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Planning and Transport Research Centre (PATREC)

CONGESTION ABATEMENT THROUGH TRAVEL DEMAND MANAGEMENT:

REVIEW OF TDM INSTRUMENTS AND APPRAISAL AND EVALUATION TOOLS

Submitted to	Demand Management Portfolio Team (Brett Hughes, Craig Wooldridge and Tom McHugh) and Dept. of Treasury – Steve Priddy
Prepared by	Courtney Babb, Brett Smith, Monir Moniruzzaman and Sharon Biermann
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EXECUTIVE SUMMARY

The functioning of urban transport systems underpins the economic and social qualities of cities. Transport systems - roads, public transport, and cycling and pedestrian infrastructure – provide the means for people to access activities, goods and services. Increased population growth has placed higher demands on urban areas and has led to increased congestion on urban road networks. In a 2007 report, the Bureau for Transport and Regional Economies forecast almost linear increases in urban traffic in Australian cities to 2020. This increase in urban traffic is likely to have significant effects on the ability of urban transport systems to function efficiently and equitably. In Perth, the report projects the social cost of congestion on Perth roads to rise from $0.9 billion in 2007 to $2.1 billion in 2020. However, the problem of solving traffic congestion in cities is complex. Building additional roads is unlikely to lead to substantial reduction in congestion levels. There are often limited opportunities to build more transport infrastructure in already spatially constrained inner and middle urban cores. Furthermore, building more transport infrastructure is likely to lead to additional demand on transport systems and has little long-term effect on alleviating congestion (Duranton and Turner 2011).

The inherent difficulties of using supply-side approaches to address urban transport problems have led to the increased recognition of the need to manage the demand for travel by single occupancy vehicles (SOV) on roads. Travel demand management (TDM) is a key policy strategy for the mitigation of urban traffic congestion. TDM is defined as any policy instrument or set of instruments aimed at influencing behaviour change, without having to supply additional road or public transport infrastructure. TDM policies have a range of potential benefits for urban areas including increasing the efficiency of road infrastructure, improving air quality, increasing healthy behaviour through active travel and facilitating economic development.

This report is the outcome of the first stage of a broader project responding to three key questions regarding the capacity of Travel Demand Management (TDM) to address issues of traffic congestion in Perth, Western Australia.

> ***1:*** *What are the key demand management instruments available for managing transport congestion in Perth and what is the relative contribution that each of these instruments can make to reducing congestion?*
> ***2:*** *What are the broader economic and social costs associated with demand managements instruments (e.g. impact on CBD retail and social equity from implementation of congestion pricing schemes)?*
> ***3:*** *What are the key lessons that Perth can learn from other jurisdictions regarding community acceptance and the successful implementation of demand management instruments?*

In response PATREC proposed a first phase of a broader project to study the relative importance of the range of factors that affect congestion, developing and applying a decision tool for decision-makers to assess the relative cost and benefits of a range of Travel Demand Management (TDM) measures in the abatement of congestion in Perth.

This report provides a preliminary review of existing travel demand instruments (TDM) and tools implemented across Australia and in selected cities around the world. The material covered in the review also considers instruments and tools that have been developed in theory, possibly proposed in practice but not as yet implemented. This review is limited to cases described in publically available written form.

The review is divided into two parts:

PART 1 provides a review of TDM experiences and investigations from around the world. It develop a working definition of TDM, capturing various perceptions on what travel demand management is thought to be and compile a matrix of measures being implemented, including the circumstances and contexts of implementation and evaluation in various jurisdictions

PART 2 aims to identify approaches to assess TDM policies targeted at congestion mitigation including measures of congestion.

Both parts of the review will lay the foundation for further analysis of TDM and its applicability to Perth.

PART 1 presents an overview of the types of TDM instruments available to transport policy makers in Perth. The range of instruments are organised within a TDM matrix, identifying three key characteristics of TDM instrument:

1. Whether the instrument provides an incentive (pull) or disincentive (push) for travel by Single Occupancy Vehicles (SOV);
2. The type of behaviour change is sought (trip substitutions, mode shift, reducing the distance of travel or changing the time of travel, or peak shift)
3. The transport market (commuting, recreational or shopping, for example) the TDM instrument operates within.

Nine categories of TDM instruments are identified and examples provided. The categories are:

1. **Improving alternative travel modes** to car travel, such as walking, cycling, public transport, taxis and smaller vehicles, incentivises mode shift by increasing the diversity of travel options available to people to access their everyday activities. The improvement of alternative modes of travel to SOV is likely to be of critical importance to the successful planning and implementation of 'push' style TDM instruments, such as through a congestion charge.

2. **Integrating transport and land use planning** at the regional and local scales can improve accessibility, reduce the distances required for travel and facilitate mode shift to public transport, cycling and walking. Integrating transport and land use planning can occur at a broad strategic policy level, guiding metropolitan development patterns, or at the local scale, through assessment of developments and subdivision.

3. **Workplace TDM instruments** are travel options provided within workplaces, offering incentives for employees to travel to work using an alternative mode to SOV, including cycling, carpooling, public transport and walking. Workplace TDM instruments may also provide the options or incentives to travel outside peak hour.

4. **Travel behaviour change programs** are targeted to changing the decision-making and behaviour of individuals in the households or workplace, usually through a range of strategies including the provision of information, support and feedback, and incentives for sustainable travel. Travel behaviour change programs have been implemented in Perth under the Travel Smart banner.

