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ABSTRACT

Transport and road traffic demand has caused signs of congestion, delays, and accidents in the last two decades, particularly in developing cities, mainly during peak hours. Hence, a multidisciplinary effort (for example, the improvement of driving habits, the provision of better infrastructure and traffic management measures, and the rationalisation of the use of public roads) is needed. This project proposed the design and implementation of a smart traffic light control system to improve the vehicular circulation of Queens Drive – Layard Street intersection, especially during peak hours. Finally, it evaluated the factors generating problems and social impact (for example, lost man-hours, environmental pollution, and accidents) to propose strategies to improve the traffic flow, reduce operational conflict, and provide a safer environment for the community. From the analysis and simulation carried out with the VISSIM software during rush hour at the intersection with traffic lights, it was found that the number of vehicles in the queue was reduced from 351 to 270 in the six possible movements within the intersection. By reducing the vehicles in the queue, pollution emissions are also reduced (297.1 g/h CO emissions and 57.9 g/h NO emissions). Finally, 270 vehicles queuing generate an extra cost in fuel, although in less quantity, reducing consumption from 17.8 to 16.7 L/h. Therefore, the proposed situation has reduced the delay and number of vehicles, yet the service level remains the same as the current situation. In addition, the proposed case includes improvements in horizontal and vertical signage, which will help mitigate risks and reduce unnecessary delays.

INTRODUCTION

Traffic congestion is a global problem that leads to delays, time loss, crashes, energy consumption, human stress, and pollution among other issues (Transportation Research Board, 2000). According to the Road Safety 2020 Annual Report, New Zealand had one of the largest increases (10.9 per cent) in the number of road fatalities in 2018 compared to the average from 2019 to 2021. In addition, New Zealand had a considerable increase in the total number of pedestrians killed on the road (11 per cent) between 2010 and 2018 (IRTAD, 2020). Therefore, in order to decrease car crashes and traffic congestion, it is necessary to manage the traffic flow in the best possible way and to develop road safety solutions through the use of modern technology and applications.

Road intersections offer research potential in traffic flow, especially in a city such as Invercargill with massive potential for improvement in terms of traffic and transport. Invercargill is located in the Southland region, with a population of approximately 57,100 inhabitants. In recent years, road demand has grown due to the increase in population and in private vehicle usage. It is perceived that the road design and traffic road devices in areas of high concentration of travel (schools, offices, stadiums, and other infrastructures) during peak hours do not satisfy the demand for transport which has resulted in increases in travel time, delays, accidents, and environmental problems.

In the specific case of the Queens Drive – Layard Street intersection in Invercargill, it has been found that different sites such as James Hargest College, Lees Street Kindergarten, and the Waihopai Bowling Club, are generating a lot of movement of people and vehicles. As a consequence, different problems can be identified affecting the community and generating high rates of traffic congestion and social impact (lost man-hours, accidents, pollution), mainly during peak hours (Figure 1).

Figure 1. Development Site Location (Google, 2021).

During the past two decades, an increase in demand for transport and road traffic has caused, particularly in developing cities, signs of congestion, delays and accidents, mainly during peak hours. Therefore, a multidisciplinary effort that includes the improvement of driving habits, the provision of better infrastructure and traffic management measures (management of the supply), and the rationalisation of the use of public roads (demand management) is urgently needed. Hence, this project proposed the design and implementation of a smart traffic light control system to improve the vehicular circulation of the Queens Drive – Layard Street intersection. Further, it evaluated the factors generating problems and social impact to propose strategies to improve the traffic flow and reduce the operational conflict and to provide a safer environment for the community. Finally, the project evaluated the implementation of a traffic light system to counteract the factors that have been generating problems with social impact to propose measures that speed up vehicle flow mainly during peak hours.

METHOD

This study followed quantitative descriptive research methodology. A survey was administered to determine the traffic volumes in terms of walking paths, cycling, parking vehicles, and right-left turning. The data collected was calculated and analysed using the operational analysis method for signalised intersections (Antunez, 2019).

A survey was administered during busy hours to collect the data from the Queens Drive intersection with Layard Street (for example traffic volumes, walking paths, cycling, parking vehicles, right-left turning, and so on). The queue length on each road (Queens Drive and Layard Street), total phases, capacity, and other variables needed to determine the cycle time for the smart traffic light system in the intersection were also examined.

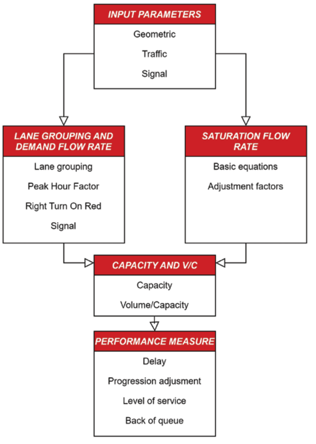


Figure 2. Operational analysis methodology for signalised intersections (Antunez, 2019).

A. Description of the methodology

The methodology (Figure 2) begins by recognising the geometric conditions and volumes at the intersection of study (Queens Drive – Layard Street), as well as determining the 'conflictive transit' which is represented by all the movements on the secondary road and the right-hand turn movement from the main road. It is necessary to know the capacity of the spaces in the main traffic stream to accommodate each of the movements under study that will use these spaces. Finally, the capacities found must be adjusted due to the impedance effects of right turners from major streets and the use of the shared lanes.

