Journal of Namibian Studies, 33 S2(2023): 2881–2916 ISSN: 2197-5523 (online)

Application of the Deming cycle for road optimization in the center of the city of Juliaca, 2021

Vara Mamani Bettsy Verónica

Civil Engineering, Faculty of Engineering and Architecture, Universidad Peruana Unión, Lima, Peru.

Abstract

Controlling traffic congestion requires a strategic and creative vision for the development of an urban center. The purpose of this research is to apply the Deming cycle to optimize vehicular traffic in the road network at the main controlled intersections of Jiron Lima, Jiron San Roman, Jiron and Jiron Ayacucho in the center of the city of Juliaca, 2021. The research is applicative, constituting as population the city of Juliaca and as study sample was chosen 1 controlled intersection of Jiron Lima with Jiron Lambayeque, 3 controlled intersections of Jiron San Roman (Jiron Sandia, Jiron Cusco and Jiron Bolivar) and 1 controlled intersection of Jiron Ayacucho with Jiron Jauregui of the city center, using as data collection instrument the vehicular gauging card. The results obtained show an improvement in the road service quality of the 5 controlled intersections by proposing segregated lanes for public and private light vehicles, 3 of the controlled intersections improved their road service quality to "B", 1 controlled intersection improved its road service quality to "A" and the remaining intersection improved its road service quality to "C", maintaining a vehicular flow free of obstructions. The duration period in the traffic signal cycles varied with respect to the application of the Webster method. It was determined that the application of the Deming cycle is a suitable method capable of optimizing vehicular traffic, reducing congestion and offering an improvement in the quality of road service.

Keywords: Deming cycle, traffic congestion, Webster method, road quality of service, segregated lanes.

1. Introduction

The vehicular bottleneck is one of the main uncertainties that challenge the largest cities in Peru since 2000, which disturbs the entire transportation system (Concha & Solis, 2018) and the environment, due to a high vehicular demand, with excessive traffic and a collapsed vehicle fleet (Rios, 2018). The dynamism, good location, commerce and job

opportunities that Juliaca hosts, generated economic progress (Tejada, 2018) that induced immigration from rural sectors. This transmuted Juliaca into the articulating axis of the macro South Region, deriving opportunities and inconveniences to the city, among them the vehicular congestion. After the pandemic in 2021, Juliaca again suffered the problem of transport congestion in the streets of the city center, generating discomfort in the carriers, resulting in an uncontrollable disorder, raising the voice of drivers and users for the prompt intervention of the authorities of the MPSR-J (Onda Azul, 2021).

According to Carla Urbina & Alexa Torres (2018), in their study aimed to "Optimize the behavior of vehicular flow at the intersection of Av. Bolognesi with Av. Gustavo Pinto in the city of Tacna", it was an applicative research. The study population is the vehicular flow that passes through the intersection of Av. Bolognesi with Av. Gustavo Pinto in the city of Tacna, taking the peak hour vehicular flow as a study sample and the vehicular capacity sheet as a study instrument. The results show a highly congested road due to the large influx of vehicles in the study area in the Tacna region, having a level of service F, and the traffic light cycles have periods of high duration; to counteract this uncertainty, it was proposed to make the distribution change from 4 phases to 2 phases in traffic lights, since, it is a technical programming of traffic lights, considering the prohibition of left-hand turns (Urbina & Torres, 2018).

According to Lucia Decurt & Jessica Jara (2018), in their study aimed to "Determine how the application of the Deming Cycle improves the level of service in a transportation company in the city of Trujillo," with an applicative methodology. The population and sample consisted of 42 service orders from Trujillo - Lima and 20 service orders from Trujillo - Piura in a period of 1 month. The results showed an improvement in the level of service from 69.5% to 79.35% with a positive result of 9.85% improvement. Concluding that the application of the Deming Cycle significantly influenced the improvement of the service level in a company in the city of Trujillo (Decurt & Jara, 2018).

Normative and conceptual framework

According to Gutierrez Pulido, 2018 "The PHVA cycle, Deming cycle or continuous improvement cycle, is very useful for structuring and implementing quality and productivity improvement projects at any hierarchical level of an organization. The PHVA cycle is very versatile, capable of being applied to any type of process and was popularized in 1920 (Cortez, 2017).

ISO 9001:2015 establishes the criteria for a Quality Management System and is the only standard that can be certified (Cortez, 2017).

The cycle is developed in an objective and profound way starting with a plan (plan), applied on a small scale or on a trial basis (do), evaluating

whether the expected results were obtained (verify) and, according to the above, acting accordingly (act), taking preventive measures so that the improvement is not reversible, or restructuring the plan because the results were not satisfactory, thus starting the cycle again" (Gutiérrez, 2018).

Figure 1: The 7 steps of the Deming cycle

Ciclo de Mejora Continua	Siete pasos
P (Plan)	1. Seleccionar el problema 2. Clarificar y subdividir el problema 3. Analizar las causas en su raíz 4. Establecer niveles exigidos 5. Definir y programar las soluciones
D (Hacer)	6. Implantar y verificar las soluciones
C (Comprobar / Verificar) A (Asegurar / Actuar)	7. Acciones de garantía

Source: Bonilla et al. (2010)

Vehicular congestion, according to the Spanish Language is the "action and effect of congesting or congesting and obstructing or hindering the passage, circulation or movement of something", the main source that generates congestion is vehicle friction (Urbina & Torres, 2018).

Therefore, from its social, practical and economic relevance, this study serves as a basis for the intervention of municipal authorities on the issue of transportation and establishes actions and proposals to deal with the problems of vehicular and environmental circulation, through a traffic study which will focus on the current problems of the road, strategic measurements and calculations working with the Deming cycle, seeking to contribute and prioritize the organization of urban transport (Picón Santamaría & Ruiz Sánchez, 2019) of the city of Juliaca in order to reduce traffic congestion in this city.

To this end, it is intended to "Apply the Deming cycle for the optimization of vehicular traffic in the road network at the main controlled intersections of Jiron San Roman and Jiron Ayacucho in the center of the city of Juliaca, 2021.

2. Method

2.1. Type of study:

- By purpose: Applied Research:

This type of research is fully associated with fundamental research, since its purpose is to solve a specific problem by answering specific questions (Hernández-Sampieri & Mendoza, 2018).

- By type of data collection: Field or in-situ research:

For this type of research, it is necessary to take in-situ data, real data that show the development depending on the study pattern during the month of August and the first week of September, 2021.

2.2. Sample design

2.2.1. Population

The research will take place in the region of Puno, province of San Román, district of Juliaca. Data was obtained from controlled intersections of vehicles moving.

2.2.2. Sample

It is a convenience sample because it is informal, so it was selected:

1 controlled intersection of Jiron Lima

- Jiron Lambayeque (E: 378354.54m N: 8287066.66m)

3 controlled intersections of Jiron San Roman:

- Jirón Sandia (E: 378391.43m N: 8286959.76m)

- Jiron Cusco (E: 378477.57m N: 8286726.87m)

- Bolivar Shred (E: 378518.30m N: 8286668.64m)

1 controlled intersection of Jirón Ayacucho

- Jiron Jauregui (E: 378324.50m N: 8286729.99m)

2.3. Inclusion and Exclusion Criteria

2.3.1. Inclusion Criteria

All types of light transport vehicles and heavy transport vehicles that move for 12 hours (07:00 a.m. to 07:00 p.m.).

2.3.2. Exclusion Criteria

Light transport vehicles and heavy transport vehicles moving before or after the hours selected by the data collection instrument form.

2.4. Data Collection Procedure

Practical

- Field work: Manual counting and data collection; two technical personnel were trained and provided with safety Epps and data collection instruments for the vehicle gauging. Vehicle gauging was carried out during 7 days, 12 hours at the 5 study intersections (Pereda & Montoya, 2018).

Operative

- Find the average daily weekly traffic (TPDS), average daily monthly traffic (TPDM), average daily annual traffic (TPDA) (MITMA & ZARAVIA, 2018).

- Calculation of peak time and peak time volume (VTHP) (Pereda & Montoya, 2018).

- Calculation of hourly maximum demand factor (MDHF) (MITMA & ZARAVIA, 2018).

