RETHINKING TRANSPORTATION: PLANNING AND BUILDING RESILIENT SYSTEMS TO MEET GLOBAL EXTERNALITIES

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ABSTRACT

Environmental sustainability has become an essential part in the planning and construction of modern transport infrastructure. External pressures and agreements to achieve environmental sustainability targets need to be considered constantly, as South Africa is a signatory to global stewardship in managing common environmental problems. Currently, there are innovative ideas in terms of making transport infrastructure more environmentally sustainable, however, many of them are expensive and often untested, especially within the South African context. As such South Africa has identified indicators and variables that represent the country's ability to respond to the global stewardship collectively, one of which is the reduction of greenhouse gas emissions. This essay argues that rather than spending money on uncertain innovations, changes in the current transportation system such as traffic control methods may result in large scale greenhouse gas emissions savings. Through an analysis of stop-controlled intersections and modern traffic circles, it is shown that the potential benefits of traffic circles may warrant their implementation over stop-controlled intersections. An increased benefit in not only traffic flow, but driver safety as well, coupled with potential large-scale greenhouse gas emissions savings are also present with the implementation of traffic circles.

1. INTRODUCTION

The reduction of global externalities must form part of the decision-making process of future investments, especially within the transportation environment. These external aspects need to be considered as countries are starting to be more conscious of the local and international impacts of their decisions. One of the key considerations is the environmental impact that transportation projects create. Through the emission of greenhouse gases created by road consumption and infrastructure development, the global environmental quality has seen steady degradation over the years.

For instance, an increase in the global temperatures has been observed due to the global warming crisis, which has in turn led to an increase in the frequency of natural disasters such as floods and droughts (Rezai et al., 2011). To combat global warming, agreements between nations including the Kyoto Protocol and The Paris Agreement have been established. Currently zero-carbon solutions account for approximately 25% of emissions. Zero-carbon emissions are where greenhouse gasses' emissions are reduced until they are as close to zero as possible with any excess emissions able to be absorbed naturally without causing any damage (UN, n.d. a). It is believed that by 2030, 70% of global emissions will be able to be accredited to zero-carbon solutions (UN, n.d. b).

The transportation sector is one in which many steps need to be taken to reduce greenhouse gas emissions. Innovations to reduce greenhouse gas emissions, such as electric vehicles, are often costly. Rather than investing in costly, potentially ineffective infrastructure, redesigning the transport system may reveal potential large-scale greenhouse gas emission savings. Traffic control methods are essential in ensuring that the movement of goods and people are done in an efficient and safe manner, whilst also minimising the pollution caused through transportation (Papafeorgiou et al., 2003). This is achieved through a variety of aspects such as markings on the road, signals (such as traffic lights and traffic officials) and signage (Stevanovic, 2019). The impact of traffic control methods will need to be assessed in areas that are directly impacted, as well as indirectly impacted as new traffic control methods could have a potential ripple effect on surrounding areas. Stop controlled intersections (hereafter referred to as stop signs) are creators of large amounts of greenhouse gas emissions, however, potential alternatives such as traffic circles allow for a large reduction in greenhouse gas emissions whilst also having an improvement in traffic flow (Sampson, 2013).

This essay is structured into four sections. The following section provides a brief overview of research that has been undertaken to compare the benefits and pitfalls of stop signs and traffic circles. In section three an environmental evaluation of stop signs and traffic circles is undertaken followed by quantify potential monetary savings that may occur between stop signs and traffic circles based off the environmental analysis. The essay concludes with a discussion of the overall findings and a recommendation that traffic circles rather than stop signs are the ideal choice when aiming to reduce greenhouse gas emissions in the transport environment.

2. COMPARISON BETWEEN STOP CONTROLLED INTERSECTIONS AND TRAFFIC CIRCLES

Within this section, stop signs and traffic circles will be discussed to highlight the difference between these traffic control measures. Currently, there is little, if any, research that has been done within the South African context regarding the efficiency of road signage.

Stop signs offer additional vehicle operating costs for drivers and their efficiency in terms of environmental sustainability. Along with the issues that other road signs face, stop signs are also one of the more ignored road signs (McKelvie, 1986; Brown et al., 1999). An example of an issue regarding stop signs is, drivers do not come to a complete stop whenever approaching a stop sign, with many slowly rolling through the stop and some not stopping at all (McKelvie,1988; Brown et al., 1999). This shows that potential pitfalls between stop signs and other road signage is the driver behaviour surrounding them. Direct characteristics of the driver can include driver age, driver gender as well as the influence drivers' behaviour can have on other drivers (McKelvy & Schamer, 1988; Gilbey & Tani, 2018). Other factors that influence driver behaviour at stop signs include time of day and the presence of passengers (McKelvy & Schamer, 1988). This brief evaluation of stop signs shows that due to the signs being ignored, they are not serving their intended road control function and when they are not being used as intended, they produce excess greenhouse gas emissions and generate additional vehicle operating costs due to vehicles having to come to a full stop.

