Smarter solutions:

reference guide v1.1

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Queensland Government

Bus priority lanes, Brisbane

Contents

The Department of Transport and Main Roads (TMR) has developed a Network Optimisation Framework (NOF) to prioritise consideration of low cost and non-infrastructure solutions within our planning and investment process.

Network optimisation solutions have a vital role to play within TMR's delivery of infrastructure. Recognising this, the framework is designed to inform a range of TMR's existing processes, ensuring that the following investment principles continue to be embedded within our decision-making:

1. Run the system – Sufficient funding will be provided to operate infrastructure and services to ensure an appropriate level of access and safety.
2. Maintain the system – Maintain existing assets, focussing on repair or rehabilitation of networks, rather than replacement, where this reduces the whole-of-life costs of transport infrastructure.
3. Build and expand the system – After sufficient funding has been allocated to run and maintain the system, investments to expand the system and improve services will be balanced to meet growing demand.

Including network optimisation solutions within our decision-making

The framework is not intended to be applied independently of TMR's existing infrastructure planning and investment processes. Rather, it provides direction and assurance that TMR prioritises low-cost and non-infrastructure solutions when responding to a range of transport problems.

The framework will be embedded as standard practice to ensure TMR is getting the most from our existing investment and using infrastructure smarter and more efficiently than before.

Smarter solutions reference guide

The *Smarter solutions reference guide* is a starting point for TMR's consideration of low cost and non-infrastructure solutions – providing information about the benefits and costs of 18 ready-to-implement solutions relevant to Queensland's transport network.

Case studies, including where the solutions have previously been implemented across Australia and the world, are included to illustrate the opportunities and challenges associated with network optimisation solutions.

Smarter solutions multi-criteria analysis tool

The network optimisation framework introduces a *Smarter solutions multi-criteria analysis tool* to TMR's infrastructure planning and investment process.

The tool provides assurance to TMR's infrastructure decision making bodies, such as the Infrastructure Investment Committee and Regional Planning Coordination Groups, that our consideration of low cost and non-infrastructure solutions aligns to the government policy direction for investment decision making.

Designed to supplement existing processes, such as the Project Assessment Framework (PAF) and OnQ, the tool provides a clear line-of-sight between the infrastructure policy, planning and investment decisions that occur across TMR – documenting consideration of network optimisation solutions from the initial stages of strategic planning through to the investment decisions and project approval.

Infrastructure planning and investment process	Network Optimisation Framework outcomes	Further information available
Regional Transport Plans and network planning		
› Outline objectives for a region's transport network that reflect a multi-modal and customer-centric approach. › Identify strategic challenges, short-term actions and future opportunities consistent with the region's transport objectives and government policy direction.	› Consider a range of funding mechanisms for delivering the region's transport objectives, including likely current and future government funding sources, the ability to stage investments and alternative financing models such as Public Private Partnerships (PPP).	**State Infrastructure Plan** for strategic approach to infrastructure funding. **Queensland Treasury** for PPP supporting guidelines.
Corridor and area planning		
› Assess whether the current and future performance of a corridor or area meets the desired transport objectives. › Identify transport challenges that can be resolved through short-term actions.	› Provide clear guidance on the relative priority of investments, including the type and mix of infrastructure and network optimisation solutions.	**Smarter Solutions Reference Guide** for data about the magnitude of expected benefits and costs for network optimisation solutions.
Route and link planning		
› Define the future function of a route or link, supported by intervention priorities that reflect local needs and the transport objectives identified in upstream planning.	› Include information about the expected impacts, benefits, outcome timeframes, alignment with transport objectives and estimated costs for all solutions proposed.	**Smarter Solutions Reference Guide** for data about the magnitude of expected benefits and costs for network optimisation solutions.
Transport System Planning Program (TSPP)		
TSPP nomination forms seeking to undertake PAF and OnQ planning will show clear evidence that projects: › reflect regional transport objectives and TMR's investment principles, particularly extending the life of existing assets through maintaining desired performance outcomes › are well-defined and reflect the scale, causes and effects of the strategic challenges they are trying to solve (short-term actions and future opportunities) › are the result of planning which has considered the capital and whole-of-life costs of solutions relative to the magnitude of any potential benefits.		
Strategic Assessment of Service Requirements (PAF) and Concept Development/Project Proposal (OnQ)		
› Determine whether a response is required to address an identified service need or strategic challenge, clearly articulating the outcomes sought to match against potential solutions.	› Consider a broad range of infrastructure and network optimisation solutions based on the magnitude of potential benefits, costs and outcome timeframes.	**Smarter Solutions Reference Guide** for data about the magnitude of expected benefits and costs for network optimisation solutions.
Preliminary Evaluation (PAF) and Options Analysis (OnQ)		
› Facilitates an assessment of the priority and affordability of potential solutions to an identified service need. › Guides decision makers on whether it is appropriate to proceed to a detailed Business Case.	› Incorporate unique criteria specific to network optimisation solutions within evaluation, ensuring they are assessed equitably with infrastructure-based solutions.	**Smarter Solutions MCA Tool** for criteria that must be used in evaluations of network optimisation solutions.
Business Case (PAF and OnQ)		
› Undertake a detailed comparative analysis of shortlisted solutions to identify the option most likely to meet the identified service need and provide value-for-money investment outcomes.	› Metrics used to evaluate solutions incorporate specific criteria that reflect the impact and benefits of network optimisation solutions.	**Smarter Solutions MCA Tool** for criteria that must be used in evaluations of network optimisation solutions.
PAF and OnQ Gate 3		
Projects that have passed through Gates 1–3 and proceed to procurement will show clear evidence that they: › have been optimally scoped to incorporate network optimisation solutions where appropriate › are appropriately timed to be triggered only after the network has been optimised and the desired performance outcomes of current infrastructure has been maximised through network optimisation solutions › support government policy direction for investment decision making by considering solutions that provide TMR with the opportunity to defer significant investments until they are required.		

Figure 1 – TMR's network optimisation framework

Network optimisation solutions are initiatives that improve the functioning of the existing transport network, without delivering new infrastructure.

These solutions improve performance by increasing the capacity of, or demand for, elements of our current transport network. Network optimisation solutions can address the supply-side and/or the demand-side of the transport network:

Supply-side interventions include those measures solutions which change the supply of network capacity, for example, the improved management of corridors or intersections.

Demand-side measures aim to influence the overall demand for transport resources, by encouraging users to shift from congested modes and routes to more efficient alternatives. These can include 'carrot' and 'stick' policies; encouraging or enabling some behaviours while disincentivising others. Examples include changes to travel fares, or the provision of park 'n' ride facilities.

There are significant benefits to be gained through the implementation of network optimisation solutions as they allow for large-scale capital expenditure to be deferred, while improving the performance of our existing network.

Public Transport	Road Transport	Intelligent Transport Solutions	Regulation and Policy
Bus priority lanes	HOV lanes	Incident management systems	Education campaigns
Public transport jump lanes	Truck restrictions	En-route information system	
Transit signal priority	Hard shoulder running	Variable speed limits	
Park 'n' ride facilities	Reversible lane	Signal optimisation	
Board all doors	Turning lanes	Lane use management system	
	Parking management	Ramp metering	

Figure 2 – Network optimisation solutions (not exhaustive list)

This *Smarter solutions reference guide* comprises a collection of 18 'ready-to-implement' low cost and non-infrastructure to get TMR thinking about how to include network optimisation solutions within our infrastructure planning and investment process.

These solutions are not the only viable alternatives to building new infrastructure, and the *Reference Guide* will continue to be updated as new solutions become available.

Implementation outcomes

Network optimisation solutions can produce a range of benefits, including greater cost efficiencies and improved infrastructure performance.

Network optimisation solutions deliver outcomes across four broad target areas:

Improved operating conditions

Changing specific conditions and performance of the wider transport network to increase capacity and improve functionality.

Targeted behavioural change

Encouraging changes to user behaviour which results in improved efficiency and reliability of the transport network.

Changing the costs of transport decisions

Changes to the cost of using a specific form of transport (for example, time) can encourage or deter different mode choices.

Better information and connectivity

Improving the availability of information allows customers to make better informed decisions.

Figure 3 – Outcomes of network optimisation solutions

Scale of implementation

Network optimisation solutions can also be classified according to their potential scale of implementation; whether they are able to be applied at an intersection or local network, corridor/route, sub-regional, or national network level. It is also important to note that network optimisation solutions may produce the best results when implemented as a package targeting a common problem, rather than individually.

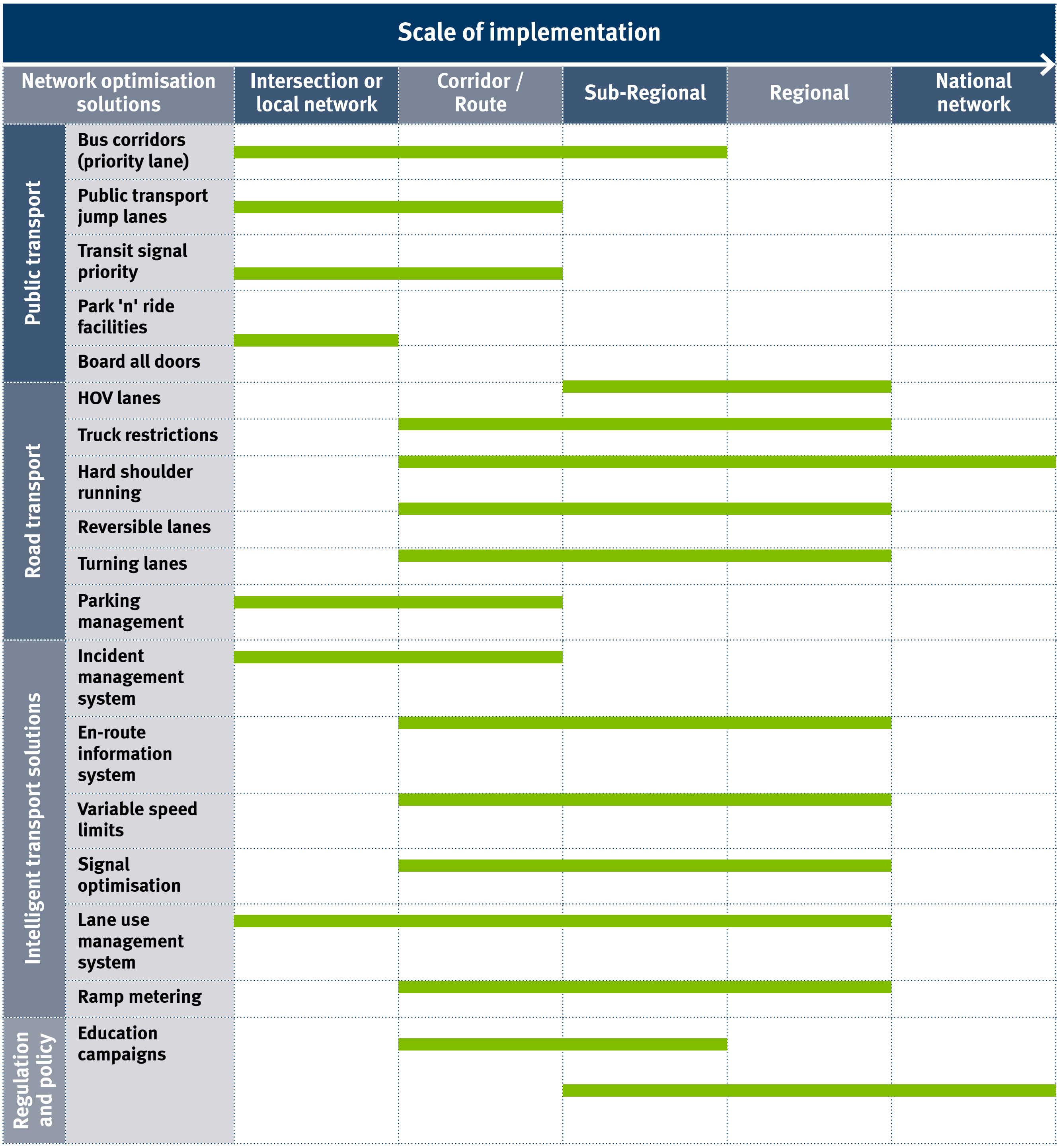

Figure 4 – Potential scale of implementation

Scale of benefits

The solutions outlined within the *Smarter solutions reference guide* provides a snapshot of local and international examples of network optimisation solutions and the outcomes and benefits which have been recorded. It is a dynamic document and will be updated annually with Queensland-specific examples.

NOF Solution	Target outcome areas	Indicative asset life	Benefits
Bus corridors (priority lane)		10+ years	• Reduced average travel time 10–25% (bus travel), 23% (car travel) • 33% reduced travel time variability • Increased bus patronage by 55–80%
Public transport jump lanes		10+ years	• Reduced average bus travel time by 2–26 seconds per intersection
Transit signal priority		5–10 years	• 25–34% reduction in intersection delay • 49% reduced travel time variability
Park 'n' ride facilities		5–10 years	• No comparable data available
Board all doors		< 5 years	• Reduction in boarding time by up to 55%
HOV lanes		5–10 years	• Increased car occupancy by 1.33%
Truck restrictions		10+ years	• Truck-related accident rates decreased by 70%
Hard shoulder running		10+ years	• Reduced average travel time by 1–3 mins along a corridor (bus) • Increased corridor capacity by 7–22%
Reversible lanes		10+ years	• Traffic capacity increased by 40%.
Turning lanes		10+ years	• Reduced delays at bus intersections by 7 to 10 seconds
Parking management		10+ years	• Reduced time in delay finding parking space by 43%
Incident management system		< 5 years	• Reduced average travel time by 0–7.4% • Reduced accident risk by 9–36%
En-route information System		< 5 years	• Significant benefits from perceived travel reliability improvements
Variable speed limits		5–10 years	• Increased travel time reliability by 22% • Reduction in overall crashes by between 20% to 57%
Signal optimisation		< 5 years	• Reduced average travel delay by 20% • Reduced emissions by 1–3%
Lane use management system		< 5 years	• Reduced travel time variability by 22% • Reduced emissions by 4–10%
Ramp metering		5–10 years	• Reduced average travel time by 12–42% • Reduced travel time variability by 34–37% • Reduced accidents by 30–60%
Education campaigns		< 5 years	• Reduction in single occupancy by 14%

Please refer to individual NOF solution summaries for more detailed information about outcomes.