B. Input parameters

Table 1 provides a summary of the input information required to perform an operational analysis for the Queens Drive – Layard Street intersection. This information forms the basis for selecting values and computational procedures in the modules that were developed specifically for the calculation of cycle time. The data required is detailed and varied and falls into three main categories: geometric, traffic, and signage.

TYPE OF CONDITION	PARAMETER
GEOMETRIC CONDITIONS	Area type Number of lanes, N Average lane width, W (m) Grade, G (%) Existence of exclusive LT or RT lanes Length of the storage bay, LT or RT lane, Ls (m) Parking
TRAFFIC CONDITIONS	Demand volume by movement, V (veh/h) Peak-hour factor, PHF Percent heavy vehicles, HV (%) Local buses stopping at the intersection, N_b (buses/h) Parking activity, N_m (number of manoeuvers/h) Arrival type, AT The proportion of vehicles arriving on green, P Approach speed, S_a (km/h)
SIGNALISATION CONDITIONS	Cycle length, C (s) Green time, G (s) Yellow-plus-all-red change and clearance interval Actuated or pre-timed operation Pedestrian push-button Minimum pedestrian green, G_p (s) Phase plan Analysis period, T (h)

Table 1. Input data needs for each analysis lane group (Antunez, 2019).

C. Traffic microsimulation modeling

The general process for developing and applying a microsimulation model to a traffic analysis problem consists of seven main tasks as shown in Figure 3.

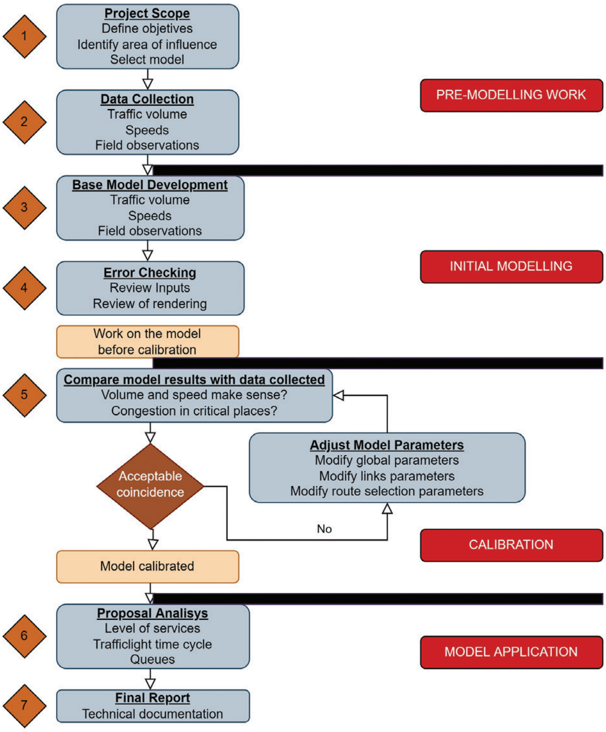


Figure 3. Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modelling Software (Haridas, 2020).

RESULTS

A. Traffic survey analysis

From the information processed on Thursday, July 9, 2021, the following peak hours were identified: 8:30 a.m. to 9:30 a.m. (morning shift), 3:15 p.m. to 4:15 p.m. (afternoon shift), and from 5:00 p.m. to 6:00 p.m. (night shift).

Of the three peak hours of the day, the peak hour that obtained the highest pedestrian volume during the day was chosen for the analysis. According to this, in the morning vehicular peak hour, a total of 2138 vehicles passed through the intersection and 158 pedestrians, while in the afternoon rush hour a total of 1985 equivalent vehicles and 125 pedestrians passed through.

B. Peak hour

According to the vehicle composition of all those who passed through the intersection, the predominant vehicle was cars (1881), which represented 88 per cent of the morning rush hour volume.

According to the pedestrian composition of the traffic survey, 98 pedestrians crossed the intersection during the morning peak hour and were mostly students and workers from the James Hargest School.

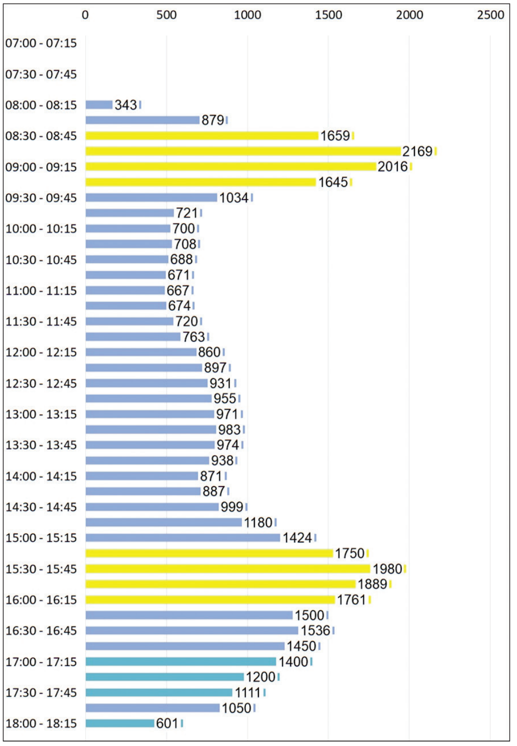


Figure 4. Vehicle Maximum Demand Chart
(Periods of maximum demand per point hour intersection:
Queens Drive – Layard Street).

