International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:11, No:9, 2017

Implementation of Congestion Management Strategies on Arterial Roads: Case Study of Geelong

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Abstract**—**Natural disasters are inevitable to the biodiversity. Disasters such as flood, tsunami and tornadoes could be brutal, harsh and devastating. In Australia, flooding is a major issue experienced by different parts of the country. In such crisis, delays in evacuation could decide the life and death of the people living in those regions. Congestion management could become a mammoth task if there are no steps taken before such situations. In the past to manage congestion in such circumstances, many strategies were utilised such as converting the road shoulders to extra lanes or changing the road geometry by adding more lanes. However, expansion of road to resolving congestion problems is not considered a viable option nowadays. The authorities avoid this option due to many reasons, such as lack of financial support and land space. They tend to focus their attention on optimising the current resources they possess and use traffic signals to overcome congestion problems. Traffic Signal Management strategy was considered a viable option, to alleviate congestion problems in the City of Geelong, Victoria. Arterial road with signalised intersections considered in this paper and the traffic data required for modelling collected from VicRoads. Traffic signalling software SIDRA used to model the roads, and the information gathered from VicRoads. In this paper, various signal parameters utilised to assess and improve the corridor performance to achieve the best possible Level of Services (LOS) for the arterial road.

Keywords**—**Congestion, constraints, management, LOS.

I. Introduction

RAPID increase in vehicles on roads is causing major congestion issues right across the world. Population growth means the addition of new vehicles to the roads to meet the daily demands of commute to work, and other activities are leading to congestion problems. These congestion problems lead to longer travel times on the roads. Congestion problems become even worse in the event of a natural disaster. Evacuation at such times becomes a mammoth task. When traffic rolls into these arterial roads simultaneously, the traffic volume rises, hindering the flow of vehicles on those roads in emergency situations. Expansion of the road network could have been a solution in the past but is not considered a viable option at present due to lack of land space, moreover with high population growth and budget restrictions in place. Managing the current road system is deemed necessary to tackle congestion problems in an emergency situation. Traffic researchers consider signal management strategy to mitigate congestion issues efficiently and economically.

The land area the cities provide for road network is not equivalent to the dwelling spaces provided which are affecting the economic growth and living standards. Steep incline in population growth in Australia is mainly due to migration and the existing road infrastructure system is not capable of accommodating this growth at the same time [1]. Moreover, Australia is prone to natural disasters. Almost every year, Australia faces major natural disasters such as disastrous flooding, devastating bush fire and catastrophic winds in all parts of the country. Managing congestion becomes a mammoth task in the event of such natural disasters.

In this paper, Traffic Signal Management strategy in arterial road congestion mitigation was carried out. Greater City of Geelong in Victoria, Australia was considered to implement these strategies and observe the effect of the strategies in relieving congestion issues. Geelong is a growing city located on the west of Melbourne. The population rise is predicted at 320,791 by 2036 with a growth rate of 34.22% [2]. The rapid pace of population growth in this city is leading to congestion problems. Furthermore, this town in Victoria suffers major flooding, and the congestion problem becomes a daunting task in these circumstances. Space limitation and availability of funding to the City Council plays a huge role. Proper congestion management strategies need to be in place so that the congestion problems can be alleviated and road network can be made usable to their full capacity without the extension of the road network. The purpose of this paper was to use the existing road infrastructure without any change in the road geometry in alleviating congestion problem in the City of Geelong.

II. Literature Review

A critical component of city evolution is the redevelopment of its existing land area [3]. The tradition step in congestion management is to invest in expanding road capacity [4], [5]. However, the expansion of roads is found to be inefficient and expensive [6]. Moreover, road capacities are not sufficient for the growth of vehicle miles travelled [3], [7]. As a result, the congestion becomes even worse. Similarly, the expansion of public transportation infrastructure is not considered a viable option to reduce traffic congestion [5].