Application of the Deming cycle: We apply the PHVA cycle, adapting the methodology of the 7 steps:

- The level of service of the road is calculated using the proposed segregated lanes for light public vehicles using the 7 steps in Figure 1 (MITMA & ZARAVIA, 2018).

- Calculation of the time at the traffic lights with the Webster method, using the 7 steps of Figure 1 (MITMA & ZARAVIA, 2018).

3. Results

A. WEEKLY SUMMARY OF VEHICLE CAPACITY

3.1. Vehicle count of Jirón Lima with Jirón Lambayeque

Controlled intersection designation No. 1: Jirón Lima with Jirón Lambayeque

Vehicle count data: 02/08/2021 – 08/08/2021

Table 01 Weekly summary of vehicle traffic counts at controlled intersection No. 1

DAYS	DIRECTION OF TRAFFIC		DT DAILY TRANSIT	Daily Factor	Fd
	N – S	W – E			
MON.	15015	5312	20327	6.714	0.959
TUES.	12805	5290	18095	7.542	1.077
WED.	14421	5775	20196	6.757	0.965
THU.	16121	5455	21576	6.325	0.904
FRI.	14822	5662	20484	6.662	0.952
SAT.	15122	5882	21004	6.497	0.928
SUN.	10497	4293	14790	9.227	1.318

Source: Own elaboration

TS = Tránsito Semanal = 136472veh
TPDS = Tránsito Promedio Diario Semanal = 19496veh/sem
TPDM = Tránsito Promedio Diario Mensual = 4549veh/mes
TPDA = Tránsito Promedio Diario Anual = 374veh/año

3.2. Vehicle count of Jirón San Román with Jirón Sandia

Name of Controlled Intersection No. 2: Jirón San Román with Jirón Sandia

Vehicle count data: 09/08/2021 – 15/08/2021

Table 02 Weekly summary of vehicle traffic counts at Controlled Intersection No. 2

DAYS	DIRECTION OF TRAFFIC		DT DAILY TRANSIT	Daily Factor	Fd
	N – S	E - W			
MON.	9572	8052	17624	6.772	0.967
TUES.	9219	7710	16929	7.050	1.007
WED.	9248	7847	17095	6.982	0.997
THU.	9375	7598	16973	7.032	1.005
FRI.	9331	7883	17214	6.933	0.990
SAT.	9256	7257	16513	7.228	1.033
SUN.	9536	7465	17001	7.020	1.003

Source: Own elaboration

TS = Tránsito Semanal = 119349veh
TPDS = Tránsito Promedio Diario Semanal = 17050veh/sem
TPDM = Tránsito Promedio Diario Mensual = 3978veh/mes
TPDA = Tránsito Promedio Diario Anual = 327veh/año

3.3. Vehicle count of Jirón Ayacucho with Jirón Jáuregui

Name of Controlled Intersection No. 3: Jirón Ayacucho with Jirón Jáuregui

Vehicle count data: 16/08/2021 – 22/08/2021

Table 03 Weekly summary of vehicle traffic counts at Controlled Intersection No. 3

DAYS	DIRECTION OF TRAFFIC		DT DAILY TRANSIT	Daily Factor	Fd
	N - S	W – E			
MON.	3968	9650	13618	7.319	1.046
TUES.	4009	10646	14655	6.801	0.972
WED.	4001	10650	14651	6.803	0.972
THU.	4129	10327	14456	6.895	0.985
FRI.	4355	10454	14809	6.731	0.962

SAT.	4370	10463	14833	6.720	0.960
SUN.	2925	9727	12652	7.878	1.125

Source: Own elaboration

TS = Tránsito Semanal = 99674veh
TPDS = Tránsito Promedio Diario Semanal = 14239veh/sem
TPDM = Tránsito Promedio Diario Mensual = 3322veh/mes
TPDA = Tránsito Promedio Diario Anual = 273veh/año

3.4. Vehicle capacity at Jirón San Román with Jirón Cusco

Name of Controlled Intersection No. 4: Jirón San Román with Jirón Cusco

Vehicle count data: 23/08/2021 – 29/08/2021

Table 04 Weekly summary of vehicle traffic counts at Controlled Intersection No. 4

DIAS	DIRECTION OF TRAFFIC		DT DAILY TRANSIT	Daily Factor	Fd
	N - S	O – E			
MON.	13953	14568	28521	6.461	0.923
TUES.	14708	11116	25824	7.136	1.019
WED.	14703	11114	25817	7.138	1.020
THU.	13091	13744	26835	6.867	0.981
FRI.	13014	13974	26988	6.828	0.975
SAT.	13070	13989	27059	6.810	0.973
SUN.	9116	14110	23226	7.934	1.133

Source: Own elaboration

TS = Tránsito Semanal = 184270veh
TPDS = Tránsito Promedio Diario Semanal = 26324veh/sem
TPDM = Tránsito Promedio Diario Mensual = 6142veh/mes
TPDA = Tránsito Promedio Diario Anual = 505veh/año

3.5. Vehicle count of Jiron San Roman with Jiron Bolivar

Name of Controlled Intersection No. 5: Jirón San Román with Jirón Bolívar

Vehicle count data: 30/08/2021 – 05/09/2021

Table 05 Weekly summary of vehicle traffic counts at Controlled Intersection No. 5

DAYS	DIRECTION OF TRAFFIC		DT DAILY TRANSIT	Daily Factor	Fd
	N – S	W- E			
MON.	25421	3185	28606	6.783	0.969
TUES.	25375	3160	28535	6.800	0.971
WED.	25338	3152	28490	6.811	0.973

THU.	26091	3953	30044	6.459	0.923
FRI.	25233	3067	28300	6.857	0.980
SAT.	25089	3097	28186	6.884	0.983
SUN.	19006	2875	21881	8.868	1.267

Source: Own elaboration

TS = Tránsito Semanal = 194042veh
TPDS = Tránsito Promedio Diario Semanal = 27720veh/sem
TPDM = Tránsito Promedio Diario Mensual = 6468veh/mes
TPDA = Tránsito Promedio Diario Anual = 532veh/año

B. CALCULATION OF TOTAL PEAK HOUR VOLUME (VTHP) OR MAXIMUM HOURLY DEMAND VOLUME (MHDV)

3.6. Total peak hour volume (TPHV) of Jirón Lima with Jirón Lambayeque (Controlled Intersection No. 1)

Table 06 TPHV or MHDV of Controlled Intersection No.1

VOLUME OF VEHICULAR TRAFFIC DURING THE BUSIEST TIME OF THE DAY	
DAY	TIME (18:00 p. m. – 19:00 p. m.)
02	2027
03	1749
04	2001
05	2194
06	2059
07	2063
08	1591
TOTAL	13684

Source: Own elaboration

TPHV = 2194veh/hora

MHDV = 2194veh/hora

3.6.1. Maximum hourly demand factor (MHDF) of controlled intersection Nº1

Table 07 MHDF of controlled intersection No. 1

DAY	5
18:00 – 18:15	537
18:15 – 18:30	571
18:30 – 18:45	557
18:45 – 19:00	529

Source: Own elaboration

$Q_{máx15}$ = Vehicle flow rate in 15 minutes = 571veh

MHDF = 0.96

3.7. Total peak hour volume (TPHV) of Jirón San Román with Jirón Sandia (Controlled Intersection No. 2)

Table 08 TPHV or MHDV of Road Intersection No. 2

VOLUME OF VEHICULAR TRAFFIC DURING THE BUSIEST TIME OF THE DAY	
DAY	TIME (18:00 p. m. – 19:00 p. m.)
09	1875
10	1655
11	1702
12	1682
13	1722
14	1627
15	1743
TOTAL	12006

