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North? South? or NorthSouth?
Curletts Road Three Lane Reversible Flow

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ABSTRACT

Traffic patterns in Christchurch changed dramatically immediately following the February 2011 earthquake. Traffic volumes and corresponding congestion increased significantly on roads in the less damaged west of the city.

A number of immediate and temporary measures were put in place to address the congestion, including a third peak period reversible lane on Curletts Road. Traffic control for this was achieved by moving cones from one side of the central lane to the other twice a day.

This paper outlines the process of identifying and assessing options to permanently optimise Curletts Road, and findings of the research. Options of four laning, peak period clearways, and three lane reversible were considered.

The three lane reversible option was concentrated on more than the other options for the following reasons:

- It would require minimal removal of parking;
- It would only require small alterations to kerb and channel and pavement construction (mainly at the kerb build out locations); and
- It is a concept which has been rarely used (if at all) in an urban environment in New Zealand.

A clear, concise, and reliable method of informing road users who join Curletts Road at intermediate points along the reversible section of the direction of travel of the central lane, was needed.

A number of international examples were examined. As a result a method utilising overhead gantries and illuminated pavement markers was developed, costed and assessed.

At the time of writing, no decisions have been made regarding the optimisation of Curletts Road.

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1 The paper notes that tidal flow arrangements operate in a couple of locations in New Zealand, but these are on bridges, with no side roads or private accesses
INTRODUCTION
This paper outlines the process followed to identify, develop, and assess options to replace a temporary three lane reversible flow arrangement with a permanent solution.

BACKGROUND
Traffic patterns in Christchurch have been in a state of more or less continuous flux since the February 2011 earthquake. In the days following the earthquake traffic patterns were affected by a number of factors, including:

- Reductions in capacity across the network caused by road closures, including all roads in the CBD red zone, closed lanes, inoperative traffic signals and numerous other damaged roads, particularly to the east of the city; and
- Changes in travel demand due to businesses relocating from damaged premises (including all businesses in the central city red zone) and householders relocating from damaged homes

Site Description
SH73 is classified as a Regional Strategic route in the State Highway Classification. Within the Christchurch urban area, it is an important link to the Lyttelton Port and Christchurch Airport

The section of Curletts Road being considered is a 750m long section of SH73 between Main South and Blenheim Roads. It is approximately 6km west of the Christchurch CBD (see figure Figure 1). Pre earthquake it was a two way two lane arterial road carrying approximately 20,300 vehicles per day (vpd). It featured a flush median, with three pedestrian refuges, along with a cycle lane, parking lane, and footpath on both sides

This section of Curletts Road is located in a residential environment, and features private property accesses along its length. There are four intersections and a signalised pedestrian crossing, in the length under consideration. In addition there is a dairy and a fish and chip shop approximately midway along the length.

Figure 1 Location of Curletts Road
Prior to the earthquakes this section of road faced the classic conflicting demands of trying to provide both access and movement that are associated with busy State Highways in residential areas. Following the earthquakes those demands increased significantly as a result of the additional traffic Curletts Road was carrying. Daily traffic volumes increased from 20,300 vpd to 22,800 vpd almost overnight. At the same time volumes increased on all approaches to the signalised intersections with Blenheim and Main South Roads. Additional lanes both up and downstream of these intersections are comparatively short, resulting in poor approach and departure rates when the intersections are nearing capacity.

As a consequence of this combination of additional demand and constrained capacity, severe congestion was experienced at the intersections

**Temporary Solution**
A number of short term emergency measures were implemented across the city in an attempt to address the changes in traffic patterns, and resulting congestion. These measures included a three lane reversible flow arrangement on Curletts Road. This arrangement was achieved by:

- Removing the existing flush median and pedestrian refuges;
- Removing the existing cycle lanes on both sides. Signage was added at each end recommending that cyclists use an alternative parallel route along Hansens Lane;
- Marking three lanes with solid lane lines between each of the lanes;
- Providing cones over the affected length of Curletts Road. These cones were moved twice a day to provide two lanes southbound in the morning, and northbound in the evening.