Figure 5 – Classification of network optimisation solutions according to outcome area and benefit duration

Bus lanes are roadway lanes dedicated to bus use and servicing priority bus movement along a traffic corridor. Bus lanes can be provided in kerbside, median or centre lanes, subject to current and future land use planning. Depending on the regulation, certain other vehicles can be permitted on bus lanes such as high occupancy vehicles (HOVs) and taxis. In addition to lanes, bus corridors, also known as busways, exist as separate roadways from general traffic for use by buses.

Where are they used?

Bus lanes can be used along congested corridors or through critical traffic areas to separate buses from general purpose vehicles. They can be designated full-time or enforceable during peak hours only, depending on the flow of general purpose vehicles and congestion trends.

Target	Supply
Timeframe	Long-term
Scale	Corridor
Outcomes	

Key findings

- Bus lanes can be effective in increasing bus travel speeds and reliability.
- Kerbside bus lanes have delivered improved travel times by approximately one minute per kilometre in peak congested traffic conditions and enable a speed advantage over general traffic.
- Median bus lanes have improved travel times by approximately 90 seconds per kilometre in congested traffic conditions. Additional travel time improvements have been shown during peak periods, where buses are able to achieve a further speed advantage over general traffic.
- Further increases in travel speeds and reliability can be gained through the integration of bus lanes with additional NOF strategies such as signal priority at intersections.
- Where traffic is generally free flowing during peak-periods, bus lanes provide only a minor speed advantage benefit for bus passengers. However, they can still significantly improve journey time reliability by reducing the risk of buses being affected by non-recurrent congestion events.
- Bus lanes are not usually physically separated from general traffic lanes. Rather, they are marked by signs and painted pavement. This can lead to compliance problems and enforcement is necessary to ensure that general traffic does not enter the bus lane. Accordingly, in many cases, kerbside bus lanes must facilitate left turning traffic at intersections to avoid disrupting effective operation.

Potential integration of NOF solutions

Bus corridors (priority lane)	**+**	**Transit signal priority**	**+**	**High occupancy vehicle lanes**

Indicative costs

	Lower Capital Expenditure $/km of repurposed shoulder or lane	Lower Operational Expenditure	Upper Capital Expenditure $/km of new lane provided	Upper Operational Expenditure	Assumptions
Bus Priority Lanes	$80,000	$16,000	$1,040,000	$210,000	**2 lane road corridor with shoulder and intersection in 1 km** **Lower:** using existing shoulder or lane as bus priority lane, no widening. Possibly have to shift all lanes over to utilise shoulder **Upper:** new purpose built lane adjacent to existing

* Costs as of May 2016

Examples of use

Example 1

Location	Windsor to Kedron (Truro Street, Lutwyche and Kedron Brook Busway Stations)
Name	Northern Busway Section (Windsor – Kedron)
Timeframe	This section opened June 2012.
Outputs	From 8 to 9am, buses travelling inbound on the busway halved their travel time in comparison to buses travelling on the local arterial road. From 3 to 7pm, buses travelling outbound on the busway improved their travel time by 48% in comparison to buses travelling on the local arterial road.

Source: Department of Transport and Main Roads. 2017. Bus Corridor Evaluation: Network Optimisation Framework. Brisbane.

Example 2

Location	Toulouse, France
Name	High quality corridor spanning 33 km
Timeframe	Construction occurred between 2004 and 2007
Outputs	Following construction, the implementation of the bus corridor increased the frequency of bus services and reduced the average bus travel time by approx. 10%. Additionally, the bus corridor reduced car journey times by 23%.

Source: Villard, C (2014). High-quality bus corridors in Toulouse and development of PT integrated and secured lanes in the city centre/France, Eltis, Retrieved from http://www.eltis.org/discover/case-studies/high-quality-bus-corridors-toulouse-and-development-ptsegregated-and-secured

Example 3

Location	Auckland, New Zealand
Name	Dominion Road Bus Lane
Timeframe	Bus lanes were implemented along a 4 km section of Dominion Road, Auckland in 1998. They operate in the peak-period, peak-direction only and are used as on street parking outside these times.
Outputs	Post-implementation reviews showed travel time reductions of 25% and reductions in travel time variability by 33%. Peak-period patronage increased by over 80% in the decade following implementation. During this period, Auckland City Council undertook rigorous public education and promotion of bus lanes.

Source: Harvey, M., Tomecki, A., and The, C. (2012). Identify, evaluate and recommend bus priority interventions, NZ Transport Agency research report 506. Retrieved from http://www.nzta.govt.nz/assets/resources/research/reports/506/docs/506.pdf

A public transport jump lane, or queue jump lane, is a short, dedicated stretch of roadway that provides public transport priority at an intersection approach. This enables transit vehicles to bypass intersection queues and increase intersection throughput. The required length of the queue jump depends upon the frequency of buses using the corridor, signal phasing and general traffic volumes.

Where are they used?

Public transport jump lanes are generally implemented on the kerbside lane of arterial intersections, although they also can share road space with left turning traffic. They are often implemented in conjunction with other bus priority measures such as 'B-Phase' signals and transit signal priority. They are commonly seen in corridors where bus priority lanes are used, however, they can also be used in isolation where intersections are the major cause of delay to bus travel time or reliability.

Target	Supply
Timeframe	Long-term
Scale	Intersection
Outcomes	

Key findings

- Public transport jump lanes allow public transport vehicles to bypass intersection queues and improve travel time and overall service efficiency.
- Public transport jump lanes can deliver travel time savings of around five seconds to one minute per bus (per intersection), depending on the current traffic conditions.
- Overall, public transport jump lanes reduce transit delays, improve travel speeds, increase corridor carrying capacity and improve service reliability.
- By optimising the efficiency of the public transport network, public transport jump lanes improve the attractiveness of public transport; increasing levels of ridership through mode shift.
- Accessibility is critical to the success of jump lanes. Public transport jump lanes must be carefully designed based on current and forecast congestion conditions; they must be built to a length that allows public transport vehicles to enter the jump lane prior to the start of the queue itself.

Potential integration of NOF solutions

Public transport jump lanes +	**Transit signal priority** +	**Signal optimisation** +	**Turning lanes**

Indicative costs

Public Transport Jump Lanes	Lower Capital Expenditure $/km of intersection	Lower Operational Expenditure	Upper Capital Expenditure $/leg of intersection	Upper Operational Expenditure	Assumptions
	$50,000	$10,000	$80,000	$20,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Gold Coast Highway, Burleigh Heads, Queensland
Name	Intersection of Gold Coast Hwy and Goodwin Terrace, Burleigh Heads, Gold Coast
Timeframe	2005 (estimate) to present
Outputs	The saving in average delay for each bus travelling in the jump lane is 5.5 seconds in the AM peak and 26.1 seconds in the PM peak[1]. The average delay for the general traffic worsens considerably due to the implementation of jump lane (between 10 to 18 seconds).

Source: Department of Transport and Main Roads. 2017. Evaluation of Public Transport Jump Lanes: Network Optimisation Framework. Brisbane.
[1] *This saving relates only to intersection approaches. Considering the jump lane allows buses to move to the front of the queues, additional savings in travel time are highly likely.*

Example 2

Location	Gold Coast Highway, Burleigh, Queensland
Name	Intersection of Gold Coast Hwy and Connor St, Burleigh Heads, Gold Coast
Timeframe	2005 (estimate) to present
Outputs	The saving in average delay for each bus travelling in the jump lane is 1.9 seconds in the AM peak and 4.6 seconds in the PM peak[2]. The average delay for the general traffic worsens considerably due to the implementation of jump lane, an average of 11 seconds in the AM peak and 14.7 seconds in the PM peak.

Source: Department of Transport and Main Roads. 2017. Evaluation of Public Transport Jump Lanes: Network Optimisation Framework. Brisbane.
[2] *This saving relates only to intersection approaches. Considering the jump lane allows buses to move to the front of the queues, additional savings in travel time are highly likely.*

Example 3

Location	Seattle, United States
Name	NE 45th Street
Timeframe	2009–present
Outputs	The overall outputs following the implementation of the bus corridor on NE 45th Street are: • 27 second reduction in the AM peak bus travel time • 12 second reduction in the PM peak bus travel time • 6 second reduction on average across an entire day.

Source: Seattle Department of Transport. (2015). Transit Improvements for NW Market and 45th Streets – More on the Way. Retrieved from http://www.seattle.gov/transportation/btg_transit_market.htm

Transit signal priority is the modification of either the operations or the environment for public transport vehicles moving through an intersection. Transit signal priority improves transit efficiency and reduces unnecessary signal delay.

Measures include:

Transit signal priority (TSP): Modifying the normal signal operation to better accommodate transit vehicles. TSP can be passive or active; conditional or unconditional:

- passive TSP—intersection signals are retimed to account for transit level speeds and set to the calibrated timing
- active TSP—the timing of each intersection signal is dynamic and responds according to real-time information as transit vehicles approach
- conditional TSP—the signal priority system is coordinated with the bus schedule and operates in strict accordance to specific schedule timing
- unconditional TSP—signal priority is available to transit vehicles each time they approach the intersection, regardless of schedule.

Where are they used?

Transit signal priority is used at congested intersections or along corridors to enable buses to move through the intersection clear of other traffic. Several bus priority treatments are usually used in combination. For example, short bus lanes leading up to intersections are combined with a short bus-only phase at the traffic light. This improves the ability for buses to bypass a queue of traffic. Other methods of signal priority do not involve physical works, rather, they ensure a higher proportion of green time is given to public transport routes or dynamically change the signal timing to reduce the likelihood that buses are delayed by a red signal.

Target	Supply
Timeframe	Medium-term
Scale	Intersection
Outcomes	

Key findings

- Transit signal priority facilitates the movement of in-service transit vehicles through controlled intersections, reducing the time spent delayed at intersection queues. This has flow-on effects to reduce transit travel times and schedule unreliability, thereby increasing the quality of service.
- A literature review for the New Zealand Transport Agency found average reduction in delays of between 7.5 seconds and nine seconds per bus, per intersection. Overall, reliability benefits were seen to be higher than travel time benefits.
- Patronage improvements were estimated at around one to two per cent per annum over 10 years.
- The literature finds no consensus around impacts of public transport signal priority on general traffic. Some studies found no impact on general traffic while others found a slight increase in delay. The implementation of transit priority at intersections is also seen to be more effective when the bus stop is located after the intersection. Accordingly, it is recommended that the location of bus stops be considered during the design of queue jump lanes.

Potential integration of NOF solutions

Bus corridors (priority Lane) +	Public transport jump lanes +	Transit signal priority +	Signal optimisation +	Turning lanes +	En-route information system

Indicative costs

Transit signal priority	Lower Capital Expenditure $/intersection	Lower Operational Expenditure	Upper Capital Expenditure $/intersection	Upper Operational Expenditure	Assumptions
	$13,000	$3000	$21,000	$5000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Gold Coast, Queensland
Name	Gold Coast Light Rail Stage 3a Microsimulation Modelling
Timeframe	2014 – present
Outputs	• Reduced light rail travel time during weekday peak periods of 20.7% with signal priority versus without signal priority • With signal priority, the average light rail vehicle travel time saving is 10 seconds per signalised intersection during weekday peak periods • With signal priority, an additional 2.6 seconds per signalised intersections, on average, during weekday peak periods for road users.
Source: Department of Transport and Main Roads. 2019. Evaluation of Transit Signal Priority. Brisbane.	

Example 2

Location	Sydney, Australia
Name	Public Transport Information and Priority System (PTIPS)
Timeframe	2001 trial
Outputs	Sydney introduced their PTIPS, which is linked to the SCATS system coordinating operation of traffic lights. Buses are fitted with GPS units and data is communicated by radio frequencies (NSW Government, 2011). The system currently only operates if buses are running 2 minutes late. When this occurs, the PITPS system generates requests that are sent to the SCATS system. These requests can extend the green or decrease red time at a particular signal to help reduce bus delays at intersections. Requests for priority can be granted or denied based on pre-set rules that relate to the general operation of the traffic signals. A 2001 trial of PTIPS on the Sydney Airport Express Bus service showed the PITPS reduced mean travel times by 21% and variability of travel time by up to 49%.
Source: Gardner, Kevin., D'Souza, Chris., Hounsell, N., Shrestha, Birendra., and Bretherton, David. (2009). (Review of bus priority at traffic signals around the world). Retrieved from http://content.tfl.gov.uk/interaction-of-buses-and-signals-at-road-crossings.pdf	

Example 3

Location	Illinois, United States
Name	Cermak Road across 15 intersections (Employing an early green and green extension TSP strategy)
Timeframe	Feasibility study (1991–1993) Design and testing (1995–1999) Construction and software development (1996) Implementation (1997)
Outputs	Following the implementation phase, the following results were recorded: • 7–20% reduction in transit travel time depending on time of day and direction of travel • the signal priority system eliminated one bus from corridor • increased speed resulted in a 30% reduction in total bus trip time along the corridor from 15 minutes to 10.5 minutes.