Source: Own elaboration

TPHV = 1875veh/time

MHDV = 1875veh/time

3.7.1. Maximum Hourly Demand Factor (MHDF) of Controlled Intersection No. 2

Table 09 MHDF of controlled intersection No. 2

DAY	9
18:00 – 18:15	466
18:15 – 18:30	495
18:30 – 18:45	483
18:45 – 19:00	431

Source: Own elaboration

$Q_{máx15}$ = Vehicle flow rate in 15 minutes = 495veh

MHDF = 0.95

3.8. Total peak hour volume (VTHP) of Jirón Ayacucho with Jirón Jáuregui (Controlled Intersection No. 3)

Table 10 TPHV or MHDV of Road Intersection No. 3

VOLUME OF VEHICULAR TRAFFIC DURING THE BUSIEST TIME OF THE DAY	
DAY	TIME (11:00 a. m. – 12:00 p. m.)
16	1454
17	1430
18	1414
19	1415
20	1485
21	1492
22	1174
TOTAL	9864

Source: Own elaboration

TPHV = 1492veh/time

MHDV = 1492veh/time

3.8.1. Maximum hourly demand factor (MHDF) of controlled intersection No. 3

Table 11 MHDF of controlled intersection No. 3

DAY	21
11:00 – 11:15	345
11:15 – 11:30	373
11:30 – 11:45	376
11:45 – 12:00	398

Source: Own elaboration

$Q_{máx15}$ = Vehicle flow rate in 15 minutes = 398veh

MHDF = 0.94

3.9. Total peak hour volume (TPHV) of Jirón San Román with Jirón Cusco (Controlled Intersection No. 4)

Table 12 TPHV or MHDV of controlled intersection No. 4

VOLUME OF VEHICULAR TRAFFIC DURING THE BUSIEST TIME OF THE DAY	
DAY	TIME (13:00 p. m. – 14:00 p. m.)
23	2831
24	2865
25	2905
26	2602

27	2565
28	2564
29	2202
TOTAL	18534

Source: Own elaboration

TPHV = 2905veh/time

MHDV = 2905veh/time

3.9.1. Peak Hourly Demand Factor (MHDF) of Intersection No. 4

Table 13 MHDF of road intersection No. 4

DAY	25
13:00 – 13:15	705
13:15 – 13:30	748
13:30 – 13:45	749
13:45 – 14:00	703

$Q_{máx15}$ = Vehicle flow rate in 15 minutes = 749veh

FHMD = 0.97

3.10. Total peak hour volume (TPHV) of Jirón San Román with Jirón Bolívar (Controlled Intersection No. 5)

Table 14 TPHV of controlled intersection No. 5

VOLUME OF VEHICULAR TRAFFIC DURING THE BUSIEST TIME OF THE DAY	
DAY	TIME (10:00 a. m. – 11:00 a. m.)
30	2677
31	2694
1	2749
2	2797
3	2792
4	2898
5	2323
TOTAL	18930

Source: Own elaboration

TPHV = 2898veh/hora

MHDV = 2898veh/hora

3.10.1. Maximum hourly demand factor (MHDF) of controlled intersection No. 5

Table 15 MHDF of controlled intersection No. 5

DAY	4
11:00 – 11:15	721
11:15 – 11:30	725
11:30 – 11:45	727
11:45 – 12:00	725

Source: Own elaboration

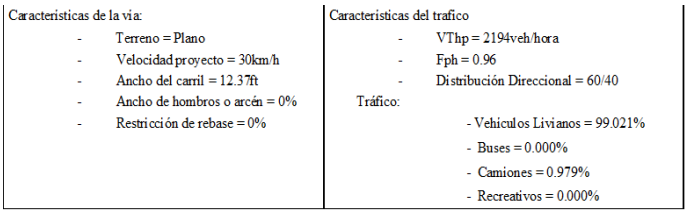
$Q_{máx15}$ = Vehicle flow rate in 15 minutes = 727veh

MHDF = 0.997

C. CALCULATION OF THE CURRENT SERVICE LEVEL

3.11. State of road service between Jiron Lima and Jiron Lambayeque (Controlled Intersection Nº1)

Figure 2: Road and traffic characteristics at controlled intersection No. 1



Source: Own elaboration

Table 16 Levels of road service at controlled intersection No. 1

NS A	274veh/ hour
NS B	492veh/ hour
NS C	783veh/ hour
NS D	1168veh/ hour
NS E	2294veh/ hour

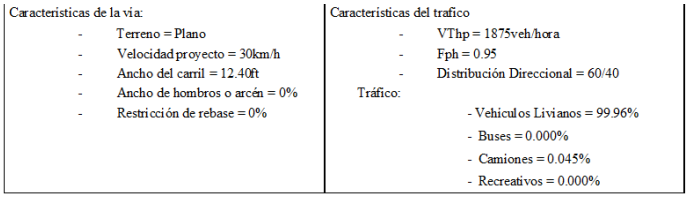
Source: Own elaboration

The quality of road service at controlled intersection No. 1 is = $\frac{2194}{0.96}$ = 2284veh/hour.

NS of controlled intersection No. 1	**D**

3.12. Condition of the road service of Jiron San Roman with Sandia (Controlled Intersection No. 2)

Figure 3: Roadway and traffic characteristics at controlled intersection No. 2



Source: Own elaboration

Table 17 Levels of road service at controlled intersection No. 2

NS A	276veh/ hour
NS B	497veh/ hour
NS C	792veh/ hour
NS D	1179veh/ hour
NS E	2315veh/ hour

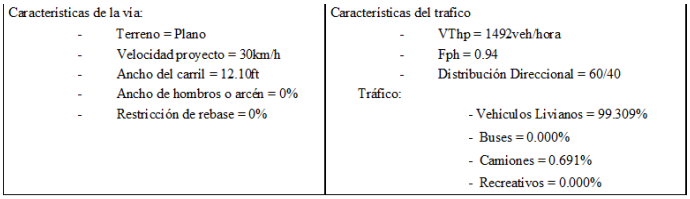
Source: Own elaboration

The current road quality of service at controlled intersection No. 2 is = $\frac{1875}{0.95}$ = 1980veh/hour.

NS of controlled intersection No. 2	**D**

3.13. State of the road service between Jiron Ayacucho and Jiron Jauregui (Intersection Nº3).

Figure 4: Roadway and traffic characteristics at controlled intersection No. 3



Source: Own elaboration

Table 18 Levels of road service at controlled intersection No. 3

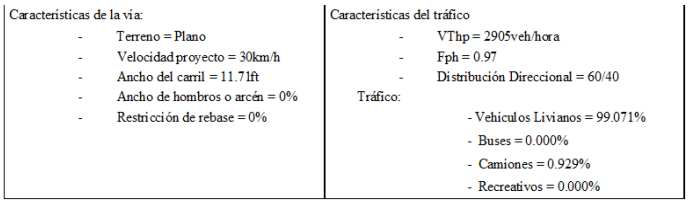
NS A	274veh/ hour
NS B	493veh/ hour
NS C	786veh/ hour
NS D	1171veh/ hour
NS E	2300veh/ hour

Source: Own elaboration

The quality of road service at controlled intersection No. 3 is = $\frac{1492}{0.94}$ = 1592veh/hour

3.14. State of road service between Jiron San Roman and Jiron Cusco (Controlled Intersection Nº4)

Figure 5: Roadway and traffic characteristics at controlled intersection No. 4.



Source: Own elaboration

Table 19 Levels of road service at controlled intersection No. 4

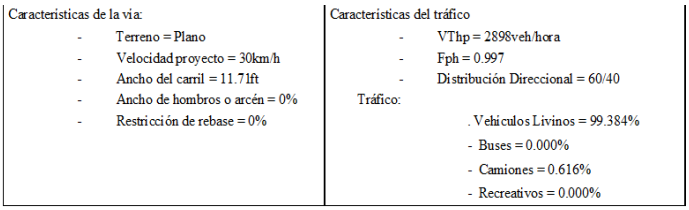
NS A	274veh/ hour
NS B	492veh/ hour
NS C	783veh/ hour
NS D	1168veh/ hour
NS E	2295veh/ hour

The quality of road service at which controlled intersection No. 4 performs is = $\frac{2905}{0.97}$ = 2996veh/ hour.

