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System approach in urban transportation case: Huánuco region-Peru

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Abstract: The growing increase in vehicles produces serious congestion problems in urban centers; This situation raises questions about the control methods of the variables of interest in this problem. The case study presented is an approach to the topic and is based on a hypothetical scenario that is modeled and simulated with a systemic approach, considering the individual movement of the vehicles. A methodology is presented for the statistical analysis of the simulation results. The article shows the main aspects in the modeling of a basic traffic control system to simulate it and observe its behavior in the rhythm of arrivals, travel times and speeds, as well as monitoring traffic, in this sense the most important aspects will be illustrated. Relevant aspects that must be addressed in the configuration of a simulation experiment, such as determining the appropriate simulation time, the number of repetitions, the warm-up period, the evaluation of indicators to submit them to the normality test, and the application of techniques of variance reduction, experiencing congestion and evaluating measures to control excessive speed. The operation of traffic lights at intersections is also modeled and evaluated.
Keywords: *Simulation, Sustainable solutions for urban mobility, Systems, Urban transportation, Vehicle congestion.*

1. Introduction

In the area of vehicular traffic, the problem lies in the international environment; during the 90s, there was an increase in the number of registered vehicles, harming the quality of life; The increase in these is due to many factors such as people's income, expansion of financial credits, the decrease in costs in the automotive industry among others [1]

The major problems of vehicular traffic in the world, is the inadequate planning and design of streets and avenues, this generates greater future problems that are difficult to combat, added to the cultural, political and economic elements of each country in addition to stress problems. and bad mood that this problem causes for the inhabitants of cities with enormous vehicular traffic problems [2]. In the international context we have India, where one of its main problems is traffic and traffic, which shows that the poor condition of many of the communication routes is in very poor condition. They do not have the corresponding signage, and they also lack a safe lighting system [2].Despite having these deteriorated roads, in India circus there are around 120 million cars. Furthermore, in this country up to 10% of deaths occur due to traffic accidents. Because Indian roads and tracks do not have proper signage, many times the operation of traffic is at the mercy of the good will of drivers who, despite not having road education, do everything possible to ensure that the traffic is not chaotic, something that is difficult to achieve. In another context, the city of Lima is ranked 7th of the 10 cities with the most traffic in the world according to the company TomTom.

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The famous rush hours in this city are growing every time, in recent years traffic has increased from 5 to 9 hours a day, and this generates a certain economic loss for individuals who need to travel to their jobs, and stress among employees increases. drivers, causing conflicts in the middle of the road over "who passes first." This is due to the exponential growth of the vehicle fleet in the city, during 2023, automotive activity increased by 1.03%, due to the greater commercialization of light vehicles, promoted by commercial strategies and fairs, as well as by public and private tenders [3]. Lima has third place with 58% of overtime journey. In other words, a 60-minute trip to Lima under normal conditions lasts, on average, almost 95 minutes. Things get worse in the mornings and afternoons.

Vehicular traffic in the city of Huánuco has become and an everyday informality, since the drivers lack a respective circulation authorization granted by the Provincial Municipality, since they lack a driver's license and in some cases they turn out to be minors, a large vehicular and pedestrian flow, puts at risk the public safety of Huanuqueña citizens.

Added to this is that drivers tend to park in zones are prohibited, but part of the blame lies with pedestrians or users of transportation services, who get on anywhere on the road, whether it is a bus stop or not, as a consequence drivers tend to park where there is a passenger.

It is very common to see a vehicle falling apart on the roads in Huánuco, this is due to a maintenance problem, where the authorities do not regularize this problem, in addition, more pollution is generated, since they emit odors and noises that are harmful to the city's ecosystem.Added to this is the exponential growth of the vehicle fleet; in 2021, between private and public vehicles in Huanuco, nearly 80 thousand vehicles have been registered in various categories, of which 71.15% are minor vehicles and 28.85% are light vehicles and heavy [4].

The population growth in Huánuco and the poor management of the authorities over time, led to its streets not having a projection, and that is why today the number of streets that exist in the city and especially their width seems limited.

2. Related Works

In recent years there has been a significant increase in tools to simulate situations where predictions are estimated for the improvement of vehicular traffic. There is numerous researches aimed at predicting and simulating broad contexts that allow correct decisions to be made. In this investigation, a universally accessible, sustainable, efficient, safe and low-carbon public transportation system is important for the improvement of the environment and the community [5].In a recent study, [6].they addressed the problem of jointly optimizing the design of the road network and vehicle routes in transportation systems; the objective was to minimize congestion and impacts on the network derived from passenger and freight vehicle traffic.

