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A Review of Current Traffic Congestion Management in the City of Sydney

For Infrastructure Australia

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Photo: Traffic at the intersection of Victoria Road and the Crescent, Sydney, New South Wales.

1. Introduction

Traffic congestion has significant detrimental impacts on the economy, environment and quality of life of the community as evidenced by:

- Increase in transportation costs associated with road and freight tasks, which negatively effects national productivity and competitiveness.
- Increased CO₂ emissions from vehicles, due to increased idle time.
- The public discontent about the lack of effective traffic management as destination travel time is increased.

Although policies and reform through congestion pricing and holistic network integration may also be required, the focus of this report will be on the ability of technology to impact congestion management.

Investment in infrastructure that has proven performance on a national and global level can be implemented to overcome current inefficiencies. Given that the government still faces a \$300 billion infrastructure deficit, budget constraints mean there is increased pressure to invest in the right project to best use public funds (Infrastructure Australia, 2013). This can be executed by effectively using the existing transport network in low cost initiatives.

2. Adaptive Traffic Control Systems (ATCSs)

Adaptive traffic control systems (ATCSs) utilise real time traffic data in an attempt to optimize the timing and length of the traffic light signals (Zhao & Tian, 2012). As a result, effective ATCSs aim to minimise stop times and delays in a bid to reduce traffic congestion in major urban areas. A large number and variety of ATCSs have been developed and researched using different control methods and structure to reduce travel times and congestion. In addition to traditional and popular ATCSs such as the Sydney Coordinated Adaptive Traffic System (SCATS), several new developments, each with similar yet different underlying principles, are being implemented around the world, including OPAC, RHODES, ACS Lite and InSync (Zhao & Tian, 2012). This section of the report will examine and review the SCATS system against Rhythm Engineering's InSync, an emerging controller in the field.

2.1. The Sydney Co-ordinated Adaptive Traffic System (SCATS)

SCATS is one of the most widely used ATCSs in Australia and the world, developed by the Roads and Traffic Authority (RTA) of New South Wales, Australia in the 1970s (Zhao & Tian, 2012). As of November 2011, more than 3,700 traffic lights within New South Wales were connected, monitored and controlled using the SCATS network (Roads & Maritime Services, 2011). The control system involves the use of inductive loops beneath the surface of the road immediately before the intersection stop line of a road. The induction loops are used to detect the presence of a vehicle in addition to measuring the degree of saturation and traffic flow over a set cycle (Samadi, et al., 2012).

The data collected via the induction loops is gathered within the local controller situated at each intersection which is then transmitted to a regional computer. The data is then analysed and assessed by the regional computer in order to calculate the most appropriate cycle lengths, splits and offsets for the network of local controllers within vicinity of the regional computer. The signal timings are then re-transmitted back to the local controllers to implement the appropriate light changes at the series of intersections (Dineen & Cahill, 2001). Figure 2.1 illustrates the general physical architecture of SCATS.

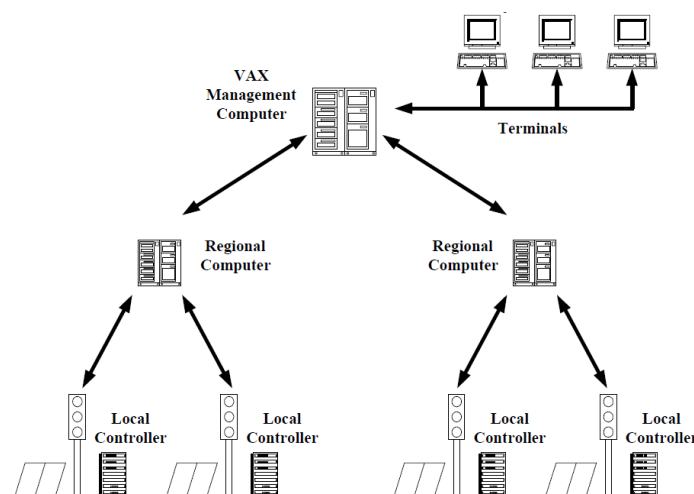


Figure 2.1: The Physical Architecture of SCATS (Dineen & Cahill, 2001).

2.2. InSync

The InSync adaptive traffic control system was developed by Rhythm Engineering in 2005 (Rhythm Engineering, 2013). The InSync control system involves the installation of Internet Protocol (IP) detection cameras at traffic intersections. The cameras are used to detect and quantify the traffic demand situation, in addition to allowing live monitoring of an intersection from an internet browser (Rhythm Engineering, 2013). Unlike most traditional control systems, InSync does not use the concept of cycle lengths, splits and offsets, which are all components of the analogue signal control. The analogue control systems rely on the use of a rotating mechanical dial which consists of marked regions dedicated to signal conditions. In its place, the InSync system uses the concept of a finite state machine. The finite state machine consists of all possible states within the intersection, which are further grouped into sequences. At any moment, a specific state can be called upon, leading to a signal transition within the machine. Using this methodology, the logic developed by local optimisation can be overridden at any time by global optimisation (Siromaskul & Selinger, 2010).