NS of controlled intersection No. 4	**E**

3.15. State of the road service of Jiron San Roman with Jiron Bolivar (Controlled Intersection No. 5)

Figure 6: Roadway and traffic characteristics at controlled intersection No. 5



Source: Own elaboration

Table 20 Levels of road service at controlled intersection No. 5

NS A	275veh/ hour
NS B	494veh/ hour
NS C	786veh/ hour
NS D	1172veh/ hour

NS E	2302veh/ hour

Source: Own elaboration

The quality of road service provided by controlled intersection No. 5 is = $\frac{2898}{0.997}$ = 2908veh/hour.

NS of controlled intersection No. 5	**E**

D. DEGREE OF SATURATION

3.16. Degree of saturation of Jirón Lima with Jirón Lambayeque (Controlled Intersection No. 1)

S = 1483veh/hv

3.17. Degree of saturation of Jirón San Román with Jirón Sandia (Controlled intersection No. 2)

S = 1460veh/hv

3.18. Degree of saturation of Jirón Ayacucho with Jirón Jáuregui (Controlled intersection No. 3)

S = 1513veh/hv

3.19. Degree of saturation of Jirón San Román with Jirón Cusco (Controlled intersection No. 4)

S = 1455veh/hv

3.20. Degree of saturation of Jirón San Román with Jirón Bolívar (Controlled Intersection No. 5)

S = 1481veh/hv

E. APPLICATION OR ADAPTATION OF THE 7 STEPS OF THE DEMING CYCLE TO THE CURRENT VEHICULAR TRAFFIC OF THE CONTROLLED INTERSECTIONS IN THE CENTER OF THE CITY OF JULIACA

PLANNING

3.21. STEP 1: Select the problem

(FORMULATION OF THE PROBLEM) (WHAT?)

Table 21 Identification and characterization of the problem

PHVA Nº	**01**	**DATA**	**06/06/22**

How is the traffic flow at the 5 controlled intersections of the research project?
The development of controlled intersections shows uncontrolled vehicular growth causing traffic jams due to the existence of informal commerce, outdated traffic studies, obsolete urban planning, poor road maintenance and deficient signaling

In what situation were the controlled intersections found?
The road condition of the controlled intersections shows a profound neglect in the maintenance of horizontal signs, vertical signs and road infrastructure.
What are the sites involved, which have such a problem? :
The controlled study intersections involving 5 directions: Jiron Lima with Jiron Lambayeque, Jr. San Roman with Jiron (Sandia, Cusco and Bolivar) and Jiron Ayacucho with Jiron Jauregui.
Since when did you become aware of the existing problems? :
It was perceived more intensely on the days when the corresponding vehicle counts were carried out at the 5 road intersections (August 2 - September 5).
How often does traffic congestion occur?
Vehicle congestion began to increase at the beginning of the 21st century. In the year 2021, after the COVID-19 pandemic, vehicles began to circulate, again causing traffic jams in different arteries of the city, including the 5 study zones.
What is the purpose of the study and how much is to be achieved??
To optimize the 5 controlled intersections under study, in the shortest possible time, for which we intend to work with the municipality, opting to apply the proposal of segregated lanes for light public vehicles and reprogram the traffic lights according to the established study.

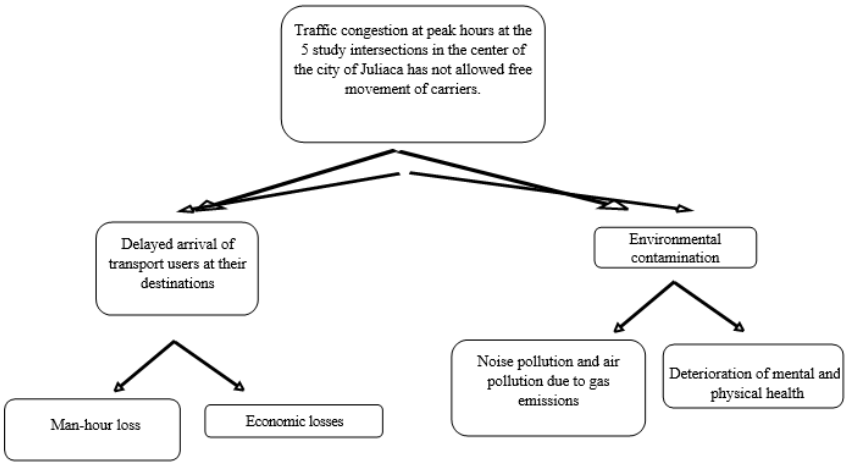
Source: Own elaboration

3.22. STEP 2: Clarifying and subdividing the selected problem

Clarification of the problem

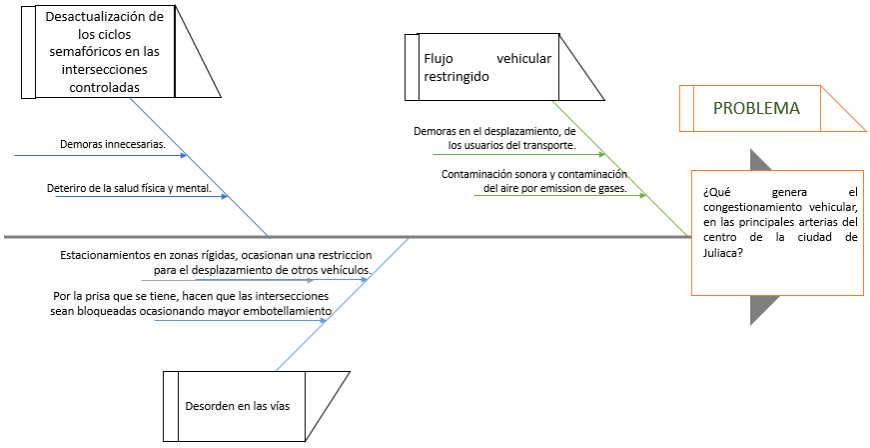
The city of Juliaca, which prioritizes commerce as its main economic activity, is unsustainable due to the uncontrolled growth of vehicles. This is caused by the existence of informal commerce, outdated traffic studies, obsolete urban planning, poor road maintenance and poor signage.

Figure 7. tep 2 - Subdivision of the problem (Road Congestion / Tree Diagram)



Source: Own elaboration

Figure 8. Potential causes (Vehicular Congestion) / (Ishikawa Diagram)



Source: Own elaboration

3.23. STEP 4 and STEP 5: Establishing required levels and defining solutions

An action plan is defined on the basis of the analysis:

- The proposal for segregated lanes for public and private light vehicles at some controlled intersections was chosen (Option created in terms of time).

- The Webster method was chosen to reschedule the time at the traffic lights (Option created in terms of time).

EXECUTION / DOING:

3.24. STEP 6: Implementing and verifying solutions

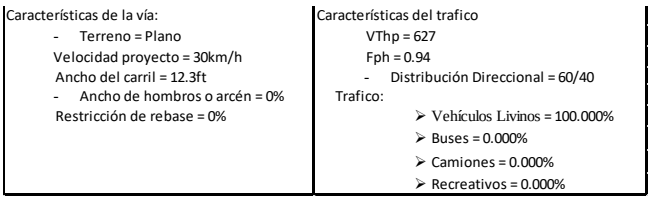
I. Optimization of the quality of road service by applying segregated lanes for public and private light vehicles at some controlled intersections.

a. State of road service - Jirón Lima with Jirón Lambayeque

The condition of the road service applying the conventional method at controlled intersection No. 1 gave "D", therefore the proposal of segregated lanes for light public vehicles: "minibus" and "motorcycles" is applied:

The direction of circulation of light vehicles "microbus" will be from N to S, depriving the deviation directions from N to E, and the transit from W to E would only include the circulation of motorcycles, depriving the deviation direction from W to S. Prohibiting the circulation of heavy transport vehicles and vehicles for private use. Performing an analysis of the quality of road service; optimizing B. Showing a minimum restriction of free vehicular flow.

