ISSN: 0974-5823 Vol. 7 No. 3 March, 2022

International Journal of Mechanical Engineering

Factors of public transport routes causing vehicular congestion: a systematic review.

Alember Alexis Rodriguez-Torres[a], Nilda Shirley Delgado-Corazao[a], Raúl Delgado-Arenas[a], Johnny Félix Farfán-Pimentel

[a]Universidad César Vallejo, Perú

Abstract

The objective of this systematic review was to know the factors of public transportation routes that cause vehicular congestion, through a systematic review of scientific articles published between 2000 and 2021. The information was collected through an intensive search in the main scientific databases such as Scopus, Scielo, REDIB, REDIB, Redalyc, Latindex, Dialnet, Alicia, among others, using search descriptors or keywords in English. This search was carried out taking into consideration essentially articles from indexed journals in English and Spanish, which contained information related to the topic to be addressed. As a result, 80 articles related to the topic were identified, in the first filter 20 articles were discriminated for duplicity, obtaining 60. After the selection process according to the inclusion and exclusion criteria was exhaustively carried out, these were reduced to 40 articles related to vehicular congestion. Finally, it was concluded that: The factors of public transport routes that cause vehicular congestion are: Transport routes, the problem of vehicular congestion, infrastructure design, efficiency of traffic controllers and traffic restrictive measures. The existence of a factor of exceptionality stands out, since the environment and the reality differ from one city to another, which allows us to infer that not all proposals are applicable or constitute the solution to all contexts, since there is a diversity of atypical factors in each study of traffic congestion. The most complex factor is the lack of road planning.

Key words: Vehicle fleet, road structure, transport flow, efficiency of traffic controllers and traffic restrictive measures.

1. Introduction

In the current context, it is observed that as a result of accelerated population growth, traffic congestion has been increasing in much of the world, specifically in the most populated cities (Ruiz, Mayorga, Aldas, & Reyes, 2019), which allows inferring that this situation will continue to worsen over time, constituting a danger for the community if the necessary measures are not taken (Bull, 2003). As is known, public transportation is of transcendental importance to carry out all economic activity, as is the case in Lima and Callao, where 77% use these means for their mobilization (Martínez, 2017). However, during the last few years, the peak hours have increased significantly, since in the past it was estimated a total of 5 hours per day of traffic, however, today, there are 9 hours per day, allowing inferring that the population of Lima is subjected to a greater number of hours in traffic (Almeida, 2019).

Currently, many cities are betting on the progress of these roads, in order to remedy this problem (Ruiz, Mayorga, Aldas, & Reyes, 2019). Thus, since 1995 to date, different means have been developed to solve this problem; however, to date, they have not been successful. Electric trains, fast corridors, and even new tracks and bypasses were created, but the problem still continues (Martínez, 2017).

Unfortunately, this problem is increasingly evident, thanks to the increase in the number of vehicles in cities, which generates an even greater demand for control systems for the road network, causing long hours of traffic caused by the same deficiencies in the system (Pérez, Bautista, Salazar, & Macías, 2014). Commonly, this problem arises when the volume of traffic is greater than the spaces available on the roads, generating high levels of complexity for its transit (Rhonmer, 2020). Therefore, the inappropriate design and maintenance of the roadway will trigger unnecessary congestion (Thomson & Bull, 2001).

The case of Bogota also stands out, where traffic jams and vehicle immobilization are generated for long periods of time, causing chaos in the population (Aaron, Gómez, Fontalvo, & Gómez, 2019). Likewise, in Costa Rica, it presents these deficiencies, since it has a disorderly transportation network, where there is a lack of tangential routes, being its only diametrical routes, the 6 intersectoral routes that operate in the capital (Quirós & Agüero, 2018).

Another factor to analyze is that, the excess of vehicular traffic and the congestion generated on the roads, is causing damage to people's health, as a consequence of the stress levels they go through trying to get to work or study centers in a timely manner. (Ledesma, et al., 2017). Thus, different investigations carried out during the last 6 years, specified that the deficiencies and collapses of urban mobility, arise as a consequence of rapid urbanization (Quintero & Quintero, 2015). Therefore, at present, traffic factors and vehicular congestion are considered as a major challenge that must be addressed.

This increase in the number of vehicles continuously causes various types of accidents, which is due to the poor design of urban roads, as well as to the lack of road safety criteria. As for congestion, it sounds reasonable to consider that an increase in road infrastructure will improve traffic flow; however, this is not always the case. The poor design of road infrastructures and the inefficient use of traffic controllers are the main factors that have triggered the major problems that cities have been experiencing

in terms of transportation (Pérez, Bautista, Salazar, & Macías, 2014). In this regard, it was mentioned that the main problem observed is the deficiency in road planning controls, causing the growth of travel times, high levels of noise pollution, loss of working hours, damage to health and frequent traffic accidents (Hernández, Mercado, León, & Román, 2017).

Theoretically, vehicular congestion was defined as a major problem caused by the increase in the demand for space on a road (Aliaga, 2019). For his part, Rivadeneira (2000) stated that vehicular congestion is generated by the amount of population that requires the use of vehicles for transportation to a fixed destination, which is usually aggravated due to the fact that the population is dynamic and highly reproductive. In this sense, the challenge of the civil engineer is to project quality civil works, planning, organizing, managing and supervising their construction, conservation and repair, based on economic technical criteria according to the needs of society. (Brenzini & Martínez, 2012).

The purpose of transportation engineering is to understand the dynamics and intervene in the transportation system, placing greater emphasis on the redesign of road axes, in order to optimize traffic and contribute to the reduction of the growing demand for it (Fernández & Valenzuela, 2004). Consequently, a very valuable part of the professional work of the civil engineer is focused on the analysis of a specific difficulty or deficiency as a phase prior to the planning, design and construction of any infrastructure project (Quintero, 2011). Likewise, the importance of carrying out road infrastructure inventories is emphasized in order to understand the operational and functional situations of a road, based on a detailed description of the physical, geometric and design characteristics (Quintero, 2011). Therefore, the factors of public transport routes that cause vehicular congestion are associated with the transport routes, the problem of vehicular congestion, the design of the infrastructure, the efficiency of traffic controllers, and traffic restrictive measures. But, this problematic also depends a lot on the controls that are given, since a deficient supervision of the compliance with the norms, causes that the users of the transport routes do not comply with what is established for the transport regulations (Pérez, Bautista, Salazar, & Macías, 2014). Therefore, the objective of the research is to know the factors of public transportation routes that cause vehicular congestion, based on a systematic review.