Source: Pitstick, M.E. (1999). Cermack Road Bus Priority Demonstration, TRB Traffic Signal Systems Committee. Retrieved from http://www.signalsystems.org; Advanced Public Transportation Systems Committee. (2002). An Overview of Transit Signal Priority, Intelligent Transportation Society of America. Retrieved from http://floridaapts.lctr.org/

Example 4

Location	Portland, United States
Name	Tualatin Valley Highway
Timeframe	1995
Outputs	The signal priority system was installed to give early green and green extensions to buses at 13 intersections. Benefits included: • Bus travel time savings of 1.7% to 14.2% per trip • 2 to 13 seconds reduction in per intersection delay • Up to 3.4% reduction in travel time variability.

Source: Lewis, V. Bus Priority Study: Tualatin Valley Highway. Tri-Met, Portland, OR, 1996.

Example 5

Location	Seattle, United States
Name	King County Metro–Transit Signal Priority Program
Timeframe	1991. Full development of the program took around 2 years as a combination of software, capital works and on-bus hardware were required.
Outputs	The signal priority system acts to extend green signal time and shorten red signal time for buses approaching intersections. Benefits included a 25–34% reduction in average intersection delay and a 5.5–8% reduction in peak hour travel times along the corridor.

Source: Harvey, M., Tomecki, A., and Teh, C. (2012). Identify, evaluate and recommend bus priority interventions, *NZ Transport Agency research report 506*. Retrieved from http://www.nzta.govt.nz/assets/resources/research/reports/506/docs/506.pdf

Park ‘n’ ride (P‘n’R) facilities are dedicated parking spaces located at public transport stations alongside public transport interchanges. They offer a staging location for travellers to transfer between vehicles to public transport, ridesharing or active transport. P‘n’R is one of many ways to access public transport services—other options include walking, cycling, feeder bus services and kiss ‘n’ ride or public drop-off.

Where are they used?

P‘n’R is best suited to providing access to public transport from lower density environments that are beyond walking and cycling distance to public transport and are, therefore, unable to support high-quality or feeder public transport services near homes.

Generally speaking, P‘n’R tends to be associated with grade-separated rapid transit infrastructure, such as commuter rail, busways or ferries (CityCats). It is not commonly provided for bus services on local streets.

TMR’s draft *South East Queensland Park ‘n’ Ride Strategy* provides further guidance around the optimal locations for P‘n’R across the region.

Target	Demand
Timeframe	Medium-term
Scale	Sub-regional
Outcomes	

Key findings

- If P‘n’R is carefully planned and managed, it can play a beneficial role in attracting long distance, private vehicle commuters to mode shift to public transport.
- P‘n’R can increase the attractiveness and cost recovery of public transport corridors in topographically constrained areas or lower-density areas with limited current opportunities for walk-up ridership or feeder bus services. For example, the Perth Northern Suburbs line P‘n’R supplies 28 per cent of the patronage, largely attributed to the low density of the suburbs in which this line runs through.
- International research suggests that for P‘n’R to be successful, there must be parking management strategies in place within key congestion areas (namely, the central business district and surrounding areas).
- Inducing behavioural change through P‘n’R occurs through two key measures; firstly, the P‘n’R must improve the quality of the public transport service, secondly, the P‘n’R must be a lower cost alternative to travelling and parking at a commuter’s destination.

Potential integration of NOF solutions

Bus corridors (priority lane)	**+**	**Park ‘n’ ride facilities**	**+**	**Parking management**	**+**	**En-route information system**

Indicative costs

	Lower Capital Expenditure $/car park	Lower Operational Expenditure	Upper Capital Expenditure $/car park	Upper Operational Expenditure	Assumptions
Park ‘n’ ride Facilities	$10,000	$2000	$40,000	$8000	**Lower:** $10,000/park for parking lot (pavement, drainage, signs and pavement marking, lighting, cameras) **Upper:** $40,000/park multi-storey parking structure

* Costs as of May 2016

Example 1

Location	Gold Coast, Queensland
Name	Commonwealth Games
Timeframe	April 2018
Outputs	It is estimated that before the Commonwealth Games 5% of people travelling to sporting events on the Gold Coast used Park ’n’ Ride. During the Commonwealth Games it is estimated that at least 26% used Park ’n’ Ride to travel to ticketed events and 9.5% of for unticketed events. This result may be attributable to: • The establishment of 13 official Park ’n’ Ride facilities being temporarily established (and many un-official sites organised by schools and sports organisations and so on) • Providing high-frequency bus services to key destinations • Implementing parking management strategies, and • Undertaking Travel Demand Management (TDM) messaging to promote Park ’n’ Ride and public transport, and discourage car usage, to achieve a mode shift from typical behaviour.
Source: Department of Transport and Main Roads. 2019. Evaluation of Park ’n’ Ride Facilities. Brisbane.	

Example 2

Location	Auckland and Wellington, New Zealand
Name	Economic benefits of park ‘n’ ride
Timeframe	2015
Outputs	Increasing the provision of Park ‘n’ Ride sites gives high returns relative to most other types of investment schemes that encourage modal shift to public transport in major urban areas, with best estimates of the BCR being in the range 2.1 to 3.8, through encouraging mode switching at times and in situations where public transport offers an attractive alternative and decongestion benefits are likely to be maximised.
Source: Wallis, I. et al. 2015. Economic benefits of park and ride. Australasian Transport Research Forum. Available at https://www.atrf.info/papers/2015/files/ATRF2015_Resubmission_148.pdf	

Boarding all doors is an operational change that permits passengers to board and discharge buses from both the front and rear doors (and middle doors where applicable). This increases the speed at which the on and off-boarding process occurs and reduces dwell time at bus stops.

Where are they used?

Boarding all doors is a process used on buses and other public transport modes where applicable. Boarding all doors is often used in coordination with electronic, pre-paid ticketing systems.

Target	Demand
Timeframe	Short-term
Scale	Corridor / Route
Outcomes	

Key findings

- Boarding all doors enhances the public transport system by optimising existing services. Using both doors increases the speed and effectiveness of on and off boarding, reducing overall travel time and improving service reliability.
- Improving the efficiency of the public transport system increases the attractiveness of bus transport; encouraging mode shift and an increase in public transport ridership.
- All-door boarding policy can be applied to:
  - all routes in a bus network
  - individual routes
  - individual stops
- Dwell time during boarding and discharging procedures typically accounts for between nine per cent and 26 per cent of a bus route's total running time.
- The implementation of boarding all doors has been shown to improve travel time by between 0.8 per cent and five per cent at stop-level, and between 4.7 per cent and 13.9 per cent for route-level.
- The benefits realised through 'boarding all doors' are largely dependent on electronic fare collection.
- System integration is essential for realising the speed and efficiency benefits of boarding and discharging procedures.

Potential integration of NOF solutions

Bus corridors (priority lane)	**+**	**Public transport jump lanes**	**+**	**Boarding all doors**	**+**	**Turning lanes**	**+**	**En-route information system**

Indicative costs

Board All Doors	**Lower Capital Expenditure $/bus stop**	**Lower Operational Expenditure**	**Upper Capital Expenditure $/bus stop**	**Upper Operational Expenditure**	**Assumptions**
	$2000	$400	$2400	$500	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	West End to Teneriffe via Brisbane CBD
Name	Blue CityGlider
Timeframe	April 2011 – present
Outputs	Rates of rear door boarding were measured at an average of 2.4 rear door boardings per stop in the AM Peak and 1.7 per stop in the PM peak. A positive correlation between the total number of boardings at a stop and the number of rear door boardings was observed (as the total number of boardings increase, so did the number and proportion of rear door boardings). The rate of rear door boardings per stop could roughly be categorised into three groups: *Low:* Less than three total boardings equates to very low rear door boarding. *Medium:* Three to six total boardings equates to approximately one third occurring via the rear door. *High:* Over eight total boardings equates to approximately a half occurring via the rear door. Bus stops in the high category were categorised by dwell time savings of 1 second per passenger action during the peak hour.

Source: Queensland Department of Transport and Main Roads. 2017. Board All Doors Evaluation: Network Optimisation Framework. Brisbane.

Example 2

Location	San Francisco, United States
Name	System-wide all door boarding
Timeframe	2012–2014
Outputs	Average bus system speeds improved by 2% (8.41mph to 8.56mph), while total dwell time reduced by 38%.

Source: SFMTA. (2014). All-Door Boarding Evaluation Final Report. Retrieved from https://www.sfmta.com/sites/default/files/agendaitems/2014/12-214%20Item%2014%20All%20Door%20Boarding%20Report.pdf

Example 3

Location	Sydney, Australia
Name	1) Westbound on Druitt St, before Kent St 2) Wynyard Stands Q and R 3) Queen Victoria Building Stands B and C on York Street 4) Elizabeth St southbound near the Cnr of Kippax St
Timeframe	(Trial) June 15–26
Outputs	The results of the trial included: • boarding time was reduced at location 1 by more than 30% • boarding time was reduced at location 2 by 20% • services were able to move away from the stop up to 40 seconds faster.

Source: O'Leary, W. (2015). Access all areas for Sydney bus commuters. Retrieved from http://www.mynrma.com.au/get-involved/advocacy/news/access-all-areas-for-sydney-bus-commuters.htm

High occupancy vehicle (HOV) lanes are restricted transit lanes dedicated for use by vehicles carrying a specified number of passengers. They are also referred to as carpool lanes, diamond lanes, transit lanes or T2 or T3 lanes in Australia and New Zealand. Typically, HOV lanes require one or more passengers in the vehicle, i.e. a minimum of two or more occupants to qualify.

Where are they used?

HOV lanes can be implemented on arterial roads, motorways, or motorway on-ramps. The successful operation of HOV lanes is dependent upon the prevailing adjacent traffic conditions and accordingly, vehicle occupancy requirements can be permanent or variable (operational during peak periods of congestion).

In Australia, the first HOV lane (also known as a T2 transit lane or T3 transit lane) was opened in 1992 along the Eastern Freeway in Melbourne. There are currently a number of T2 and T3 facilities in Canberra, Sydney and Brisbane.

In Auckland, New Zealand, there are several short HOV 2+ and 3+ lanes throughout the region, commonly known as T2 and T3 lanes. There are also T2 priority lanes along Auckland's Northern, Southern, North-Western and South-Western Motorways.

HOV lane enforcement is a significant issue for road controlling authorities. The issue is complicated by the fact that in some jurisdictions there are also a number of exempt vehicle classes such as motorcycles, charter buses, emergency vehicles and law enforcement vehicles when on duty. In 2009 and 2010, it was found that non-compliance rates on HOV lanes in Brisbane, Australia, were approaching 90 per cent.

Target	Supply
Timeframe	Medium-term
Scale	Corridor / Route
Outcomes	

Key findings

- HOV lanes increase the efficiency of the transport network by increasing person throughput and vehicle speed while reducing total travel time and the number of vehicles travelling along relevant network corridors.
- The reallocation of lane use encourages behavioural change; promoting ride-sharing and increased public transport patronage in response to the reduction in general purpose vehicle lane capacity.
- It is broadly recognised that, at high levels of congestion, HOV lanes can have a distinct impact on motorist behaviour. However, the reduction in single occupancy vehicle journeys ranges from between one per cent and 47 per cent. In instances where HOV lanes are successful in redistributing vehicles across a network corridor, travel times can be reduced by up to 34 per cent.
- On arterial roads, the number and location of entries and exits will be important to the success of the HOV lane. Too many entries and exits will significantly reduce the benefits of the HOV lane and rapidly increase construction and operational costs.
- There is concern that HOV lanes on motorways can be counterproductive due to a lack of compliance and unnecessary lane changing.

Potential integration of NOF solutions

Bus corridors (priority lane) + **High occupancy vehicle lanes**

Indicative costs

HOV Lanes	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$9000	$1800	$17,000	$3400	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Northern Virginia, United States
Name	Henry G. Shirley Memorial Highway, between Washington, DC, and the Capital Beltway
Timeframe	Opened in 1973 as a HOV4+ lane. Still in operation today.
Outputs	Morning peak hour (6.30am to 9.30am). In 2005, the average travel time in the HOV facility was 29 minutes, versus 64 minutes in the general traffic lanes.
Source: Samuel, Peter. (2005). HOV lanes clogged with hybrids-complicate toll plan. Retrieved from http://tollroadsnews.com/news/hov-lanes-clogged-with-hybrids--complicate-toll-plan	

Example 2

Location	Trondheim, Norway
Name	Holtermanns Road / Elgester Street
Timeframe	Implemented 9 May 2001
Outputs	Evaluation of effectiveness through ex-ante and ex-post data recorded: • car occupancy increased from 1.33 persons per car to approximately 1.38 persons per car • average travel time reduction of 35 seconds per vehicle • peak travel time reduction of max. 2 minutes.
Source: Torbjorn Haugen. (2004). Evaluation of HOV-Lanes in Norway, SINEF Roads and Transport	

Truck restrictions designate the lanes in which heavy vehicles may operate, generally restricting heavy vehicles to the left hand lanes of a highway or motorway. The restrictions are designed to reduce the interaction of heavy vehicles with other traffic with the aim of reducing the crash rate of all vehicles and the travel time of the general traffic.

Where are they used?

Truck restrictions are used on specific routes that have a high percentage of long haul trucking and/or heavy truck traffic. Truck restrictions can be permanent or integrated with intelligent transport systems (ITS) to become dynamic and adapt to real-time traffic conditions.

Target	Supply
Timeframe	Medium-term
Scale	Corridor / Route
Outcomes	

Key findings

- Congestion and public safety becomes a significant concern as the ratio of freight traffic increases within mixed vehicle corridors. By restricting heavy vehicles to particular lanes, the safety of the corridor is enhance through the reduction of truck-related accidents.
- It must be confirmed that the corridor has an adequate number of heavy vehicles. A very large number of heavy vehicles (more than can be accommodated in the allocated freight lanes) would result in spillage to general traffic lanes.
- Truck restrictions can be taken a further step through the implementation of dedicated freight lanes. The implementation of a dedicated freight lane can have significant impacts on the accessibility, mobility, safety and time reliability of freight along a corridor.
- For freight lanes, the number and location of entries and exits will be important to the success of the solution. Too many entries and exits will significantly reduce the benefits of the freight lane and rapidly increase costs.