Usually, infrastructure improvement is seen as effective to reduce traffic problems for a smaller area such as the inner city or a segment of an expressway with heavy traffic volumes [8], [9]. The upgrading of existing network systems is more

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efficient and provides greater congestion relief. Upgrading existing networks also results in a reduction of vehicle travel hours and vehicle travel miles. Daily savings in time, distance, and travel speed may seem small, but when accumulated they translate into large savings in total travel time, petrol consumption, and driver frustration [10]. For many years, the most common solution for traffic congestion has been to build more and wider roads, but road building is not a viable long-term solution for small island states like Singapore, where land is scarce [11].

Gartner [12] developed a demand responsive traffic signal control approach. Shepherd [13] provided a good summary of the models developed by Gartner. The method was designed mainly for congested or over-saturated traffic conditions where queues persist and do not get cleared totally. The dynamics of queue formation and dissipation becomes critical in demand responsive situation. Therefore, a dynamic formulation is necessary. Over the past few decades, most of the procedures proposed in this approach were ad-hoc.

Traffic signals are an essential element to manage the transportation network [14]. The basic purpose of traffic signals is to ensure the safe and orderly flow of traffic, protect pedestrians and vehicles at busy intersections and reduce the severity and frequency of accidents between vehicles entering the intersections.

Placing the traffic signals at the correct place will improve the congestion on the roads, placing them at wrong locations will cause accidents and hinder the traffic flow of the road [15]. Traffic signals could lead the way to improve the LOS on the roads when utilised properly. Gartner [12] deduced that traffic-signal methodology could be effective in relieving congestion problems without the implementation of steps which might require an enormous amount of money or land space. The study further suggested that under ideal situation online traffic timing plans work well due to the fact they have complete vehicle arrival information and the availability of responsive control strategies which aid in relieving delays on roads. Research conducted by Gartner [12] proposed that if traffic signal systems developed in a way that can adapt real-time traffic conditions provide better demand-responsive models while compared to historical or predicted values. Historical values are way far off from the results based on real-time traffic, given the system should be capable cope up with frequent updating of traffic data, and not stick to controlled periods of a specified length.

III. Methodology

A. What Is SIDRA?

SIDRA (Signalized & un-signalized Intersection Design and Research Aid) is a computer software package that models traffic intersections such as at-grades intersections, roundabouts and pedestrian signals for light vehicles and heavy vehicles [16]. This software provides a platform capable of design and evaluation of individual intersections and network of intersections. It can be utilised to analyse signalised intersections, signalised and un-signalised pedestrian crossings, roundabouts (un-signalised), signalised roundabouts with give-way or stop signs. SIDRA is also capable of modelling different movement classes such as light vehicles, heavy vehicles, buses and large trucks with taking into account of different vehicles characteristics.

SIDRA intersection is also a leading micro-analytical traffic evaluation tool that takes into account lane by lane and vehicle path models to deliver estimates for capacity and performance statistics like delay, queue length, stop rate etc. [16]. SIDRA's unique lane-based model which incorporates arrival and departure patterns for signalised sites which help to determine signal coordination effects as a function of signal offsets for network analysis. Moreover, SIDRA's user-friendly interface aids in determining signal timings for any particular road geometry which allows designing of simple as well as complex phasing arrangements. SIDRA's unique traffic model platform allows calibration of various road facilities which incorporate local conditions, help traffic engineers to implement measures for different scenarios for existing and future intersection performances under different road conditions efficiently alleviating congestion problems improving both the economy and community services. For this particular research, SIDRA 6.0 version used to model the corridor.