This review article is intended as a technical proposal; as a fundamental tool to identify the factors of public transportation routes that cause vehicular congestion in various realities and types of urban intersections, which are the focus of interest of large national and international metropolises, taking into account the population explosion and the increase in population and vehicle fleet in parallel. In this way, the elaboration of this article is justified with a theoretical, practical and social criterion, which was considered as the ideal strategy to promote a wide and rigorous research on the subject that will allow us in the medium and long term to overcome the problem of vehicular congestion by assuming new transportation policies, with modern and efficient alternatives based on civil engineering, according to the needs exposed in the present.

2. Method

The present study was carried out under the systematic review modality. This type of research is characterized by having clear and structured summaries of all the information collected, which, is oriented to give an answer to a specific question (Moreno, Muñoz, Cuellas, Domancic, & Villanueva, 2018).. This was characterized by describing the transparent and comprehensible structuring procedures used to collect, select, criterionally evaluate and synthesize the evidence related to the Factors of public transport routes that cause traffic congestion: A systematic review. The following criteria were followed for the systematic search of documents in this research: (i) Inclusion criteria: articles related to the factors of public transport routes causing vehicular congestion; articles from countries in the Americas, Europe and Asia were included; articles in English were included; the time interval of the studies considered is between the years 2000 and 2021. (ii) Exclusion criteria: We excluded articles that have not been cited in other research; dating from before 2000.

Regarding the search methodology of the documents, the present research corresponded to a systematic review of academic articles from the period 2000 to 2021. The information was collected through an intensive search in the main scientific databases such as Scopus, Scielo, REDIB, Redalyc, Latindex, Dialnet, Alicia, among others, using search descriptors or keywords in English such as: Factors of public transportation routes that help to vehicular congestion in lima: a systematic review.

The aforementioned search was carried out taking into consideration essentially articles from indexed journals in English and Spanish, which contained information related to the topic to be addressed, establishing as one of the criteria that they could have qualitative, quantitative and/or mixed approaches. As a result, 80 articles related to the topic were identified, of which 40 were finally selected. For the systematic review in this research, information from scientific articles and systematic reviews was consulted. Systematic reviews were considered because they focus on a specific question, which is answered in a structured manner, complying with the defined conditions (Reyes, 2020). As for the scientific articles, they were taken into account because they recruit the characteristics to be approved for publication, being reliable sources for the study. (Delgado, 2011).

3. Results

From the application of the search procedures, 80 articles were selected, of which 40 were discarded because they did not have the necessary support to answer the question posed, so that the work was completed with a total of 40 articles, which represent 50% of what was initially found, as shown in the following figure:

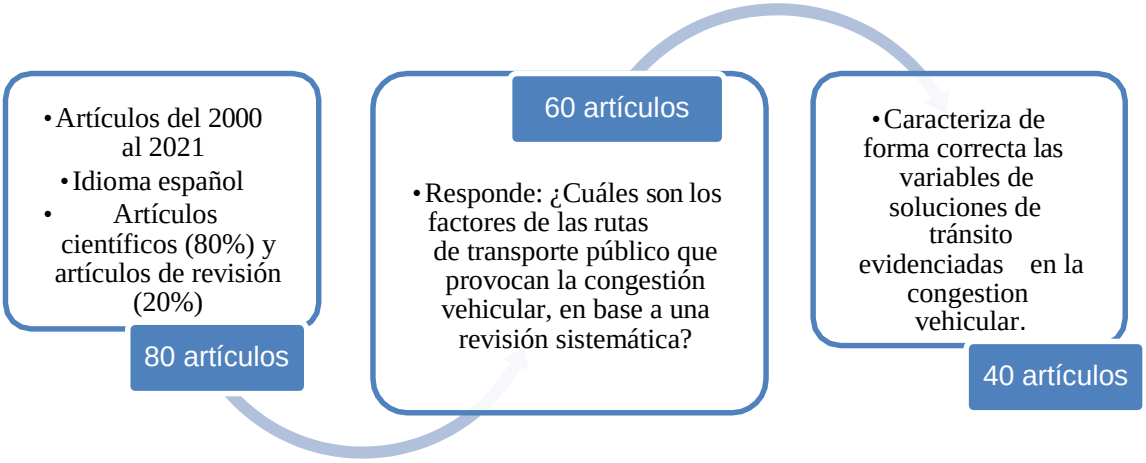

Figure 1. Selection processes

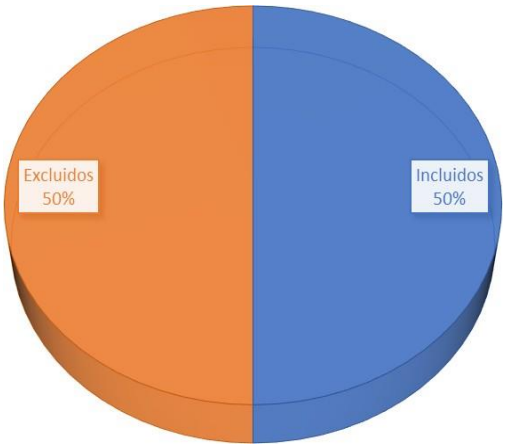

Figure 2. Included and excluded items.

The following table shows the 40 articles used for the development of this research, where the essential characteristics of the topic, the year of publication, the countries where the study was carried out, the methodological design and the results found are shown:

Table 1

Matrix of items used

N°	Database	Title of research	Type of document	Country
1	Dialnet	Public bus services versus congestion and pollution in Lima and Callao.	AC	Peru
2	Redalyc	Analysis of vehicular traffic flow through a macroscopic model.	AR	Colombia
3	Researchgate	Lima, the third worst traffic in the world	AC	Peru
4	Springer	Traffic congestion relief associated with public transport: state-of- the-art	AC	Korea
5	Scielo	Traffic model for the interconnection of networks and operators through mpls-te.	AC	Colombia
6	Dialnet	The road accident rate on Spanish roads from a territorial perspective	AR	Spain
7	Redalyc	The cost and perception of traffic congestion caused by urban public transport in the city of Ambato, Ecuador	AC	Ecuador
8	Alicia	Optimization of vehicular flow at the intersection of Bolognesi Ave. with Basadre and Forero Ave. in Tacna city.	AC	Peru
9	Dialnet	Proposal for the Optimization of Urban Public Transport Routes: Case Study - Street Closings at Tuxtla Gutiérrez City	AC	USA
10	Scielo	Solving the vehicle routing problem with stochastic demands using spiral optimization	AC	Colombia
11	Researchgate	Analysis of passenger transportation routes through the network analyst tool of arcgis. Case applied in the city of Medellin	AC	Colombia