Indicative costs

Truck restrictions	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$60,000	$12,000	$110,000	$22,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Pacific Motorway between Logan River and Nerang (South of Smith Street Exit 66)
Name	Pacific Motorway Truck Lane Restriction AIMSUN Modelling Project
Timeframe	Transport model
Outputs	The model tested a single lane and dual lane restriction. Results showed that single lane restriction delivered a number of benefits for the general traffic (better travel times, faster speed and reduced delays), however, the operation of heavy vehicles was severely impaired. The dual lanes restriction, while providing consistent distribution of benefits across all vehicle types, was shown to be slightly less beneficial for general traffic when compared with the single lane restriction scenario.
Source: Department of Transport and Main Roads. 2017. Evaluation of truck restrictions: Network Optimisation Framework. Brisbane.	

Example 2

Location	Pacific Motorway truck lane restriction
Name	Pacific Motorway between Springwood and Robina
Timeframe	Implemented on the 1st August 2017.
Outputs	Trucks are restricted to use only the two left-hand lanes between Springwood (Exit 20) and Robina (Exit 79). After implementation of TULL, the road safety risk associated with speed variability and lane changing on the M1 has reduced. Compliance with TULL is very high at approximately 80%. 60% of road users and 40% of heavy vehicle operators interviewed supported the continuation of TULL as a permanent measure.
Source: ARRB. 2018. Gold Coast 2018 Commonwealth Games M1 Management Plan Outcomes.	

Example 3

Location	South Carolina
Name	I-85 Highway
Timeframe	Implemented in 2001.
Outputs	Truck restrictions on two high crash segments of the I-85 Highway in South Carolina: truck-related accident rates decreased by 78%. Subsequently, truck lane restrictions were expanded to 170 kilometres of interstates in South Carolina. Since this implementation truck crashes on interstates in South Carolina have increased slightly, but fatalities involving heavy trucks have decreased.
Source: Zeitz, R. 2003. Low cost solutions yield big savings. Public Roads, 67(3), 48–50. Available at https://www.fhwa.dot.gov/publications/publicroads/03nov/11.cfm	

Hard shoulder running (HSR) uses the shoulder lane of a highway or motorway as a traffic lane to create an extra lane, relatively cheaply, at fixed periods where there are known congestion bottlenecks. During other times of the day the lane acts as an emergency stopping area for vehicles in the case of an accident or traffic incident. The use of the shoulder lane may be for general purpose travel or for restricted use by public transport e.g. buses, and is most often accompanied by the use of overhead gantries and variable speed limit signs.

Where are they used?

HSR makes use of existing road pavement along the outside edge of a highway or motorway usually reserved for emergency use as an extra traffic lane when the road capacity becomes constrained. The use of the hard shoulder as a lane is usually dynamic, that is, the time that the lane is made available for use is adjusted to respond to both recurrent and non-recurrent congestion.

Target	Supply
Timeframe	Long-term
Scale	Corridor / Route
Outcomes	

Key findings

- HSR reduces congestion by improving the efficiency and safety of the traffic network. Increasing the capacity of the road network reduces the density of traffic flow, allowing vehicles to optimise their speed and maneuverability. Research findings report that HSR can increase the average speed of traffic by up to nine per cent.
- The impact of HSR on motorway safety is divided within the literature. By reducing the volume of vehicles per lane, some literature reports that HSR reduces the risk of congestion-induced accidents. However, contrary research contests that converting the emergency lane into a general purpose lane increases the risk of accidents.
- The successful deployment of HSR is complex and must incorporate dynamic sensors, monitors and information systems to manage speed and merging traffic. The implications of this system on the safety of the impacted motorway are, therefore, highly dependent on existing traffic conditions and motorist behaviour.
- Many jurisdictions are now mandating lower operating speeds where the hard shoulder isn't available for disabled vehicles.
- On motorways, the number and location of entries and exits will be important to the success of the hard shouldering solution. Too many entries and exits will reduce the benefits of hard shouldering and rapidly increase costs.

Potential integration of NOF solutions

Hard shoulder running	+	Lane use management systems	+	Incident management system	+	Variable speed limits

Indicative costs

Hard Shoulder Running	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$180,000	$40,000	$290,000	$60,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Birmingham, United Kingdom
Name	M42
Timeframe	Pilot scheme started in 2006 with an 11 mile section along the M42. A significant proportion of the United Kingdom motorway now has part-time (dynamic) or full-time hard shoulder running with variable speed limits and incident management technology. This includes substantial sections of interurban corridors such as large parts of the M1 between London and Leeds.
Outputs	The Highway Agency has reported a reduction in accidents on completion of the initial trial. A paper published in March 2011 showed that, across the three years of the pilot, accidents involving personal injury had been cut by more than half (56%), with no fatalities recorded. Casualties per billion vehicle miles travelled are down by just under two-thirds (61%).
Source: Hill, Adam. (2013). Traffic monitoring and hard shoulder running, ITS International. Retrieved from http://www.itsinternational.com/categories/detection-monitoring-machine-vision/features/traffic-monitoring-and-hard-shoulder-running/	

Example 2

Location	Holland
Name	A15, A27, A28 and A50
Timeframe	The principle of HSR discussed since 1993. Has been adopted as policy since 2004. Currently up to 1,000 km of roadway uses HSR.
Outputs	Reporting has revealed that HSR has increased overall capacity by between 7% and 22% (depending on usage levels) by decreasing travel times from one to three minutes and increasing traffic volumes up to 7% during congested periods.
Source: US Department of Transportation. (n.d.) Efficient Use of Highway Capacity Summary, Federal Highway Administration. Retrieved from http://ops.fhwa.dot.gov/publications/fhwahop10023/chap4.htm	

Example 3

Location	Germany
Name	Various
Timeframe	HSR has been in operation since 1996. Installed on over 200 km of currently congested corridors across the country
Outputs	Facilities with speed harmonisation have seen a reduction of up to 29% in accidents with personal damage, a reduction of up to 27% in accidents with heavy material damage, and a reduction of up to 3% in accidents with light material damage.
Source: US Department of Transportation. (n.d.) Efficient Use of Highway Capacity Summary, Federal Highway Administration. Retrieved from http://ops.fhwa.dot.gov/publications/fhwahop10023/chap4.htm	

Reversible lanes are used to increase the capacity of road space in response to recurrent and non-recurrent congestion and/or significant tidal flow traffic conditions.

Note: Contraflow lanes (as opposed to reversible lanes / tidal flow lanes) refer specifically to lanes which can be quickly reversed in the case of significant natural disasters such as hurricanes and flooding. Contraflow lanes are not reversible lanes / tidal flow lanes and, therefore, do not form part of the suite of everyday traffic management devices.

Reversible lanes can be dynamic or static:

- dynamic lanes respond to traffic conditions, temporarily increasing the capacity of congested roads by changing the direction of traffic flow on one or more lanes across a multilane corridor
- static lanes provide permanent accommodation for strong directional traffic along a corridor.

Where are they used?

Reversible lanes can be used on any multi-lane corridor, arterial road or highway/motorway. They are used to accommodate traffic volume and flow by instantly increasing road capacity by using the existing capacity of other lanes. The direction of traffic along a contraflow lane can be indicated through overhead signage or through the implementation of a physical barrier.

Target	Supply
Timeframe	Long-term
Scale	Corridor / Route
Outcomes	

Key findings

- Reversible lanes are used to effectively manage recurrent congestion during peak traffic flow periods. By reallocating the road to support additional capacity in the direction of peak flow, reversible lanes increase the flow of traffic along a corridor.
- Advantages of reversible lanes include:
  - maximising volume-to-capacity ratio by manipulating the lane capacity to support the direction of greatest flow
  - increasing vehicle speed across the specific corridor, subsequently increasing vehicle throughput and reducing total travel time
  - improving merge conditions by increasing road capacity and subsequently increasing headway distances. Merging is supported at slower speeds and with greater merge gap acceptance
  - improving travel time reliability
  - improving the efficiency of traffic during non-recurrent congestion, improving incident management and accident clearance time.

Potential integration of NOF solutions

Bus corridors (priority lane)	+	Lane use management systems	+	Incident management system

Indicative costs

	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Reversible Lanes	$2,700,000	$540,000	$4,150,000	$830,000	3 lane highway with shoulder converted to 4 lanes w/ hard shoulder Lane width reduced 4 lines removed and repainted

* Costs as of May 2016

Examples of use

Example 1

Location	Brighton, Brisbane
Name	Houghton Highway
Timeframe	1982–2010
Outputs	The reversible lane allowed for road capacity to be added without the construction of a new bridge. Construction of the reversible lanes was minor ($1.5 million in 2016 dollars) compared to the construction of a new bridge ($360 million in 2016 dollars). A traffic model, developed to test the impact of the reversible lanes, found that the presence of the reversible lane improved traffic throughput by just over 40% during peak hour[1]. In addition, the model estimated the reversible lanes improved travel time along the corridor by an average of 130 to 160 seconds (or 40%) during peak hour.

Source: Department of Transport and Main Roads. 2017. Evaluation of reversible lanes: Network Optimisation Framework. Brisbane.

[1] *The reversible lane made use of a general traffic lane. As such the reversible lane only adds capacity in one direction (either southbound during the AM Peak or northbound during the PM peak) and this is where the benefits outlined above are experienced.*

A turning lane is a short, dedicated section of roadway that facilitates the additional flow of traffic through an intersection, specifically for turning vehicles. Turning lanes prevent turning traffic from unnecessarily stopping or being delayed in traffic at intersection signals.

Where are they used?

Turning lanes are implemented on the kerbside turning lane of arterial intersections. They serve as left turn only lanes but are signed to allow public transit vehicles to proceed straight through the intersection.

Target	Supply
Timeframe	Long-term
Scale	Intersection
Outcomes	

Key findings

- Turning lanes allow turning vehicles to bypass intersection queues to improve travel time and road network flow. Increasing the efficiency of vehicle turning movements through an intersection increases throughput and reduces congestion both between and within intersections.
- There is only limited literature for this type of intersection treatment. *Transit Cooperative Highway Research Program Report 118* estimates travel time savings in the range of five per cent to 15 per cent for one-sided queue jump lanes.
- Like public transport jump lanes, turning lanes must be carefully designed based on current and forecast traffic conditions. They must be built to a length that allows general purpose vehicles to enter the jump lane prior to the start of the queue itself.

Potential integration of NOF solutions

Public transport jump lanes + **Transit signal priority** + **Signal optimisation** + **Turning lanes**

Indicative costs

Turning lanes	Lower Capital Expenditure $/lane	Lower Operational Expenditure	Upper Capital Expenditure $/lane	Upper Operational Expenditure	Assumptions
	$50,000	$10,000	$80,000	$20,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Seattle, United States
Name	NE 45th Street
Outputs	A 27-second reduction in bus travel time was achieved during the morning peak, with a 12-second reduction during the afternoon peak, and a six-second reduction, on average, across an entire day.
Source: Kittelson and Associates. (2007). *Bus Rapid Transit Practitioner's Guide*, Transit Development Corporation. Washington, DC: Transportation Research Board.	

Example 2

Location	Denver, United States
Name	Lincoln Street and 13th Avenue
Outputs	Reduced delays at bus intersections by seven to ten seconds.
Source: Kittelson and Associates. (2007). *Bus Rapid Transit Practitioner's Guide*, Transit Development Corporation. Washington, DC: Transportation Research Board.	

Parking management refers to the use of pricing, permits, or time limitations to manage demand for on-street (and sometimes also off-street) parking.

According to Auckland Transport (2015), there are four main types of on-street parking management policies:

- **unrestricted parking**—no limitations on parking.
- **time restricted**—with a range of time limitations and enforcement used to ensure compliance.
- **reserved parking**—reserved for a certain type of user, such as mobility card holders, taxis, freight vehicles in loading zones, or neighbourhood residents.
- **priced parking**—with varying rates applying, sometimes alongside a time restriction. The best practice approach to parking pricing is demand-responsive variable pricing, updated either on a continuous basis (as in San Francisco) or a quarterly basis (as in Auckland).

As this list suggests, implementing parking management requires agencies to monitor and enforce on-street parking. These policies can be combined with removal of minimum parking requirements, a common variety of planning regulation that requires developers to provide a minimum quantity of parking with new land uses. Minimum parking requirements have been shown to be both ineffective and inefficient for parking

Target	Demand
Timeframe	Long-term
Scale	Sub-regional
Outcomes	

Where are they used?

Parking management strategies are typically applied at a sub-regional level, primarily in congested inner city areas and along congested arterial roads. It is usually necessary to apply parking management policies for multiple streets, to avoid the potential for demand to spillover onto neighbouring streets.

Auckland Transport (2015) provides guidelines for implementing parking management policies. They target an occupancy rate of approximately 85 per cent, which ensures that one in seven spaces is available at any given time. In order to achieve this, they have specified a set of triggers for when new parking management policies should be implemented, or when prices should be changed, as detailed below.