Layard Street approach (East → West)

From the total of vehicles displaced by this approximation, 52 private vehicles (cars), two vehicles for the transportation of people, five cargo transport vehicles, and three motorcycles; making a total of 410 vehicles that took to the UCP equivalency representing a total of 332 cars.

Two movements are generated: the first is the turn to the right (movement 30) with 251 vehicles (205 cars) representing 13.1 per cent and the second to the left (movement 32) with 159 vehicles (127 cars) that represent 8.1 per cent of the vehicle volume in the hour of maximum demand of the morning shift.

A total of 71 pedestrians from North-South and South-North crossed this approach (movements P1 and P2).

Queens Drive approach (North → South)

Of the total vehicles displaced by this approximation, 191 private vehicles (cars), 69 vehicles for transportation of people (67 rural vans, 2 minibuses, and 0 buses), 14 cargo transportation vehicles, 43 minor transportation vehicles (bicycles) and 14 motorcycles; making a total of 724 vehicles that, taken to the UCP equivalence, represent a total of 658 cars.

Three movements are generated in this approach: the first is the front turn (movement 10) with 601 vehicles (553 cars) representing 35.4 per cent. The second to the right (movement 11) with 120 vehicles (104 cars) represents 6.6 per cent and the third U-turn (movement 13) with 3 vehicles (2 cars) represents 0.1 per cent of the vehicle volume in the hour of maximum demand of the morning shift.

A total of 75 East-West and West-East pedestrians crossed this approach (movements P3 and P4).

Queens Drive approach (South → North)

Of the total vehicles displaced by this approximation, 146 private vehicles (cars), 73 vehicles of transportation of people (73 rural vans, 0 minibuses, and 0 buses), 7 vehicles of cargo transportation, 408 small transportation vehicles (moto-taxi), and 6 motorcycles; making a total of 640 vehicles that, taken to the UCP equivalence, represent a total of 569 cars.

Three movements are generated: the first is the front turn (movement 21) with 433 vehicles (391 cars) representing 20.05 per cent. The second from the left (movement 22) with 147 vehicles (129 cars) representing 8.26 per cent and the third U-turn (movement 23) with 60 vehicles (50 cars) represents 3.18 per cent of the vehicle volume in the hour of maximum demand of the shift the following day.

C. Cycle time calculation

In an intersection with traffic lights, where all the vehicles continue straight ahead, the rates would be maximum flow rates, at approximately equal intervals. However, at the Queens Drive – Layard Street intersection, the situation is more complex due to the presence of heavy vehicles and turn movements to the left and right.

Adjustment for heavy vehicles

According to Highway Capacity Manual (2000), the heavy-vehicles factor (F_{HV}) represents the impact that heavy vehicles have on passenger cars. Heavy vehicles are defined as those with more than four tyres touching the pavement. The heavy-vehicles factor accounts for the additional space occupied by these vehicles and for the difference in operating capabilities of heavy vehicles compared with passenger cars.

Heavy or commercial vehicles (trucks and buses mostly), due to their longer length and less acceleration power than cars, need more time to clear the intersection.

The following data (PC and PB) in Table 2 was extracted from the traffic survey. Equivalent automobiles commonly used for both trucks (EC), and for buses (EB), vary from 1.4 to 1.6. In this research an average value of 1.5 was considered.

DATA		Queens Drive – Layard Street Intersection
PC	% Trucks in the intersection.	4%
PB	% Buses in the intersection.	5%
EC	Cars equivalent to a Truck.	1.5 cars/truck
EB	Cars equivalent to a Bus.	1.5 cars/truck
Heavy Vehicles Factor (F_{HV})		**0.96**

Table 2. Adjustment for heavy vehicles factor (F_{HV}) results.

Peak-Hour Factor

According to Antunez (2019), this approach involves a study of the entire peak hour but divides it into four 15-minute analysis periods. This analysis allows the account for queues that carry over the next analysis period. Therefore, when demand exceeds capacity during the study period, a more accurate representation of the delay experienced during the hour can be achieved by this method.

$$\mathrm{PHF} = \frac{VHM}{4 \times V_{15}} \tag{1}$$

PHF: Peak Hour Factor

VHM: Volume per hour of maximum demand

V_{15}: 15-minute traffic flow more loaded

TIME	No. of Vehicles
08:00 - 08:15	477
08:15 - 08:30	537
08:30 - 08:45	*633*
08:45 - 09:00	511
08:00 - 09:00	*2158*

$$FHP = \frac{2158}{4 \times 633}$$

FHP = 0.9

Equivalent car flows of straight crossing

On the other hand, it is required to have factors for the movements of turn (right and left turns), since these manoeuvres generally consume more time than vehicles that continue straight through the intersection.

The conversion factors that are used to convert cars that turn left or right to equivalent cars that continue straight are calculated using the following tables.