The alteration of signal timing and signal phasing is a key approach which was utilised in this research to improve the flow of traffic. The phasing and timing tab in SIDRA 6.0 was used to model such alteration to the existing cycle. The tab includes the sequence editor, phase and sequence data, timing options and advanced tab. In the sequence tab, the collected phase sequence data from VicRoads were imported and validated by using the dedicated radio buttons. In the phase sequence adds, clone, delete or change options are present. Sequence editor tab consists of phase selector and Phase Editor options. The sequence editor tab is used for defining phases by specifying vehicle movement class and pedestrian movement. Phase selector tab is for selection of specific phase, and phase editor is to edit the name & vehicle movement. The phase sequence data tab includes variable phase at the intersection. The phase sequence and signal time are edited by the use of this tab. The total phase time, red signal time and green signal time are imported and changed accordingly to the demand. To assess the intersection performance and the network as a whole data sets collected from VicRoads were imported and validated. The model considered a practical cycle time for all traffic signals.

B. Strategies Applied to Reduce Congestion

Strategies that were utilised to overcome the congestion in the Shannon Avenue corridor are mentioned below:

Signal Cycle Change

The signal cycle means the total operational time for red, yellow and green signals. Changing the red and green times for various directions can improve intersection conditions. Modification of signal phases can also improve intersection conditions.