Issue	Trigger	Response
Demand pressure in currently unrestricted areas	Demand for on-street parking regularly exceeds 85% at peak times	• Introduce time restrictions to local demand or paid parking to encourage turnover of spaces • Establish new residential parking schemes
Demand pressure in residential areas	Parking demand regularly exceeds 85% of available supply in residential areas at peak times where off street parking options are constrained (e.g. heritage zones, or areas where off-street parking constraints apply)	• Introduce or alter time restrictions (suited to local demand) to encourage turnover of spaces (with resident parking permit schemes where appropriate) • Establish new residential parking scheme • Introduce paid parking areas to manage the high demand
Demand pressure in areas with time restrictions	Occupancy levels for time-restricted spaces regularly exceed 85% at peak times	• Investigate opportunities to reduce the time restriction and/or introduce additional time restrictions on adjacent streets • Introduce paid parking with no time limits and use demand responsive pricing

Issue	Trigger	Response
Demand pressure in areas with paid parking	Occupancy rates for paid paring in on street spaces regularly exceed 85% at peak periods	• Increase parking charges, in line with Policy 1C • Consider provision of additional off-street parking, consistent with the investment criteria

Key findings

- There is significant evidence for the extensive benefits of parking management, primarily for pricing (demand) policies and supply restrictions.
- Demand-responsive priced parking ensures that sufficient parking spaces are available to motorists travelling along a corridor. This is effective in reducing localised congestion resulting from circling within a restricted area to find a vacant parking space.
- Priced parking increases the cost of travel, encouraging motorists to shift modes or re-time their trip, thereby reducing the total demand for vehicle travel.
- Parking management is a highly beneficial measure in controlling congestion. Studies have indicated that managing parking through pricing (rather than through maximum time restrictions) replicated many of the benefits achieved through congestion / road pricing.
- Similarly, restricting parking supply is highly effective in reducing vehicle traffic by limiting the availability and accessibility of parking. These parking limitations result in more absolute changes in travel behaviour than pricing policies.
- Restricting parking supply is highly effective in managing commuter traffic; however, some businesses report anecdotal evidence that limiting the convenience of parking has significant negative impacts on patronage. Importantly, various studies conducted across the United Kingdom and United States show no systematic relationship between the provision and convenience of parking spaces at different types of urban centres and their economic performance.
- Literature suggests that, to be successful, parking management strategies should aim to keep about 15 per cent of parking spaces vacant at all times to ensure there is usually a carpark free for someone that is willing to pay a market price for it. This reduces circling to a minimum and its associated negative impacts of congestion and emissions.
- Individual parking management strategies can reduce parking requirements by between five and 15 per cent, however, if combining a variety of parking and other transport strategies, reductions can be between 20 and 40 per cent.

Potential integration of NOF solutions

Park 'n' ride facilities	**+**	**Parking management**

Indicative costs

Parking Management	Lower Capital Expenditure $/park	Lower Operational Expenditure	Upper Capital Expenditure $/park	Upper Operational Expenditure	Assumptions
	$300	$60	$500	$100	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Auckland, New Zealand
Name	Eden Terrace, a city fringe suburb
Timeframe	In 2013, Auckland Transport introduced a paid parking scheme with no time limits in Eden Terrace, a city fringe suburb with conflicting parking demands from commuters, residents and local businesses.
Outputs	Evidence provided by Mr Scott Ebbett (Parking Design and Policy Manager at Auckland Transport) for hearings on parking policies in the Proposed Auckland Unitary Plan provides some information on the Eden Terrace scheme. Mr Ebbett reports data on outcomes after Auckland Transport's implementation of parking management policies. For example, the following Figure shows how parking occupancy has declined from overly high levels — approaching 100% throughout much of the day — following the implementation of paid parking on Upper Queen Street in the city centre fringe. According to Mr Ebbett: *'A member/representative of The Uptown (Eden Terrace) business association has reported that complaints about parking in this area are substantially reduced and he now only gets positive comments from businesses.'* Because the adoption of paid parking has reduced parking occupancy, it is likely to have both (a) improved amenity for businesses and residents in the area, who face lower competition for parking spaces and less visual clutter and (b) reduced search times for people seeking to travel to the area.
Source: Auckland Unitary Plan Independent Hearings Panel. (30 June 2015). Statement of rebuttal evidence of Scott Andrew Ebbett on behalf of Auckland Council. Shoup, D. (2005). Parking requirements: will they reduce traffic congestion? Chicago: American Planning Association	

Example 2

Location	San Francisco, United States
Name	SFPark
Timeframe	Implemented 2011
Outputs	A key part of the SFPark strategy was the introduction of demand responsive pricing, which was adjusted every 8 weeks based on occupancy rates. For on street facilities, a target of 60–80% occupancy was set. If this was exceeded, pricing would be increased, if below the target it would be decreased. SFPark also introduced a range of improvements to improve the user experience for those looking and paying for parking. SFPark was initially introduced for a period of two years with data monitoring from a wide variety of sources so a comprehensive evaluation could be carried out. The strategy was rolled out in some areas of the city while others areas were retailed as control areas for the purpose of monitoring. The program was found to have a number of benefits: • drivers found it easier to find a parking space, with a 43% reduction in the time it took to find a space • reduction in circling for parking led to a reduction in peak congestion, traffic volume, emissions and vehicle miles travelled • both traffic and transit speed improved, seen as result of a reduction in circling, and in double parking.
Source: San Francisco Municipal Transportation Agency. (2014). SFPark: Pilot Project Evaluation. Retrieved from http://sfpark.org/wp – content/uploads/2014/06/SFpark_Pilot_Project_Evaluation.pdf	

An incident management system is a dynamic messaging system that provides real-time emergency and incident response information to motorists. Incident management systems inform motorists of emergency incidents and non-recurrent congestion so that traffic behaviour can respond to changing conditions.

Where are they used?

Incident management systems are used along highways and motorways to relay real-time information to motorists. Messaging display can be either roadside or overhead, depending on existing systems and land use.

Some in-vehicle navigation systems are enabled with technology capable of relaying this information to motorists. Currently, incident management systems are used by TMR to respond to incidents, providing information to motorists and support the management of traffic.

Target	Supply
Timeframe	Short-term
Scale	Corridor / Route
Outcomes	

Key findings

- Advancing traffic surveillance technologies have improved the ability for incident management systems to provide real-time information to effectively guide motorist behaviour.
- The primary objectives of incident management systems are to reduce secondary incidents, increase and improve the use of alternate routes, decrease detection times, decrease delays and improve accident clearance times (time from accident detection and confirmation that lanes are available for traffic).
- Currently, TMR uses the STREAMS integrated intelligent transport system which integrates incident management with traveller information, motorway management, vehicle priority systems and traffic signal management.
- Across these functions, STREAMS operates with the objective of increasing the efficiency of the transport network by reducing total travel time, reducing vehicle operating costs, improving safety, reducing emissions, increasing capacity and by measuring and comparing network performance.

Potential integration of NOF solutions

Hard shoulder running	+	Reversible lanes	+	Lane use management systems	+	Incident management system	+	En-route information system	+	Variable speed limits

Indicative costs

Incident Management System	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$243,000	$50,000	$440,000	$90,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	California, United States
Name	74-mile-stretch of Interstate 5 from the Mexico-US border to Orange County, CA
Timeframe	Dataset combines 2008 weather data with geometric information, road work information, and 2008 accident data.
Outputs	The report's data suggests that secondary crashes represent approximately 5.2% of all primary incidents. The report finds mild evidence that changeable message signs reduce secondary crashes; their influence extends approximately 35.4 km downstream from their location, with a maximum of approximately 17.7 km.
Source: Kopitch, L., and Saphores, Jean-Daniel Maurice. (2011). Assessing effectiveness of changeable message signs on secondary crashes, Transportation Research Board.	

Example 2

Location	Minnesota, United States
Name	Various–I–35E, TH–77, TH–169
Timeframe	One message system installed in July 1996 and a further three installed in July 1999 were selected for a before and after. Study published in November 2002. Statistical analysis of multiple hazard warning system sites considering discrete diversion choice, travel time savings and total delay.
Outputs	There is a significant improvement on diverting vehicles during an incident through an alternate route if the hazard warning message also provides the motorists with the ideal alternate road to travel. Travel time is reduced by 7.38% during non-peak hour incidents. No travel time savings were realised during non-incident situations but this also could be attributed to the increase in traffic volumes. Total delays (vehicle minutes) were also significantly reduced once the message signs were introduced including the use of ramp metering.
Source: Levnson, D., and Huo, H. (2002). Effectiveness of variable message signs. Retrieved from http://nexus.umn.edu/papers/vms.pdf	

Example 3

Location	South-East Queensland
Name	Unplanned incident management for transport (UPLIFT)
Timeframe	March 2017
Outputs	• The annual economic cost of incident-related congestion in South-East Queensland is approximately $437 million (however depending on the source, it could be in the range of $281 to $690 million) and congestion-causing incidents in South-East Queensland have an average duration of 1 hour and 20 minutes • Reducing the duration of incidents can have significant travel time savings to road users. The greatest savings are on motorways as opposed to arterial roads, and during the peak periods • On a motorway in a peak period, by reducing a 30 minute to 2-hour incident by just 2 minutes can save 292 vehicle-hours. For a peak period, motorway incident that is over 2 hours in direction, reducing the duration by 10 minutes results in a saving of 481 vehicle-hours. For a medium length (1-2 hour) incident on an arterial road, reducing the reduction by 5 minutes can save 64 vehicle-hours • Economic analysis of Incident Management Solutions to reduce the duration of incidents and return traffic to typical operating conditions suggest a positive BCR of between 1.65 and 3.33
Source: Department of Transport and Main Roads. 2019. Incident Management Systems Discussion Paper. Brisbane.	

En-route information systems are dynamic messaging systems (DMS) that use changeable message signs to inform motorists of real-time traffic conditions. En-route information systems can warn motorists of downstream queues, current weather conditions or traffic incidents, provide travel time estimates, direct through-traffic to alternative lanes and inform motorists of alternative route information

Where are they used?

En-route information systems are used on corridors to provide motorists with advanced information about the flow of traffic or changed conditions. En-route information systems convey this information through road-side or overhead message boards or through in-vehicle navigation systems.

Target	Supply
Timeframe	Short-term
Scale	Corridor / Route
Outcomes	

Key findings

- There is strong evidence supporting the use of en-route information systems to influence driver behavior; improving the efficiency of the transport network by encouraging motorists to adjust their route to match current traffic circumstances.
- A Swedish study found that up to 40 per cent of road-users select an alternate route after receiving real-time information through en-route information systems. This change in behaviour (diversion to alternate route) improves the efficiency of the transport network by reducing traffic on the congested corridor, improving the flow of vehicles as a percentage of capacity (including the capacity of alternate routes).
- The capacity for en-route information systems to improve the efficiency of the transport network is highly dependent on a number of factors, including:
    - The availability and accessibility of an alternative route.
    - The capacity of the alternative road network. Depending on the scale of vehicle diversion, the network may become heavily loaded and may lead to subsequent delays.
    - The timing and visibility of information, including simplicity of message to enable motorists to read while maintaining vehicle speed.
    - The nature of the information. A study conducted in Paris found that 80 per cent of drivers preferred to be informed on travel time rather than queue lengths.
- While the overall effectiveness of en-route information systems is highly dependent on many variables, the total benefits can be enhanced through the integration of other NOF strategies to form a multi-dimensional solution. For example, en-route information systems can be coupled with variable speed limits to improve the safety and flow of vehicles along the motorway, in addition to promoting the use of alternate routes to eliminate non-recurrent congestion.
- With the emergence of in vehicle signs and related Cooperative Intelligent Transport Systems (C–ITS), a number of the European countries are now placing this solution on hold.

Potential integration of NOF solutions

Hard shoulder running ✚	Reversible lanes ✚	Lane use management systems ✚	Incident management system ✚	En-route information system ✚	Variable speed limits

Indicative costs

En-route Information System	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$250,000	$50,000	$440,000	$90,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Missouri, United States
Name	DMSs on freeways in rural areas in southeast Missouri were evaluated
Timeframe	Report published September 2012.
Outputs	In surveys, motorists were highly favourable towards DMSs. Motorists seemed to be very satisfied with how MoDOT was using their DMSs in rural areas. Overall, 94% of the surveyed motorists said they took the action provided by the DMSs. Within the subgroups, 96% of work-related trip makers said they took action versus 89% of recreational trip makers. Nearly all truck drivers (98%) said they took the action advised by DMSs. The survey revealed that 41% of drivers relied solely on DMSs to get the traveler information.

Source: Edara, Praveen., Sun, Carlos., Keller, Clay., and Hou, Y. (2011). Evaluating the Benefits of Dynamic Message Signs on Missouri's Rural Corridors, *University of Missouri-Columbia*. Retrieved from http://library.modot.mo.gov/RDT/reports/TRyy0947/cmr13004.pdf

Example 2

Location	Europe
Name	VMS (variable-message sign) field trials conducted in nine cities as part of European Union-sponsored research projects carried out between 1994 and 1999
Timeframe	Study published February 2007
Outputs	For continuous information describing the traffic state on a major route, information increases the use of the major route and reduces use of alternative routes if there are no traffic problems reported on the major route. Travel time information was well regarded by drivers and found to be effective in inducing route changes. In general, the deployments of VMS to inform drivers of traffic conditions have proved successful in terms of improving network travel times and reducing environmental impacts. Whilst such changes have been relatively small, driver perception of the benefits is much higher. This is potentially very significant in terms of the role that VMS can play in the development of integrated transport strategies, as the provision of information may encourage greater acceptance of a range of demand management measures.
Source: Chatterjee, Kiron., and Mcdonald, Mike. (2007). Effectiveness of using variable message signs to disseminate dynamic traffic information: Evidence from field trails in European cities, *Transport Reviews*, 24(5). Retrieved from http://www.tandfonline.com/doi/full/10.1080/0144164042000196080	

Example 3

Location	Saudi Arabia
Name	2 km section of a two-lane, rural highway
Timeframe	A data set of 36,013 observations from both experimental and control sections at two study sites was collected and analysed. The data included vehicle speed, volume, and classification; time headway, time of day and visibility distance.
Outputs	A Dutch fog warning system including a text warning ('fog') and dynamic speed limit VMS signs on a motorway, reduced speeds in fog by 8 to 10 km/h, although in extremely dense fog, the system had an adverse effect on speed. This was due to the too high 'lowest possible speed limit' display in the VMS (60 km/h). More uniform speed behaviour was obtained due to the introduction of the system. Although the warning system was ineffective in reducing speed variability, mean speed throughout the experimental sections was reduced by about 6.5 kph. This reduction indicates that the warning system appeared to have a positive effect on driver behaviour in fog even though the observed mean speeds were still higher than the posted advisory speed. From relationships found in the literature between mean driving speed and number of crashes, a speed reduction of only 5 kph would yield a 15% decrease in the number of crashes.
Source: Siegener, W., Traeger, K., Martin K., and Beck, T. (2000). Accident occurrence in the area of route information and management systems, allowing particularly for traffic load.	