12	Redalyc	Environmental traffic management: how transportation engineering contributes to the improvement of the urban environment.	AC	Chile
13	Scielo	A methodology for creating feeding routes in mass transit systems	AC	Colombia
14	Scielo	Analysis of vehicular mobility in the department of La Guajira using simulation. The case of Riohacha and Maicao.	AC	Colombia
15	Scopus	System optimal routing of traffic flows with user constraints using linear programming	AC	Spain
16	Dialnet	Transparency on the road	AC	Spain
17	Alicia	Vehicle congestion and the urban transportation authority of lima and callao	AC	Peru
18	REDIB	Internal and external cost functions in a strategic freight forwarding model	AC	Colombia
19	Dialnet	Classification of the routes of Costa Rica's public transport network by bus mode	AC	Costa Rica
20	Dialnet	Examples of pavement breakdown with bituminous pavements	AC	Spain
21	MDPI	Traffic Flow Density Model and Dynamic Traffic Congestion Model Simulation Based on Practice Case with Vehicle Network and System Traffic Intelligent Communication	AC	Romania
22	ECLAC	Urban traffic congestion: economic and social causes and consequences	AR	Chile
23	Dialnet	Sustainable transportation and its role in environmental development.	AC	Colombia
24	Springer	A system dynamics model for determining the traffic congestion charges and subsidies	AC	China
25	Dialnet	Road inventories and categorization of the road network in traffic and transportation engineering studies.	AC	Colombia
26	Redalyc	Civil engineer profile: a view from his generic and specific competences	AC	Venezuela
27	Scielo	Work and health in cab drivers.	AC	Argentina
28	ECLAC	Latin America and the Caribbean: sustained economic growth, population and development.	AC	Chile
29	Nature Portfolio	Trafc networks are vulnerable to disinformation attacks	AC	
30	Dialnet	Impact of Latin American public transportation systems on urban mobility and the environment	AR	Venezuela
31	ECLAC	Traffic congestion. The problem and how to deal with it	AR	Chile
32	Hindawi	Evaluation, Classification, and Influential Factors Analysis of Traffic Congestion in Chinese Cities Using the Online Map Data	AR	China
33	Dialnet	Electric roads, solar roads: Sections adapted to new mobility	AC	Spain
34	Scopus	Robust traffic wave damping via shared control open access	AC	Italy
35	Hindawi	Research on Traffic Congestion Based on System Dynamics: The Case of Chongqing, China	AC	China
36	Alicia	Vehicular transport congestion and its incidence in health and environment in the city of Puno	AC	Peru
37	LATINDEX	New intelligent transportation systems for a developing city.	AC	Peru
38	Redalyc	Efficiency of public transport in the city of Morelia, Michoacán (Mexico) in 2015: an analysis of the data envelope	AR	Colombia
39	Scielo	Effect of vehicular speed reduction on the durability of an asphalt layer.	AC	Chile
40	Scielo	Traffic control based on intelligent agents	AR	Mexico

Therefore, of the total number of articles mentioned, they were grouped in terms of the period of antiquity, with 11 articles corresponding to the period 2000 to 2015 to analyze the events according to their evolution, and the remaining 29, corresponding to the last 5 years, as expressed in the following figure:

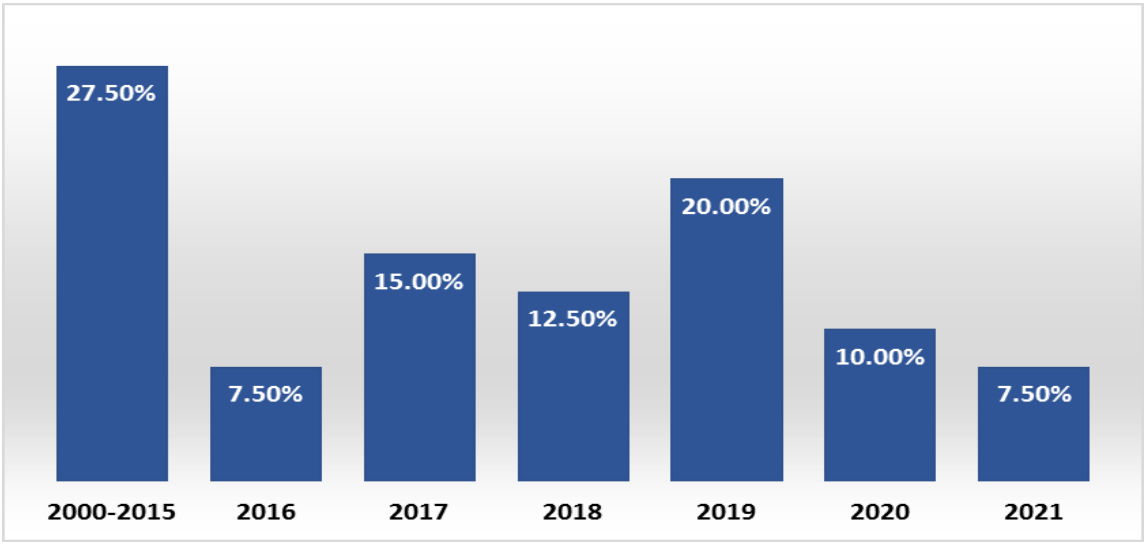

Figure 3. Articles collected by year

The following figure shows the percentage values of each of the search engines, highlighting among them: ECLAC databases, Alicia, Dialnet, Hindawi, REDIB, MDPI, Springer, Researchgate, Latindex, Nature portfolio, Scopus, Redalyc, scIELO, excluding institutional repositories. In this sense, it can be seen that Dialnet has the highest percentage, with a total of 10 articles, accounting for 25% of the sources consulted.