Figure 8: Road and traffic characteristics at controlled intersection No. 1



Source: Own elaboration

Table 22 Levels of service at controlled intersection No. 1

NS A	276veh/hour
NS B	497veh/hour
NS C	792veh/hour
NS D	1179veh/hour
NS E	2316veh/hour

Source: Own elaboration

The quality of road service with the implementation of the proposal for segregated lanes for light public vehicles at controlled intersection No. 1 is $= \frac{627}{0.94}$ = 667veh/hour

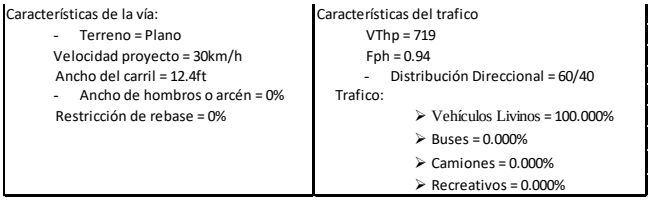
NS of controlled intersection No. 1	**B**

b. Level of Service - Jirón San Román with Jirón Sandia

The state of the road service applying the conventional method in the controlled intersection Nº2 gave "D", therefore the proposal of segregated lanes for light vehicles for public use: "microbus" and "motorcycles", and private vehicles is applied.

The direction of circulation of light vehicles "microbus" will only involve a deviation in the direction of Jiron Ayacucho, and in the direction E to W and with a deviation direction from E to S, only private vehicles will participate and only motorcycles for public use. Prohibiting the circulation of heavy transport vehicles. Performing an analysis of the quality of road service; optimized to B. Showing a minimum restriction of free vehicular flow.

Figure 9: Roadway and traffic characteristics at controlled intersection No. 2.



Source: Own elaboration

Table 23 Levels of service of controlled intersection No. 2.

NS A	276veh/ hour
NS B	497veh/ hour
NS C	792veh/ hour
NS D	1179veh/ hour
NS E	2316veh/ hour

Source: Own elaboration

The quality of road service with the implementation of the proposed segregated lanes for light vehicles for public and private use at controlled intersection No. 2 is = $\frac{719}{0.94}$ = 765veh/hour

NS of controlled intersection No. 2	**B**

c. Level of service – Jirón Ayacucho with Jirón Jáuregui

The state of the road service applying the conventional method at controlled intersection No. 3 gave "D", therefore the proposal of segregated lanes for light public vehicles: "microbus" and "motorcycles", and private vehicles is applied.

The direction of circulation of light vehicles "microbus" will only involve a deviation from N to E in the direction of Jiron Jauregui, and in the direction W to E and W with deviation to the S, only vehicles for public

use, motorcycles, will participate. Prohibiting the circulation of heavy transport vehicles. Performing an analysis of the quality of road service; optimized to C. Showing a stable free vehicular flow.

Figure 10: Roadway and traffic characteristics at controlled intersection No. 3

Características de la vía:	Características del trafico
- Terreno = Plano	VThp = 1017
Velocidad proyecto = 30km/h	Fph = 0.96
Ancho del carril = 12.10ft	Trafico:
- Ancho de hombros o arcén = 0%	Vehículos Livianos = 100.000%
- Restricción de rebase = 0%	Buses = 0.000%
	Camiones = 0.000%
	Recreativos = 0.000%

Source: Own elaboration

Table 24 Levels of service of Road Intersection Nº3

NS A	276veh/hour
NS B	497veh/hour
NS C	792veh/ hour
NS D	1179veh/hour
NS E	2316veh/hour

Source: Own elaboration

The quality of road service with the implementation of the proposed segregated lanes for light vehicles for public and private use at controlled intersection No. 3 is = $\frac{1017}{0.96}$ = 1056veh/hour

NS of controlled intersection No. 3	**C**

d. Level of service – Jirón San Román with el Jirón Cusco

The state of the road service applying the conventional method in the controlled intersection Nº4 gave "E", for this reason the proposal of segregated lanes for light vehicles for public use: "microbus" and "motorcycles", and private vehicles is applied.

The direction of circulation of light vehicles "microbus" will only involve the deviation from W to S in the direction of Jr. San Roman, and in the direction from W to E and the deviation from N to E, only public use vehicles will participate; motorcycles. Prohibiting the circulation of heavy transport vehicles. Performing an analysis of the quality of road service; optimized to B. Showing a minimum restriction of the free vehicular flow.

Figure 11: Roadway and traffic characteristics at controlled intersection No. 4

Características de la vía: - Terreno = Plano Velocidad proyecto = 30km/h Ancho del carril = 11.70ft - Ancho de hombros o arcén = 0% - Restricción de rebase = 0%	Características del trafico VThp = 505 Fph = 0.97 Trafico: Vehículos Livianos = 100.00 % Buses = 0.000% Camiones = 0.000% Recreativos = 0.000%

Source: Own elaboration

Table 25 Levels of service at controlled intersection No. 4

NS A	276veh/hour
NS B	497veh/hour
NS C	792veh/hour
NS D	1179veh/hour
NS E	2316veh/hour

Source: Own elaboration

The quality of road service with the implementation of the proposed segregated lanes for light vehicles for public and private use at controlled intersection No. 4 is = $\frac{505}{0.97}$ = 520veh/ hour

NS of controlled intersection No. 4	**B**

e. Level of service – Jirón San Román with el Jirón Bolívar

The state of the road service applying the conventional method at controlled intersection No. 5 gave "E", therefore the proposal of segregated lanes for light public vehicles is applied: "microbus" and "motorcycles".

The directions of circulation of light vehicles "microbus" will be: N to S, W to E and with deviation from N to E towards Jiron Bolivar. In the W direction with deviation to the S side, only public vehicles will be allowed to participate; motorcycles in the direction of Jiron San Roman.

Prohibiting the circulation of heavy transport vehicles. Performing an analysis of the quality of road service; optimized to A. Showing no restriction of free vehicle flow.

Figure 12: Roadway and traffic characteristics at controlled intersection No. 5

Características de la vía: - Terreno = Plano - Velocidad proyecto = 30km/h Ancho del carril = 11.7ft - Ancho de hombros o arcén = 0% - Restricción de rebase = 0%	Características del tráfico VThp = 460veh/hora Fph = 0.96 Trafico: Vehículos Livianos = 100.000% Buses = 0.000% Camiones = 0.000% Recreativos = 0.000%

Source: Own elaboration

Table 26 Levels of Service of Controlled Intersection No. 5

NS A	276veh/hour
NS B	497veh/hour
NS C	792veh/hour
NS D	1179veh/hour
NS E	2316veh/hour

The quality of road service with the implementation of the proposal of segregated lanes for light vehicles for public and private use; at controlled intersection No. 5 = $\frac{460}{0.96}$ = 480veh/ hour

NS of controlled intersection No. 5	**A**

II. Time at traffic lights, analyzed by the Webster method

It was programmed according to the total volume of vehicles, taken from the vehicle capacity recorded in the months of August and September 2021 and according to formulas proposed by the Webster method.

Table 27 Distribution of traffic light time at the 5 study intersections, actual times and times found with the Deming cycle method

NUMBER OF CONTROLLED INTRSECTIONS	**REAL**						Total time per phase or semaphore cycle	**WITH THE INTERVENTION OF THE WEBSTER METHOD AND THE PHVA CYCLE**						Total time per phase or semaphore cycle
	PHASE I (seg)			PHASE II (seg)				PHASE I (seg)			PHASE II (seg)			
IC – Nº1	38	5	32	30	5	40	75	56	3	41	35	3	62	100
IC – Nº2	46	1	57	49	2	53	104	44	3	41	35	3	51	88
IC – Nº3	45	3	32	32	3	45	80	34	3	44	38	3	40	81
IC – Nº4	55	0	55	54	2	54	100	48	3 s	48	42	3	54	99
IC – Nº5	92	2	19	19	0	92	111	60	3	36	30	3	66	99

Source: Own elaboration

Table 28 Action plan

PLAN DE ACCIONES								
PROBLEM	**ROOT CAUSE**	**No.**	**ACTIONS**	**WHO?**	**WHEN?**		**COMMENTS**	**AVAILABILITY**
					Start	**End**		
Traffic lights not working properly and not updated according to traffic volumes	Cars are at risk of being involved in traffic accidents due to the breakdown of traffic lights and unmaintained signals. Non-productive time.	1	Change the time at the traffic lights (traffic light cycle) of the 5 intersections, through the analysis of the Webster method. Improve the level of service of the road by means of accessible and economic proposals, capable of improving the behavior of the traffic being more fluid. Carry out general maintenance of all traffic lights and signals on the road.	Líder PDCA			The purpose of this research work is to optimize road intersections through effective analysis and methodologies.	**AVAILABLE**
Traffic accidents and environmental pollution	Noise pollution Air pollution caused by gas production.	3	Implement a plan to include penalties for the entry of heavy vehicles and personal use vehicles during rush	Líder PDCA			Involve the MPSR-J, the creation and participation of transportation authorities (traffic police and municipal inspectors).	**NOT AVAILABLE**

			hours to counteract congestion and noise pollution.				Subsidize parking areas of the MPSR-J, for a more fluid roadway without vehicles parked in rigid zones.	

