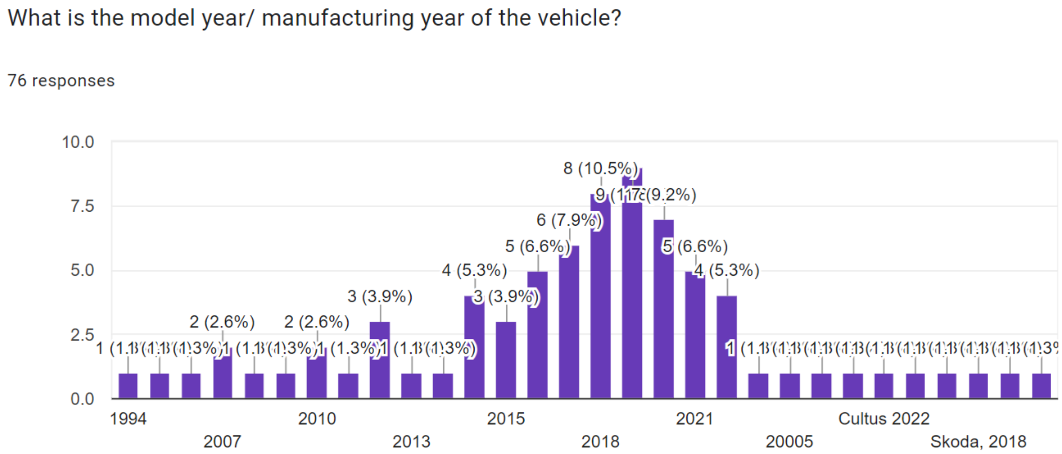
The survey consisted of 24 multiple-choice questions to assess the use of auto start-stop system by drivers and their response based on the type of traffic signals they come across. The drivers were asked if they would like to have traffic signals equipped with countdown timers and whether these help them reduce emissions by switching engines off using auto start-stop system. Ethical practices were followed by obtaining consent from all participants, and making sure participants were aware of the purpose of the survey and their rights with all data collected adhering to General Data Protection Regulation (GDPR) guidelines.

3.2 Results

1. The survey data in Fig. 2 revealed that around 40% of participants owned vehicles manufactured before 2015, which lacked the auto start-stop feature. This means these cars continuously pollute the urban air in busy traffic situations or at traffic signals. By implementing countdown traffic signals at crossroads, drivers can be informed about the remaining duration before the traffic signal changes, allowing them to decide whether to pass, stop, keep the engine running, or turn it off according to the countdown timer.

   Additionally, it might be possible to invent prototype start-stop kits for retrofitting these vehicles. These kits would enable the start-stop feature to operate automatically based on preset measures, minimizing tailpipe emissions in busy urban traffic without driver intervention.

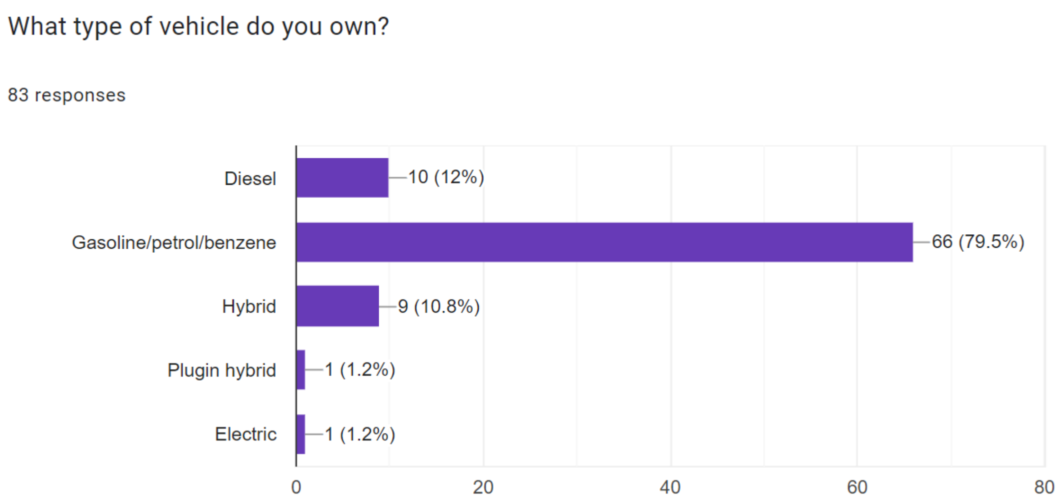
Fig. 2: Manufacturing year of the vehicles driven by the survey participants



No. of Participants (N) = 77

2. Fig. 3 reveals the preferences of participants regarding the types of vehicles they own. It is evident that most vehicle owners prefer driving gasoline/benzene vehicles.