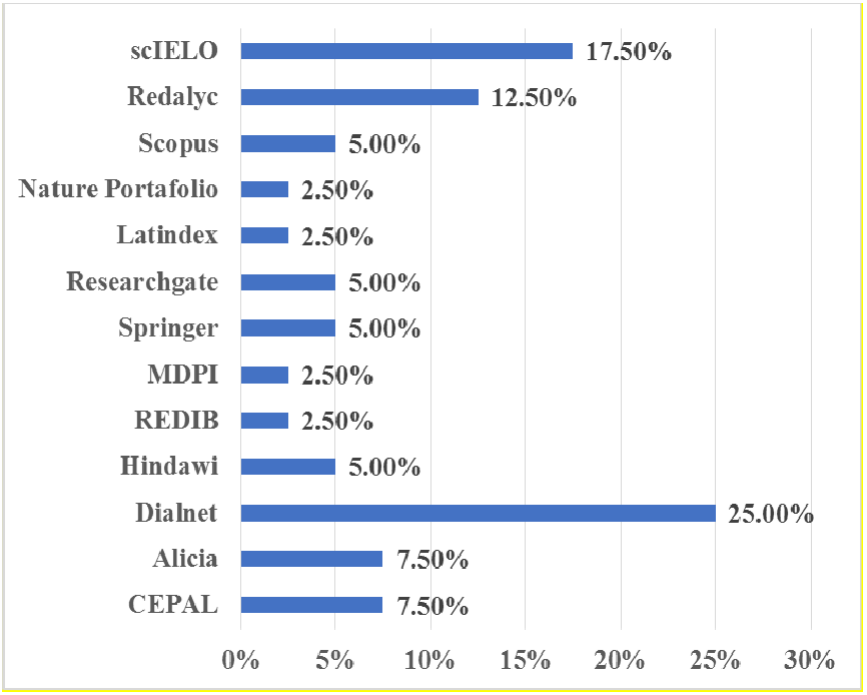

Figure 4. Percentage values according to search engine

As for the type of documents used, it can be seen in the following figure that greater interest is given to the preparation of scientific articles, the percentage values being represented in the following way: 80% of the sources corresponding to scientific articles and 20% correspond to systematic review articles.

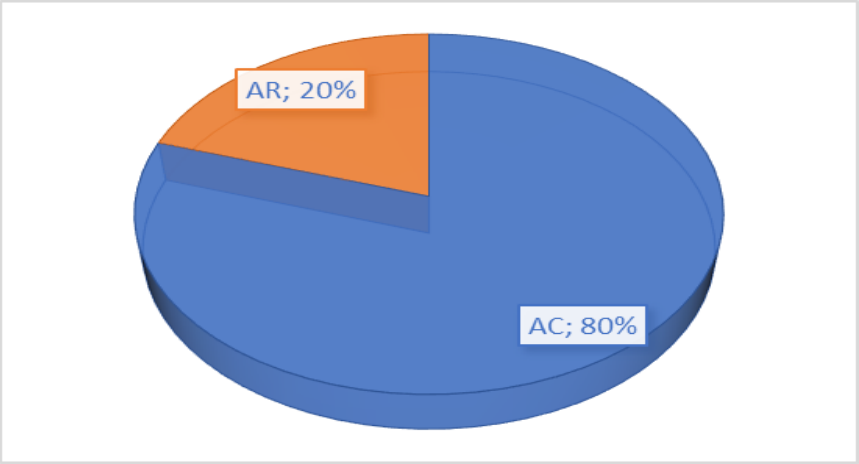

Figure 5. Percentage distribution according to document type

Regarding the origin of the articles, Colombia has the highest percentage of scientific publications related to the topic under study, with 25%, followed by Peru with 15%. The following table shows the percentage values for the origin of the publications:

Table 2

List of origin of the articles

Country	No. of items	Percentage of items (%)
Argentina	1	2.50%
Chile	5	12.50%
China	3	7.50%
Colombia	10	25.00%
Korea	1	2.50%
Costa Rica	1	2.50%
Ecuador	1	2.50%
USA	2	5.00%
Spain	5	12.50%
Peru	6	15.00%
Romania	1	2.50%
Mexico	1	2.50%
Italy	1	2.50%
Venezuela	2	5.00%
Total	40	100.00%

The following table shows the particularities and similarities that were detected in reference to the factors of public transport routes that cause vehicular congestion from a systematic review. In this regard, it became evident that this problem has been a problem since previous years, which, with the increase in population and the increase in the number of vehicles in the cities, has become increasingly chaotic, with people being more and more exposed to long hours in traffic. If this situation continues in this way, in the following years it will be impossible to circulate in the cities of the world, affecting the mental health of the inhabitants as well as causing environmental changes due to the pollution that is generated. (Ledesma, et al., 2017)..

4. Discussion

Therefore, this section presents the main findings of the review in the following order: Table 3

Analysis of the problems and alternative solutions to reduce traffic congestion.

N°	Author	Problem	Proposed solution
1	(Martinez, 2017)	The process of motorization, the massive purchase of cars and exuberant supply of cabs.	Create additional lanes to increase vehicle capacity in the the peak direction, as well as to increase the green light time at traffic lights, allowing vehicles to circulate without having to stop at red lights for extended periods of time.
2	(Almeida, 2019)	The excessive increase in the vehicle fleet, the deficient investment capacity in road infrastructure projects, and the massive need for passenger transportation.	That the entities responsible for transportation and communications services, as well as the ATU, take the necessary immediate measures to mitigate the vehicle problem.
3	(Nguyen, Young, Currie, & Gruyter, 2020)	The increase in the vehicle fleet and the increase in population.	Explore the mode shift from public transport to automobile, estimate the impacts of creating congestion throughout the public network, and determine the net impact of congestion.
4	(Conrado, Serna, Garcia, & Florez, 2016)	Population growth and demand for public transportation.	Use Arcgis Network Analyst as a tool to optimize transportation routes in terms of distance, time, coverage, among others.
5	(Ospina, Toro, & Gallego, 2017)	Transport overload and amount of demand.	Design methodologies to find feeder routes in unconnected areas for a mass transit system, with the purpose of increasing coverage levels and optimizing the system's occupancy rate.
6	(Thomson & Bull, 2001)	The high number of transportation and road traffic demand	Analyze the consequences of traffic congestion and intervene simultaneously through adequate demarcation, new traffic lights, rationalization of transportation, and improvement of driving habits.
7	(Pérez, Bautista, Salazar, & Macías, 2014)	Deficiency in road infrastructure design and the use of inefficient traffic controllers.	Rethink the model used to obtain an analytical solution.
8	(Bull, 2003)	Deficiencies in the design and care of the roadway.	To design a long-term strategic vision for the development of the community, which allows for the compatibility of transit, growth and competitiveness.
9	(Restrepo, Salcedo, & Sánchez, 2017)	Long queues due to traffic.	Evaluate previous traffic models in order to propose a new one.
10	(Urbina, Torres, & Calderón, 2019)	Vehicle saturation	Implement a traffic light system and increase the number of lanes.
11	(Hernández, Mercado, León, & Román, 2017).	The collapse of streets and the lack of street maintenance.	Design a proposal to optimize public transportation routes, seeking to reduce the time and cost of transportation for users.
12	(Aaron, Gómez, Fontalvo, & Gómez, 2019)	The large number of vehicles and the current traffic regulations do little to improve the flow of traffic.	Restrictive transit measures
13	(Rodríguez, Gallego, Pardillo, Casado, & Guirao, 2020).	Road accident rate	Adapt traffic signals to reduce delays and mitigate conflict points.
14	(Fernández & Valenzuela, 2004)	Congestion, pollution, noise pollution, segregation, congestion hazards, visual intrusion, and inaccessibility to public transportation,	Apply broader techniques in transportation engineering to contribute to efficient urban and environmental management.