Left Turn (E_v Left)

The conversion factors take into account the greater time consumed when turning due to the presence of vehicles.

(*) For vehicles entering from Layard Street direction E>W, there are no opposite traffic lines, so the E_v for left-hand turns would be 1.1. (E_v = 1.1).

(**) For vehicles entering from Queens Drive heading N>S, there are 03 opposite lines with a traffic flow of approximately 600 vehicles, so the E_v for left-hand turns from Queens Drive N>S would be four. (E_v = 4).

For vehicles entering from Queens Drive in the S>N direction, there are no left-hand turns as it is a "T" intersection, so the E_v for left-hand turns does not exist (zero).

Opposite Flow (vehicle/h)	Number of opposing lanes		
	1	2	3
0 (*)	*1.1*	*1.1*	*1.1*
200	2.5	2	1.8
400	5	3	2.5
600 (**)	*10*	*5*	*4*
800	13	8	6
1000	15	13	10
>1200	15	15	15

Table 3. Equivalent direct cars for left-hand turns (Antunez, 2019).

Right Turn (E_v Right)

Here, the conversion factors take into account the longest time consumed when turning due to the presence of pedestrians.

(***) For vehicles entering from Queens Drive in the N>S direction, according to the pedestrian counts in the traffic survey, it was possible to count around 200 pedestrians most of them students and staff of the James Hargest School.

For vehicles entering from Queens Drive in the S>N direction, there are no right-hand turns as it is a "T" intersection. Therefore, the E_v for right-hand turns does not exist (zero).

Pedestrian volume at the closest crossing (pedestrian/h)	Equivalent
None (0)	1.18
Low (50)	1.21
(***) Moderate (200)	*1.32*
High (400)	1.52
Extreme (800)	2.14

Table 4. Equivalent direct cars for right-hand turns (Antunez, 2019).

Table 5 shows the factors from every access to the intersection obtained from the previous tables.

In this way, the volume per hour of maximum demand ($VHMD$) was converted to direct automobile flows, using the following expression.

$$Q_{ADE} = \frac{VHMD}{FHP}\left(\frac{1}{F_{HV}}\right)(E_v) \qquad (2)$$

Q_{ADE}: Equivalent car flows of straight crossing.
$VHMD$: Volume per hour of maximum demand
F_{HV}: Adjustment for Heavy Vehicles
FHP: Peak Hour Factor
E_v Equivalent car flows for right and left turns

	Layard Street E>W	Queens Drive N>S	Queens Drive S >N
Heavy Vehicles Factor (F_{HV})	0.96	0.96	0.96
Peak-Hour Factor (PHF)	0.90	0.9	0.90
Left Turn Factor (E_v Left)	1.10	4.00	0
Right Turn Factor (E_v Right)	1.32	0	1.32

Table 5. Resume of factors for Q_{ADE} calculation.

Table 6 shows the values obtained so far for the 03 vehicular accesses to the intersection of Queens Drive – Layard Street in equivalent car flows of straight crossing.

	Layard Street E>W (no. of vehicles)	Queens Drive N>S (no. of vehicles)	Queens Drive S>N (no. of vehicles)
Volume ADE Left	377	989	0
Volume ADE Right	121	0	570
Volume ADE Straight	0	755	614
Volume ADE TOTAL	**498**	**1744**	**1184**

Table 6. Results for Q_{ADE} calculations.

D. Phase change interval

The purpose of the phase change interval is to alert users of a change in the assignment of the right to use the intersection. To calculate the phase change interval, the time driver reaction, deceleration time and space and the time needed to clear the intersection were considered.

The formula where the term $(v/2a)$ represents the time necessary to travel the stopping distance with deceleration 'a' and velocity 'v', and the term $(W+L)/v$ is the time to cross the intersection. The first two terms, $t+v/2a$, identify the interval of amber change, and the third term, $(W+L)/v$, is associated with the interval of change in everything red.

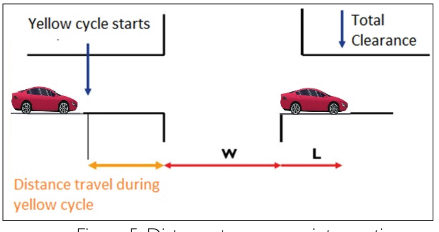


Figure 5. Distance to cross an intersection.

$$Y = \left(t + \frac{v}{2a}\right) + \left(\frac{W + L}{v}\right) \quad (3)$$

(A_i) YELLOW + (TR_i) ALL RED

Y: Phase shift interval, yellow plus all red (s)

t: Driver perception-reaction time (usually 1.00 s)

v: Car approach speed (m/s) (v=50 km/h in Invercargill CBD)

a: Deceleration rate (usual value 3.05 m/s^2)

W: Intersection width (m)

L: Vehicle length (suggested value 6.10 m)

A_i: Yellow/Amber Interval of time (s)

TR_i: Total Red Interval of Time (s)

Table 7 shows the values obtained for the 03 vehicular accesses to the intersection Queens Drive – Layard Street for the Phase Change Interval calculation.