The problem was modeled in congested transportation networks, such as in an urban center, a heuristic algorithm was used to find the best network configuration and the best vehicular routes. In a study published in Tunneling and Underground Space Technology, the authors present an innovative solution to address the problem of last mile delivery in urban environments. The proposed approach is based on underground logistics systems (ULS), using tunnels or pipelines to transport goods, a strategy that is efficient in terms of space, energy and carbon emissions [7]. The results obtained by showed that the developed model and algorithm can help optimize emergency routes, contributed to better decision making in emergency situations. This approach has the potential to significantly improve the effectiveness of incident management systems [8]. Urban transportation is a complex system that involves various interconnected parts, such as road infrastructure, vehicle types, regulation, and user behavior. In this context, a systemic approach is essential to address problems such as congestion and environmental pollution. An efficient transportation system must consider not only routes and vehicles, but also the impact on the urban environment and people's quality of life. In the study carried out by [9] proposed a public transportation reorganization system to improve urban vehicle flow in the district of

Huánuco, Peru. Its approach reflects a systemic vision when analyzing the congestion caused by the lack of adequate infrastructure and the disorder in public transport services such as buses, minibuses, combis, coasters and motorcycle taxis. The study is based on four stages: data collection, creation of the transportation network, zoning and connectivity, and the generation of an origin/destination matrix for public transportation. This systemic approach allowed us to design a mass transit system with one main route and seven feeder routes, proposing changes that would positively affect the entire urban transportation system. Researchers point out that urban public transport plays a crucial role in sustainable development and in the transition from private vehicles to public transport systems. In their case study on Elbasan, they analyzed the operation of urban transport terminals, identified problems and proposed recommendations to improve the quality of public transport. Additionally, the study addressed the challenges and implications of the transition from private vehicles by highlighting the importance of modernizing public transportation systems to meet community mobility needs [10]. The urban transportation system encompasses all elements related to transportation within a city, including infrastructure, rolling stock and traffic flows, which together form a functional entity. In cities, especially in commercial and business areas, the high concentration of human activities leads to traffic congestion. To address this problem, both supply and demand side strategies were implemented, with the aim of reducing the negative externalities associated with transportation. The author highlights that city-level strategies, such as transit-oriented development, seek to encourage the use of public transportation and reduce dependence on private automobiles [11]. The author proposed a proposal to improve the fluidity of vehicular traffic through simulation and optimization of traffic light scheduling. Using the Simulation of processes and changing traffic light times, it was possible to reduce queues and waiting times for drivers, which resulted in better road operation. In summary, various studies have demonstrated the importance of addressing urban transportation problems in developing countries through the implementation of sustainable policies and strategies. The use of simulations and genetic algorithms can be an effective tool to improve traffic efficiency and flow, reduce congestion and promote more sustainable urban mobility [12]. In this article, the authors developed a simulation method of the random order execution process to help the transport company "Trans-Service" Ltd. make decisions about using its own fleet or hiring leased vehicles, as well as as the rational sequence of orders. They used a transportation cycle simulation model with discrete time and a random incoming flow of orders. They applied rules to select and distribute orders among existing vehicles. The results show the dependencies of the number of orders received, executed and rejected by the carrier, as well as the number of own vehicles used and unfulfilled orders requiring leased fleet, under different inflow intensities and order compatibility levels [13]. In the study carried out by xx, freight rates for the transportation of bulk soybeans were analyzed within the unimodal and multimodal systems. These researchers evaluated in detail the transfer of this important commodity from São Simão, a large soybean producer in the state of Goiás, Brazil, to Osvaldo Cruz, an important processing center in São Paulo. Using statistical and simulation techniques, they were able to compare the resulting rates when using a unimodal system based solely on road transportation, versus a multimodal approach that combines different modes of transportation. Their findings demonstrated that, for the specific route studied, the multimodal system managed to significantly reduce final freight rates by 33.3% compared to exclusive road transport. This research highlights the importance of applying an integrated transportation systems approach, seeking to optimize logistics costs for low value-added products such as soybeans, where freight costs represent a considerable portion of the final price [14]. In the study, an exhaustive analysis of the transportation systems in Colombia was carried out, focusing on their relationship with the country's competitiveness. The researchers applied a qualitative methodology based on interviews with eight experts, who answered thirteen open questions on the topic. The results obtained revealed important deficiencies in the Colombian transportation infrastructure, highlighting the preponderance of the land mode as the most used, despite the high costs it entails and its negative impact on national competitiveness [15].