This temporary operation met the immediate objective of providing additional capacity at peak times, and the cones provided clear visual and physical delineation between opposing traffic flows. However, it had a number of shortcomings, including:

- The moving of the cones twice a day was very labour intensive, hence costly;
- The cones were prone to being knocked over or removed;
- The loss of the flush median made right turns difficult;
- The loss of the flush median, along with the pedestrian refuges made crossing this busy section of State Highway more difficult; and
- The loss of cycle facilities made cycling a less attractive option.

A permanent solution which optimised the corridor by increasing capacity, particularly at peak times, was sought.

**OPTIONS CONSIDERED**
Three options were identified as best meeting the objectives of improving peak period capacity, whilst being able to be implemented comparatively quickly, and minimising impacts on private land, and therefore property acquisition requirements. These three options are outlined below:

1. **Four Laning**
   In order for this option to be achieved within the existing road reserve, the original parking and cycle lanes would need to be removed.

2. **Peak Period Clearways**
   This option enabled the provision of off peak kerbside parking lanes, which would become traffic lanes during peak periods

3. **Three Lane Reversible**
   This option is fundamentally a permanent version of the temporary operation which was put in
place following the earthquake, but with permanent and less labour intensive traffic control to replace moving the cones twice a day.

Preliminary designs and cost estimates were developed for each of the three options, and an initial assessment of their effectiveness was conducted.

The development of designs and estimates was comparatively straight forward for the four laning and clearway options. These methods of optimising carriageway capacity have been used successfully in other urban environments in New Zealand.

The three lane reversible option was much less straightforward to develop a design and subsequent cost estimates for. The project team was unable to identify an example of a reversible lane in operation on a New Zealand urban road which provided access for side roads and private properties. There are examples of reversible lanes operating in locations with limited access such as bridges and tunnels. The Auckland Harbour Bridge is probably the best known example, whilst the Panmure Bridge has had a reversible central lane since the mid 1960s.

Because urban reversible lanes are rare in New Zealand, their design and operation are not covered in any local design manuals or codes. It was therefore decided to research international best practice to identify any applicable design manuals, or methods used elsewhere which may be suitable for the Curlett's Road environment.

RESEARCH METHODOLOGY

The research into international best practice for three lane reversible operations in an urban environment consisted of three phases:

1. A Literature Review to identify any standards, guidelines, or codes used for the design and operation of reversible lane systems, and to identify locations where such systems are used, and the control mechanisms used in those locations
2. A review of identified similar operations using Google Earth and Google Streets to observe the control mechanisms in place, and
3. Discussions with road authorities who have implemented reversible flow operations in urban situations to get information on the roading environment, the control mechanisms they used, the issues they experienced, their assessment of the effectiveness of the operation, and any other positives or negatives associated with the reversible flow operation.

LITERATURE REVIEW

There is little literature available on reversible flow design and operations. Much of what is available refers to one of the following:

- Locations which have a clearly defined start and finish, with no intermediate accesses. These include bridges, tunnels and freeways;
- Occasional temporary traffic management for major events. This typically included traffic management near to major events centres or stadia.
- One off traffic management to assist with emergency evacuation associated with forecast natural disasters such as hurricanes.

Wolshon and Lambert (2004) surveyed roading authorities in North America and elsewhere to identify reversible lane practices. The majority of their respondents were from the United States and Canada, and described 45 reversible lane systems. Of these 12 were on urban arterials, and were operated daily to address peak period commuter traffic.

The methods used to control the operation of these systems typically consisted of either fixed permanent signs outlining the hours of operation of the reversible lanes, or overhead illuminated
signs with crosses or arrows indicating open or closed lanes. The illuminated overhead sign systems were generally supplemented by fixed permanent signs. Examples of fixed signage and overhead illuminated signage are shown in Figure 2 and Figure 3 below.

![Figure 2 Example of Fixed signage](image1)

![Figure 3 Example of Overhead Illuminated Signage](image2)

The simple sign systems tended to have been in use for a number of years, which meant that regular users were very familiar with the system.