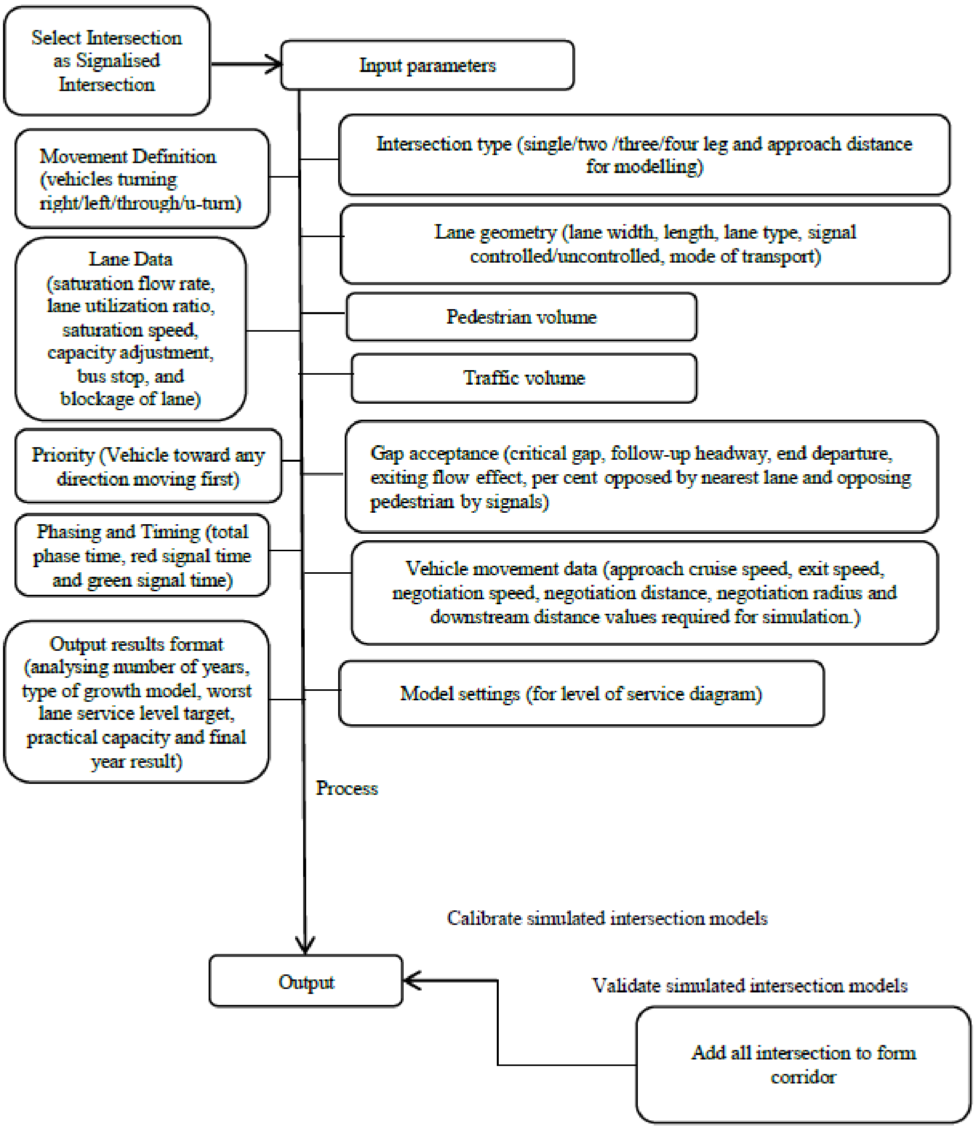

Fig. 1 Flow chart of Sidra Software

The strategies are applied on each intersection separately. The better individual resultant strategies were implemented to the corridor and simulated to determine the best strategies for the corridor as a whole.

Travel Speed

Travel speed is a key factor when it comes to congestion on the roads. Allowing traffic to move at a quicker pace will help to reduce the travel time. Considering the road conditions the travel speed limit was raised from 50 km/h to 60 km/h in the corridor. The increased speed reflected in improving the travel speed for the whole corridor and resulted in an improved LOS.

Adding Signalised Intersections

Signalized intersections considered when the traffic volume increases to a point where some of the movements need a separate time frame to complete the movement. Adding a signalised intersection will ensure an orderly flow of traffic on the road while improving the safety as well. In this particular research, some of the un-signalised intersections were replaced by signalised intersections to improve the LOS on the road. Since the traffic volumes increase dramatically in an emergency situation, this strategy becomes even more efficient than under normal conditions.

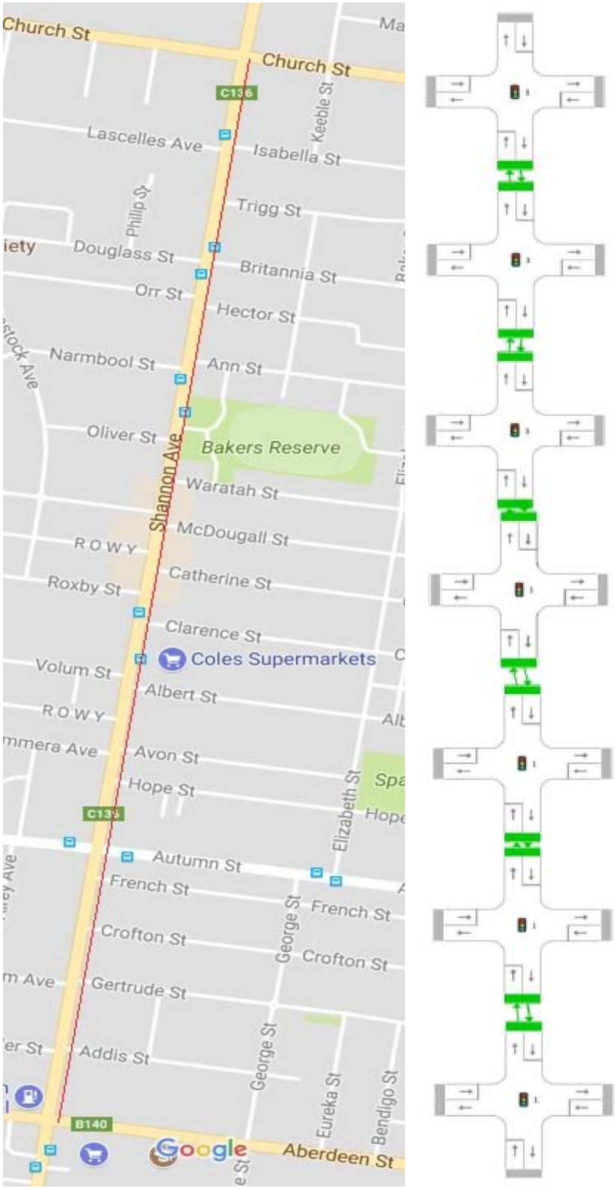

Fig. 2 Shannon Avenue corridor from Google maps and the SIDRA model from left to right respectively

Shannon Avenue corridor in Geelong is chosen as the site for this project, which is a major arterial that connects to a highway. Congestion is a major issue in this corridor, which consists of signalised intersections with several other minor intersections without signals. Out of the signalised intersections, Shannon Avenue and Aberdeen Street intersection is the major, as it acts as a bottleneck which connects to the other intersections and improving the performance of this intersection was deem necessary as it determines the performance of the other intersections within the corridor. As traffic inflow is major at this intersection, it faces many issues with congestion.