3. Theoretical framework

3.1. Transportation

According to [28] it is an activity of the tertiary sector, understood as the movement of objects or people from one place (point of origin) to another (point of destination) in a vehicle (transport means or system) that uses a certain infrastructure (transport network). . This has been one of the tertiary activities that has experienced the greatest expansion over the last two centuries, due to industrialization; to the increase in trade and human movement both nationally and internationally

3.2. Transurban Bearing

Mentions [29] urban transportation refers to the movement of people and goods within a city or metropolitan area. It is a vital component of urban infrastructure and plays an important role in the economic, social and environmental development of a city. Michael Taylor, in his book "Urban Transportation and Transportation Planning in Cities," Taylor highlights the importance of considering urban transportation as a complex system. It proposes that an effective urban transportation system must take into account key elements, such as physical infrastructure (streets, highways, railways), modes of transportation (cars, bicycles, public transportation), transportation demand, travel patterns population mobility and efficient resource management.

3.3. The Public Transport

[30] It is the term applied to collective passenger transportation. Unlike private transportation, public transportation travelers have to adapt to the schedules and routes offered by the operator. Travelers usually share the means of transportation and it is available to the general public. It includes various means such as buses, trams, minibuses, buses. Demand transportation day.

Mentions [29] It refers to the number of trips made in an urban area and how it varies over time. Understanding transportation demand involves analyzing the factors that influence transportation mode choice, such as cost, availability, convenience, and user preferences.

3.4. Modes of Transportation

[28] Urban transportation modes include private vehicles (cars, motorcycles), public transportation (buses, trains, trams), bicycles, walking, and other modes of transportation such as electric scooters and car-sharing systems. The analysis of the different modes of transport involves considering their efficiency, capacity, accessibility and sustainability.

3.5. Planning of Transportation

A recent study [10] evaluated the functionality of urban transport terminals in Elbasan City. The study identified potential shortcomings in their modernization process and provided actionable recommendations to enhance the quality of urban transit services. It also investigated the challenges and impacts associated with transitioning from private vehicles to urban public transport systems within the city.

3.6. I havetools - VISSIM

Vissim is a simulation software, designed to simulate multimodal traffic at a microscopic level, that is, it can simulate the interaction of the different modes of transport involved. In this case, the simulation model is used at a microscopic level, meaning that we can see each vehicle in detail, observing which route each one chooses, whether they make lane changes, the separation between them,

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etc. The software allows you to represent the details of the infrastructure of the analyzed network, that is, number of lanes, width, slope, curves, etc. Another virtue of this software is that it allows us to work on a background image that can be imported from a geographic information system such as Google Maps or Google Earth or work on the map that the program includes.