Variable speed limits (VSL) are enforced through dynamic speed indicators that adjust to weather and traffic conditions, reducing the speed limit for areas of congestion, accidents or for special events.

Where are they used?

VSL are primarily used on motorways to manage recurrent and non-recurrent congestion, displayed either overhead or on road-side portable message signs. VSL can also be utilised on arterial roads in certain conditions such as non-recurrent congestion due to traffic incidents or road works.

Target	Supply
Timeframe	Medium-term
Scale	Corridor / Route
Outcomes	

Key findings

- VSL are designed to avoid or delay the onset of demand driven congestion and reduce supply driven congestion by controlling motorway speed for incident management and flow (speed) homogenisation.
- Traffic instability and safety risk caused by small time headways, large speed variance and frequent disturbances are avoided by varying the speed limit to manage the flow of vehicles along a corridor (Federal Highway Administration, Variable Speed Limits, 2014).
- VSL systems have been shown to improve speed compliance by approximately five per cent and reduce primary accidents by up to 30 per cent.
- Studies conducted in the UK and Munich found that variable speed limit systems can increase vehicle throughput by 1.5 per cent, increasing the immediate network capacity by approximately 30 per cent.
- VSL systems are very effective in improving safety during incident management by reducing speed to limit the inflow of traffic to the bottleneck area at the traffic incident approach. Reducing the speed of upstream traffic accelerates queue dissipation of congested areas.
- Overall, variable speed limit systems improve traffic safety and manage congestion / traffic flow by providing motorists with real-time speed limits that reflect the current driving environment (specifically when compromised by traffic congestion, incidents or adverse weather).

Potential integration of NOF solutions

Hard shoulder running +	**Reversible lanes** +	**Lane use management systems** +	**Incident management system** +	**En-route information system** +	**Variable speed limits**

Indicative costs

Variable Speed Limits	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$140,000	$30,000	$240,000	$50,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Bruce Highway (between Uhlmann Road and the Pine River), South-East Queensland
Name	Bruce Highway
Timeframe	February 2016.
Outputs	In the first year of VSL signs being used on the Bruce Highway, motorists experienced a nearly 50% drop in rear end casualties. The severity of crashes also reduced, with the percentage of hospitalisation crashes dropping from 43% to 20%. Variable speed limits have also been used on the Logan and Ipswich Motorways, and are proven to help reduce crashes and improve travel times by minimising stop/start congestion patterns with smoother traffic flows.
Source: http://statements.qld.gov.au/Statement/2018/8/17/m1-speed-limits-maintained-with-new-measures-to-reduce-travel-times-during-congestion	

Example 2

Location	Tasmania, Australia
Name	Tasman Highway between Liverpool Street, Hobart and the Cambridge Road Interchange, including the Tasman Bridge
Timeframe	January 2013–September 2013
Outputs	There was a 57% overall crash reduction over a 24-hour period in the first six months of operations.
Source: The Department of State Growth. (2013). Variable Speed Limit System – Tasman Highway, *Tasmanian Government*. Retrieved from http://www.transport.tas.gov.au/roadsafety/speed/variable_speed_limit_system_-_tasman_highway	

Example 3

Location	Michigan, United States
Name	Interstate 96
Timeframe	2002
Outputs	The average speed of motorists appeared to increase through the deployment areas in most instances when the VSL system was operating. This was the case when and where other factors, such as ramps, did not add to congestion or require that speed limits be kept low.
Source: Federal Highway Administration. (2004). A Field Test and Evaluation of Variable Speed Limits in Work Zones, US Department of Transportation. Retrieved from http://safety.fhwa.dot.gov/speedmgt/vslimits/docs/michiganvsl.pdf	

Example 4

Location	West Yorkshire, United Kingdom
Name	M62 Junctions 25 to 30: Smart Motorway
Timeframe	The smart motorway scheme commenced in October 2011, experiencing over 144,000 vehicles per day and suffering heavy congestion and unpredictable journey times. At a cost of $275m, the scheme was officially open to traffic in September 2013.
Outputs	The VSL technology was used with hard shoulder running opened up in some sections during congested periods. Highways England has reported travel time reliability improved by 22% while reducing emissions by up to 10% due to traffic running more smoothly. Personal injury accidents have reduced by 55.7% and an overall reduction in severity of accidents with zero fatalities at the time the information was published.
Source: Highways England. (n.d.) M62 Junctions 25 to 30: Smart Motorway, *UK Government*. Retrieved from http://www.highways.gov.uk/roads/road-projects/m62-junctions-25-to-30/	

Signal optimisation is the dynamic coordination of traffic signals to adapt to changing traffic circumstances. Various detectors (e.g. in-pavement / loop detectors, video image processing detectors and demand button detectors) provide feedback to the signal control system, altering the lights as required. Signal optimisation ensures that intersection signals reflect current traffic conditions to optimise movements and increase the efficiency of the entire corridor.

In circumstances where signals are already coordinated between (and across) intersections, signals may be optimised using dynamic information to ensure that the timing and phasing supports the efficient movement of vehicles.

Where are they used?

Signal optimisation is primarily used at arterial intersections. The service can be well used to manage dynamic timing of signal phases at traffic signals, evaluating the best phasing for current traffic situations.

Target	Supply
Timeframe	Short-term
Scale	Intersection / stop
Outcomes	

Key findings

- The coordination and optimisation of intersection signal timing can significantly improve network performance by reducing or removing unnecessary delay at signalled intersections.
- Signal optimisation increases intersection throughput, improving the speed and flow of traffic across intersections and through the surrounding traffic network.
- Data collected from a local study on the effectiveness of STREAMS technology on Moggill Road, Brisbane, found that total travel time was reduced by 13 per cent during weekdays and up to 17 per cent on weekends. International evidence supports these impacts.
- Central to the coordination of traffic signal timing is the management of intersection queues. Queue management is reported to be the most effective measure in managing vehicle flow and congestion within an oversaturated network where queue spillback blocks adjacent traffic lanes or nearby intersections.
- Evidence across the literature reports that the effectiveness of traffic signal optimisation is reduced under the following circumstances: inadequate roadway capacity and short traffic signal spacing; kerbside frictions (e.g. parking, loading, multiple driveways); wide variability in traffic speeds; and heavy turn volumes.

Potential integration of NOF solutions

Public transport jump lanes +	**Transit signal priority** +	**Signal optimisation** +	**Turning lanes**

Indicative costs

Signal optimisation	Lower Capital Expenditure $/intersection	Lower Operational Expenditure	Upper Capital Expenditure $/intersection	Upper Operational Expenditure	Assumptions
	$100,000	$20,000	$130,000	$30,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Sandgate Road, North Brisbane
Name	Sandgate Road - Corridor Signal Optimisation
Timeframe	May to October 2016
Outputs	The optimisation resulted in: • An average travel time saving of 2-5% along the Sandgate Road corridor for weekdays and 11-17% on weekends • Throughput on the road increased at a higher rate (10% compared to around 5-7%) than other major roads on the north side of Brisbane • In the first year and based on travel time savings alone, the improved operating conditions are estimated to produce an economic benefit of $606,000 and a BCR of 5.56 • In an urban context with alternative congested roads, the travel time savings may only be short-term as more demand is induced, however overall this should still have a positive impact across the broader network.
Source: Department of Transport and Main Roads. 2019. Evaluation of Signal Optimisation. Brisbane.	

Example 2

Location	Mount Nebo Road, Mackay
Name	Mackay Network Optimisation
Timeframe	2018
Outputs	The optimisation resulted in: • An average travel time saving of 10.2% across the corridor • The afternoon (4-5pm) northbound travel time was reduced by 23.8% • Improved operating conditions are expected to save the community $2.1 million in the first year of operations.
Source: Department of Transport and Main Roads. 2019. Evaluation of Signal Optimisation. Brisbane.	

Example 3

Location	Brinsmead-Kamerunga Road, Cairns
Name	Cairns Intelligent Pedestrian Crossing Solution Trial
Timeframe	2016-2017
Outputs	The trial resulted in: • 20% reduction in inbound queue length • $204,000 saving in annual operating costs during the AM peak • Reduced frustration to road users from appearing to sit on red for no reason.
Source: Department of Transport and Main Roads. 2019. Evaluation of Signal Optimisation. Brisbane.	

Example 4

Location	Queensland, Australia
Name	STREAMS
Timeframe	First installed in 1969—currently in use
Outputs	During the pilot program on Moggill Road (between the Kenmore Village Roundabout and Coonana Street), the following outputs were recorded: • travel time reductions of 13% weekdays • travel time reductions of up to 17% weekends.
Source: Pitt, Warren. (2008). Improved time reliability for Sandgate Road and Mains Road traffic [Media Statement], Queensland Government. Retrieved from http://statements.qld.gov.au/Statement/Id/60402	

Example 5

Location	Swansea, England
Name	Swansea Bus
Timeframe	Implemented before 1994
Outputs	Through the collection of sample data, the following impacts of signal coordination were noted: • passive priority—2% decrease in bus travel time • green extension/red reduction—11% decrease in bus travel time.
Source: Highways England. (n.d.) M62 Junctions 25 to 30: Smart Motorway, UK Government. Retrieved from http://www.highways.gov.uk/roads/road-projects/m62-junctions-25-to-30/	

Example 6

Location	Tennessee, United States
Name	Traffic Signal Optimisation Study
Timeframe	2009
Outputs	Enhanced signal coordination across seven corridors, linking a total of 223 signalised intersections. The outputs were: • 20% reduction in delay across all seven corridors (greatest reduction in a single corridor of approximately 37%) • reduced fuel consumption by nearly 6% along the seven corridors • improvements in air quality—volatile organic compounds were reduced by 3%, nitrogen oxides by approximately 1% and carbon monoxide by nearly 1%.
Source: ITS International. (2009). Signal optimisation reduces congestion, improves travel times. Retrieved from http://www.itsinternational.com/sections/cost-benefit-analysis/features/signal-optimisation-reduces-congestion-improves-travel-times/	

Lane use management systems (LUMS) are dynamic information systems that specify lane use in response to real-time traffic information. Lane use changes include lane closure, VSL and contraflow.

Where are they used?

LUMS are used on motorways to manage recurrent and non-recurrent congestion. LUMS uses real-time sensor information to actively manage lane use, monitoring traffic flow and congestion.

Target	Supply
Timeframe	Short-term
Scale	Corridor / Route
Outcomes	

Key findings

- It is widely reported that LUMS operate as a highly effective measure in providing real-time information to motorists that facilitates a proactive change in behaviour to manage the flow of vehicles along a motorway.
- Primarily used to reallocate traffic in response to recurrent and non-recurrent congestion, LUMS decrease the vehicle flow breakdown by effectively managing traffic in real time. Accordingly, LUMS can significantly improve the safety of the motorway.
- It has been shown that LUMS can reduce primary incidents by between 11 and 30 per cent, secondary accidents by an average of 35 per cent, and the incidents of injury by between 10 and 42 per cent.
- The literature reports that, by facilitating the appropriate management of traffic, LUMS can increase motorway capacity (five–10 per cent), increase traffic flow past a bottleneck (four–five per cent) and increased throughput (1.5–22 per cent).
- Overall, the key benefits of LUMS include improved safety, better managed lanes during an incident, maintenance of higher throughput in the event of an incident and reduced response time to an incident as result of real-time information monitoring.

Potential integration of NOF solutions

Hard shoulder running	+	Reversible lanes	+	Lane use management systems	+	Incident management system	+	En-route information system	+	Variable speed limits

Indicative costs

Lane Use Management System	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
	$630,000	$130,000	$1,040,000	$210,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Case studies in Australia, USA, UK, Germany and the Netherlands.
Name	Economic benefits of Smart Motorway applications
Timeframe	2017
Outputs	A review of case studies in Australia, USA, UK, Germany and the Netherlands found that on average LUMS (in conjunction with Variable Speed Limits) increases capacity by 4.9%, reduces crashes by 24.9% and reduces congestion by 12.2%.
Source: Wang, B. et al. 2017. Economic benefits of Smart Motorway applications. Australasian Transport Research Forum 2017 Proceedings, Auckland.	