Infrastructure expansion was not possible in some of the intersections due to space problems and financial inputs. The pre-disaster and post-disaster performance assessed without the application of any traffic management strategies on the corridor. The focus was on improving the North-South and South-North through movement for the chosen intersection, East-West or West-East movement will not affect the performance of the corridor. LOS was the determiner of how the corridor is performing at certain road conditions.

The LOS for a signalised intersection is the criteria by which the quality of traffic service assessed for a particular intersection. The LOS range between LOS A (relatively congestion-free) and LOS F (congested).

LOS was satisfactory at the pre-disaster situation for the chosen intersection but got extremely worse at the post-disaster scenario. The research aim was to improve the post-disaster scenario. Post-disaster traffic volume increase is determined by increasing the amount of traffic coming into the corridor by growth factor over the design life of the intersections. The corridor post-disaster situation assessed in that way. Incorporating the high volume traffic into our model and applying proper congestion management strategies helped to improve the overall corridor performance in a post-disaster scenario.

Changing traffic signal timings was considered the viable option and furthermore to improve the LOS, changing the travel speed and adding signalised were found to be other available options, keeping in mind the road constraints. The corridor performance improved quite significantly taken into account viable the available traffic congestion management strategies discussed above.

C. LOS after Disaster with no Strategies

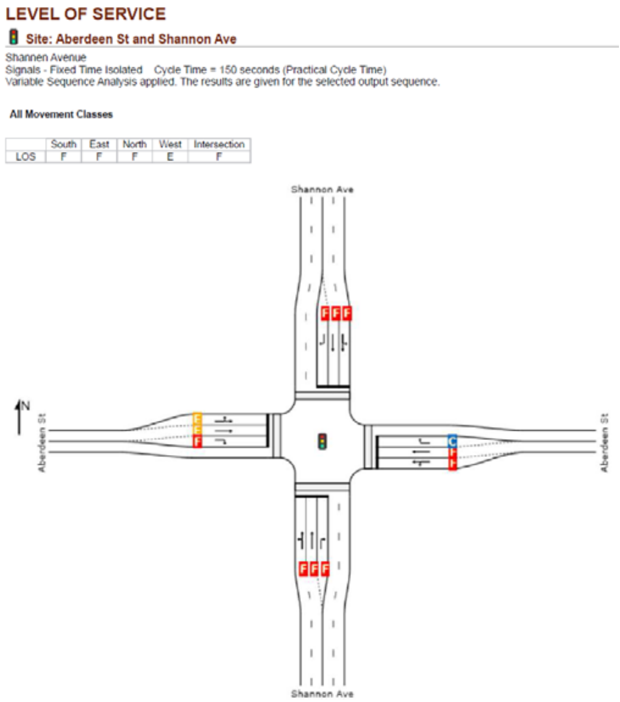

Fig. 3 Aberdeen Street and Shannon Avenue LOS output without the application of the strategies

Fig. 3 determines the LOS for the Aberdeen Street and Shannon Avenue intersection which is a major intersection in the Shannon Avenue corridor. This corridor incorporates the incoming of the high volume of traffic from the South to the North through movement during the post-disaster scenario and creates a major problem for the rest of the intersections within the corridor resulting in huge delays and a major increase in travel time, affecting the overall corridor performance. The data were collected from VicRoads imported into Sidra, and the results were analysed and keeping in mind to achieve optimal LOS for the South-North through movements. An LOS of F(congested) is obtained for the corridor which is the worst possible condition for the South to North through movement and traffic management strategies are deemed necessary to tackle the situation.