The US Federal Highway Administration (FHWA) Manual of Uniform Traffic Control Devices (MUTCD) includes a minimum standard for reversible flow systems. Typically that signage is fixed permanent signage. An extract from that document is shown in Figure 4 below.
In addition to published literature, colleagues from a number of offices worldwide provided locations of, and information on, urban reversible flow operations that they were aware of.

**REVIEW OF SIMILAR OPERATIONS**

Using the literature review and inputs from colleagues, a number of reversible flow operations from the United Kingdom, United States, and Canada were identified as being similar to the Curletts Road operation insofar as they were not located on bridges, tunnels or freeways, and that they operated daily during peak commuter periods.

Google Maps and Earth were used to look at each of the broadly similar operations to identify:

- The nature of the road and surrounding environment, including the number and nature of intersections, the frequency of private accesses, the number of lanes, presence of parking, and topography of the road and surrounding land;
- The nature of the traffic control used during the operation of the reversible lane, including the nature and spacing of signs, signals, overhead gantries, and pavement markings; and
- The presence and nature of pedestrian and cyclist facilities.

Two operations were chosen to investigate further. Chebucto Road in Halifax, Canada was considered to bear the greatest resemblance to Curletts Road, and Coronation Drive in Brisbane was chosen because it utilised a number of technological innovations which may have been appropriate for Curletts Road.

The local body engineers responsible for implementing both of these operations were contacted. They shared their experiences in the implementation and operation of the reversible lanes, particularly with respect to the components of the system, safety, public acceptance, the nature of the problem they were addressing, effectiveness, and any other issues encountered. These two operations are described below, along with a summary of the comments from the implementation engineers.

**Chebucto Road, Halifax**

This reversible lane operation is located in urban Halifax and has the following features:

- The reversible section is approximately 500m long;
- It carries approximately 20,000vpd
• There is a major shopping mall with a 200m frontage, and two accesses to the parking area on one side;
• The remainder is residential with driveway accesses to single dwelling residences along both sides;
• Three side roads access the road;
• There is a signalised intersection at one end of the reversible section, and a two lane roundabout at the other;
• It was implemented in 2008
• There is no on road parking;
• There are footpaths on both sides, but no specific cycle facilities;
• Traffic control is achieved through:
  o Signs outlining the hours of operation, and lane closure information at both ends of the operation, and at intermediate side roads;
  o Pavement marked gateway treatments at either end. These are located at the transitions to and from three lane reversible operations;
  o Overhead gantries with illuminated red crosses signifying lane closed, and green arrows signifying lane open. Gantries were located to ensure that there is a gantry visible in both directions from all locations along the reversible section. Six gantries were required to achieve this visibility due to curves. This equates to approximately 100m spacing; and
  o Fixed signs at each side road approach describing the reversible lane operation.

Figure 5, Figure 6, and Figure 7 show Google Street images of the Chebucto Road three lane reversible lane operation.

The Halifax Regional Municipality engineer responsible for its implementation had the following comments about this the Chebucto Road reversible lane:
• In his opinion, the operation had been safe. He was unaware of the reversible lane operation contributing to any crashes in the three years it had been operating at that stage.
• They did not seriously consider any other options for marking the reversible lanes. Moveable barriers were considered inappropriate for that location.
• There had been some public opposition to the project as a whole. That opposition was largely opposed to providing increased road capacity, and the removal of some mature trees which was required for localised road widening. There was little public opposition to a three lane reversible lane per se.
• “As an engineer, I think this project was a safe and effective way of making better use of an existing three lane street. As a driver who uses Chebucto Road as part of my daily commute, the project has made a significant difference in reducing vehicle delay and congestion.”

