Articles

Vehicle density and its impact on pavement wear in Guayaquil based on business development in port cities

Densidad vehicular y su impacto en el desgaste del pavimento en Guayaquil basado en el desarrollo de negocios en ciudades portuarias

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ABSTRACT

Increasing vehicle density in Guayaquil has raised concerns about its impact on the quality of road infrastructure, particularly on the wear and tear of asphalt pavement. This study aims to assess the relationship between vehicular traffic and pavement deterioration in the city, focusing on several areas with different levels of density. Counting cameras and traffic sensors were used to record the volume of vehicles, categorising them into light and heavy, as well as visual inspections to measure pavement wear. The results revealed that areas with high vehicle density had a higher degree of pavement deterioration, with a significant increase in cracking and cracking. The data show that heavy traffic is a major contributor to accelerated road wear, which in turn can impact road safety and public health by releasing more pollutants into the air.

Keywords: Vehicle Density, Pavement Wear and Tear, Urban Traffic, Road Infrastructure

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RESUMEN
El aumento de la densidad vehicular en Guayaquil ha suscitado preocupaciones sobre su impacto en la calidad de las infraestructuras viales, particularmente en el desgaste del pavimento asfáltico. Este estudio tiene como objetivo evaluar la relación entre el tráfico vehicular y el deterioro del pavimento en la ciudad, centrándose en diversas áreas con diferentes niveles de densidad. Se emplearon cámaras de conteo y sensores de tráfico para registrar el volumen de vehículos, categorizándolos en ligeros y pesados, así como inspecciones visuales para medir el desgaste del pavimento. Los resultados revelaron que las zonas con alta densidad vehicular presentaron un mayor grado de deterioro en el pavimento, con un aumento significativo en las fisuras y el agrietamiento. Los datos muestran que el tráfico pesado contribuye de manera determinante al desgaste acelerado de las vías, lo que a su vez puede repercutir en la seguridad vial y en la salud pública al liberar más partículas contaminantes en el aire.
Palabras clave: Densidad vehicular, Desgaste del pavimento, Tráfico urbano, Infraestructura vial

INTRODUCTION

Rapid urbanisation and increasing vehicle density in cities have generated significant concerns regarding the quality of road infrastructure and the well-being of the population. In Guayaquil, a growing city, the increase in vehicular traffic has led to accelerated wear of the asphalt pavement, which not only affects the durability of roads, but also contributes to the release of particulate matter into the air. This phenomenon is of particular concern, as fine particulate matter, such as PM10 and PM2.5, is associated with multiple public health problems, including respiratory and cardiovascular diseases.

Previous research, such as that of Pinto and Méndez (2015), has shown that the implementation of paving programmes can significantly reduce resuspension of particulate matter. In their study on the 'Evaluation of the impact on air quality associated with the resuspension of particulate matter by the paving of the Caracolí - Ciudad Bolívar Main Road,' it was found that interventions in road infrastructure were able to reduce PM2.5 and PM10 concentrations by 95%. These results underline the need to apply environmental criteria in the planning and execution of public works, highlighting the fundamental role of entities such as the Special Administrative Unit for Road Rehabilitation and Maintenance (UAERMV).

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However, the increase in impervious surface areas, as pointed out by Duque and Forero (2016) in their analysis of 'Environmental pollution and effects on public health due to the use of pavements in urban areas,' also contributes to the increase in the pollution load in the urban environment. Vehicle emissions account for approximately 40% of carbon dioxide (CO2) emissions and an alarming 80% of carbon monoxide (CO) emissions. This situation results in higher pollutant concentrations on roads than in residential and commercial areas, exacerbating health problems among the exposed population.

In addition, the study by Alvarado (2013) emphasises the importance of continuous air pollution measurements in order to comply with air quality standards established by international organisations. To this end, it is not enough to implement emission control and reduction measures during the autumn and winter months; it is crucial to establish permanent strategies that adapt to seasonal variations. This includes not only the improvement of pavement conditions, but also traffic regulation and proper maintenance of road infrastructure.