The next step was to determine options, which could help to alleviate the congestion problems faced by the intersection in a post-disaster scenario. The viable options that were present were replacing the un-signalised intersections with signalised intersections, changing the travel speed in the corridor and furthermore changing the signal timings phase for each intersection individually and the corridor as a whole.

D.LOS Post-Disaster with Strategies

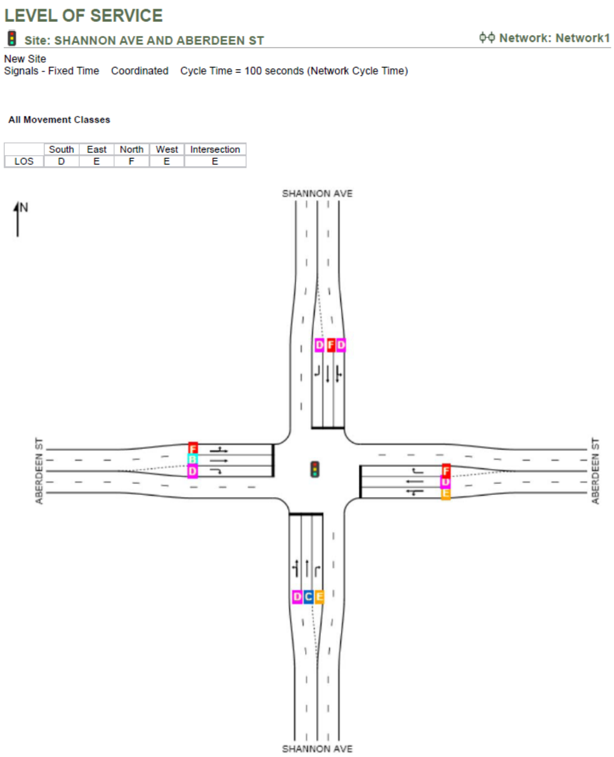

Fig. 4 Aberdeen Street and Shannon Avenue LOS output with the application of the strategy

First and foremost, the signal timing was imported for each of the intersection within the corridor individually and the practical cycle time was applied, then test and validated for each intersection in the corridor. The research implemented a strategy of treating all the intersections within the corridor as a network and after that a practical cycle time was added to the whole network to assess the corridor performance and the also the individual intersection performance. This particular step proved effective as the LOS for the Aberdeen Street and Shannon Avenue intersection improved while enhancing the LOS of the network as a whole.

After the implication of traffic congestion strategies discussed above the overall LOS for the entire network improved quite significantly, for instance, the condition of the major intersection Aberdeen Street and Shannon Avenue improved remarkably. The South to North through movement which is the major concern of this research for the post-disaster scenario improved markedly, and it was found the strategies work efficiently providing an LOS C for the South to North movement, which is acceptable given the high traffic volume incoming during the post disaster scenario.

IV. Conclusion

The research provided an overview of the modelling of a traffic network/corridor using the SIDRA 6.0 software in alleviating the congestion issues faced by a city in Victoria after a disaster. Each intersection within the corridor calibrated using the relevant parameters, and the collected data sets from VicRoads used for model validation. After the modification of signal phases, the intersection performance improved. Signal timing strategies were applied on each intersection separately and the corridor as whole to achieve the best results. Incorporating travel speed increase along with improved signal phase order and cycle timing, resulted in the intersection to get cleared more quickly and queue distance to get shorter resulting in better LOS. Proposing measures to improve the LOS for each intersection within the corridor was the main target.

In future, research could continue to implement this strategy into other arterial roads and furthermore the future research could aim at incorporating several other congestion management strategies such as the removal of on street parking and allowing unidirectional traffic at peak times and improve the overall congestion problems within the arterials and provide a better LOS.

Acknowledgment

The Authors would like to thank the support and collaboration of Geelong City Council and VicRoads for providing this research with the required data.

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