Source: Own elaboration

VERIFICATION

STEP 7: Warranty actions

Is there an improvement in the quality of road service at the 5 study intersections?

Yes, 3 of the controlled intersections improved to B, 1 controlled intersection to C and the remaining intersection to A.

Is the time found consistent with the Webster method?

Yes, as shown in Table 27, this methodology takes into account the volumes per access and lane, including red, green and amber times.

ADJUST/ACTUATE

The actions used are efficient in the 5 controlled intersections, so it is not necessary to perform another cycle.

The actions taken with expected and optimal results may be selected for further research.

Note: If the action was not effective, it is necessary to perform another cycle, since it is necessary to improve the quality and productivity of each activity.

3.26.1. Comparison of the current state of the track with the application of the Deming cycle

The following is a comparison of the results of the road service level with and without the PHVA cycle intervention.

3.26.1. Comparison of current service level vs. service level applying the Deming cycle

Road Intersection Nº1, Nº2 and Nº4

The quality of road service with the application of the PHVA or Deming cycle and the proposal of segregated lanes for light vehicles for public and private use. We have in controlled intersection Nº1, controlled intersection No. 2 and controlled intersection No. 4, an improvement of

road quality from D to B and 2 of them from E to B, making the 3 intersections indicate "good conditions for free circulation" (Ministry of Transport and Communications, 2018).

Road Intersection Nº3

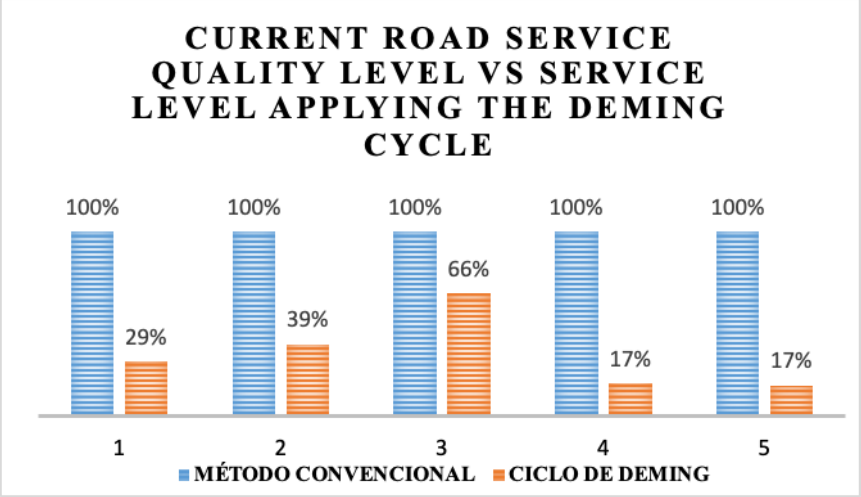
The quality of road service with the application of the PHVA or Deming cycle and the proposal of segregated lanes for light vehicles for public and private use. Controlled intersection No. 3 shows an improvement in road quality from D to C, making the intersection "remain in a stable zone" (National Research Council, 2000).

Road Intersection No. 4 and No. 5

The quality of road service with the application of the PHVA or Deming cycle and the proposal of segregated lanes for light vehicles for public and private use. An improvement in road service quality from E to A is had at controlled intersection No. 5, making the intersection indicate "fluid circulation" (Ministry of Transport and Communications, 2018).

3.26.1. Comparison of the current road service quality with the application of the PHVA cycle (Figure 13)

Figure 13. Percentage comparison of current road quality of service vs. applying the Deming cycle

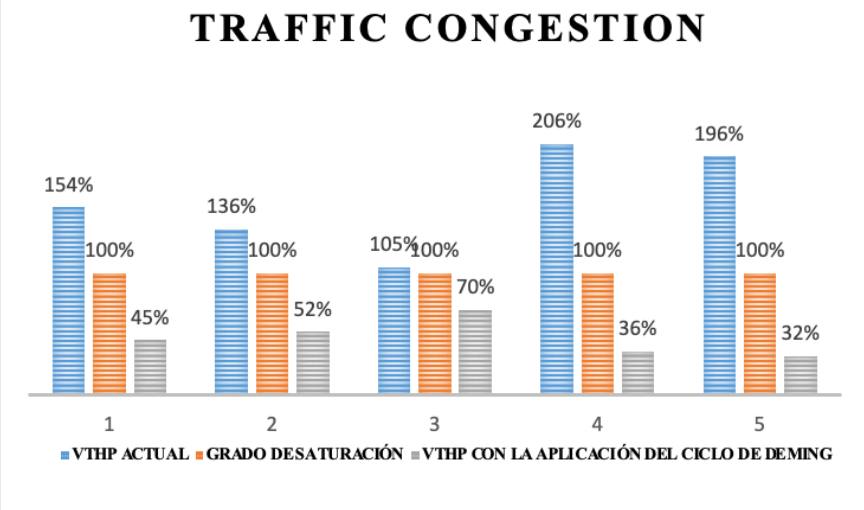


Source: Own elaboration

With the participation of segregated lanes for light vehicles for public and private use within the PHVA or Deming cycle, the quality of road service improved in the controlled intersection Nº1 by 71%, in the controlled intersection Nº2 by 61%, in the controlled intersection Nº3 by 34%, in the controlled intersection Nº4 and Nº5 by 83%, with respect to the conventional method, taking the data to analyze the VTHP divided by the FHP, reducing vehicular congestion, which is shown below, at

controlled intersection Nº4 and Nº5 by 83%, with respect to the conventional method, taking as data to be analyzed the VTHP divided by the FHP, reducing vehicular congestion, the percentage reduction of which is shown in Figure13.

Figure 14. Percentage comparison of vehicular congestion.



Source: Own elaboration

With the participation of segregated lanes for light vehicles for public and private use within the PHVA or Deming cycle, improving the flow of the roads. At controlled intersection Nº1, traffic congestion was reduced by 55%, at controlled intersection Nº2 by 48%, at controlled intersection Nº3 by 30%, at controlled intersection Nº4 by 64% and at controlled intersection Nº5 by 68%; regarding the number of vehicles registered in the degree of saturation.

3.26.2. Current semaphore times vs. semaphore times applying the Deming cycle and Webster's method

Controlled Intersection No. 1

The intervention of the PHVA or Deming cycle and the Webster method in the finding of the times in the traffic lights in the controlled intersection No. 1 had a slight difference in the optimal cycle of 25 seconds, indicating that it is necessary to make the change in the times of the phases of the traffic lights of the controlled intersection, since there is more vehicular traffic in the North to South direction.

Controlled Intersection No. 2

The intervention of the PHVA or Deming cycle and the Webster method in the finding of the times in the traffic lights in the controlled intersection No. 2 had a slight difference in the optimal cycle of 16 seconds, which will require a change in the phases of the traffic lights of

the intersection because there is more vehicular traffic in the north-south direction, it is also required to add more time to the amber color.

Controlled Intersection No. 3

The intervention of the PHVA cycle or Deming cycle and the Webster method in the finding of the times in the traffic lights in the controlled intersection No. 3 had a minimum difference in the optimal cycle of 1 second, indicating that it will not be necessary to make a change of times in the phases of the traffic light.

Controlled Intersection No. 4

The intervention of the PHVA or Deming cycle and the Webster method in the finding of the times in the traffic lights in the controlled intersection No. 4 had a minimal difference in the optimal cycle of 1 second, indicating that it will not be necessary to make a change of times in the phases of the traffic lights, rather it is required to make a readjustment in the optimal cycle by adding the time in the amber color.