Example 2

Location	Indiana, United States
Name	10 mile section of the Interstate 65
Timeframe	January to April 2012
Outputs	Reversible lanes and the ramp metering strategies improved traffic conditions on the motorway in the major flow direction. Implementation of the HOV lane strategy resulted in improved traffic flow conditions on the HOV lanes but aggravated congestion on the general purpose (GP) lanes. TThe reversible lane and ramp metering strategies were found to be economically feasible with positive net present values (NPV), with the NPV for the reversible lane strategy being the highest.
Source: Paleti, Chaitanya., Peeta, Srinivas., and Sinha, Kumares. C. (2014). Identifying Strategies to Improve Lane Use Management in Indiana, Indiana Department of Transportation and Purdue University. Retrieved from http://ntl.bts.gov/lib/54000/54400/54426/fulltext 2_.pdf	

Example 3

Location	Birmingham, United Kingdom
Name	M42 Active Traffic Management (ATM)
Timeframe	Different elements of the ATM system have come online since construction began in 2003. Evaluation report was completed in 2009 when the system was fully operational.
Outputs	• 9% increase in observed capacity • 9–24% reduction in travel times • 22% reduction in the variability of travel times • vehicle emissions reduced between 4% and 10%.
Source: U.S. Department of Transportation. (2011). Managed Lane Chapter for the Freeway Management and Operations Handbook, Sect 8.8.3, Federal Highway Administration. Retrieved from http://www.ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/revision/jan2011/mgdlaneschp8/fmoh_mgdlaneschp8.pdf	

Example 4

Location	Kentucky, United States
Name	Nicholasville Road (US-27), Lexington
Timeframe	Study undertaken by Kentucky Department of Transport 1980
Outputs	Assessment of a 4.2 km long reversible segment: Travel delays were reduced and speeds increased during the morning and evening peak periods, and the benefit–cost ratio was computed to be 6.90 to 1. However, it was also noted that delay to minor-flow direction traffic increased during off-peak periods as well as during the evening peak period.
Source: Transportation Research Board of the National Academies. (2004). Convertible Roadways and Lanes: A synthesis of highway practice, National Cooperative Highway Research Program. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_340.pdf	

Ramp metering uses signals at motorway ramps to regulate the rate and space of traffic entering the motorway. Ramp metering is a dynamic system that uses sensors to control the flow of traffic based on actual conditions.

Where are they used?

Ramp metering is primarily used on motorway on-ramps as a dynamic system that adjusts to current traffic conditions for both recurrent and non-recurrent congestion. Ramp metering is used to improve the flow of traffic onto a motorway by coordinating on-ramp movement to prevent motorway slowing.

The application of bypass lanes at motorway on-ramps (where HOV lanes, public transport or freight is given priority) is a slight variation of this solution that can also be effective.

Target	Demand
Timeframe	Medium-term
Scale	Corridor / Route
Outcomes	

Key findings

- Ramp metering is one of the most widely implemented smart motorway strategies due to the ease of implementation and immediate realisation of impacts. According to the Victorian Government, the principal actions of ramp metering are:
  - headway management of entering traffic; dispersing vehicles to control the even distribution of traffic into the merge area
  - managing the flow of entering vehicles when motorway is near capacity; such that traffic can safely enter the motorway, where traffic conditions would previously have been considered unstable
  - ensuring the overall mainline motorway volume is within bottleneck capacity at critical bottlenecks by coordinating traffic across multiple metered ramps.
- By managing entrance ramp inflow, ramp metering has numerous impacts which increase the efficiency of the transport corridor, including maintaining flow; optimising throughput; managing optimum speed; reducing primary and secondary accidents; and facilitating flow recovery following incidents and hazards.
- Across various studies, the literature shows that ramp metering can reduce the number of primary accidents by 24 to 50 per cent, reduce total travel time by increasing vehicle speed by eight to 26 per cent and increase vehicle throughput by between five and 10 per cent.
- In order to support the efficient operation of ramp meters, ramp signal frequency must be coordinated with both motorway movement and the volume of ramp queue overflow. Additionally, the physical capacity of motorway on-ramps must be sufficient to support adequate vehicle storage.

Potential integration of NOF solutions

Lane use management systems	+	Incident management system	+	Ramp metering	+	Variable speed limits

Indicative costs

Ramp Metering	Lower Capital Expenditure $/ramp	Lower Operational Expenditure	Upper Capital Expenditure $/ramp	Upper Operational Expenditure	Assumptions
	$130,000	$26,000	$190,000	$38,000	See Appendix 1

* Costs as of May 2016

Examples of use

Example 1

Location	Queensland, Australia
Name	M1/M3 Freeway HERO Pilot
Timeframe	Implementation of HERO coordinated ramp metering algorithm in September 2011
Outputs	• average AM peak inbound travel speeds have increased by 7% from 70km/h to 75km/h • average AM peak inbound traffic flows have increased by 4% with an additional 150 vehicles per hour throughput • average AM peak inbound travel productivity has improved by 8% • the proportion of AM peak inbound trips with good reliability has improved by 37%.

Source: Transport and Main Roads, M1/M3 HERO Ramp Signaling Implementation Pilot (Paper supplied by TMR)

Example 2

Location	Victoria, Australia
Name	M1 ramp metering
Timeframe	Implemented 2007
Outputs	• accidents reduced by 30% on the motorway and 60% in the City Link tunnel • travel time reduced by 42% during peak periods on the motorway and 48% in the tunnel • greater than 50% increase in sustainable peak flows • reduced fuel consumptions and costs.

Source: Transmax. (n.d.). City of Melbourne: Community benefits realised after improving Victoria's most congested freeway with a STREAMS ITS solution. Retrieved from https://www.transmax.com.au/cms/streams-intelligent-transport-system/case-studies/city-of-melbourne-vic-roads-case-study

Example 3

Location	Paris, France
Name	A6 Motorway
Timeframe	Report published March 2013
Outputs	The study analysed the impacts of ramp metering. Travel times were reduced by 12–17% for the motorway and metered on-ramps depending on the control strategy employed. The standard deviation of the travel time was reduced by 34–35%.

Source: Bhouri, N., Haj-Salem, Habib., and Kauppila, J. (2011). Isolated versus coordinated ramp metering: Field evaluation results of travel time reliability and traffic impact, *Transportation Research Part C: Emerging Technologies*, 28, pp 155-167. Retrieved from http://www.sciencedirect.com/science/article/pii/S0968090X11001537

Marketing and public education programs increase public awareness and understanding of the impacts and costs of congestion. By increasing awareness, education should encourage mode shift and an increase in ride-sharing and public transport. Education campaigns can also target active transport and parking management and can provide information relating to changes in road management.

Where are they used?

Education campaigns are used on a broad scale through various marketing and media channels. The scope of each campaign determines the target audience and mechanism of distribution.

Target	Demand
Timeframe	Medium-term
Scale	Corridor / Route
Outcomes	

Key findings

- Education campaigns serve three primary functions within the transport system:
  1. They increase the awareness of available transportation choices.
  2. They can encourage travelers to try new, more efficient travel choices for the first time.
  3. They can increase or maintain the frequency that people use more efficient travel modes, routes or times.

There is limited literature available on the specific, isolated impacts of education and marketing campaigns on the demand for the transport network. In most instances, education and marketing is used alongside other service enhancements to optimise and enhance outcomes. For example, marketing campaigns are often launched following the implementation of public transport route improvements or as a public policy initiative to enhance awareness. These campaigns increase public awareness and subsequently improve the likelihood of behavioural changes and mode shift.

Indicative costs

Education Campaigns	Costings are variable and determined based on current behaviour and the required scale and scope of the behaviour change intervention

Example 1

Location	North Lakes, Gold Coast
Name	TransLink North Lakes Local Area Marketing (LAM)
Timeframe	28 January 2018 to 25 February 2018
Outputs	A statistically significant change in: • the amount of people in the North Lakes area that describe their main means of transport to work or university/TAFE etc as train, and • infrequent public transport users increased their frequency with 2% using public transport fortnightly before the campaign and 11% after the campaign. Detailed analysis of go card transaction supports the claim that the campaign had a positive impact on infrequent public transport users. The analysis shows the segment of pre-campaign users who used public transport less than once per week, were undertaking 51% more public transport trips than in the pre-campaign benchmark period. Rail patronage from the stations nearest to North Lakes, Mango Hill and Mango Hill East, have been increasing at a high growth rate (on average ~25% compared to the same month in the previous year) over the 2017-2018 year.
Source: Department of Transport and Main Roads. 2019. Education campaigns evaluation. Brisbane.	

Example 2

Location	Gold Coast (Robina), Mackay and Cairns; QLD, Australia
Name	Active Towns Pilot Program
Timeframe	July 2012 – June 2015 (3 years)
Outputs	The key findings were: • Use of Active Travel infrastructure has increased strongly in Robina, slightly in Cairns but remained steady in Mackay • High awareness of infrastructure initiatives funded under the Active Towns pilot program. Awareness improved in Mackay and Cairns with the most considerable improvement sighted in the Gold Coast results • Positive attitude towards the infrastructure delivered • Improved awareness of some key laws relating to cyclists • Continued perception of friction between motorists and cyclists on roads • Cycling attitudes and safety perception have improved in some aspects, but in general have tended to remain steady.
Source: Department of Transport and Main Roads. 2019. Education campaigns evaluation. Brisbane.	

Example 3

Location	Ipswich, Gold Coast, Cairns and Townsville
Name	Healthy Active School Travel (HAST) Initiative
Timeframe	2013 – 2014
Outputs	Over the duration of the program: • 11.2% increase in children who actively commuted a mixed uptake of walking, cycling and skateboarding/scootering • 19.9% of parents reported that their child's use of active trnasport had increased • CBA returned a BCR of 1.44 (based on a 10-year evaluation period).
Source: Deloitte. 2016. Evaluation of the Healthy Active School Travel (HAST) Initiative. Brisbane	

Example 4

Location	Queensland, Australia
Name	TravelSmart Workplaces
Timeframe	October 2010 to October 2011
Outputs	TravelSmart was a program implemented in 2008 to address traffic congestion in South East Queensland. The TravelSmart Workplaces project engaged 10 workplaces across government agencies, local councils and private organisations providing information to assist in the promotion of walking, cycling, carpooling and public transport. The key measures of success included: • reduction in car mode share • steady or improved public transport and cycle mode shares • around 11% changed their behavior as a result of the program (self-reported) • overall, vehicle kilometres travelled (VKT) per person remained consistent across the project period. However, some workplaces experienced significant reductions, e.g. VKT for State Library employees reduced from 71 km per respondent to 48.7 km per respondent.
Source: Department of Transport and Main Roads, TravelSmart Assessment Report, January 2012	

Example 5

Location	Alameda, Saskatchewan, Canada
Name	TravelChoice Program
Timeframe	Trialled from 3 April to 1 July 2006
Outputs	TravelChoice was implemented to reduce driving and congestion while promoting healthy physical activity. TravelChoice used targeted outreach tactics to connect residents with information and incentives to add physical activity to their daily routines. In addition, post implementation survey results revealed that drive-alone trips were reduced by 14%, primarily due to a 34% increase in public transport and 5% increase in carpooling.
Source: Seattle Department of Transportation. (2008). Best Practices: Transportation Demand Management (TDM). Retrieved from http://www.seattle.gov/transportation/docs/ump/07%20seattle%20best%20practices%20in%20transportation%20demand%20management.pdf	

Example 6

Location	Europe, Australia and the United States
Name	International Public Transportation Association Project
Timeframe	2004
Outputs	The pilot project in Europe resulted in a 10% reduction in car usage in the targeted area, while the large-scale individualised marketing efforts in Australia yielded up to 14% reductions. The first U.S. pilot project in Portland, Oregon reduced car travel by 8% in the first area selected for the pilot and resulted in a 27% increase in travel by carpool, vanpool, transit, bicycling and walking in that same area.
Source: Federal Highway Administration. (2015). The Demand-Side Framework, US Department of Transportation. Retrieved from http://www.ops.fhwa.dot.gov/publications/mitig_traf_cong/demand_framework.htm	

Appendix 1 – Estimated capital and operating expenditure

Note: Where costs have been derived from International examples, currency has been converted to Australian Dollars at 0.76 AUD/USD. All costs are in May 2016 prices.

Bus Corridors (Priority Lane)	Lower Capital Expenditure $/km of repurposed shoulder or lane	Lower Operational Expenditure	Upper Capital Expenditure $/km of new lane provided	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$80,000**	**$16,000**	**$1,040,000**	**$210,000**	Assume 2 lane road corridor with shoulder and intersection in 1 km **Lower:** using existing shoulder or lane as bus priority lane, no widening. Possibly have to shift all lanes over to utilised shoulder **Upper:** new purpose built lane adjacent to existing
Pavement Marking and Signage					
Grinding off existing pavement marking and RRPMs	$6500		$6500		Removal of lines @$6/m and $2/RRPM = $6.5/m x 1000 m
New signage	$1000		$1000		$500/sign @ 500 m intervals
New pavement marking	$16,500		$20,625		**Lower:** $5/m + new RRPMs @ $8 each = $5.5/m x 1000 m x 3 **Upper:** + 25%
Painted pavement marking (BUS LANE)	$1700		$2125		**Lower:** $85/m²x 4 m² x pavement paint every 200 m = $1700 **Upper:** + 25%
Enforcement: Cameras, monitoring, police presence					
Cameras and ITS	$15,000		$30,000		Supply and installation of camera and components @ $15,000 each **Lower:** cameras every 1 km **Upper:** or every 500 m
Traffic Signals/Infrastructure Update					
Signal phases updated	$30,000		$40,000		$7500 to $10,000 per signal, assume intersection every 250 m

New signals for Bus Priority	$2000		$7500		**Lower:** lantern update $2000 **Upper:** traffic signal post footing @ $2000 Traffic signal post @ $2000 Traffic signal mast arm @ $1500 Traffic signal @ $2000
Any widenings and associated kerb works					
Demolish existing kerb, footpath etc.			$15,000		$15/m for 1000 m
Demolish/relocate existing signage			$2000		$200/sign assume a sign every 100 m
Demolish/ relocate existing traffic signals	$4000		$5500		50% to 75% of new signals
Demolish existing kerbs and islands	$375		$750		**Lower:** $15/m² for an assumed 2 x 12.5 m² island **Upper:** +100% (more/bigger islands)
New asphalt			$300,000		**Lower:** no lower as no widening works **Upper:** utilise existing shoulder pavement 3 m of new pavement 3 m x 1000 m = 3000 m² @ $100/m² = $300,000
New kerb			$40,000		Assume 1000m @ $40/ m =
Tree removal			$10,000		$500/tree assume 20 trees/km
PUP relocation works as part of widenings					
Telstra (pits, conduits, cabinets, etc.)			$200,000		$200/m
Energex (Power, lighting, pits, conduits, cabinets, etc.)			$150,000		Relocate poles $5000 each every 40 m + ancillary works $50,000
Watermains (mains, manholes etc.)			$110,000		$110/m water
Sewer			$90,000		$45/m + $3000/pit/100 m + fitting etc. = $90/m