Simulation Model

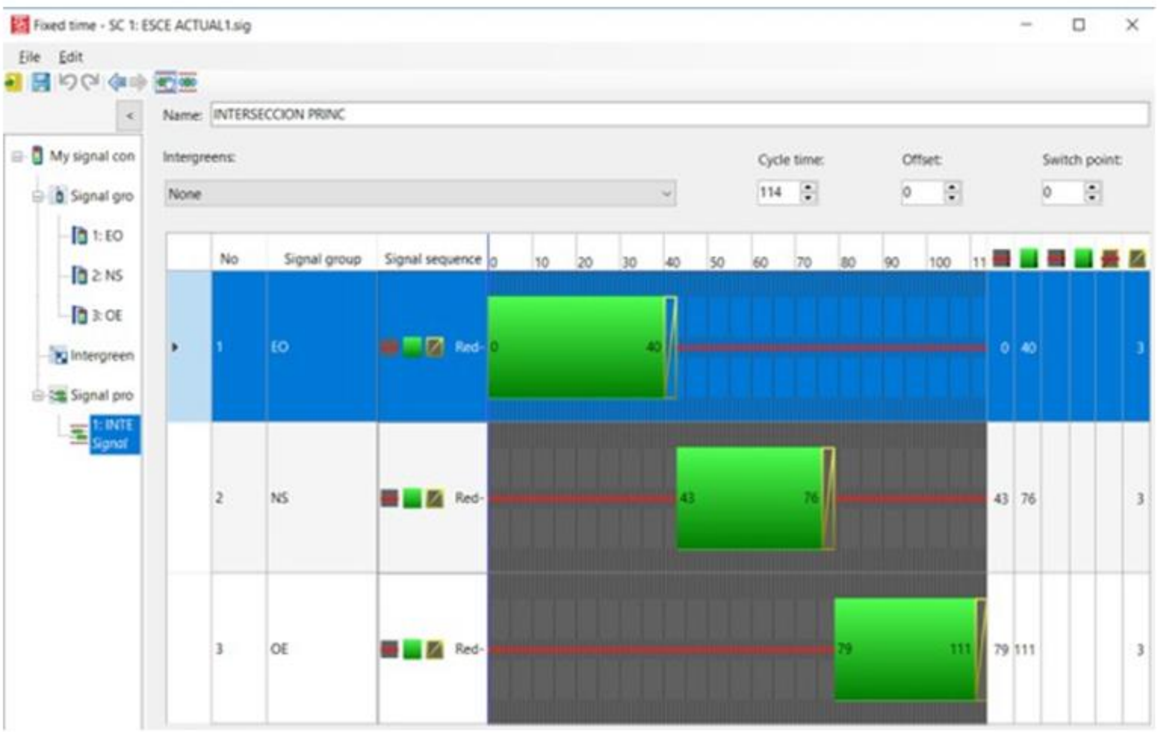

Figure 1.
Traffic simulation model.

This simulation contains data on the type of vehicles and their speed. These specifications are close to the real ones, since the variability that occurs between drivers, signs or external activities gives us unforeseen situations; however.

Table 1.
Speed facts.

Camión	30 – 45km/h
Bus	30 – 60km/h
Microbús	30 – 60km/h
C2R2.	15 – 30 km/h
Autos	50 – 60km/h
Moto Lineal	10 – 20km/h
Moto Taxi	10 – 20km/h

If the speed of the vehicles has been configured as follows:

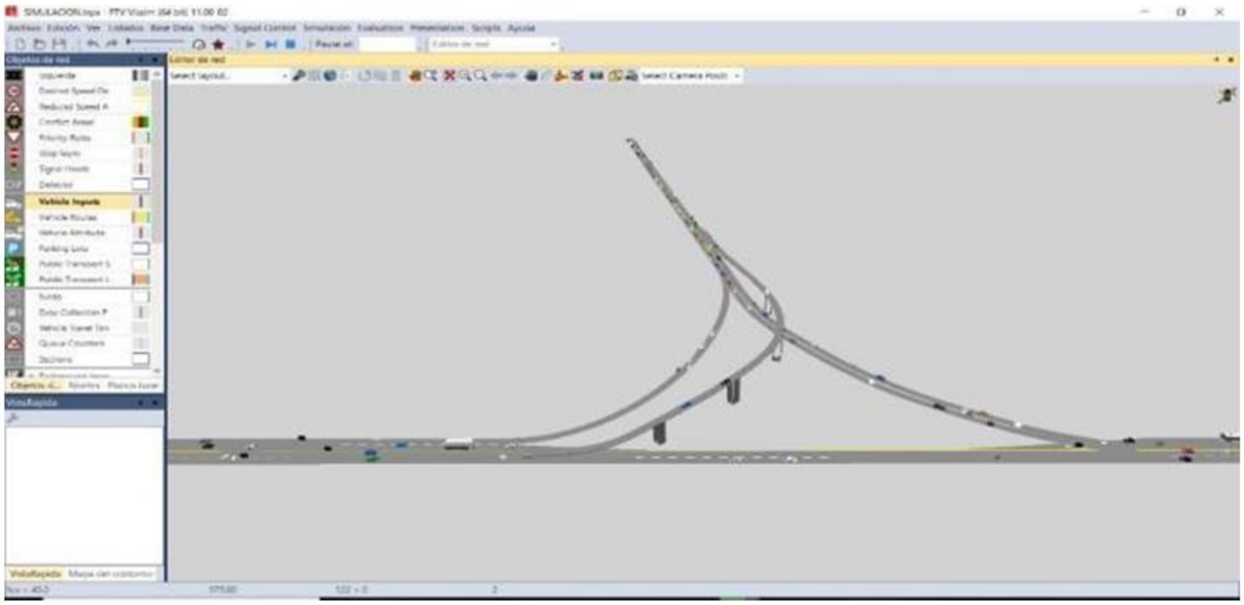

Figure 2.
Panoramic view of the intersection.

The computer-simulated intersection helps us understand the path that the vehicles travel, as well as the dimensions of this intersection.

Figure 3.
Panoramic view to the turns.

This panoramic view shows the directions that vehicles take to move at intersections, where the complexity of the routes and the indication of traffic that is generated can be seen. It can be seen that vehicle feeding occurs in three ways, which are divided into two each. It is marked in three colors, red, yellow and blue. All of these interact, it is sensed that where the three colors meet there will be a greater flow of vehicles and greater traffic.