15	(Garcia, 2019)	The problem of road accidents	Develop new ways to manage roads through transparent information gathering.
16	(Ruiz, Mayorga, Aldas, & Reyes, 2019)	Residents are unhappy about paying taxes to reduce traffic congestion	Study society's willingness to pay for an externality and estimate the cost accordingly.
17	(Quirós & Agüero, 2018)	Fare problems for users of public transportation routes.	Identify the branches with rate per kilometer values that differ from the normal behavior of each group, in order to allocate resources for the evaluation of operational anomalies and propose solutions to prevent the problem from being passed on as costs to the users of the service.
18	(Gelves, Mora, & Lamos, 2016)	Deficiencies in the routing of vehicles with stochastic demands	Applying the Spiral Optimization algorithm
19	(Angeleli, Morandi, Savelsbergh, & Speranza, 2021)	Static traffic	The creation of routing systems that contribute to improving vehicular flow by restricting users through linear programming.
20	(Almeida, 2018)	Traffic, economic losses, reduced productivity and competitiveness, damage to health.	Restrict the circulation of vehicles, and invest in an integrated urban mass transit system with the safety and quality expected by users.
21	(Marquez, 2008)	Deficiencies in freight transportation	Analyze external and internal cost functions, with the purpose of carrying out a strategic remodeling of freight transportation.
22	(Payán & Pérez, 2019)	Deterioration of pavements and the creation of cracks due to asphalt wear.	Analyze the factors that cause pavement failures in order to develop design systems more adapted to reality.
23	(Zadobrischi, Mihai, & Dimian, 2020)	The increase in accidents and fatalities, due to poor traffic management.	Use alternative routes to reduce traffic risks.
24	(Quintero & Quintero, 2015)	Congestion, lack of accessibility to transportation service, and environmental impacts	Use alternative transportation systems that contribute to reduce congestion, such as: subway, Bus Rapid transit, zero fuel consumption transportation systems, bicycles, etc.
25	(Jia, Yan, Shen, & Zheng, 2017)	Urban traffic congestion and vehicular gas pollution.	It is suggested that a system dynamics model be used to establish traffic congestion charges and subsidies.
26	(Quintero, 2011)	Damage to the roads, deformations, landslides, among other road problems were found.	Carry out traffic engineering studies as well as design road inventories and categorization studies in order to find the results and provide effective solutions.
27	(Brenzini & Martinez, 2012)	The civil engineering professional does not have the necessary skills to perform efficiently.	Implement within the curriculum, the competency profile of the civil engineering professional, so that he/she is trained with the essential tools to be able to perform efficiently, responsibly, with values and ethics.
28	(Ledesma, et al., 2017)	The health risks caused by traffic congestion.	Optimize working environments and take care of drivers' health. Therefore, the collective cooperation of workers is required in order to contribute to an improvement in working conditions in the transportation sector.
29	(Rivadeneira, 2000)	Sustained economic growth, population and development	It is recommended to implement a program that optimizes the use of resources in relation to the specific needs of each country.
30	(Waniek, Raman, Alshebli, Hsien, & Rahwam, 2021)	Traffic networks and their vulnerability to disinformation attacks	After receiving the disruptive impact of the attack, it is imperative to detect and effectively counteract such disinformation.
31	(Rhonmer, 2020)	Deficiencies of Latin American public transportation systems in urban mobility and the environment.	It is recommended to analyze the process of urbanism in Latin America that is transformed with dominant rates of urbanization, causing a greater need for mobility.

32	(Changzhi, Changwei, Wenbo, & Dayong, 2016)	Assessment, classification and analysis of traffic congestion influencing factors in Chinese cities using online map data	It is recommended that a classification system be created to predict the factors influencing traffic congestion levels in the cities studied.
33	(Diaz, 2019)	High levels of vehicular congestion leading to the use of electric and solar roads.	Employ an electric transport mechanism that works under a wireless charging model, where electricity is transported by waves, making the battery self-recharging.
34	(Jiang, Astolfi, & Parisini, 2021)	The problem of traffic wave damping on a single-lane circular track and the modeling of human drivers' driving habits.	The shared control technique that takes into account a model of the driving habits of human drivers for the treatment of the traffic wave damping problem on a single-lane circular roadway
35	(Yingsheng, Xin, & Xuejunu, 2019)	Traffic congestion based on system dynamics: case study of Chongqing, China.	That the government implement new methods associated with the development of science and technology.
36	(Aliaga, 2019)	High levels of traffic congestion and its impact on health and the environment.	Implement strategies for the control of vehicles on the roads where a specific timetable is established for urban transportation companies, thus avoiding health problems and environmental damage due to vehicle pollution.
37	(Martinez, 2018)	Vehicular chaos	Use intelligent systems to control vehicular traffic by transmitting information to users.
38	(Delfin & Melo, 2017)	Efficiency of public transportation based on data envelopment analysis.	Implement measures to control the frequency and schedule of transportation services, in order to avoid long waiting times for the use of transportation units.
39	(Rondón, Reyes, & Urazán, 2013).	Excessive vehicular speed and structural deficiencies of transportation routes.	To carry out an analysis of the responses obtained in laboratory tests on the stiffness and strength levels of an asphalt mixture in order to know the effects of speed reduction on thick asphalt layers.
40	(Castán, Ibarra, Laria, Guzmán , & Castán, 2014).	Heavy traffic and poor traffic signals.	Use intelligent traffic light systems.

Note: Personal elaboration

(*) Non-experimental sources, therefore, do not show quantifiable data.

The following is a summary of the contributions of the different articles analyzed, subdivided as follows: Table 4