Calculation determines one (01) traffic light phase Layard Street, in the same way 01 phase for Queens Drive, each one with their respective times of yellow and all red necessary for the pass between phases. Finally, the total lost time is calculated, adding the Phase Shift Interval (Y) of both phases, which results in the Total Lost Time (L_t) of 10 seconds of non-effective time or non-green time, which was used for the following calculations.

		Layard Street E>W	Queens Drive N>S	Queens Drive S>N
t	Driver perception time	1.00s	1.00s	1.00s
v	Car approach speed	13.80m/s	13.80m/s	13.80m/s
a	Deceleration rate	3.05m/s^2	3.05m/s^2	3.05m/s^2
W	Intersection width	19.3m	16.7m	16.7m
L	Vehicle length	6.10m	6.10m	6.10m
A_i	Yellow Interval of time	3.3s	3.3s	
TR_i	All Red Interval of time	1.8s	1.6s	
		Phase 01	*Phase 02*	
Y	Phase shift interval	5.1s	4.9s	
L_t	Total Lost Time (Yellow+All Red)	*10.0s*		

Table 7. Results for phase change interval.

E. Maximum vehicular flow ratio

According to Antunez (2019), we need to calculate the optimal cycle time or minimum cycle time in each intersection, allowing all traffic in waiting for the green signal to go through the intersection. To do this, we must find the Y_i (Maximum Vehicular Flow Ratio) values of Queens Drive (N>S) and Layard Street (E>W). The Y_i value is equal to the relationship between the flow existing in the lane divided by its saturation flow.

$$Y_i = \frac{Q_{imax}}{S} \quad (4)$$

Y_i: Maximum vehicular flow ratio

Q_{imax}: Maximum or critical adequate flow (Q_{ADE}) per lane (vehicles/h/lane)

S: Saturation flow (1750 vehicles/h/lane)

(*) the saturation factor (S=1750 vehicles/h/lane) is recommended in the Highway Capacity Manual, for signalised intersections.

		Queens Drive N>S	Layard Street E>W
Q_{imax}	**Maximum adequate flow**	989 vehicles/h/lane	377 vehicles/h/lane
S	**Saturation flow**	1750 vehicles/h/lane	1750 vehicles/h/lane
Y_i	**Maximum vehicular flow ratio**	**0.57**	**0.22**

Table 8. Maximum vehicular flow ratio (Y_i).

F. Total Cycle Length

Based on field observations and simulation of a wide range of traffic conditions, the delay minimum of all vehicles at an intersection with traffic lights can be obtained for an optimal cycle time.

$$C_0 = \frac{1.5L_t + 5}{1 - \Sigma_{i=1}^{\phi} Y_i} \qquad (5)$$

C_o: Optimal cycle time (s)

L_t: Total time lost per cycle

Y_i: Maximum value of the ratio between the current flow and saturation.

φ: number of phases

Consequently, the effective total green time for the intersection can be determined:

		Phase 01	Phase 02
L_t	Total Lost Time (Yellow+All Red)	10s	
Y_i	Maximum vehicular flow ratio	0.21	0.17
φ	Number of phases	2.0 phases	
C_o	Optimal Cycle Time (Green+Yellow+All Red)	91.3s	

Table 9. Results for optimal cycle time.

$$g_T = C_o - L_t \qquad (6)$$

g_T: Total green time per cycle

C_0: Optimal cycle time (seconds)

L_t: Total time lost per cycle

C_0	Optimal Cycle Time (Green+Yellow+All Red)	91.3s
L_t	Total Lost Time	10s
g_T	Green effective time	**81.3s**

G. Green effective time per phase

Finally, the distribution of the total effective green time in the phases was determined with the following formula.

$$g_i = \frac{Y_i}{\Sigma_{i=1}^{\varphi} Y_i}(g_T) \qquad (7)$$

g_i: Green time relative per phase

Y_i: Maximum vehicular flow ratio

g_T: Total green effective time

φ: number of phases

		Time (second, s)
Yi_1	Maximum vehicular flow ratio-Phase 01	0.21
Yi_2	Maximum vehicular flow ratio-Phase 02	0.17
g_T	Green effective time	81.3
g_{i1}	Green time for Phase 01	44.9
g_{i2}	Green time for Phase 02	36.3

Table 10. Results for Green time relative per phase.

H. Time distribution diagram per phase in Peak Hour

As demonstrated in the calculation, theoretical cycle time required for the correct movement of vehicles is shown in Figure 6.

This means, that as long as the optimal theoretical conditions are presented at the intersection of Queens Drive – Layard Street, there are no obstacles to the passage of vehicles and their flow is continuous, the times that are theoretically obtained should be sufficient to satisfy the traffic demand.

G1 = 45s	A1 = 3s	Tr = 2s	C0=91
G2 = 36s	A1 = 3s	Tr = 2s	

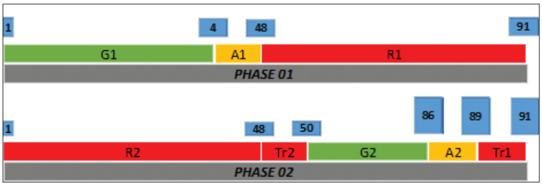


Figure 6. Time distribution diagram.