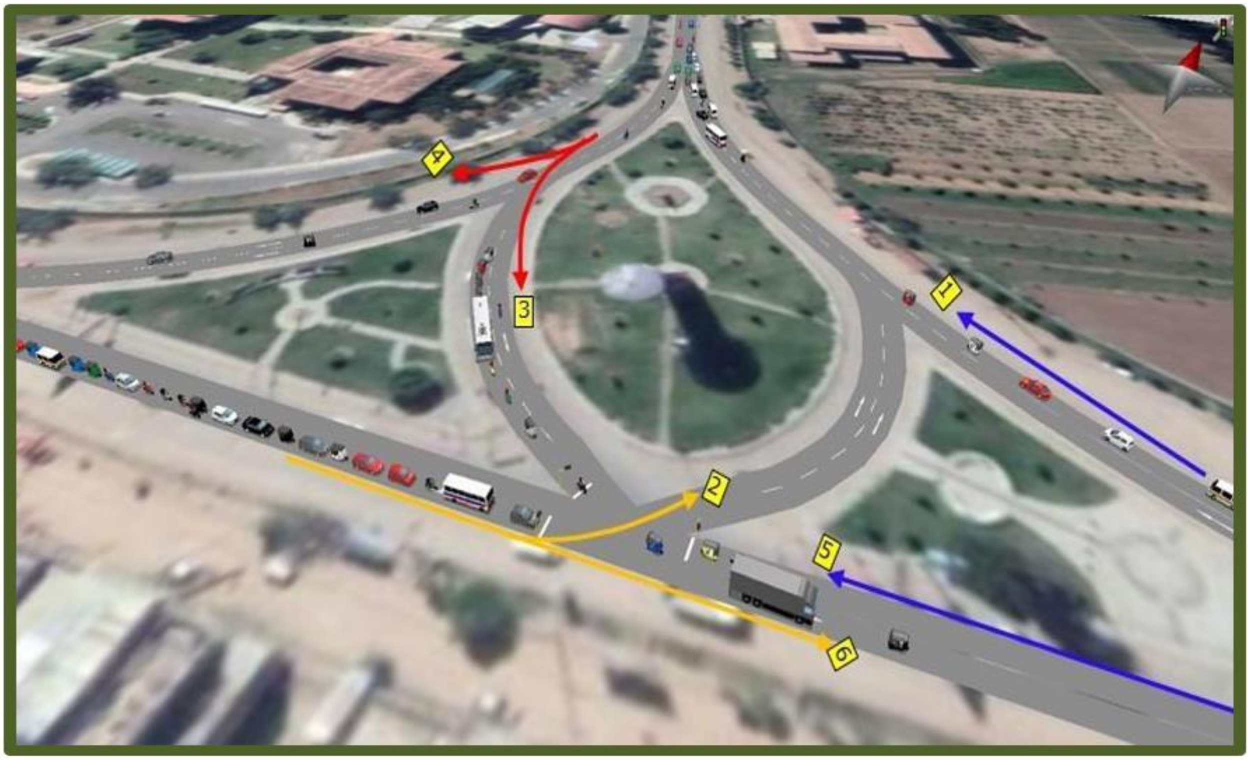

Figure 4.
Scene project

This view allows us to observe the complex of intersections and the shape it has from another angle.

3. Results

Table 1.
Data processing.

Aforo según puntos de giro

	06:00 a 07:00 am	07:00 a 08:00 am	12:00 pm a 01:00 pm	1:00 pm a 02:00 pm	5:00 pm a 06:00 pm	6:00 pm a 07:00 pm	7:00 pm a 08:00 pm
Punto 1	1344	2872	1273	1411	1468	1419	1400
Punto 2	308	1786	272	311	273	373	426
Punto 3	774	1922	923	1077	683	794	769
Punto 4	716	1767	840	974	914	1191	1051
Punto 5	568	1057	515	493	586	556	532
Punto 6	1131	1906	1337	1320	1191	1800	1675
Total	4840	11309	5159	5584	5114	6131	5851

Note: According to the turning points to evaluate the vehicular traffic system of the Cayhuayna oval intersection. Huanuco.