Category induction

Categories	Contributions
Transportation routes	It is suggested to classify roads according to the environment through which they run (road, crossroads or urban road) and no longer by their structural importance or traffic load, but rather, it is proposed to see what is the environment through which they circulate, since depending on this the infrastructures will be susceptible to different treatments (Rodriguez, Gallego, Pardillo, Casado, & Guirao, 2020). It is suggested to comply with the legislation where it is established that municipal authorities intervene in public transport, allowing to reduce congestion through the efficient use of roads. (Martínez, 2017). The instruction also establishes design criteria for the cross section of the road, both in the pedestrian zone and in the traffic lanes, highlighting the influence of the reduction of the roadway width as an element of traffic calming. Conrado, Serna, García, & Florez (2016) consider that the most appropriate response to vehicular congestion is not found in the construction or enlargement of the road network, but on the contrary, it is found in the correct planning and optimization of mass transportation, achieving greater efficiency and effectiveness in the good use of existing resources, in addition to controlling investments in infrastructure and influencing the sustained maintenance of roads, ensuring the access of individuals and satisfying the demand of users. According to Garcia (2019) The functionality of each section requires the provision of information on traffic demand and the estimated level of service throughout all hours of the year, which is reflected in various annual congestion indicators, including average travel speeds. However, studies have shown that many researchers evaluate the impact of traffic congestion through vehicle control, but the most appropriate way to measure traffic is through a study based on people and their mobility needs, which is a more concrete study in terms of impact. (Nguyen, Young, Currie, & Gruyter, 2020).
Vehicle congestion problems	Traffic congestion in cities constitutes the greatest challenge that our municipal authorities must face and resolve (Pérez, Bautista, Salazar, & Macías, 2014). Thomson & Bull (2001) pointed out that vehicular congestion is generated in conditions in which social demand approaches the capacity of the transited infrastructure, therefore, the period that transport delays increase disproportionately compared to those used in situations of low demand. The demographic explosion and the demand of the increase of the vehicle fleet aggravate the vehicular congestion in the big cities, besides that it is also related to the lack of investment given to the projects of design and maintenance of road infrastructures under the massive need of people. In just one year (2016-2017), the National Superintendence of Public Registries indicated that the vehicle load has increased by 35% in Callao and Lima. (Almeida, 2019). In practice, the main cause of traffic congestion is the friction or interference generated between vehicles in the traffic flow. This means that there are certain stretches of road where they tend to circulate using an average speed, specified by the speed demarcations, the frequency of intersections, and other conditions; but there are also certain stretches of high concentration where each additional vehicle experiences its own delay and by hindering the mobility of others, the congestion phenomenon begins. (Bull, 2003). Likewise, the imperfections of the roads and the inadequate maintenance that is given to them are evident. A key demonstration is the lack of a correct demarcation of the traffic lanes, their unjustified changes, or the bad establishment of bus stops, located specifically in places of a reduction in the width of the roadway, constituting the main cause of traffic congestion. (Thomson & Bull, 2001). At the level of population health we find that some studies have managed to determine that stress isone

	of the most significant consequences in the problems of vehicular congestion. In addition, it has been evidenced that the gradual increase in the number of vehicles has increased pollution, severely affecting the health of individuals (León, Sornoza, Reyes, & Andrade, 2018).
Infrastructure design	The inadequate design of road infrastructure and intersections of main avenues, including poor traffic signals, as well as the lack of traffic signs, are characteristic in the department of Tacna. (Urbina, Torres, & Calderón, 2019). Likewise, inadequate road design and maintenance will lead to unnecessary congestion. (Thomson & Bull, 2001). The poor design of road infrastructures and the inefficient use of traffic controllers are the main factors that have triggered the major problems that cities have been experiencing in terms of transportation. (Pérez, Bautista, Salazar, & Macías, 2014). It is a mistake to think about redesigning road axes and optimizing intersections in order to solve the increased traffic demands. This does nothing but evidence the deficient and old practice of trying to increase road capacity and the speed of cars. There is an inexplicable neglect of pedestrians, of the rights of public transport users and also of residents. According to (Garcia, 2019) Roads have been developed to provide a quality service, both in terms of safety, mobility and comfort, seeking an overall cost that makes them efficient and sustainable. Until now, it has been taken for granted that this was the case, but the reality is very diverse and, in general, little perceived by users, except for regrettable situations of pavement condition. For (Almeida, 2018) points out that the complex transportation situation in major cities such as Lima and Callao is due to the deficiency in planning and sustained updating of the transportation system, associated with low investments in road infrastructure and the lack of a sustainable development master plan.
Efficiency of traffic controllers	It is evidenced that vehicular traffic congestion is deficient, and that the control system, commonly lack efficiency and effectiveness (Urbina, Torres, & Calderón, 2019). In this sense, Martinez (2018), mentioned that transport intelligence systems allow significantly improving the efficiency and productivity of the use of transport infrastructures by making an adequate distribution of the existing demand on the capacity of transport routes; in addition, to contribute to the reduction of road congestion, overcoming unforeseen incidents, and contributing to the reduction of fuel consumption by making a better distribution of traffic to less congested roads. With respect to traffic controllers, it is considered that an adequate efficiency in the inventories of signaling and control devices allows a satisfactory evaluation of the parameters of function and sufficiency, based on the topographic and geometric characteristics of the road. These inventories make it possible to evaluate the types of signs, existing markings, the number of traffic lights and other devices installed on the site. (Quintero, 2011).
Restrictive traffic measures	According to Estupiñan's study (2018) cited in Ruiz, Mayorga, Aldas, & Reyes (2019) the increase in the number of vehicles, together with deficient territorial planning, have generated incalculable losses due to negative situations such as congestion, road accidents and pollution. One of the traffic control measures is the restriction of vehicles, based on their license plate numbers, in certain areas in order to mitigate the negative externalities of transportation such as environmental pollution, congestion and road safety. (Rhonmer, 2020). Likewise, it was proposed as a way to reduce delay times due to traffic congestion, that the provider increase the service rates in the different routers, in such a way that they can be used at a level of less than 60%, thus satisfying the restrictions in reference to the length of the queues and the long periods of delay and loss of time. (Restrepo, Salcedo, & Sánchez, 2017)..

5. Conclusions

The various sources have been analyzed and it was concluded that the main cause of traffic congestion is the accelerated population growth and the increase in the number of vehicles,

Likewise, it was possible to determine that the factors of the transportation routes that cause vehicular congestion, based on a systematic analysis from 2001 - 2021, are: transportation routes, the problem of vehicular congestion, infrastructure design, efficiency of traffic controllers and traffic restrictive measures. Also, the existence of a factor of exceptionality was evidenced, since the environment and the reality differ from one city to another, which allows us to infer that not all proposals are applicable or constitute the solution to all contexts, since there is a diversity of atypical factors in each study of traffic congestion. The most complex factor is the lack of road planning, therefore, it is very important to analyze in detail each component that influences the recovery of a pre- existing road.

And finally, it was proven that using as an alternative the creation and design of new routes, bypasses, or bridges, will not necessarily be the solution to the problem of vehicular congestion, being one of the most efficient alternatives to reduce congestion,

to take restrictive measures for circulation; One of the most efficient alternatives to reduce congestion is to take restrictive measures for circulation, using systems such as the "pico y placa" applied since 2020 in the capital, whose central axis is to restrict the circulation of vehicles according to their license plate number, allowing them to travel on certain routes only on pre-established dates, being their non-compliance sanctioned with tickets, or, otherwise apply the policy of the stick, such as the yellow line, avoidance and other roads, in which in order to travel a tax must be paid, so that the social costs for the free transit through the roads, limit the number of users of the same.