(pers comm July 2011)
Figure 5 Chebucto Road Tidal Gate

Figure 6 Chebucto Road Peak Period
Coronation Drive, Brisbane
This reversible lane operation was located on Coronation Drive in Brisbane, and has the following features:

- Total length of reversible flow approx 1.2km;
- The route runs along Brisbane River;
- It carries approx 50,000 vpd;
- The project was a combined bus lane & reversible lane project with a total of 5 lanes:
  - 1 Peak time Bus lane in kerbside lanes in each direction;
  - 1 lane in each direction fixed;
  - Central lane reversible;
- There are a number of signalised T intersections along the route;
- There is only 1 private access to route (a service station);
- A combination of illuminated arrows and crosses on overhead gantries, illuminated road studs, and physical gates at either end were used to control traffic direction; and.
- There were no specific cycle facilities

The Brisbane City Council Engineer responsible for its implementation had the following comments about the Coronation Drive reversible lane:

- Gantry were spaced so that 2 were always visible. Gantry were also placed either side of intersections;
- Red crosses and white arrows were used on gantries to indicate lane open and closed respectively. There was concern in the team that green arrows may be confused with traffic signals at intersections;
- Variable Message Signs (VMS) were also installed on gantries to allow further flexibility to control traffic and inform motorists in the case of special events or incidents;
- Two communications networks were used for gantry signage (one for each side of road) to
give redundancy if one was damaged;

- Modified airport runway lights were used for road studs. They gave very good visual guidance; but:
  - They were quite expensive ($200 - $300k);
  - They had some maintenance issues as they got older; and
  - He was not sure if he would use them if doing a similar operation again. He would consider only using them in the transition area.

- Non standard paint markings were used on reversible lane (9m line, 3m gap) to highlight that it was a different lane;

- Moveable physical barrier gates were used at each end to open or close the central lane;

- The central lane was closed down completely before opening to the other direction
  - Lane closures were progressive in direction of travel, and slower than vehicle speed in lane;
  - They originally allowed 30 minutes to change direction, but that came down to about 10 minutes over time; and
  - Lane change over was co-ordinated with signal controls.

- CCTV cameras were installed over the entire length of reversible lane. Direction changes were monitored in a control room, and there was a provision of a manual override if a problem was identified:

- A “Fail Safe” system was installed. The central lane was closed down completely if the Fail Safe system was triggered. The conditions which triggered the Fail Safe system included:
  - The gantry signs & road studs were electronically monitored to ensure consistency of message. The “Fail Safe” system was triggered if an inconsistency was identified; and
  - The barrier gates were also electronically monitored. The Fail Safe system was triggered if the monitoring indicated that one of the gates had been hit. The system was occasionally triggered in high winds;

- There were a number of false alarms which triggered the Fail Safe system. These resulted in significant congestion;

- He was unaware of any head on collisions in reversible lane;

- There was a reasonably even distribution of traffic across the fixed and reversible lanes when the reversible lane was open;

- This was quite a complex arrangement with number of variables, including bus lanes and reversible lanes. It therefore required specialist software to run the system. This made it quite expensive to implement and operate:
  - Construction cost was approximately AU$5M (2002), which included widening & construction of bus lanes; and
  - Operating costs were $500 - $600k per annum. This included having a specialist technician on call 24/7

- They considered detector loops to monitor vehicle direction. This would enable warning messages to be shown on the gantries. However, they concluded that the time taken to put messages up, and the reaction times of motorists would be too long to prevent a collision;

- The system was implemented in 2002. It was decommissioned in 2009 due to:
  - Construction of a new bridge across the Brisbane River. The revised traffic flows made the reversible lane system redundant;
  - Significant negative community feedback, especially regarding the bus lanes; and
  - High operational costs

(pers comm July 2011)
CURLETTS ROAD REVERSIBLE LANE OPTIONS

The safe operation of any reversible lane system is dependent on all road users clearly understanding which direction the reversible lane(s) is operating at any given time. Consequently most of the effort of this project was concentrated on identifying methods to ensure that all road users had a clear understanding of the reversible lane operation generally, and specifically, the direction this central lane was operating at any given time.

It was considered that it was relatively straight forward to inform road users at either end of a reversible lane section about the direction of travel on the reversible lanes, and to remind them as they travelled along the route. Clear, concise messages at the the entry point, and repeated along the affected length can inform and remind road users quite effectively.