DISCUSSION

The results indicate that the Queens Drive – Layard Street intersection experiences traffic congestion at different times during the day. The factors considered in the study were the time of the day, types of vehicles, and road infrastructure.

The time of the day is one of the many factors that affect traffic congestion. Drivers often tend to overtake and speed up when in a hurry. According to Green (2003), in an extensive analysis using Australian crash data from 1994 to 1998, related crashes were observed during the afternoon and on weekends, suggesting a relationship with late night and drinking. However, as shown in Vehicle Maximum Demand Chart there is not much difference in traffic volume for the daily morning routine (8:30 a.m.–9:30 a.m.) and afternoon (3:30 p.m.–4:30 p.m.).

According to the evaluation carried out on the operational behavior of the intersection under study, it was verified that one of the main factors that have been generating traffic congestion is right-hand turns. However, all right-hand turns (three turns) are currently being made without supervision or control, causing vehicles to be stationary in the central part of Queens Drive and obstruct the passage of cyclists.

Another factor generating traffic congestion is the deficiencies in the geometric road design on Layard Street. This road has only one lane entrance, while the vehicular flow that circulates along Queens Drive (three lanes) is entering a single lane from Layard Street; for this reason, the intersection area is currently being used as a transition zone from three to one lane, where a bottleneck has been generated, causing the formation of queues within the intersection.

In relation to right-hand turns, the American Association of State Highway and Transportation Officials (AASHTO), reported that right-hand turns reduce the capacity of intersections and slow the flow of vehicles. Hence, it is recommended that drivers try to avoid them through other alternatives such as indirect left-hand turns, roundabouts, or traffic signals, among others.

The operational problems of the intersection of Queens Drive and Layard Street lead to the degradation of the quality of urban life, due to the impacts derived from the traffic identified in the field.

A. Project design and approach

For this project, civil works such as underground canalisation and ramps will be carried out. Works corresponding to traffic lights and signalling will be carried out at the intersection of the canalisation in tracks and sidewalks, installation of boxes and bases for the traffic light poles.

Location			Poles (unit)		Traffic Light (unit)		Controller (unit)
Line	Bound	Approach	Flag	Post	Vehicular	Pedestrian	
Queens Drive	N-S	North	-	3	4	-	-
	S-N	South	1	-	3	-	1
Layard Street	E-W	East	1	-	2	-	-
TOTAL			2	3	9	0	1

Table 11. Traffic light distribution.

Installation of three pedestal posts and two flag posts, nine vehicular traffic lights, and one controller traffic light as detailed in Table 11 is proposed.

In the proximity to each pedestal post and at the interconnection points, we propose building six junction boxes the same that will be connected between pipes under the road, and will serve for the corresponding electrical installations (Figure 7).

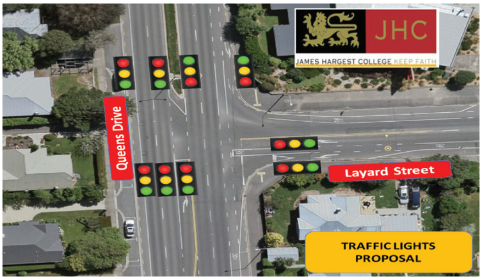
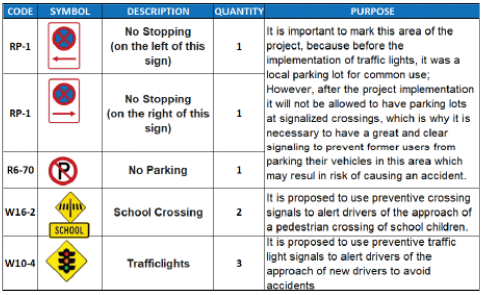


Figure 7. Traffic lights positioning.

Traffic signs are another parameter within traffic engineering whose objective is to use different colors, shapes, images, and signs to help road ordering both in urban areas and highways. It is proposed the following traffic signs, listed and explained in Figure 8, be put in the different locations as specified in Figure 9.



CODE	SYMBOL	DESCRIPTION	QUANTITY	PURPOSE
RP-1		No Stopping (on the left of this sign)	1	It is important to mark this area of the project, because before the implementation of traffic lights, it was a local parking lot for common use; However, after the project implementation it will not be allowed to have parking lots at signalized crossings, which is why it is necessary to have a great and clear signaling to prevent former users from parking their vehicles in this area which may resul in risk of causing an accident.
RP-1		No Stopping (on the right of this sign)	1	
R6-70		No Parking	1	
W16-2	SCHOOL	School Crossing	2	It is proposed to use preventive crossing signals to alert drivers of the approach of a pedestrian crossing of school children.
W10-4		Trafficlights	3	It is proposed to use preventive traffic light signals to alert drivers of the approach of new drivers to avoid accidents

Figure 8. Traffic signs proposal.

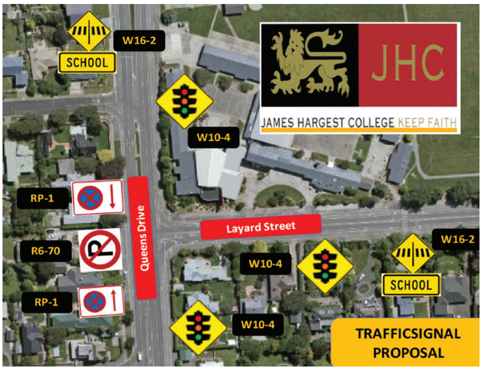


Figure 9. Location of traffic signs.