Public Transport Jump Lanes	Lower Capital Expenditure $/leg of intersection	Lower Operational Expenditure	Upper Capital Expenditure $/leg of intersection	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$50,000**	**$10,000**	**$80,000**	**$20,000**	
Pavement Marking and Signage					
Grinding off existing pavement marking and RRPMs	$163		$204		Removal of lines @$6/m and $2/RRPM = $6.5/m x 25 m
New signage	$1000		$2000		$500/sign
New pavement marking	$275		$344		**Lower:** $5/m + new RRPMs @ $8 each = $5.5/m x 25 m x 2 **Upper:** + 25%
Painted pavement marking	$7500		$9375		**Lower:** $85/m² x 25 m x 3.5 m = $7500 **Upper:** + 25%
Traffic Signals/Infrastructure Update					
Signal phases updated	$7500		$10,000		$7500 to $10,000 per signal
New signals for Bus Priority	$2000		$7500		**Lower:** lantern update $2000 **Upper:** traffic signal post footing @ $2000 Traffic signal post @ $2000 Traffic signal mast arm @ $1500 Traffic signal @ $2000
Any widenings and associated kerb works					
Demolish/relocate existing signage	$600		$1000		$200/sign
Demolish/ relocate existing traffic signals	$4000		$5500		50% to 75% of new signals
Demolish existing kerbs and islands	$375		$750		**Lower:** $15/m² for an assumed 2 x 12.5 m² island **Upper:** + 100% (more/bigger islands)
New pavement	$7500		$13,750		**Lower:** utilise existing pavement under island with min. resurfacing and 3 m of new pavement 3 m x 25 m = 75 m2 x $100/m² = $7500 **Upper:** 3.5 m lane with 2 m shoulder = 5.5 m x 25 m length = 137.5 m² x $100/m² = $13,750
New kerb	$360		$450		Assume 12 m perimeter @ $30/m
Tree removal	$2500		$5000		$500/tree assume 5 to 10 trees

PUP relocation works as part of widening					
Telstra (pits, conduits, cabinets, etc.)	$4,000		$5,000		$200/m
Energex (pits, conduits, cabinets, etc.)	$5,200		$6,500		Relocate poles $5000 each every 40 m + ancillary works $50/m
Watermains (mains, manholes etc.)	$2,400		$3,000		$110/m water
Sewer	$2,000		$2,500		$45/m + $3000/pit/100m + fitting etc. = $90/m

Transit signal priority	Lower Capital Expenditure $/intersection	Lower Operational Expenditure	Upper Capital Expenditure $/intersection	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$13,000**	**$3000**	**$21,000**	**$5000**	
Traffic Signals/Infrastructure Update					
Signal phases updated	$7500		$10,000		$7500 to $10,000 per signal
New infrastructure i.e. Unconditional TSP for approaching vehicles at signals	$5000		$10,000		Assume 4 leg intersection
Signal transmitter on bus	$500		$1000		4 buses

Park 'n' ride Facilities	Lower Capital Expenditure $/car park	Lower Operational Expenditure	Upper Capital Expenditure $/car park	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$10,000**	**$2000**	**$40,000**	**$8000**	
Construction cost for car park					
Construction cost for car park	$10,000		$40,000		**Lower:** $10,000/park for parking lot (pavement, drainage, signs and pavement marking, lighting, cameras **Upper:** $40,000/park Multi-storey parking structure (report states $30,000)

Boarding all doors	Lower Capital Expenditure $/bus stop	Lower Operational Expenditure	Upper Capital Expenditure $/stop	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$2000**	**$400**	**$2400**	**$500**	
Bus stop slabs to accommodate rear boarding – extension of slabs					
Bus stop slabs to accommodate rear boarding – extension of slabs	$1920		$2400		Extended from 4 m to 8 m, verge 4 m = 4 m x 4 m = 16 m^2 x $120/$m^2$

High Occupancy Vehicle (HOV) Lanes	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$9000**	**$1800**	**$17,000**	**$3400**	
Monitoring					
Cameras, associated infrastructure (pits, conduits etc.)	$7500		$15,000		Supply and installation of camera and components @ $15,000 each Cameras every 2 km lower or 1 km upper
Signage					
	$1000		$1250		$500/sign @ 500 m
Pavement Marking					
	$320		$400		$80/$m^2$ for 2 m^2/sign on pavement every 500m

Truck restrictions	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$60,000**	**$12,000**	**$110,000**	**$22,000**	
Signage					
	$1000		$1250		$500/sign @ 500 m
ITS					
	$50,000		$100,000		$100,000 to $200,000 every 2 km

Hard Shoulder Running	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$180,000**	**$40,000**	**$290,000**	**$60,000**	**3 lane highway with shoulder converted to 4 lanes w/ hard shoulder Lane width reduced to accommodate so 4 lines removed and repainted**
Grinding off existing pavement marking and RRPMs					
	$26,000		$32,500		Removal of lines @$6/m and $2/RRPM = $6.5/m x 1000 m x 4 lines
New pavement marking					
	$22,000		$27,500		**Lower:** $5/m + new RRPMs @ $8 each = $5.5/m x 1000 m x 4 lines **Upper:** + 25%
Gantries					
	$60,000		$100,000		$300,000 to $500,000 Gantries every 5 km – smaller
Dynamic Sensors to monitor and manage speed etc.					
Variable Speed Limit Signage	$50,000		$100,000		$100,000 to $200,000 every 1 km
Emergency Stopping Bays/ Emergency Refuge Areas					
Signage	$3000	$3750			Including Chevrons etc. = every 2 km
Pavement	$10,000	$20,000			Approx. 200 m^2 x $100/$m^2$ = $20,000 **Lower:** every 2 km **Upper:** every 1 km
Reversible Lanes	**Lower Capital Expenditure $/lane**	**Lower Operational Expenditure**	**Upper Capital Expenditure $/lane**	**Upper Operational Expenditure**	**Assumptions**
Possible Capital Works	**$2,700,000**	**$540,000**	**$4,150,000**	**$830,000**	**New 'zipper' trucks on Golden Gate Bridge will move barrier day and night**
Roadside VMS					
	$200,000		$400,000		$100,000 to $200,000 every 500 m
Overhead Signage					
Gantries	$600,000		$1,000,000		$600,000 to $1,000,000 Gantries every 1 km
'Zipper' barrier transfer machine					
	$1,400,000		$2,000,000		As per costs from Golden Gate Bridge
Transferrable barrier					
	$500,000		$750,000		Normal concrete barrier is $300/m. Assume transferrable is $500/m to 50/m

Possible Capital Works	$50,000	$10,000	$80,000	$20,000	Assume 25 m lane
Pavement Marking and Signage					
Grinding off existing pavement marking and RRPMs	$163		$204		Removal of lines @$6/m and $2/RRPM = $6.5/m x 25 m =
New signage	$1000		$2000		$500/sign
New pavement marking	$275		$344		**Lower:** $5/m + new RRPMs @ $8 each = $5.5/m x 25 m x 2 **Upper:** + 25%
Painted pavement marking (like bike lane)	$7500		$9375		**Lower:** $85/m² x 25 m x 3.5 m = $7500 **Upper:** + 25%
Traffic Signals / Infrastructure Update					
Signal phases updated	$7500		$10,000		$7,500 to $10,000 per signal
New signals for Bus Priority	$2000		$7500		**Lower:** lantern update $2000 **Upper:** traffic signal post footing @ $2000 Traffic signal post @ $2000 Traffic signal mast arm @ $1500 Traffic signal @ $2000
Any widenings and associated kerb works					
Demolish/relocate existing signage	$600		$1000		$200/sign
Demolish/ relocate existing traffic signals	$4000		$5500		50% to 75% of new signals
Demolish existing kerbs and islands	$375		$750		**Lower:** $15/m² for an assumed 2 x 12.5m² island **Upper:** +100% (more/bigger islands)
New pavement	$7500		$13,750		**Lower:** utilise existing pavement under island with min. resurfacing and 3 m of new pavement 3m x 25m = 75m² x $100/m² = $7500 **Upper:** 3.5m lane with 2m shoulder = 5.5 m x 25 m length = 137.5m² x $100/m² = $13,750

New kerb	$360		$450		Assume 12 m perimeter @ $30/m
Tree removal	$2500		$5000		$500/tree assume 5 to 10 trees
PUP relocation works as part of widenings					
Telstra (pits, conduits, cabinets, etc.)	$4000		$5000		$200/m
Energex (pits, conduits, cabinets, etc.)	$5200		$6500		Relocate poles $5000 each every 40 m + ancillary works $50/m
Watermains (mains, manholes etc.)	$2400		$3000		$110/m water
Sewer	$2000		$2500		$45/m + $3000/pit/100m + fitting etc. = $90/m

Parking Management	Lower Capital Expenditure $/park	Lower Operational Expenditure	Upper Capital Expenditure $/park	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$300**	**$60**	**$500**	**$100**	
Signage					
	$50		$63		Assume signage is per 10 spaces @ $500/sign
Parking Meters					
	$250		$350		Assume meter is per 20 spaces @ $5000/m

Incident Management/ Hazard Warning System	Lower Capital Expenditure $/ km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$243,000**	**$50,000**	**$440,000**	**$90,000**	
Gantry VMS					
	$120,000		$200,000		$600,000 to $1,000,000 Gantries every 5 km
Roadside VMS					
	$100,000		$200,000		$100,000 to $200,000 every 1 km
Fully smart motorways					
Cameras	$7500		$15,000		Supply and installation of camera and components @ $15,000 each Cameras every 2 km lower or every 1 km upper
Loops	$15,000		$18,750		$2,500/loop every 500 m across 3 lanes including detector equipment

En-route Information System	Lower Capital Expenditure $/ km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	$243,000	$50,000	$440,000	$90,000	
Gantry VMS					
	$120,000		$200,000		$600,000 to $1,000,000 Gantries every 5 km
Roadside VMS					
	$100,000		$200,000		$100,000 to $200,000 every 1 km

Fully smart motorways					
Cameras	$7500		$15,000		Supply and installation of camera and components @ $15,000 each Cameras every 2 km lower or every 1 km upper
Loops	$15,000		$18,750		$2500/loop every 500 m across 3 lanes including detector equipment

Variable Speed Limits	Lower Capital Expenditure $/km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$140,000**	**$30,000**	**$240,000**	**$50,000**	
Gantry VMS					
	$60,000		$100,000		$300,000 to $500,000 Gantries every 5 km – smaller
Roadside VMS					
	$50,000		$100,000		$100,000 to $200,000 every 2 km
Fully smart motorways					
Cameras	$7,500		$15,000		Supply and installation of camera and components @ $15,000 each Cameras every 2 km lower or every 1 km upper
Loops	$15,000		$18,750		$2500/loop every 500 m across 3 lanes including detector equipment

Signal optimisation	Lower Capital Expenditure $/ intersection	Lower Operational Expenditure	Upper Capital Expenditure $/intersection	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$100,000**	**$20,000**	**$130,000**	**$30,000**	
Loop detectors					
	$40,000		$50,000		4 way intersection, dual carriageway, 2 loops/lane = 16 x $2500/loop including detector equipment
Video image processing detectors					
	$60,000		$75,000		Supply and installation of camera and components @ $15,000 each x 4

Lane Use Management Systems (LUMS)	Lower Capital Expenditure $/ km	Lower Operational Expenditure	Upper Capital Expenditure $/km	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$630,000**	**$130,000**	**$1,040,000**	**$210,000**	
Gantry LUMS					
	$600,000		$1,000,000		$600,000 to $1,000,000 Gantries every 1 km
Cameras					
	$7500		$15,000		Supply and installation of camera and components @ $15,000 each Cameras every 2 km lower or every 1 km upper
Loops					
	$15,000		$18,750		$2500/loop every 500 m across 3 lanes including detector equipment

Ramp Metering	Lower Capital Expenditure $/ ramp	Lower Operational Expenditure	Upper Capital Expenditure $/ramp	Upper Operational Expenditure	Assumptions
Possible Capital Works	**$130,000**	**$26,000**	**$190,000.00**	**$38,000**	
Detector loops on motorway and on ramp + end of queue ramp					
	$25,000		$31,250		3 lane highway and 2 lane on-ramp @ 2 loops/lane on highway and ramps Supply and installation of loop detectors @ $2500/loop including detector equipment

Traffic/Ramp Signals (conduits, cables etc.)					
	$12,500		$15,625		25m of electrical and comms conduits @ $100/m = $2500 Supply and install of cable jointing pits 2x @ $2000/each = $4000 Traffic signal post footing @ $1300 Traffic signal post @ $1500 Traffic signal @ $1500 Traffic Signal Controller Base = $1500 **Upper:** +25% to account for mast arms and bigger post footings
Signage					
			$2000		2 x signs 2 x advance warning signs
Pavement widening or additional lane for queuing					
	$87,500		$137,500		**Lower:** utilise existing 2 m shoulder so only need 3.5 m x 250 m = 875 m² x $100/m² = $87,500 **Upper:** 3.5m lane with 2 m shoulder = 5.5 m x 250 m length = 1375 m² x $100/m² = $137,500

Education Campaigns	Lower Capital Expenditure $/campaign	Lower Operational Expenditure	Upper Capital Expenditure $/campaign	Operational Expenditure	
Costings are variable and determined based on current behaviour and the required scale and scope of the behaviour change intervention.					The Queensland Government committed funding from 2008 to 2012 to deliver the TravelSmart program which consisted of three projects: Communities, Schools and Workplaces and Destinations. Annual funding was approximately $185,000 (2012).

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