Factors Considered

There are significant factors which influence the ability to convey clear information to all road users on this section of Curletts Road, including:

- The presence of multiple midpoint accesses on Curletts Road, including three side roads, and numerous private residential property accesses;
- Significant pedestrian and cyclist demands due to the proximity of Riccarton High School, and the presence of a dairy and fish shop approximately midway along the section of Curletts Road under consideration.
- Many of these road users approach Curletts Road at, or close to, a right angle. They therefore may not see signage oriented towards road users travelling along Curletts Road.

Option Developed

It was considered necessary to provide clear, obvious, and consistent information which was visible from every location on the road. The reversible lane option developed for cost estimates and assessment included the following mechanisms to inform drivers which direction the central lane is flowing at any given time, and replace the existing setup using cones:

- 4 x Overhead gantries with illuminated lane use markers over each lane. These consist of white arrows to indicate that the lane is open in that direction, with red crosses to indicate the lane is closed. A drawing of a proposed overhead gantry is shown in Figure 8;
- Orange illuminated pavement markers. The tidal gates at each end will consist of “iiiilevel”: intelligent road markers at 2.5m centres. These markers are recessed into the pavement, and are less than 4mm proud of the surface. The remainder of the tidal flow section would use “Smartstud” intelligent road markers at 5.0 centres. These markers are placed on the pavement, and are approximately 20mm proud of the surface. The recessed markers were chosen for the tidal gates because all vehicles entering the tidal flow lane would need to cross the markers at this location. It is felt that raised markers may indicate to motorists, though the audible and physical feedback that they were crossing a lane line. The raised markers were chosen for the remainder precisely because they would remind motorists, though the feedback, that they were changing lanes.
- Variable TW 7 signs at the start of the reversible lane in each direction (100 – 120m from the Blenheim Road and Main North Road intersections). These signs will indicate that the central lane is closed, and that vehicles will need to merge to the left. The effectiveness of these signs is reduced by the fact that they will be located in the left hand berm, and may not be readily visible to vehicles in the right lane leaving the intersections. Locations in the existing central islands at each intersection were also considered. However it was felt that the close proximity to the signalised intersections would result in many motorists not seeing the signs. It was also considered that the narrowness of the islands would make the signs vulnerable to damage.
ISSUES TO BE ADDRESSED

A reversible lane operation has a number of advantages when compared with the other options considered (four laning, and peak period clearway). These include:

- It allows parking on both sides of the road at all times;
- It addresses congestion at peak times;
- It allows optimisation of the existing infrastructure without extensive pavement construction or land acquisition.

However, a number of potential issues were identified by both the design team and safety auditors, including:

Safety
There are potential safety issues if motorists are not clear about which direction the tidal lane is flowing. We consider that the potential for confusion is greatest at the mid block private property accesses. Drivers who exit their driveways at the same time on most days may not expect the tidal lane to be flowing in the opposite direction if they should enter the road at a different time.

Pedestrians
Curletts Road is a residential area. On site observations suggest that there is a reasonable pedestrian demand generated by Riccarton High School, and by the shops on the eastern side of Curletts Road. The current tidal flow arrangement has required the removal of the existing pedestrian refuges. This has resulted in deterioration in the pedestrian environment, particularly at mid block points remote from the signalised pedestrian crossing and signals at Blenheim and Main South Roads. It may also result in an increase in the level of risk for pedestrians crossing the road.

Cyclists
The original cycle lanes on Curletts Road have been removed in conjunction with the existing tidal flow operation. Cyclists are currently being advised to use Hanson Lane rather than Curletts Road. However, on site observations have indicated that a number of cyclists are still using Curletts Road. These cyclists can travel in the existing parking lane over most of the length of the tidal flow. There are pinch points for cyclists at the kerb build outs for the former pedestrian refuges, or if they encounter a vehicle parked in the parking lane.

This could be partially addressed by providing a two way combined pedestrian and cycle lane or path between Blenheim Road and Tensing Place. This enables cyclists accessing Riccarton High
School to use Tensing Place (which is a low volume road) to cycle to the rear access of the school.

The Main South Road end is more constrained than the Blenheim Road end, and there is less opportunity to provide a two way footpath and cycle path. There may be room to provide on road cycle lanes between the Main South Road intersection and the first kerb build out. This could then connect, across the kerb build out, to the parking lane.