B. Standard time cycle during no peak hours/regular hours

Based on the traffic survey, the low number of vehicles entering the intersection from Layard Street is approximately two to three vehicles every 15 minutes during non-peak hours. It allows proposing a Standard Cycle Time during regular hours or no peak hours (9:30 a.m.–3:00 p.m. and 4:00 p.m.–8:30 a.m.) that will offer a permanent green for both directions of Queens Drive and a permanent red on Layard Street as shown in Figure 10.

According to the traffic survey, the entry of vehicles through Layard Street is low during non-peak hours (around two to three vehicles every 15 minutes). However, eventually, vehicles will come and enter the intersection from Layard Street (East-West).

In this sense, the implementation of an electromagnetic loop is proposed to detect the presence of vehicles on Layard Street which will be in the Standard Cycle Time Non-Peak Hours, giving a time of 10 seconds to release the Layard Street vehicles input.

The Activated Cycle Time (Figure 11) will occur when a vehicle is positioned on top of an electromagnetic sensor to pass the traffic flow of Layard Street. This vehicle will wait for 10 seconds and then will have 10 seconds to cross, after this, the cycle time will return to the Standard Cycle Time Non-Peak Hours until the next vehicle.

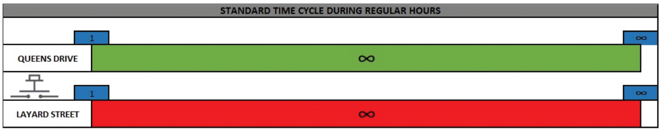


Figure 10. Standard time cycle diagram during regular hours.

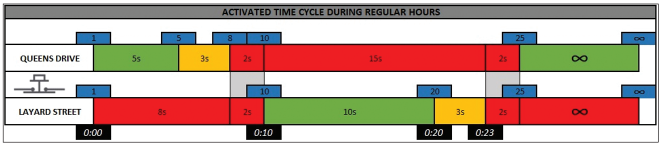


Figure 11. Activated time cycle diagram during regular hours.

G1 = 45s	A1 = 3s	Tr = 2s	C0=91
G2 = 36s	A1 = 3s	Tr = 2s	

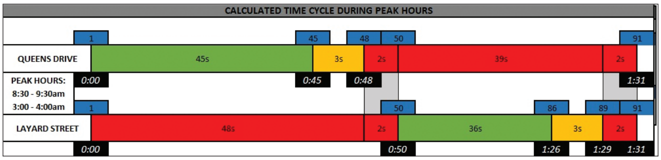


Figure 12. Calculated time cycle diagram during peak hours.

C. Calculated time cycle during peak hours

The traffic light times for the Calculated Time Cycle during peak hours (Figure 12) were determined based on the behaviour of the flow of vehicles and pedestrians performed in the Cycle time calculation, in order to avoid conflicts between vehicles when turning.

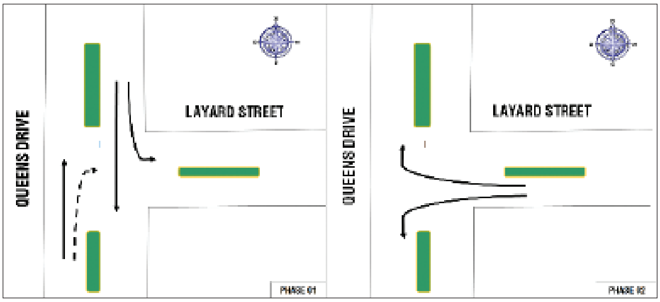


Figure 13. Phase diagrams.

Likewise, various parameters were used to obtain optimal road capacity for each access and the shortest delay time at the intersection during peak time.

Morning Peak Hour: 8:30–9:30 a.m.

Afternoon Peak Hour: 3:00–4:00 p.m.

Figure 12 shows the traffic light plan with its cycle (green, amber, and red); the electromagnetic loops will not be active during peak hours.

The Traffic Light Plan proposed with the Cycle Time of 91 seconds, will regulate the vehicular movement through two different states of the traffic light, as shown in Figure 13.

D. Simulation

The intersection simulation was carried out with the support of VISSIM software, with the purpose of presenting the intersection operation. VISSIM is a microscopic modeller that uses the algorithms included in the 2000 HCM of the Transport Research Council (Antunez, 2019). VISSIM's strength is its ability to optimise the scheduling of traffic light times and phases of isolated intersections, and the operation of networks and corridors. It also allows estimating the service levels representative of the functionality and operation of a road network.

Scope of the simulation

Traffic simulation is a tool widely used by traffic engineers to evaluate the behavior of the road due to possible modifications in vehicular traffic, alternative signalling configurations, and the construction of new roads.

An identical scenario was created in terms of road infrastructure, vehicular traffic and pedestrian access to the James Hargest school, and road marking of the intersection in order to create a model that simulates all possible factors that directly or indirectly affect traffic in Queens Drive – Layard Street.