6. References

1. Aaron, M., Gómez, C., Fontalvo, J., & Gómez, A. (2019). Analysis of Vehicular Mobility in the Department of La Guajira using Simulation. The Case of Riohacha and Maicao. *Información tecnológica*, 30(1), 321-332. Obtenido de https://dx.doi.org/10.4067/S0718-07642019000100321
2. Aliaga, W. (2019). Vehicular transport congestion and its incidence in health and environment in the city of Puno. *Revista Científica Investigación Andina*, 19(1), 226-249. Retrieved from https://revistas.uancv.edu.pe/index.php/RCIA/article/view/746/644
3. Almeida, A. (2018). Vehicular congestion and the urban transport authority of Lima and Callao. *Grupo RPP Noticias.* Retrieved from https://alicia.concytec.gob.pe/vufind/Record/RULI_3b90286a8f51f607809dd41e194d0d7f
4. Almeida, A. (2019). Lima, the third traffic in the world. *Revista grupo RPP Noticias*. Retrieved May 23, 2021, from https://www.researchgate.net/profile/Alexandre-Del-Savio/publication/338412309_Lima_el_tercer_peor_trafico_del_mundo/links/5e13a533a6fdcc28375daeb7/Lima- el-tercer-peor-trafico-del-mundo.pdf
5. Angeleli, E., Morandi, V., Savelsbergh, M., & Speranza, M. (2021). System optimal routing of traffic flows with user constraints using linear programming. *European journal of operations research*, 293(3), 863-879. Retrieved from https://www.sciencedirect.com/science/article/pii/S0377221720310894
6. Brenzini, D., & Martínez, M. (2012). Civil engineer profile: a view from his generic and specific competences. *Orbis Revista Científica Ciencias Humanas*, 8(22), 28-48. Retrieved from https://www.redalyc.org/articulo.oa?id=70923776002
7. Bull, A. (2003). Traffic congestion. The problem and how to deal with it. *CEPAL Review*, 81. Retrieved May 26, 2021, from https://repositorio.cepal.org/bitstream/handle/11362/27813/6/S0301049_es.pdf
8. Castán, J., Ibarra, S., Laria, J., Guzmán , J., & Castán, E. (2014). Intelligent agent-based traffic control. *Polibit Journal (*50), 61-68. Retrieved from https://redib.org/Record/oai_articulo507602-control-de-tr%C3%A1fico- basado-en-agentes-inteligentes
9. Changzhi, B., Changwei, Y., Wenbo, K., & Dayong, W. (2016). Evaluation, Classification, and Influential Factors Analysis of Traffic Congestion in Chinese Cities Using the Online Map Data. *Mathematical Problems in Engineering*, 1-10. Retrieved from https://www.researchgate.net/publication/308626923_Evaluation_Classification_and_Influential_Factors_Analysis_of_Traffic_Congestion_in_Chinese_Cities_Using_the_Online_Map_Data
10. Conrado, A., Serna, U., García, J., & Florez, O. (2016). Analysis of Passenger Transportation Routes through Network Analyst Tool of Arcgis. Case Applied in Medellin City Analysis of Passenger Transportation Routes through Network Analyst Tool of Arcgis. Case Applied in Medellin City. *Ingenierias USBMed.* , 7(2), 89-95. Retrieved from https://www.researchgate.net/publication/308905321_Analisis_de_Rutas_de_Transporte_de_Pasajeros_Mediante_la_Herramienta_Network_Analyst_de_Arcgis_Caso_Aplicado_en_la_Ciudad_de_Medellin_Analysis_of_Passenger_Transportation_Routes_through_Network_Analys
11. Delfin, V., & Melo, A. (2017). Public transport efficiency in the city of Morelia, Michoacán (Mexico) in 2015: a data envelopment analysis. *Journal of the Faculty of Economic Sciences: Research and Reflection,* 30(2), 7-23. Retrieved from https://www.redalyc.org/articulo.oa?id=90952679002
12. Delgado, W. (2011). Types of scientific articles. *Revista Estomatológica Herediana*, 21(3), 123-124. Retrieved from https://www.redalyc.org/articulo.oa?id=421539365001
13. Diaz, J. (2019). Electric roads, solar roads: sections adapted to a new mobility. *Technical journal of the spanish road association (*219). Retrieved from https://dialnet.unirioja.es/servlet/revista?codigo=2677
14. Estupiñan, N. (2018). Shared mobility: a paradigm shift for equity and inclusion. *Transport and development in Latin America*, 1, 9-10.
15. Fernández, R., & Valenzuela, E. (2004). Transit environmental management: how transportation engineering can contribute to the improvement of the urban environment. *EURE Journal*, 30(89), 97-107. Retrieved from https://www.redalyc.org/articulo.oa?id=19608906
16. Garcia, A. (2019). Transparency on the road. *Revista de la Asociacion Tecnica de Carreteras*, 180. Retrieved from http://www.atc-piarc.com/rutas_historico.php?rID=211
17. Gelves, N., Mora, R., & Lamos, H. (2016). Solving the vehicle routing problem with stochastic demands using spiral

optimization. *Revista Facultad de Ingeniería*. Retrieved from http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0121-11292016000200002

18. Hernández, G., Mercado, M., León, S., & Román, F. (2017). Proposal for the Optimization of Urban Public Transport Routes: Case Study - Street Closings at Tuxtla Gutiérrez City. *Global Partnerships for Development*

and Engineering Education., 29-21. Retrieved from http://www.laccei.org/LACCEI2017- BocaRaton/full_papers/FP213.pdf

19. Jia, S., Yan, G., Shen, A., & Zheng, J. (2017). A System Dynamics Model for Determining the Traffic Congestion Charges and Subsidies. *Arabian Journal for Science and Engineering*, volume, 42, 5291-5304. Retrieved from https://doi.org/10.1007/s13369-017-2637-5

20. Jiang, J., Astolfi, A., & Parisini, T. (2021). Transportation Research Part C: Emerging Technologies. *Sciencedirect Magazine*, 128. Retrieved from https://www.sciencedirect.com/science/article/pii/S0968090X21001297?via%3Dihub

21. Ledesma, R., Poo, F., Úngaro, J., López, S., Cirese, A., Enev, A., & Tosi, J. (2017). Work and Health in Taxi Drivers. *Science & Work Journal*, 19(59), 113-119. Obtenido de https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-24492017000200113&lng=es&nrm=iso

22. León, C., Sornoza, J., Reyes, G., & Andrade, A. (2018). Use of Technology for software construction that allows recommending solutions in vehicle. *International Journal of Innovation and Applied Studies*, 24(4), 1424-1439. Retrieved from http://www.ijias.issr-journals.org/abstract.php?article=IJIAS-18-146-02