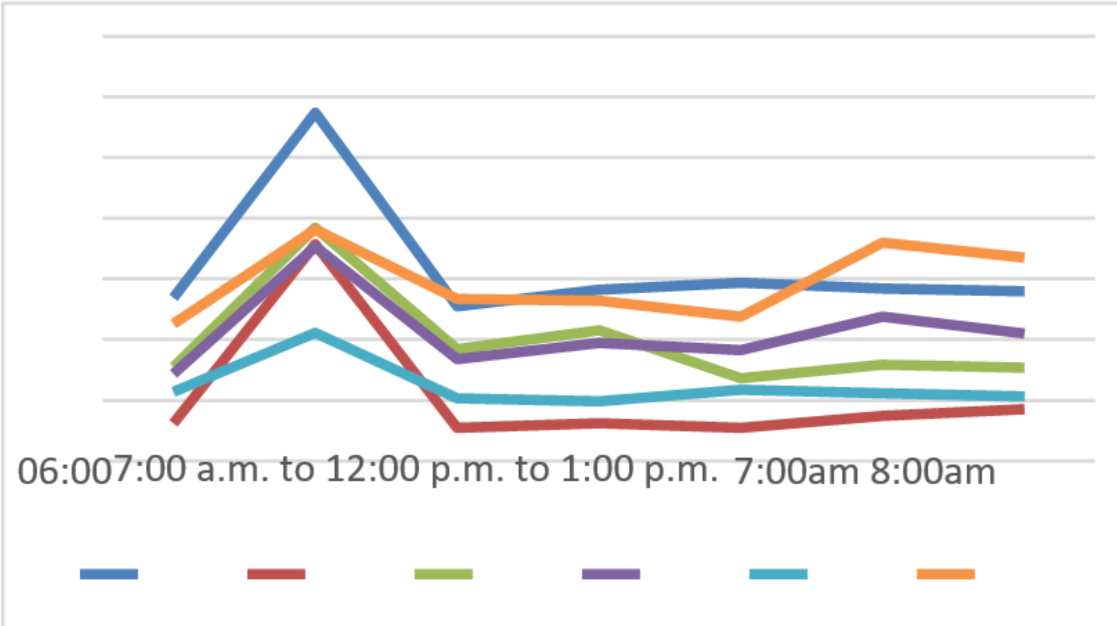

Figure 5.
Capacity according to the turning points to evaluate the vehicular traffic system at the intersection of the Cayhuayna – Huánuco oval.

Note: It can be seen that the greatest vehicle capacity occurs between 7 and 8 am. Likewise, it is observed that the maximum capacity is at point 1 and the lowest at point 5.

Table 3.
Total gold according to schedules to evaluate the vehicular traffic system of the intersection of the Cayhuayna - Huánuco oval.

Aforo total según horarios para evaluar el sistema del tránsito vehicular de la intersección del ovalo Cayhuayna - Huánuco.

	LIVIANOS				PESADOS										
					MICRO (Custer)	OMNIBUSES		CAMIONES							
MOTO LINEAL	MOTO CAR	AUTOS	CAMIONETAS	COMBIS	CUSTER B2	OMNIB.B2	OMNIB.B3-1	CAM.C2	CAM.C3	CAM.C4	TRAILER T2S2	TRAILER T3S3	C2R2	C3R3	TOTAL /15min.
590	782	1114	27	87	6	2	11	21	8	2	3	0	0	0	**2,651**
617	774	1137	41	74	12	15	18	14	12	3	3	0	0	0	**2,718**
664	862	1185	47	83	8	0	15	12	14	0	3	0	0	0	**2,891**
640	912	1300	42	83	15	2	19	20	14	2	5	0	0	0	**3,050**
2511	3329	4736	156	326	41	18	61	66	47	6	14	0	0	0	**11309**

Note: It can be seen that the highest capacity for vehicular traffic occurs at point 1. Likewise, it is observed that the maximum capacity occurs at all points from 7 to 8 am.

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Table 4.
Afgold According to schedules.

Horario	Punto 1	Punto 2	Punto 3	Punto 4	Punto 5	Punto 6	Total
06:00 a 07:00 am	1344	308	774	716	568	1131	4840
07:00 a 08:00 am	2872	1786	1922	1767	1057	1906	11309
12:00 pm a 01:00 pm	1273	272	923	840	515	1337	5159
1:00 pm a 02:00 pm	1411	311	1077	974	493	1320	5584
5:00 pm a 06:00 pm	1468	273	683	914	586	1191	5114
6:00 pm a 07:00 pm	1419	373	794	1191	556	1800	6131
7:00 pm a 08:00 pm	1400	426	769	1051	532	1675	5851

Note: According to schedules for the vehicular traffic system of the intersection of the Cayhuayna - Huánuco oval. Figure 2 *Afgold according to schedules to evaluate the vehicular traffic system at the intersection of the Cayhuayna – Huánuco oval.*

Table 5.
Queue length for each turn of the vehicular traffic system at the intersection of the Cayhuayna - Huánuco oval.