The digital architecture of InSync performs optimisation on two levels; local and global. On the global level, the control system uses the concept of platoons and focuses on moving these platoons through the selected traffic corridor with the highest level of efficiency. One technique of achieving this is through the control of the green timings of each intersection; allowing platoons to travel through without disturbance (see section 3 on Green Wave). As a result, the primary focus of the global optimiser is to ensure that the intersections interconnect in order to allow these platoons to travel through with green signals. The control of the intersections outside of the green time is then the responsibility of the local optimiser, requiring no use of a regional computer.

The local optimiser uses an algorithm which deals with the volume and delay of individual vehicles. The algorithm, known as the 'greedy' algorithm, aims to limit the time each vehicle must spend at an intersection by applying weightings to each of the vehicles. Therefore, a corridor with a greater demand of vehicles will have a greater weighting and priority to smaller corridors (Siromaskul & Selinger, 2010). In addition, the local parameters can be used to give higher priorities to individual vehicles, such as buses or emergency vehicles (see section 4 on Priority Traffic Signals).

2.3. Comparison

While both of the adaptive traffic controllers aim to reduce time spent at traffic intersections, travel time, the number of stops and the vehicle volume, the architecture and control methodologies behind both differ. SCATS, uses reactive control methods, whereas the InSync controller uses both reactive and proactive methodologies (Stevanovic, 2010). In 2010, a study was conducted by HDR engineering (Selinger & Schmidt, 2010) in order to assess and compare the performance and costs related to InSync, SCATS and ACS-Lite. Using these results, the InSync control system and SCATS will be compared in order to make further recommendation on the better or more feasible technology.

The first section of the HDR report compared the operational aspects of the control systems, based on arterial travel time reduction, reduction in stops and reduction in delay across different intersections of the U.S. As shown in Figures 2.3.1-2.3.3, InSync outperformed both SCATS and ACS-Lite in all three performance categories during the AM and PM peak hours. However, it must also be noted that the report examined the technologies from different intersections, meaning the results provide only estimates to how they can be compared.

ARTERIAL TRAVEL TIME REDUCTION

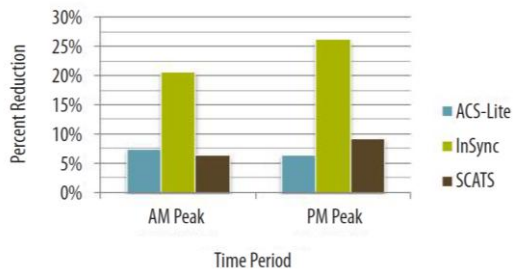


Figure 2.3.1: A comparison in the reductions of travel times on arterial roads (Selinger & Schmidt, 2010).

REDUCTION IN STOPS

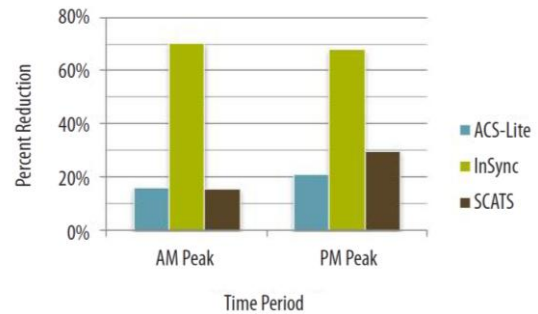


Figure 2.3.2: A comparison in the reductions in stops experienced (Selinger & Schmidt, 2010).

REDUCTION IN DELAY

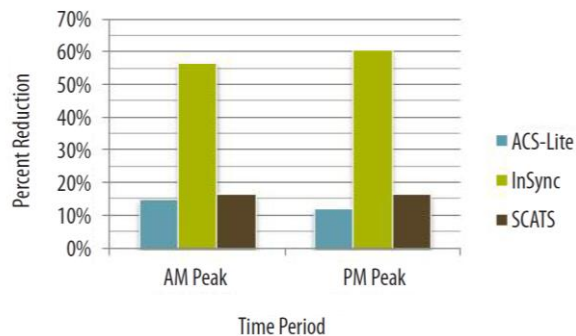


Figure 2.3.3: A comparison in the reductions in delay experienced (Selinger & Schmidt, 2010).