Asphalt paving in Guayaquil faces additional challenges arising from climatic conditions, such as heavy rains that can shorten pavement life to less than two years (Castro V., 2015). This situation is exacerbated by factors such as inadequate planning, incorrect use of materials, and ineffective public management, which have led to many roads being in deplorable conditions. The quality of the wearing courses, whether hot or cold, is crucial to ensure the durability and functionality of the pavement (Table 1). In particular, cold mixes, which use hydrocarbon binders and asphalt emulsions, are essential for the maintenance of secondary roads and require careful management to avoid premature deterioration.

Table 1. *Functional properties of asphalt slabs.*

FUNCTIONAL PROPERTIES OF ASPHALT MIXTURES
Safety Slip resistance Transversal regularity Visibility (road markings)
Comfort Longitudinal regularity Transversal regularity Visibility Noise
Durability Bearing capacity Resistance to surface disintegration
Environment Noise Recyclability
Workability

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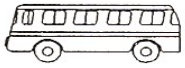
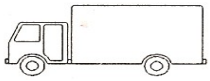
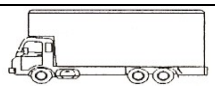
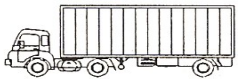
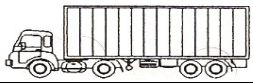
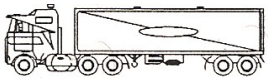
The objective is to evaluate the relationship between vehicle density and pavement wear in different areas of Guayaquil. The aim is to determine how the volume of traffic, especially heavy vehicles, influences pavement quality and the release of pollutants into the air. Through the collection and analysis of data on vehicle density and pavement condition, it is hoped to provide evidence to support the implementation of effective policies for traffic management and the preservation of road infrastructure. (Figure 1). By addressing these issues, this study will contribute to fostering a healthier and more sustainable urban environment, protecting the health of citizens and improving the quality of life in Guayaquil.

Figure 1 General classification of vehicles

TIPO DE VEHICULO		No. de EJES	ESQUEMA	SIMBOLO
VEHICULOS LIVIANOS	AUTOMOVILES	2		P
	CAMIONETAS			C
VEHICULOS PESADOS	AUTOBUSES	2		B
	CAMIONES	2		2-S
		3		3-S
				2-S1
		4		2-S2
		5		3-S2
			OTRAS COMBINACIONES	
VEHICULOS	CAMIONES Y/O REMOLQUES ESPECIALES	VARIABLE		En variable
	MAQUINARIA AGRICOLA			
	BICICLETAS Y MOTOCICLETAS			
	OTROS			

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MATERIALS AND METHODS

This study was carried out in several areas of Guayaquil, with a particular focus on the Mucho Lote 2 urbanisation. This area was chosen because of its high vehicle density and evident wear of the asphalt pavement, which provides an ideal context for assessing the impact of traffic on road infrastructure and air quality.

To investigate the relationship between vehicle density and pavement deterioration, several data collection techniques were employed. First, counting cameras and traffic sensors were installed at strategic locations on selected roads. These devices were configured to record the volume of vehicles at different times of the day, including peak periods such as the morning and evening rush hours. Through this system, data on the total number of vehicles was recorded and classified into light and heavy vehicles, giving a clear picture of the load on the roads and its relationship to the observed wear and tear.

This process included not only the identification of cracking and deformation, but also the collection of information on pavement slippage. A rating system was adopted to classify the pavement condition into different categories, from 'very good' to 'very bad', facilitating standardised comparison between road segments.

To enrich the analysis, a geospatial mapping of the pavement condition was carried out using Geographic Information System (GIS) tools. This technique not only allowed visualisation of the affected areas, but also helped to identify wear patterns in relation to traffic density, providing a geographical context that is valuable for the research.