Controlled Intersection No. 5

The intervention of the PHVA or Deming cycle and the Webster method in the finding of the times in the traffic lights in the controlled intersection No. 5 had a difference in the optimal cycle of 12 seconds, indicating that the analysis was performed correctly and it will be necessary to change the phases of the traffic light, although it is true that the vehicular traffic in the north to south direction is greater, there is no need to exaggerate in placing a high time in the green color, it is also essential to add more time in the amber color.

Discussion

The correlation diagram and Pearson's r correlation statistic will be used in the hypothesis test. Pearson's correlation is the measure of linear dependence that ranges between -1 and +1 between 2 quantitative variables, explaining the influence of one variable on the other variable.

It is based on the following ranges shown in Table 29.

Table 29 Correlation coefficient range

R	Degree of correlation
-1.00	Perfect negative correlation
-0.90	Strong negative correlation
-0.70	Strong negative correlation
-0.50	Medium negative correlation
-0.25	Weak negative correlation
-0.10	Very weak negative correlation
+/− 0.00	No correlation between variables

0.10	Very weak positive correlation
0.25	Weak positive correlation
0.50	Medium positive correlation
0.70	Strong positive correlation
0.90	Strong positive correlation
1.00	Perfect positive correlation

Source: Hernandez et al., 2016, pp. 304 - 305

The general hypothesis statement is:

Null Hypothesis

H0 = "The application of the PHVA cycle will have no connection with the optimization of vehicular traffic of the road network in the main controlled intersections of Jiron Lima, Jiron San Roman, Jiron and Jiron Ayacucho in the center of the city of Juliaca, 2021."

Alternative Hypothesis

H1= "The application of the PHVA cycle will have connection with the optimization of vehicular traffic of the road network in the main controlled intersections of Jiron Lima, Jiron San Roman, Jiron and Jiron Ayacucho in the center of the city of Juliaca, 2021."

Hypotheses H0 and H1 will be highlighted to determine whether the Deming methodology is suitable for optimizing the required controlled intersections. For this reason, the hypothesis test known as Pearson's r will be used, and specific hypotheses 1 and 2 will be tested.

Specific hypothesis test Nº1

Null Hypothesis

H0 = "The quality of service level without the application of the PHVA cycle and the proposal of segregated lanes for light vehicles for public and private use will have no connection with the optimization of vehicular traffic of the road network in the main controlled intersections of Jiron Lima, Jiron San Roman and Jiron Ayacucho in the center of the city of Juliaca, 2021."

Alternative Hypothesis

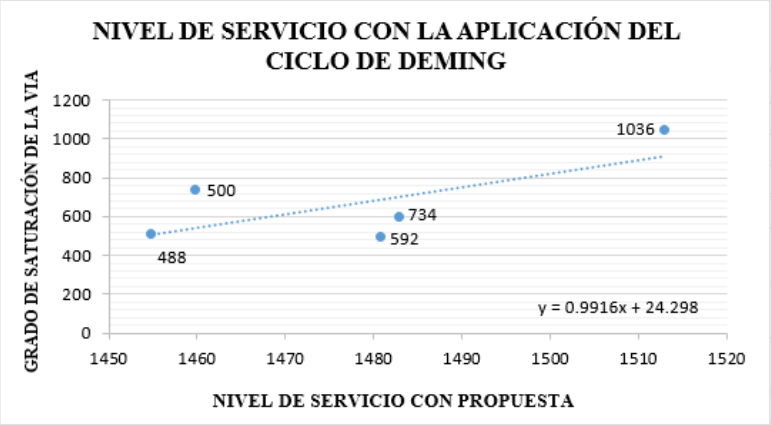
H1= "The quality of the level of service with the application of the PHVA cycle and the proposal of segregated lanes for light vehicles for public and private use will have no connection with the optimization of vehicular traffic of the road network in the main controlled intersections of Jiron Lima, Jiron San Roman and Jiron Ayacucho in the center of the city of Juliaca, 2021".

The specific hypothesis No. 1 has the following information, taken from the analysis performed in step 6 of the PHVA cycle and from the analysis of the actual service quality:

Table 30 Correlation coefficient of road service quality with PHVA cycle intervention.

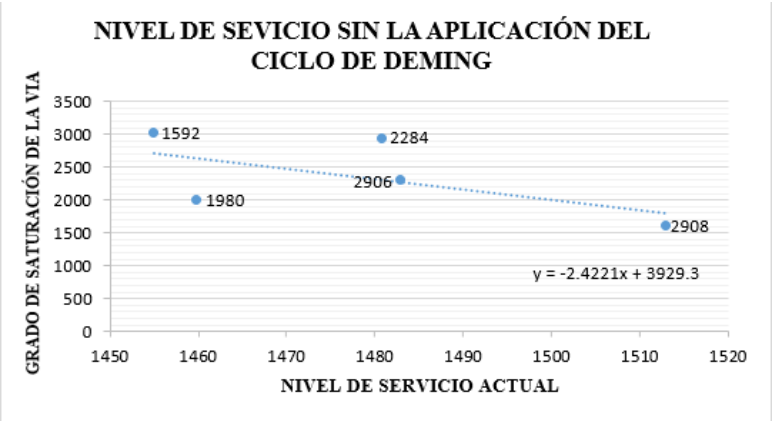
	Degree of saturation in road transportation	Service level with proposal	Current service level
	1483	592	2284
	1460	734	1980
	1513	1036	1592
	1455	500	2996
	1481	488	2908
Arithmetic mean =	1478.40	670	2352
Standard deviation =	952.70	227.02	600.93
Correlation coefficient =		0.70	-0.60

Figure 15. Service level with the intervention of the PHVA cycle



Source: Own elaboration

Figure 16. Service level without the intervention of the PHVA cycle



Source: Own elaboration

Specific hypothesis test decision No. 1

According to the range of linear correlation; service level quality with PHVA or Deming cycle intervention, the hypothesis test showed an r = 0.70, indicating a degree of “significant positive correlation.”

According to the linear correlation rank; service level quality without the intervention of the PHVA or Deming cycle, the hypothesis test showed an r = -0.60, indicating a degree of “average negative correlation.”

Specific hypothesis testing No. 1

The analysis of the alternative hypothesis has a significant positive linear relationship, being the influence of one variable on the other more powerful, opting to give validity to the alternative hypothesis and reject the null hypothesis.

Therefore, the proposal of segregated lanes for light vehicles for public and private use improves the quality of service, offering a fluid movement to users.

Specific hypothesis test No. 2

Null Hypothesis:

H0= The times for each phase and the traffic light cycles, without the application of the PHVA cycle and the Webster method will have no connection with the optimization of the vehicular traffic of the road network in the main controlled intersections of Jiron Lima, Jiron San Roman and Jiron Ayacucho in the center of the city of Juliaca, 2021."

Alternative Hypothesis:

H1= "The times for each phase and the traffic light cycles, with the application of the PHVA cycle and the Webster method will have no connection with the optimization of the vehicular traffic of the road

network in the main controlled intersections of Jiron Lima, Jiron San Roman and Jiron Ayacucho in the center of the city of Juliaca, 2021."