The second area investigated by the HDR report was the overall cost of each technology per intersection. InSync was seen to have the lowest cost per intersection, with an average of \$28,700 USD, whereas the cost of SCATS was up to \$60,000 USD per intersection. However, it has also been reported that the costs of installation for SCATS are in the range of \$20,000 - \$30,000 USD (Zhao & Tian, 2012), bringing the cost in line with the cost of InSync. It must be noted that a majority of the intersections within Sydney are fitted with the SCATS technology, therefore, for most intersections, the cost would not be required.

From the findings of HDR engineering, InSync was found to have the lowest cost and operational benefits of each of the systems. However, with the SCATS controllers currently installed across a large portion of intersections across Sydney and NSW, the installation costs and time required for the specific technology can be disregarded. With regards to performance, InSync has been seen to result in greater traffic congestion relief, with lower travel times, fewer stops and a reduction in delay. Similarly, the use of IP cameras with the InSync control system would allow the visual monitoring of all intersections across urban environments, resulting in more rapid and efficient detection of traffic delays, accidents or poor weather conditions.

Another potential area of improvement with InSync arises with its usage of Ethernet communication (Stevanovic, 2010). The rollout of the National Broadband Network (NBN) in Australia, currently taking place and predicted to finish by 2021 (NBN Co. Limited, 2010) has been estimated to reach internet communication speeds of up to 100 megabits per second. In addition, the network is predicted to reach approximately 93 per cent of premises' across Australia (NBN Co. Limited, 2010). If the InSync Ethernet communication systems were to operate within this network, instantaneous and reliable transmission of data from both the controllers and IP cameras to control authorities could be achieved in order to provide real time information of conditions.

3. Green Wave

Green wave is a traffic management control strategy which synchronises the green phase of traffic lights to allow the efficient flow of traffic. Once a vehicle has been detected by a sensor, it will progressively receive green signals at intersections without the vehicle stopping for the desired distance (Kelly, 2011). The cars are grouped in platoons of varied sizes, determined by signal timings, which progress through the green wave at uniform speed (Kerner, 2013). The spaces that are left between the platoons have an ideal time gap which can be exploited by platoons in the other direction in a grid road structure without interference (Cools, 2012) .

This can be implemented statically with the use of timers that control the green light signals for a pre-determined speed. However, the model has a high probability of green wave breakdowns which can occur when there is a disturbance in which vehicles cannot maintain the uniform speed. Usually, this arises when there is turn-in traffic from a cross street which enters the green wave traffic. Leading to queue formation during the red phase and forces the decrease in vehicle speed, this speed disturbance propagates through the green wave. An adaptive control system can overcome this inefficiency using real-time sensor data on traffic lights, which can account for the delay time by measuring the inflow and outflow of vehicles through an intersection. Dynamic systems which link traffic light signals is possible with the use of area traffic control systems (ATCSs) that use algorithms to interconnect complex intersections.

The main advantage of the green wave traffic signal optimisation arises with the consistent flow of traffic, resulting in the reduction of congestion from stopping and starting in addition to wasteful energy and emissions. Results from a case study in Manchester, showed that there was a 7.6% decrease in CO₂ emissions and more significantly, a 35.2% reduction in journey time compared to an unsynchronized network (Kelly, 2011).

4. Priority Traffic Signals

There is scope for improvement to the green wave idea as it can be extended to the use for emergency vehicle pre-emption (EVP) by detecting when emergency vehicles are approaching an intersection and changing the signals to prioritise the movement of these vehicles. This similar logic can be used to solve congestion issues, especially from the build-up of traffic during peak hour, which is exacerbated by larger vehicles such as buses. Buses and emergency vehicles can be fitted with transponders for the use of GPS and infrared to communicate with detectors upstream, in order to prioritise the bus flow through traffic using the green-wave progression from coordinated signal controllers (Gardner, 2009).

Traffic-adaptive pre-emption technique has shown to improved travel-time of these vehicles by 39% (Kamalanathsharma, 2012). Bus priority has been implemented in Portland USA using encoded infrared communication technology to extend a green period downstream when a priority request is made (Gardner, 2009). As flow theory suggests, larger vehicles contribute more to congestion; therefore, by fitting these sensors on buses there would be significant improvement in the average speed of public transport. Thus, a reduction in traffic time would incentivise more road users to adopt public transport. The flow-on effect would reduce the number of private vehicles, hence further decreasing congestion.

5. Floating Car Data

The current traffic control system in Sydney relies on stationary monitoring units, such as the induction loop, to gather traffic data. The data gathered by these detectors is incomplete and does not provide a clear picture of the nature of traffic in Sydney. It is impossible to infer from the gathered data any useful information on travel times or the volume of congestion.