Additionally, to measure air quality in the area, measurements of particulate matter, specifically PM10 and PM2.5, were taken. Air quality monitors were installed at strategic points within the development and operated continuously for a period of [specify duration]. These devices were selected for their ability to provide accurate real-time data on particulate matter concentrations in the air. Measurements were carried out at different times of the day, allowing variations in pollutant concentrations to be observed in relation to vehicle activity.

In addition, meteorological factors were taken into account, as variables such as temperature, humidity and wind speed influence the dispersion and concentration of particulate matter. Nearby meteorological stations were used to obtain data to complement the air quality analyses, which enriched the understanding of how climatic conditions impact pollution.

Once all the data were collected, they were subjected to statistical analysis using specialised software such as SPSS or R. Regression and correlation analyses were applied to determine the relationship between vehicle density, pavement wear indicators and particulate matter concentrations. This statistical approach not only identified significant patterns and trends, but also provided a deeper understanding of the interaction between traffic and pavement deterioration.

In addition, a comparative analysis was carried out between areas of high vehicle density and those with less traffic, allowing for an assessment of differences in pavement wear

and air pollution levels. This comparison was not only based on traffic volume, but also considered the characteristics of the predominant vehicles in each area.
On completion, all necessary permits were obtained for the installation of the monitoring equipment and the carrying out of the measurements. Confidentiality and respect for the privacy of residents in the selected areas was ensured, while complying with local and ethical regulations for research. The combination of these methods and techniques provided a solid framework for assessing the impact of vehicle density on asphalt pavement wear in Guayaquil, allowing the generation of relevant conclusions that could contribute to the formulation of public policies aimed at improving air quality and the durability of road infrastructure.

RESULTS

The results of the air quality monitoring in the Mucho Lote 2 urbanisation revealed he analysis of the pavement in the Mucho Lote 2 urbanisation revealed significant wear and tear in areas of heavy vehicular traffic, especially those with heavy and continuous traffic. During visual inspections, cracks and deformations were observed in the wearing course, which is 8.10 cm thick. These cracks vary in size and depth, being more pronounced in sections where the pavement is subjected to constant loading, such as intersections and deceleration areas.
In situ measurements indicated that the pavement shows clear signs of fatigue, particularly in areas where heavy traffic is frequent. The cracks are characterised by longitudinal and transverse development, with variable depths reflecting advanced wear. These deformations were associated with a combination of factors, such as the lack of adequate maintenance and the initial pavement design, which was not prepared to withstand the observed traffic volume for a prolonged period of time.
In addition, climatic conditions, such as heavy rainfall and temperature fluctuations, have accelerated pavement deterioration, especially in areas with insufficient drainage. Water accumulations during the rainy season have caused weakening of the lower pavement layers, resulting in increased cracking and surface degradation in several areas of the development. This problem was particularly evident in sections where water was not draining adequately, exacerbating the exposure of the pavement structure to premature wear.
The mapping of the affected areas, carried out using Geographic Information System (GIS) tools, showed a heterogeneous distribution of damage. The most critical areas are concentrated at the points where the pavement has been subjected to the greatest stresses, such as major intersections and the busiest stretches. Although areas with less traffic also showed some degree of wear, damage was less severe, which reinforces the idea that volume and vehicular load are determining factors in the deterioration observed.
Pavement analysis identified two main types of damage. Structural damage (classified as Class A) reflects deep deformations and cracks that compromise the integrity of the

pavement, mainly caused by deficiencies in the pavement base and the constant loading of heavy vehicles. These structural damages are more common in the most heavily trafficked sections. On the other hand, functional damage (classified as class B) is related to surface wear of the pavement, such as erosion and loss of material, affecting the comfort and safety of road users, but without immediately compromising the complete structure of the road.

The results of this study reveal that pavement wear in Mucho Lote 2 is directly related to traffic volume and local climatic conditions. The lack of regular maintenance and deficiencies in the initial pavement design have exacerbated this deterioration, making it evident that immediate interventions are needed to prevent further deterioration of the road infrastructure.