Punto	Longitud de cola (m)		% Variación
	Actual	Propuesta	
1	176.83	89.14	-98%
2	105.47	158.51	33%
3	194.57	149.14	-30%
4	175.85	85.14	-107%
5	134.07	75.14	-78%
6	135.06	149.52	10%

Note: The evaluation of all the turns shows the predominant vehicles such as cars, followed by motorcycle taxis and linear motorcycles with a good participation. Among heavy vehicles, the predominant one is the C2 type truck, followed by the B3-1 bus. The presence of Trailers T3S3 or C2R2 or C3R3 has not been appreciated.

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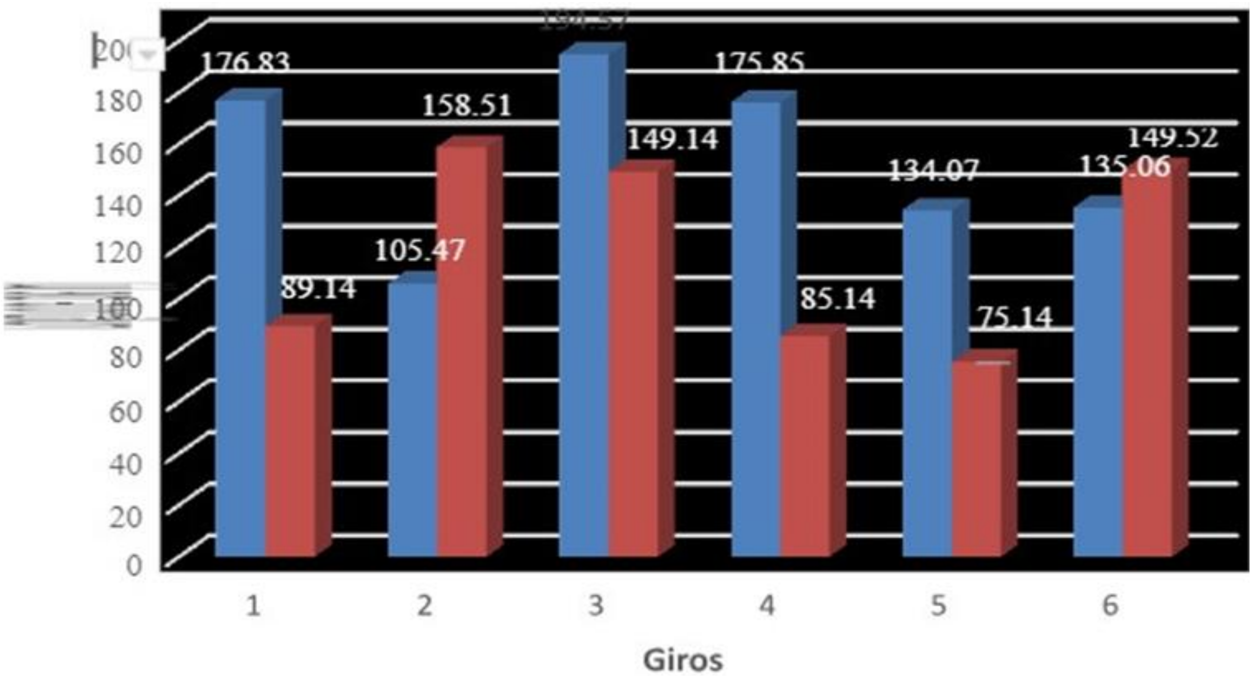

Figure 6.
Queue length for each turn of the vehicular traffic system at the intersection of the Cayhuayna - Huánuco oval.

Note: It can be seen that the longest tail length occurs in the movement - turn No. 03 (194.57 m.) and the shortest occurs in the movement - turn No. 02 (105.47 m.) On the other hand, it can be seen that, in the proposal, the greatest variation occurs in the movement – turn No. 04 (-107%) and the least variation in the movement turn No. 06 (10%).

Table 6.
Delays of vehicles for each turn of the vehicular traffic system at the intersection of the Cayhuayna - Huánuco oval.