In contrast, traffic circles used to be the preferred traffic control method that was implemented in the past. However, they were deemed to be dangerous due to high entry speeds. On the other hand, modern traffic circles have lower entry speeds as well as other improvements which resulted in an increase in the safety and traffic flow. In terms of

safety, traffic circles generate thirty to fifty percent of accidents in comparison to equivalent intersections which use traffic signals (Sampson, 2013). Traffic circles offer an improved traffic flow, with drivers being able to seamlessly integrate into the traffic circles should circumstances allow for it. Traffic circles have superior capacity to both two-way stops and all-way stops (also known as four way stops). Pedestrians and cyclists are safer at traffic circles as well (Sampson, 2013). This is due to safety provisions made for other road users at traffic circles, such as placing pedestrian crossing one car length behind the yield which in turn reduces the likelihood of a pedestrian being hit by a vehicle as there is likely to be a vehicle occupying the space after the traffic circles (Sampson, 2013).

Through the comparison of stop signs and traffic circles as traffic control methods it seems that traffic circles appear to be a more viable option than stop signs when referring to traffic flow as well as the safety of road users.

3. ENVIRONMENTAL EVALUATION

In 2003, Mandavilli et al. (2003) analysed intersections with all way stops and traffic circles in both morning and evening peak hours. The vehicle flow per hour at the traffic circles and all way stops were similar, with an average vehicle flow used to calculate the greenhouse gas emission amounts of the vehicles using the transport infrastructure. The researchers used software for their analysis which included aspects such as traffic volume, speed and variation within the road in terms of the turning movements of vehicles and the road geometry. Four greenhouse gas emission measures were selected for analysis, which included Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Oxides (NO_X) and Hydrocarbons (HC). These emissions are all measured in kilograms per hour.

The study found that all four emissions measures represented a sizeable percentage of savings when using a traffic circle in the morning, but especially in the evening. The average savings in the morning for the four emissions measures is a 18.75% savings whilst the evening presents a savings of 53.5% in emissions (Mandavilli et al., 2003). It is important to note that both Nitrogen Oxide and Hydrocarbons emit less than a kilogram an hour and Carbon Monoxide produces between 6 and 12 kilograms an hour. A focus must be placed on Carbon Dioxide emissions as this is the most harmful greenhouse gas due to it being the largest portion of global warming gas generate by human activities (EPA, 2020). The simulation revealed that Carbon Dioxide emissions could decrease from 138.91 kg/hr to 117.18 kg/hr (16% savings) in the morning and 335.7 kg/hr to 138 kg/hr (59% savings) in the evening by changing from stop signs to traffic circles (Mandavilli et al., 2003). This shows that not only are traffic circles better for road user safety and traffic flow, but in terms of creating a sustainable transport system, they are an ideal choice over a stop-controlled intersection.

The savings occur due to the way that the two intersections are designed. Stop signs are designed to bring the car to a full stop. This has a negative impact on emissions as the car will need to burn excess fuel to take the car from an idle position and propel the vehicle when it is safe to do so. In comparison, a traffic circle aims to have traffic slow down and enter the traffic circles seamlessly, only stopping when it is unsafe to enter the traffic circles due to other vehicles or possibly a pedestrian crossing. Through the vehicles rarely stopping, the extra emissions generated due to the vehicles having to propel themselves forward from a standing start does not occur. This results in the traffic circles generating less greenhouse gas emissions than stop signs when there is the same volume of traffic. This means traffic circles can facilitate a larger amount of traffic volume than while producing less than, or equal emissions than a stop sign.

4. QUANTIFYING THE COST OF EXCESS EMISSONS

As of July 2022, South Africa was one of 46 countries in the world to have placed prices on greenhouse gas emissions with other countries looking to implement this (Black et al., 2022). As of 2023, South Africa has a carbon tax of R159 per tonne of carbon dioxide (KPMG, 2023).

The potential carbon dioxide savings from the above stop sign to traffic circles research done by Mandavilli et al. (2003), shows that carbon dioxide emissions saved equalled 219.43 kg per day during the morning and evening periods combined. This figure can in turn be used to calculate an annual carbon dioxide emission for this single intersection. A total of 80 091.95 kg of carbon dioxide emissions can be saved by changing from a stop-controlled intersection to a traffic circle which equals a monetary value of approximately R12 735 with this number set to grow each year. The cost savings for one traffic circles can be quantified, showing that not only are greenhouse gas emission savings able to occur at traffic circles but also financial savings when assessing private vehicle operating cost.

5. CONCLUSION

The goal of the essay was to compare the environmental impact of stop signs and traffic circles. Through the above analysis, it was shown that stop signs are not the most environmentally efficient traffic control method. Compared to stop-controlled intersections, traffic circles are more efficient.

The advantages created using a traffic circle instead of a stop sign are linked and have a causal relationship. A noticeable improvement in traffic circles is the improved traffic flow compared to that of a stop-controlled intersection. Through the improved traffic flow, vehicles do not have to stop as frequently as they are able to merge at lower speeds into the traffic circles. The less the vehicles come to a full stop, the lower the greenhouse gas emissions produced by those vehicles. The greenhouse gas emissions savings are substantial; traffic flow and the safety of all road users are better when compared to stop signs. The greenhouse gas emissions savings hold not only an environmental benefit but also a monetary one for South Africa. This is due to less emissions being generated, which in turn causes less carbon tax to be paid. Through all the factors established in this essay, traffic circles need to be strongly considered as an alternative to a stop-controlled intersection.

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