Fig. 3: Vehicle type the participants own and drive

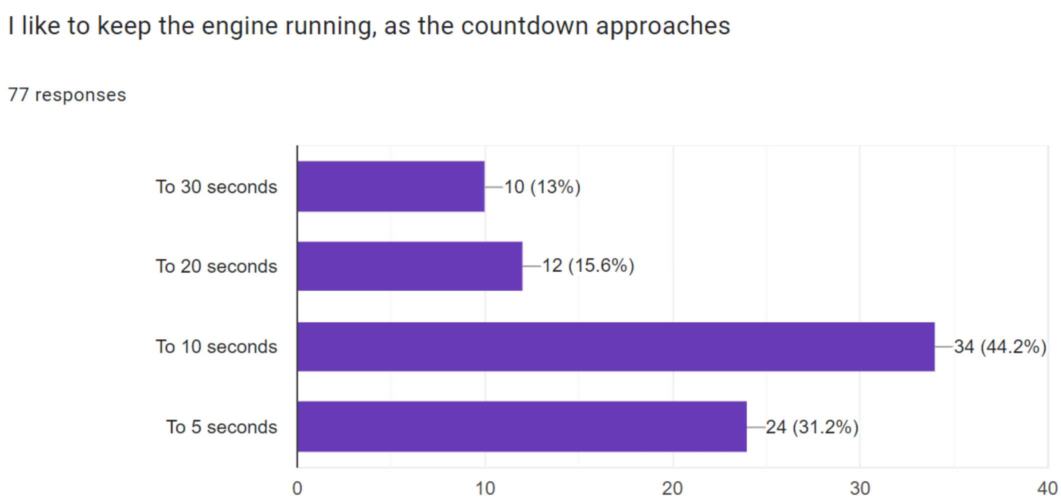


No. of Participants (N) = 90

Out of 90 participants, only 3 own electric vehicles (EVs), indicating a significantly lower adoption rate compared to internal combustion engine (ICE) vehicles. This suggests that various barriers still hinder people from purchasing EVs over ICEs. To close this gap and make EVs more common on the roads, improvements in charging infrastructure, reduced charging times, and lower costs to buy EVs, are needed. These changes could increase EV acceptance among citizens and significantly contribute to reducing transport-related CO_2 emissions over time.

3. Fig. 4 reveals the willingness of citizens to respond to traffic countdown timers. The data indicates that most people are aware of urban pollution and its causes.

Fig. 4: Driver's preferences at the count-down timer traffic signals



No. of Participants (N) = 80

Around 60 out of 83 participants are willing to turn off their vehicle engines at countdown timer traffic signals, even for duration of less than 10 seconds. This demonstrates their understanding of climate change and their commitment to reducing tailpipe CO_2 emissions. Such active participation is crucial for quickly reducing emissions, achieving the goal of sustainable cities, and aligning with state efforts to combat global warming.

4 Methodological Limitations

On-line surveys even though are inexpensive, fast and efficient for data collection, they also have some limitations. A major issue is the difficulty to affectively engage the target group that receives the survey, thus limiting the control over responses. Another concern is that people don't actively participate and engage in the online surveys as traditional data collection methods, such as paper-based, in person or on a telephone call.

5 Analysis

The study reveals several critical factors regarding urban CO2 pollution and public perception. The data indicates that implementing both the start-stop feature and traffic countdown timers can significantly reduce CO2 emissions in urban areas, improve traffic flow, and minimize time wastage, thereby enhancing the overall transportation system. People are aware of urban pollution and related diseases, and they are willing to actively participate in efforts to reduce pollution and combat rising global temperatures. According to the collected data, there are many older vehicles on the roads lacking innovative features like start-stop. Citizens show a willingness to turn off the engines at busy traffic signals or during traffic jams if they know the waiting time is longer than usual. This awareness suggests the potential for behavioral change if the duration of stops is made clear through countdown timers.

The preference for internal combustion engine (ICE) vehicles over electric vehicles (EVs) or hybrids is evident due to reasons such as easier maintenance, greater flexibility, time-saving, stress-free operation, better infrastructure, and other benefits. While EVs promise lower emissions, their acceptance is hindered by factors such as limited charging infrastructure, high costs, time-consuming charging, and quick battery power drain. The data also shows that people are willing to turn off their vehicles if they are aware of the waiting duration, even if it is just 5 or 10 seconds remaining on the countdown timers. This motivation, combined with the auto start-stop feature, can significantly improve urban air quality, reduce pollutants, and lower disease rates. In the long term, it has economic benefits, too.

Overall, the study suggests positive attitude of participants to reduce CO2 pollution by implementing auto start-stop feature in vehicles and countdown timers on traffic signals. People are eager to adopt these measures for the sake of addressing climate change. Continued efforts could help achieve the goals of the European Green Deal (EGD) and the United Nations Sustainable Development Goals (UNSDGs).

6 Conclusion

This paper explores cost-effective and sophisticated solutions to combat urban air pollution, particularly due to the increasing number of vehicles on busy urban roads. Despite the continuous growth of traffic in urban areas, state policies and regulations aimed at reducing carbon emissions to improve urban air quality have not been very fruitful. However, by embracing technological advancements that could impact drivers' behaviour on busy intersections in urban areas and promoting environment friendly practices, greenhouse gas emissions can be substantially reduced. These initiatives not only offer viable alternatives to traditional practices but also pave the way for achieving essential urban development goals.

The paper also highlights the potential benefits to install countdown timer on traffic signals to reduce carbon emissions from urban transportation, reflecting public interest in combating air pollution through voluntary actions. It emphasizes the importance of aligning technological advancements, cost-effective solutions, and citizens' willingness to tackle urban air pollution, particularly from the increasing volume of cars in metropolitan areas due to growing urbanization. Public awareness plays a crucial role in fostering greater participation in minimizing urban air pollution efficiently. For policy-makers, transport authorities and experts, this research offers valuable insights into the implementation of countdown timer based traffic signals and vehicle auto start-stop feature's role to mitigate the GHGs, enhance traditional transport management methods, and promote sustainable practices in urban development.

The study also suggests avenues for further research, emphasizing the need for integrated approaches leveraging various technological innovations to effectively reduce greenhouse gas emissions for present and future generations.

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