Punto	Retrasos (seg)		% Variación
	Actual	Propuesta	
1	40.7	32.51	-25%
2	217.33	31.34	-593%
3	45.22	29.13	-55%
4	30.18	19.7	-53%
5	173.15	21.51	-705%
6	445.66	33.35	-1236%

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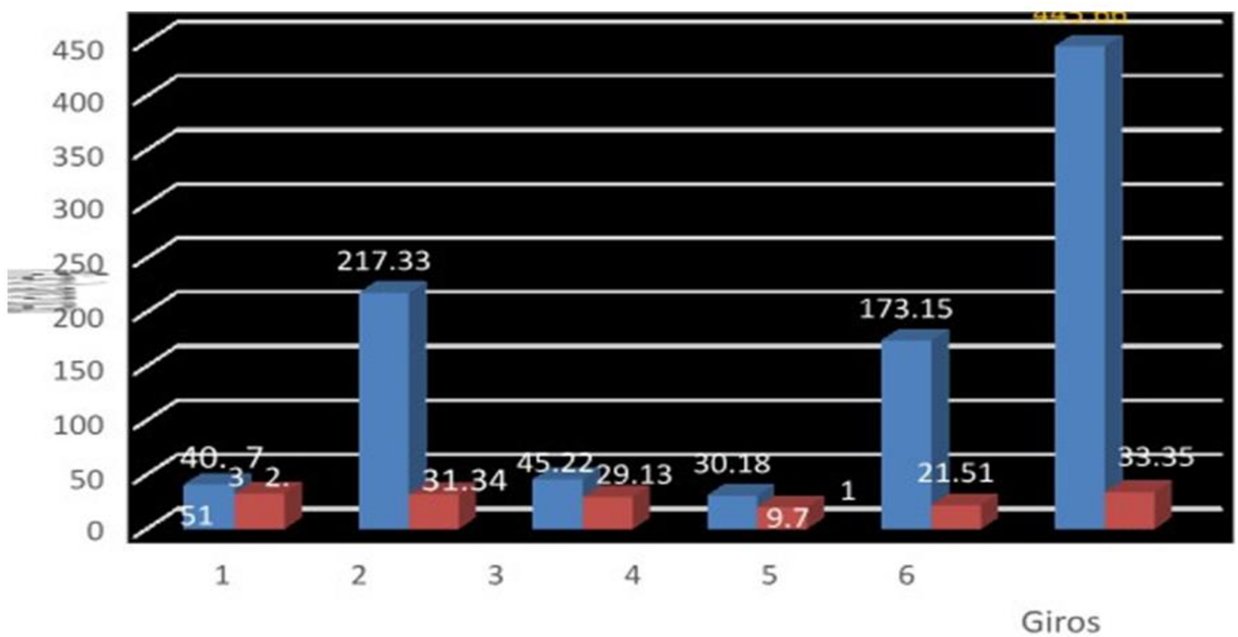

Figure 7.
Long maximum queue length for each turn of vehicular traffic system at the intersection of the Cayhuayna -Huánuco oval.

Note: It can be seen that the greatest maximum tail length occurs in the movement - turn No. 03 (243.48 m.), followed very closely by the movement - turn No. 02 (243.09 m.) and the shortest occurs in the movement - turn No. 02 (128.99 m.). On the other hand, it can be seen that, in the proposal, the greatest variation occurs in the movement – turn No. 06 (-107%) and the least variation in the movement turn No. 01 (-25%).

Table 7.
Evaluation of the current and proposed level of service for each turn of the vehicular traffic system at the intersection of the Cayhuayna – Huánuco oval.

Giros	Nivel de servicio			
	Actual	Característica	**Propuesta**	Característica
1	LOS_C	Sincronía regular	LOS_C	Sincronía regular
2	LOS_F	Sincronía deficiente	LOS_C	Sincronía regular
3	LOS_C	Sincronía regular	LOS_B	Sincronía buena
4	LOS_D	Sincronía desfavorable	LOS_B	Buena sincronía
5	LOS_F	Sincronía deficiente	LOS_B	Buena sincronía
6	LOS_F	Sincronía deficiente	LOS_C	Sincronía regular

Note: The table shows a favorable change in the service level between the proposed and the current level for each turn. It can be seen that the most notable changes occur in turn No. 02, 05 and 06, which would no longer have poor synchrony and would have regular, good and regular synchrony respectively. Likewise, it can be seen that there was an improvement in turn 02, going from unfavorable synchrony to good synchrony.

4. Conclusion

- The proposal to implement turns using the PTV VISSIM 7 software improved the level of service at the T-type intersection of the Cayhuayna oval. With a probability of error of 4.2%, lower than the 5% significance level, it was possible to improve the quality of circulation on the oval. To address the problems of congestion and traffic chaos, engineering solutions were applied, such as the creation of an overpass and a depressed road.

- As a result of the capacity of all the turns, we can conclude that the time of maximum demand is from 07:00 to 8:00 in the morning, with a volume of 11,309 vehicles, and the type of vehicle that predominates is the automobile, which represents the 41.88% of the total volume of vehicles in the HMD

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