The term 'floating car data' refers to data that is provided either from a mobile phone or GPS unit that is stationed inside the moving car. Mobile phones continuously transmit location data, along with a timestamp, to the service provider. The speed that the phone is moving at can be derived from this data, and hence used as indicator of congestion. A report by Gühnemann et al. in 2003 analysed a trial whereby a large number of taxis in different European cities were fitted with GPS to track their journey. Each taxi has an individual I.D and from the data collected, a database has been generated showing which roads of each city experience large amounts of congestion, and at what times of the day. It was reported that, 'Depending on the intensity with which measures can be implemented (e.g. share of vehicles equipped with dynamic routing systems or the utilization of adaptive traffic signal control systems) and the specific situation', Prognos And Keller (2001) estimate an increase in network capacities by 3% to 10% for Germany (Gühnemann, et al., 2003).

6. Parking Detection

Parking-related traffic contributes to 30% of congestion, as vehicles circle around their destination to find an available place to park (Zhao, et al., 2012). A parking detection and guidance system could be used to acquire real-time data of available parking spaces for road users, decreasing congestion to some extent.

Established parking management schemes employ the use of fixed sensors and roadside units (RSU). These sensors or units are wireless detectors that are installed in the car space to sense the presence of a vehicle. The data collected is then processed by the central control unit. The parking status can then be displayed on variable message signs (NRMA, 2013) for vehicles searching for parking spaces. The city of San Francisco has installed these sensors throughout car spaces across the city, under the SFPark project, which additionally uses mobile phone application technology to navigate vehicles to available on-street parking. However, the shortcoming of this scheme is that the estimated costs of installation and the parking management system are between \$250-\$800 per spot (Zhao, et al., 2012).

Other initiatives are user driven applications such as the Waze integrated with Google Maps that automatically crowd sources traffic information by tracking where and how users drive, in order to report changes in road conditions (Arthur, 2013). The advantage of this technology is that it is free and can be used as a method of calculating the volume of cars in congested pinch-points; this data can then be used to optimize the current intelligent transport systems.

7. Japan as a Case Study

The traffic control system in Japan is a multi-faceted Intelligent Transport System that serves to not only ease congestion, but to aid in safer driving and minimise the environmental impacts associated with congestion. A number of different traffic control subsystems are in operation, and these are collectively referred to as the Universal Traffic Management System (UTMS). Each of the subsystems serves unique functions which are operated under the Vehicle Information Communication System (VICS).

The VICS analyses traffic data to inform drivers of road conditions. A large number of detection devices, such as video cameras, infrared sensors and ultrasonic detectors have been installed on the roads in Japan to gather data on traffic and road conditions. The data collected at the detection units is relayed to a central data processing unit for analysis. The information on traffic conditions provided by the analysis is then communicated to drivers in a number of different ways, including its transmission to the vehicle's on-board navigation system, being displayed on electronic bulletin boards and broadcasted over the radio (Hollborn, 2002).

7.1. Public Transportation Priority Systems (PTPS) and Emergency Vehicle Pre-emption (EVP) Systems

The PTPS acts to promote the use of public transport, thereby easing congestion. An infrared sensor detects each priority vehicle as it approaches a set of traffic lights, with the length of each phase of traffic signals adjusted to minimise the number of stops. Using EVP systems, emergency vehicles are also given priority through intersections. The information regarding emergency vehicles is also sent to the on-board navigational units of cars in the near vicinity to warn them of the approaching emergency vehicle (UTMS Society of Japan, 2013).

7.2. Environmental Protection Management Systems (EPMS)

The EPMS is made possible by the installation of roadside exhaust and noise sensors and infrared sensors. The sensors detect if the exhaust or noise pollution along a particular road is becoming heavier than a certain standard and, if this is the case, the traffic control centre will warn cars of congestion via one of the above discussed methods and suggest alternative routes.

Japan also uses electronic tolling on 87% of its tollways and, according to the Government of Japan (2013), the reduction in congestion at toll points alone reduces annual carbon dioxide emissions by 210,000 tonnes per year. The government also claims that accidents on the Metropolitan Expressway have decreased by 60% as a result of transmitted alerts (Government of Japan, 2013).

8. Recommendations

Analysis of the discussed ATCS technologies has identified areas of possible improvement to the existing SCATS infrastructure in Sydney. The InSync technology is both relatively cheap to implement and has proven to be an effective traffic controller. It is therefore recommended that, following identification of congested channels using floating car data, InSync control configurations and IP cameras be integrated into existing infrastructure to ease congestion. Using this technology, Green Wave ideology can be adopted to optimise traffic flows. Furthermore, utilisation of InSync technology allows for future accommodation of priority traffic signals such as those currently employed in Japan.

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