None of the reversible lane operations studied for this project included on road cycle facilities. One was parallel to an off road facility which appeared to predate the reversible lane operation. The lack of cycle facilities on reversible lane operations is likely to reflect the fact that reversible lanes are generally implemented in locations where space is constrained.

Technology Failure
This operation is totally reliant on technology. If there is a power failure, the illuminated studs and gantry signs will not function. This could be addressed by a back up power supply. Software and communications failures may also result in failure to display consistent and understandable messages.

Private Property Access
Vehicles turning right into private driveways are likely to cause delays to following vehicles, and may result in nose to tail crashes. Options identified to address this included:

- Prohibit right turns into and out of private accesses. However, motorists are likely to make the manoeuvres despite them being prohibited, particularly given that a significant detour is likely to be required to turn left into or out of many of the properties;
- Close the central lane to through traffic during off peak times. It may then function as a de facto flush median. There are some issues with this arrangement:
  - At 3.5m it is much wider than desirable for a flush median, and my be used as a passing lane;
  - The central lane would have 3 potential functions depending on the time of day (northbound, southbound, or "flush median"). This is likely to add another layer of confusion for motorists and pedestrians.

Snow Clearing
The illuminated markers are likely to be vulnerable to damage during snow clearing operations. However, notwithstanding the three major snow events in the past two years, snow clearing operations are typically rare events in Christchurch.

Illuminated Marker Colour
The Safety Audit Team questioned the use of yellow illuminated markers. They felt that the colour red has a “No go” connotation which may have more impact than a row of yellow studs which would not look the same as a No Passing line.

However, red raised reflective pavement markers (RRPMs) and red banded edge markers are only used on the left hand side of the carriageway, and yellow illuminated markers may be brighter than red.

It was recommended that the illuminated pavement marker colour be investigated further should this option progress.

Sustainability of Solution
Due to the volatile landuse patterns and wider road network configuration the number of trips along Curletts Rd and the intersecting roads have been changing significantly over the past two years.
since February 2011. It has been found that the effectiveness of the current tidal lane has
degraded in the past six months due to the increases in demand on Curletts Rd. Further the peak
demand direction appears to have reversed. These issues have been further impacted by the
opening of the Christchurch Southern Motorway. Therefore the value of the solution and the ability
to consistently operate it is degrading.

**Significant Maintenance and Operational Costs**
This solution would require ongoing operational management to ensure appropriate operation and
has ongoing communications and electricity supply costs. Further resurfacing of the pavement
would result in the illuminated pavement markers and their control cable needing to be replaced.
The maintenance and operational costs are therefore significant.

**CONCLUSIONS**
There are a number of international examples where reversible lanes have been used safely in
urban areas. They can address peak hour capacity issues in a cost effective manner. They
optimise the use of existing infrastructure, and provide additional vehicle capacity at the times it is
most needed.

However, there are significant safety issues with vehicles travelling in different directions in the one
lane at different times. Those issues are more difficult to address on a road with intermediate
 accesses than on one without accesses.

In addition, by their very nature, reversible lanes concentrate on providing additional vehicular
capacity in environments where space is constrained. This often makes it more difficult to provide
quality facilities for pedestrians and cyclists.

**Current Direction**
No decisions have been made regarding the best method to optimise the Curletts Road. The
Christchurch Southern Motorway between Barrington Street and Halswell Junction Road has
recently opened. It is anticipated that this will take some of the pressure off Curletts Road through
alleviation of demand both on Curletts Rd and Blenheim and Main South roads where they
intersect with Curletts Road. Traffic patterns on Curletts Road and surrounding roads are being
monitored following the opening of the Southern Motorway.

However the project to improve the congestion on this Regional Strategic State Highway
continues. Given the issues with the tidal lane and the changing demands, the option of peak
period clear way lanes is being progressed.

**REFERENCES**
Highway Practice. *NCHRP Syntheses 340 – Transportation Research Board*

Uniform Traffic Control Devices