The pavement wear observed in the Mucho Lote 2 urbanisation reflects a complex interaction between heavy traffic, climatic conditions and lack of proper maintenance. Although the results show considerable pavement deterioration, it is crucial to further examine the underlying factors that have contributed to this process and how the findings can be applied to future road infrastructure improvements.

One of the most prominent factors in this study is the impact that heavy traffic has on pavement life. Areas with higher heavy vehicle traffic, such as intersections and sections where vehicles tend to decelerate, showed more accelerated wear, suggesting that the original design was not adequate to support current vehicle loads. This finding is consistent with previous studies indicating that when pavement design is not aligned with the reality of the traffic it supports, wear is significantly accelerated. Therefore, it is imperative to review pavement regulations and specifications to ensure that infrastructure is designed not only for current traffic, but also for future projections.

The impact of climatic conditions, in particular water accumulation and temperature fluctuations, is another critical factor that accelerated pavement deterioration. Areas with insufficient drainage showed a higher level of cracking and deformation, which reinforces the importance of integrating more efficient drainage systems into paving projects. It is well known that water infiltrating into pavement layers reduces their structural capacity, which in turn increases the likelihood of irreparable damage to the surface.

Also, the lack of regular maintenance is a recurrent problem that aggravates the pavement situation. Although the Mucho Lote 2 development is an area of high vehicular density, preventive and corrective measures have not been sufficient to mitigate the effects of this continuous traffic. Evidence shows that a proactive approach to maintenance, with periodic repairs and prevention of water accumulation, could have significantly extended pavement life and reduced long-term repair costs.

The pavement analysis also revealed a deficiency in the construction methodology, which affected both the structural and functional performance of the asphalt. While the strength of the pavement overlays is critical, the analysis suggests that the underlying layers were not adequately prepared for the loads they are currently carrying. This

observation reinforces the need for more in-depth studies on pavement bases and sub-bases during the planning phase, especially in urban areas with high traffic.
In terms of implications for future interventions, this study highlights the need to review urban planning policies, especially in areas with high vehicle density such as Mucho Lote 2. It is not only crucial to improve the quality of the materials used, but also to develop design strategies that consider the combined impact of traffic and climatic conditions. In addition, it is essential to incorporate advanced monitoring technologies, such as traffic sensors and GIS tools, to facilitate continuous pavement condition monitoring and informed maintenance decisions.
The findings of this study confirm the importance of a comprehensive approach that encompasses planning, implementation and maintenance of road infrastructure. Although pavement wear is a natural process, it can be significantly mitigated with proper design, quality materials and regular maintenance. This would not only improve the durability of the pavement, but also have a positive impact on the safety and quality of life of the inhabitants of the Mucho Lote 2 development.

CONCLUSIONS

The analysis carried out in the Mucho Lote 2 urbanisation leads to the conclusion that the wear of the asphalt pavement is the result of a combination of structural, vehicular and environmental factors, which, if not addressed in a comprehensive manner, will continue to degrade the road infrastructure at an accelerated rate. Deficiencies in the original pavement design, specifically in heavy load carrying capacity and the lack of an adequate drainage system, stand out as the fundamental problems that have contributed to the observed deterioration. Without proper planning that takes into account traffic growth projections and climatic variations, the service life of the pavement is considerably reduced.
The implementation of regular preventive maintenance programmes that include repairing cracks and improving drainage in critical areas is essential. In addition, measures need to be taken to ensure that the pavement design is in line with current and future traffic demands, especially in terms of heavy vehicular loading. The preventive approach, combined with a rigorous analysis of pavement conditions prior to pavement construction, will not only prolong the service life of roads, but also reduce the costs associated with emergent repairs and disruption to vehicular traffic.
This study highlights the need to develop more robust road planning that incorporates sustainable solutions in both design and environmental impact management. While climatic conditions cannot be controlled, it is possible to mitigate their adverse effect through the implementation of more resilient materials and improved water management on roads. In summary, timely and well-planned intervention can minimise the effects of pavement wear and improve the safety and quality of life of the inhabitants of the Mucho Lote 2 development.

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