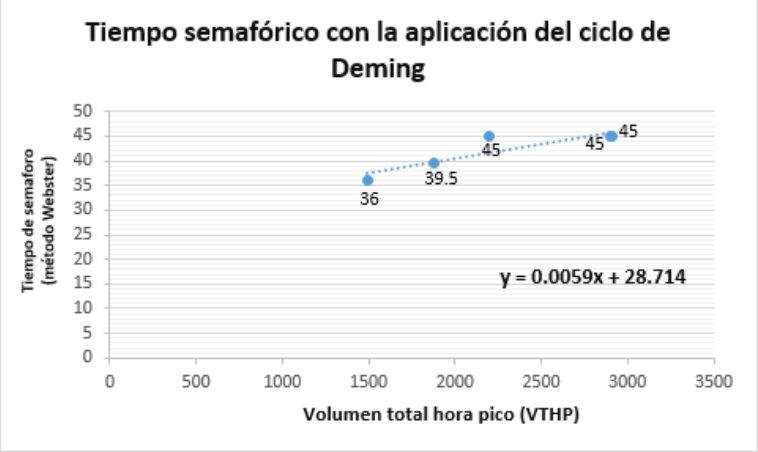
The specific hypothesis 1 has the following information, taken from the analysis performed in step 6 of the PHVA cycle and from the analysis of the actual service quality:

Table 31 Correlation coefficient of traffic light timing

	VTHP	Optimal average time	Current average time
	2194veh/hr	45.00	34.00
	1875veh/hr	39.50	47.50
	1492veh/hr	36.00	38.50
	2905veh/hr	45.00	54.50
	2898veh/hr	45.00	55.50
Arithmetic mean =	2273	42.10	46.00
Standard deviation =	625.43	14.98	9.55
Correlation coefficient =		0.89	0.73

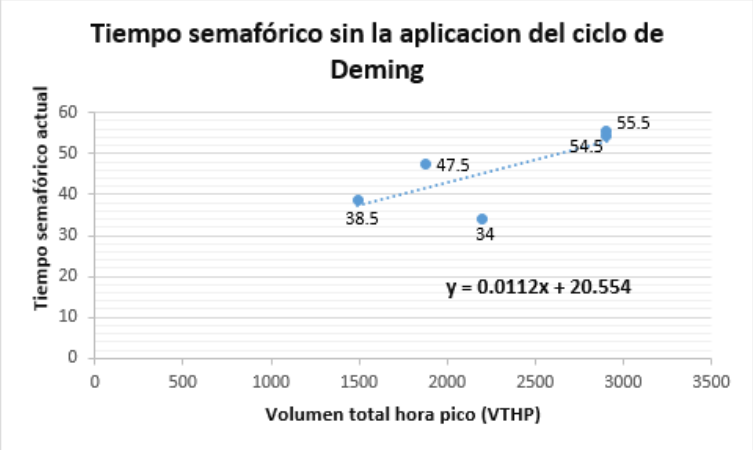
Source: Own elaboration

Figure 17. Semaphore time with the intervention of the PHVA or Deming cycle



Source: Own elaboration

Figure 18. Semaphore time without the intervention of the PHVA or Deming cycle



Source: Own elaboration

The VTHP, if high, the green time period will also be high.

According to the linear correlation range; traffic light time with PHVA or Deming cycle intervention, the hypothesis test showed an r = 0.85, indicating a degree of "considerable positive correlation".

According to the range of linear correlation; the semaphore time without the intervention of the PHVA or Deming cycle, the hypothesis test showed an r = 0.73, indicating a degree of "considerable positive correlation".

The hypothesis test to both variables indicates that there is a considerable positive relationship in the 2 variables, but by having an r of 0.85 already reaching a strong positive correlation, it is decided to choose that linear correlation that expresses the variable when the PHVA or Deming cycle and the Webster method intervene.

Specific hypothesis testing No. 2

The analysis of both hypotheses resulted in a strong and significant positive linear relationship, but the strong positive linear relationship is accepted because the influence of one variable on the other is stronger, choosing to validate the alternative hypothesis and reject the null hypothesis.

Therefore, if the total peak hour volume is greater, more time in the green color is needed, so that there is a greater vehicular flow and thus the road networks can be optimized.

4. General Conclusion

The intervention of the PHVA or Deming cycle, which stands out for being a cycle that seeks continuous improvement in each of its processes, optimized vehicular traffic by improving the quality of service provided to transport users of the 5 controlled intersections. With the participation of the Webster method within the PHVA cycle, it was possible to obtain the time period of the phases and the traffic light cycles, having as results cycles very similar to the ones in situ, choosing to reprogram the controlled intersections No. 1, No. 2 and No. 5 and the 2 remaining controlled intersections, only changing the phases adding time in the amber color.

With the participation of segregated lanes for public and private light vehicles within the PHVA or Deming cycle, the quality of the level of service improved or optimized at controlled intersections No. 1, No. 2, No. 4 to B; controlled intersection No. 3 to C and controlled intersection No. 5 to A, the improvement goes hand in hand with the decrease in VTHP. When subjected to Pearson's r correlation coefficient (hypothesis test), obtaining a considerable positive linear relationship of 0.70, showing the influence of one variable on the other.

There is a percentage improvement, in the controlled intersection No. 1 the vehicular congestion was reduced by 55%, in the controlled intersection No. 2 by 48%, in the controlled intersection No. 3 by 30%, in the controlled intersection No. 4 by 64% and in the controlled intersection No. 5 by 68%; with respect to the number of vehicles registered in the degree of saturation.

5. Recommendations

It is required to make authorized stops where pedestrians feel safe and do not cause disorder when taking the "micro", prohibiting the transit of private vehicles at some intersections, will help to reduce congestion and find a constant flow even at peak hours in the district of Juliaca. And abide by Supreme Decree N° 025-2021-MTC Article Nº162, which indicates the maximum speed in Jirones of 30km/hv.

The application of segregated lanes for light vehicles is necessary to be used in the study's cotroladas intersections, since it gives positive results, the same proposal was used in the Jiron San Roman with the Jiron 2 de Mayo giving favorable results, without the appearance of bottlenecks; because it can only transit private vehicles and motorcycles, the absolute prohibition for vehicles of urban use "micros".

By means of the visual analysis of the road it is revealed that the horizontal signaling such as: The painted pedestrian walkway has minimal maintenance since there is deterioration of the road markings due to the excess of vehicles and pedestrians, the sidewalk sardinels are

not maintained either, since the paint is dissipating, also required is the placement of signs indicating prohibited stops, placement of signs indicating the maximum speed, intersection of roads (SP 11), shoulders (SP-25), maximum total weight allowed (SP-38) and (SR-31), cycle lane signs (SP 59), left turn only (SR-07), right turn only (SR-05) and (SR-07), no freight vehicles (SR-18), no parking (SR-28), no parking and stopping (SR-28A), cycle route (SR-37), one-way traffic (SR-38), no passenger drop-off or pick-up (SR-41), no loading or unloading (SR-43), bicycle lane (SI-11), crosswalk (SI-24), pavement markings such as arrows indicating direction, and stop line markings.

The prohibition of private vehicles at some controlled intersections and heavy load vehicles from 7:00 a.m. to 7:00 p.m. in the center of the city of Juliaca, in order to reduce traffic volume and avoid congestion.

And as Juliaca is a commercial axis for its regulation it is required to take alternatives: As the ORDINANCE No. 325/MLV, which gave the District Municipality of La Victoria, created on September 27, 2019.

• Creation of new markets for the proper relocation of informal street commerce.

• Creation of ordinances, where it contemplates solutions as well as ORDINANCE No. 325/MLV, which gave the District Municipality of La Victoria, created on September 27, 2019.

• Be authorized to sell in green areas (squares, markets among others), without affecting the pedestrian and vehicular traffic routes, only for 1 year until their proper relocation to new markets.

• Greater participation of municipal authorities in charge of enforcing pedestrian and vehicular zones.

• Create talks on the benefits of being a formal merchant, seeking awareness to not occupy areas of pedestrian or vehicular use, seeking road safety for all transport users.

To control the speed of vehicles, it is recommended to:

• More presence of police and traffic inspectors, so that they can ensure good vehicular circulation. According to a study by Fundación MAPFRE, the presence of traffic officers reduces fatal accidents by 5%. The presence of the agents will also enforce compliance with the maximum speed limit of 30 km/hv (Decreto Supremo Nº 025-2021-MTC).

• The ISA (Intelligent Speed Adaptation System), this system works with sensors and has a GPS, which establishes the speed limits in each section as the signs are showing.

• Insertion of a control device (traffic light) that shows an amber color, if the allowed speed is exceeded, it will immediately activate the phase change: amber to red; indicating alert.

• Educate transport users through the implementation of workshops to enable them to act with caution.

The insertion of humps or road humps is recommended as they are fixed structural devices, excellent speed reducers (Sistema Nacional de Carreteras, 2011) that positively influence the optimization of different roads, since reducing the speed in an urban area to 30 km/h (Supreme Decree N° 025-2021-MTC - Article 162) prevents traffic accidents, always being the pillar road safety.

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