Simulation of the current situation

The interaction between traffic volumes and geometric conditions of the intersection of Queens Drive – Layard Street was represented in a model, in order to know the operational characteristics and the value of the different performance indicators.

The simulation of the current situation was carried out considering the vehicular flows of the morning rush hour on Thursday 7 August 2021, where 2138 vehicles' Conversion Pattern Unit (CPU) and a circulation speed of 50 km/h were recorded according to the observations and data collection at the intersection under study.

From the simulation of the current situation, the generation of delays and queues in the turns to the right was identified; in addition, right-hand turns from Queens Drive into Layard Street are made at the discretion of drivers, which could lead to accidents if not controlled.

Table 12 shows the average indicators of about 10 simulations carried out during the rush hour.

- According to the traffic survey, there are 2138 vehicles passing through the intersection, of which 351 vehicles are queuing in the six possible movements within the intersection.
- These 351 vehicles stopped in queues still generate pollution that accumulates in the environment of the intersection where there is a large number of schoolchildren (328.9 g/h CO Emissions and 64.0 g/h NO Emissions).
- Finally, 349 vehicles queueing use extra fuel, due to the vehicles still running but stopped by congestion (17.8 L/h).

Simulation of the proposed situation

The projected situation will be simulated to consider implementing traffic lights at the intersection of Queens Drive – Layard Street in order to optimise the flow of the traffic network and thus clearly identify problems related to road infrastructure.

From the comparison of the level of service obtained in the current situation, it improves with the projected situation (with a traffic light intersection) and does not suffer major changes in Intersection Capacity Utilisation (ICU) service levels. However, the implementation of traffic lights give a slightly lower service level. In terms of delays, it increases the safety of right turns by having an exclusive time for the crossing.

UNSIGNALISED INTERSECTION						
Movement	Queue (m)	Queue Length Max	Vehicles	CO Emissions (g/h)	NO Emissions (g/h)	Fuel Consumption (L/h)
Queens NS - Queens NS	7.8	38.7	93	55.6	10.8	3.0
Queens NS - Layard	7.8	38.7	53	97.0	18.9	5.3
Layard - Queens NS	1.6	50.9	47	48.4	9.4	2.7
Layard - Queens SN	1.6	50.9	13	16.6	3.2	0.8
Queens SN - Layard	0.5	26.9	109	57.4	11.2	3.0
Queens SN - Queens SN	0.5	26.9	36	53.9	10.5	3.0
			351	**328.9**	**64.0**	**17.8**

Table 12. Simulation results – no traffic light signals.

SIGNALISED INTERSECTION						
Movement	Queue(m)	Queue Length Max	Vehicles	CO Emissions (g/h)	NO Emissions (g/h)	Fuel Consumption (L/h)
Queens NS - Queens NS	10.1	37.6	72	46.3	9.0	2.7
Queens NS - Layard	10.1	37.6	41	88.0	17.1	4.9
Layard - Queens NS	1.0	35.8	35	45.5	8.9	2.7
Layard - Queens SN	1.0	35.8	10	14.7	2.9	0.8
Queens SN - Layard	0.4	20.5	84	55.5	10.8	2.9
Queens SN - Queens SN	0.4	20.5	28	47.1	9.2	2.7
			270	**297.1**	**57.9**	**16.7**

Table 13. Simulation results – with traffic light signals.

From the simulation of the proposed situation with traffic lights, there is greater order and fewer queues in the right-hand turns. Additionally, right-hand turns from Queens Drive to Layard Street are made at the discretion of traffic lights, which could reduce accidents due to human error.

Table 13 shows the average indicators of about 10 simulations performed during rush hour at the intersection with traffic lights.

- The number of vehicles in the queue was reduced from 351 to 270 in the six possible movements within the intersection.
- By reducing the vehicles in the queue, pollution emissions are also reduced (297.1g/h CO emissions and 57.9g/h NO emissions).
- Finally, 270 vehicles queuing generate an extra cost in fuel, although in less quantity, reducing consumption from 17.8 to 16.7 L/h.

CONCLUSION

From the analysis carried out with the VISSIM software, it was found that the proposed situation has reduced the delay and vehicles, and the service level remains the same as the current situation. On the other hand, it should be noted that the proposed situation includes improvements in horizontal and vertical signage that influence avoiding risks and reducing unnecessary delays. Implementing a new monitoring study six months after the improvement proposals have been implemented, in order to optimise traffic light cycles and measure the effectiveness of the implemented measures is recommended. New traffic light devices to be installed at the intersection must be in accordance with the technical parameters mentioned in "P43 Specification for Traffic Signals" (Waka Kotahi NZ Transport Agency, 2020). Executing maintenance on civil works and maintenance that will consist of repainting the horizontal signs every three months after their implementation is recommended. The handling of the data obtained in the field must be ordered and well-annotated to facilitate the work in the office. Installation of horizontal and vertical signages that are sufficiently visible to road users, considering all harmful elements such as trees, walkways, and posts that limit vision is also recommended. Future studies on the times of traffic lights, depending on the growth rate of the vehicle fleet, in order to avoid future congestion problems, need to be conducted.

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