23. Marquez, L. (2008). Internal and external cost functions in a strategic freight transportation model. *Revista Facultad de Ingeniería*, 17(25). Retrieved from https://redib.org/Record/oai_articulo1695757-funciones-de- costos-internos-y-externos-en-un-modelo-estrat%C3%A9gico-de-transporte-de-carga

24. Martínez, M. (2017). Public bus services versus congestion and pollution in Lima and Callao. Revista economía, 40(79), 47-86. Retrieved May 15, 2021, from https://dialnet.unirioja.es/servlet/articulo?codigo=6414015

25. Martínez, M. (2018). New intelligent transportation systems for a developing city, Lima - Peru. *Revista ECIPERÚ*, 5, 2, 8-11. Retrieved from https://revistas.eciperu.net/index.php/ECIPERU/article/view/307

26. Moreno, B., Muñoz, M., Cuellas, J., Domancic, S., & Villanueva, J. (2018). Systematic Reviews: definition and basic notions. *Revista Clinica Periodoncia Implantol*, 11(3), 184-186. Obtenido de https://scielo.conicyt.cl/pdf/piro/v11n3/0719-0107-piro-11-03-184.pdf

27. Nguyen, D., Young, W., Currie, G., & Gruyter, C. (2020). Traffic congestion relief associated with public transport: state-of-the-art. *Public Transport Journal*, 12(2). Retrieved from https://www.researchgate.net/publication/339459698_Traffic_congestion_relief_associated_with_public_transpor t_state-of-the-art

28. Ospina, D., Toro, E., & Gallego, R. (2017). A methodology for creating feeding routes in mass transit systems.

Revista Facultad de Ingeniería, 26(45), 9-21. Obtenido de http://doi.org/10.19053/01211129.v26.n45.2017.6052

29. Payán, F., & Pérez, F. (2019). Examples of Pavement Rupture with Bituminous Pavements. *Revista de la asociación técnica de carreteras*, 180. Retrieved from http://www.atc-piarc.com/rutas_descargar.php?numID=180

30. Pérez, F., Bautista, A., Salazar, M., & Macías, A. (2014). Vehicular traffic flow analysis through a macroscopic model. *Dyna Magazine*, 81(184), 36-40. Retrieved May 20, 2021, from https://www.redalyc.org/pdf/496/49630405005.pdf.

31. Quintero, J. (2011). Road inventories and categorization of the road network in Traffic and Transportation Engineering studies. *Revista Facultad de Ingeniería*, 20(30), 65-78. Retrieved from https://dialnet.unirioja.es/servlet/articulo?codigo=3758451

32. Quintero, J., & Quintero, L. (2015). Sustainable transportation and its role in the development of the urban environment. *Revista Ingeniería y Región*, 14(2), 87-97. Retrieved from https://dialnet.unirioja.es/servlet/articulo?codigo=5432139

33. Quirós, C., & Agüero, J. (2018). Classification of the routes of the Costa Rican bus mode public transport network. *Revista de la Universidad de Costa Rica*, 28(2), 112-136. Retrieved from https://dialnet.unirioja.es/servlet/articulo?codigo=6493541

34. Restrepo, C., Salcedo, O., & Sánchez, J. (2017). Traffic model for the interconnection of networks and operators through MPLS-TE. *Revista Facultad de Ingeniería*, 26(44), 85. Retrieved from https://www.researchgate.net/publication/312963037_Traffic_model_for_the_interconnection_of_networks_and_ operators_using_MPLS-TE/link/588b4655aca272137ab081bf/download

35. Reyes, H. (2020). Review articles. *Revista médica de Chile*, 148(1), 103-108. Retrieved from https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0034-98872020000100103&lng=en&nrm=iso&tlng=en

36. Rhonmer, W. (2020). Impact of Latin American public transport systems on urban mobility and the environment. *Publications in Science and Technology*. (13), 38-53. Retrieved May 17, 2021, from https://dialnet.unirioja.es/servlet/articulo?codigo=7474439

37. Rivadeneira, S. (2000). Latin America and the Caribbean: Sustained Economic Growth, Population and Development. *CEPAL Review*. Retrieved from

https://repository.eclac.org/bitstream/handle/11362/7163/S9980528_es.pdf?sequence=1&isAllowed=y

38. Rodríguez, A., Gallego, J., Pardillo, J., Casado, N., & Guirao, B. (2020). Road accidents in Spanish crossings under a territorial approach. *Revista Técnica de la Asociación Española de la Carretera*. (228), 38-50. Retrieved from https://dialnet.unirioja.es/servlet/revista?codigo=2677

39. Rondón, H., Reyes, F., & Urazán, C. (2013). Effect of decreasing vehicular speed on the durability of an asphalt layer. *Ingeniare. Chilean journal of engineering*, 21(1), 139-146. Obtenido de https://dx.doi.org/10.4067/S0718-33052013000100012

40. Ruiz, E., Mayorga, M., Aldas, S., & Reyes, P. (2019). The cost and perception in society due to vehicular congestion caused by urban public transport in the city of Ambato, Ecuador. *Revista espacios*. *magazine*, 2. Retrieved May 24, 2021, from https://www.revistaespacios.com/a19v40n43/a19v40n43p22.pdf

41. Thomson, I., & Bull, A. (2001). Urban traffic congestion: causes and economic and social consequences. *Cepal Journal*. Retrieved May 20, 2021, from https://repositorio.cepal.org/handle/11362/6381

42. Urbina, C., Torres, A., & Calderón, R. (2019). Optimization of vehicular flow at the road intersection of Av. Bolognesi and Av. Gustavo Pinto in the city of Tacna. *Revista Ingeniería investiga*, 1(1), 65-71. Retrieved from http://revistas.upt.edu.pe/ojs/index.php/ingenieria/article/view/123

43. Waniek, M., Raman, G., Alshebli, B., Hsien, J., & Rahwam, T. (2021). Traffic networks are vulnerable to disinformation attacks. *Scientific Reports* (5329). Retrieved from https://www.nature.com/articles/s41598-021- 84291-w

44. Yingsheng, S., Xin, L., & Xuejunu, L. (2019). Research on Traffic Congestion Based on System Dynamics: The Case of Chongqing, China. *Complexity Journal*, 1-13. Retrieved from https://downloads.hindawi.com/journals/complexity/2020/6123896.pdf

45. Zadobrischi, E., Mihai, L., & Dimian, M. (2020). Traffic Flow Density Model and Dynamic Traffic Congestion Model Simulation Based on Practice Case with Vehicle Network and System Traffic Intelligent Communication. *Symmetry Magazine*, 12(7). Retrieved from https://www.mdpi.com/2073-8994/12/7/1172/htm