5. **Information and communication services** provide information about the performance of transport systems, communicated in an effective and convenient manner to travellers so that informed choices may be made. These include the use of mobile phone technology to communicate congestion on roads so that people may choose to change the route, time or mode of travel.

6. **Management of road space** can occur through the restriction or prioritisation of particular modes in areas or road lanes, by managing the impact (speed and volume) of motorised vehicles in order to improve other modes of travel such as cycling and walking, or by providing a more informed road classification system that enables future planning for all modes of transport.

7. **Governance and administration** includes regulatory mechanisms that facilitate relationships between public and/or private organisations and local businesses so that alternatives to travel by SOV are facilitated.

8. **Parking TDM instruments** can manage travel demand by either creating pricing signals of the existing parking supply, or by increasing or restricting the amount of parking supply in key locations. Parking demand management schemes include parking pricing strategies that reflect the real-time demand for parking spaces – parking spaces are higher at peak times and lower at off-peak times, creating an incentive for people to travel outside peak times.

9. **Taxes and charges** are pricing mechanisms that create a disincentive for SOV use. Introducing direct costs to travel and using pricing signals to reflect demand on the transport system, provides a disincentive to drive at particular times or places. Taxes and charges are 'push' measures.

PART 2 complements the TDM instrument review by presenting the typical tools used for appraising TDM initiatives at various stages of the generic TDM decision framework. An overview is provided of the possible appraisal tools, evaluation procedures, performance measures and congestion measures that may be used as the basis for selecting, implementing and reviewing TDM initiatives. An international review of the tools used to appraise the potential effectiveness of employing a particular TDM instrument (or suite of instruments) to a specified market, route or area is presented. In addition, this part examines a number of evaluation cases where the actual performance of a TDM instrument was reviewed after its implementation. It concludes with an overview of congestion indicators and congestion measures used in TDM appraisal and evaluation to measure performance against the objective of congestion reduction. T

TDM project and program appraisal are the most commonly described tools presented in the literature. Sketch tools developed in the United States dominate the findings. The most commonly used tools were developed to assess workplace TDM projects. However, the general approach of estimating the effect of behaviour change and its impact on the transport network is a common theme throughout all the models reviewed. Whilst cost-benefit analysis is a preferred appraisal methodology in transport appraisal in general, it has not been widely adopted in tools designed specifically for TDM appraisal, although its potential for this has been recognised. The most promising of the appraisal tools reviewed is TRIMMS because it extends the basic estimation of behavioural response to include a calculation of the private benefits as well as externalities. Also, TRIMMS has a cost-benefit analysis module. Tools can be used in combination to improve efficiency. Subjective assessment tools such as short-listing and rapid appraisal (Rose 2007a, b) offer a method whereby short-listing limits the number of initiatives to be appraised and a sketch model such as TRIMMS can be used for the rapid appraisal.

At the level of support for strategic and policy direction setting, where portfolios of TDM initiatives need to be assessed, there are fewer tools reported in the literature, particularly in relation to transport and TDM, presenting a substantial opportunity for innovation. Marginal abatement cost curves are borrowed from climate research. These tools cannot be readily transferred to congestion analysis because the basis of the change is behavioural; in climate science the basis of the change is usually an improvement in technology. However, marginal abatement is effectively another way of reporting a cost-benefit result. In addition to the learning from cost abatement curves applied in other field such as in climate science, learning from this review of the wider application and reporting of experiences in developing and using project appraisal and evaluation tools, can be brought to bear in developing an appropriate strategic TDM policy assessment tool for Perth. The learning is twofold: firstly, continuous project monitoring and evaluation will yield a database of evidence in terms of TDM elasticities and secondly, project appraisal tools or components of tools together with impacts and effectiveness measures and project-level valuations, provide inspiration for upscaling to the strategic policy level.

Travel demand management is the application of demand strategies to improve the efficiency of the transport system. A primary focus of demand management is to encourage alternatives to the use of single occupancy vehicles on the journey to work, with the primary aim of reducing congestion. In addition to reviewing TDM appraisal tools, this review has considered the range of impact measures used to determine the expected and actual effects of TDM on the transport system and benefits to travellers. Key measure of TDM effectiveness on the transport system are: reduction in number of car (in particular, SOV) trips; increased public transport ridership; and increased number of trips by walking or cycling. Whilst indicators that measure change in aggregate number of trips per mode per time of day are useful, any appraisal based on cost-benefit analysis will need to make use of economic indicators which considers the economic value of the benefits to travellers. Key indicators of value are the marginal willingness to pay for: travel time savings, system reliability, vehicle operating costs, improvements to air quality and greenhouse gas emissions and noise. Public transport measures of crowding and comfort can also be included because these outcomes may be affected by TDM's that shift car travellers onto public transport. Benefits related to health, fitness and safety can be included as complimentary benefits.

With a primary objective of TDM being to reduce congestion levels, this review specifically considered measures of congestion used to monitor change. A range of congestion indicators have been developed but are all essentially some variation of a composite measure using travel time saving.

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PART 1: THE TRAVEL DEMAND MANAGEMENT MATRIX: AN INTERNATIONAL REVIEW OF TDM INSTRUMENTS

1 INTRODUCTION

1.1 The Purpose of Developing the TDM matrix

Travel demand management (TDM) is the application of demand strategies to improve the efficiency of the transport system. A primary focus of demand management is to encourage alternatives to the use of single occupant vehicles (SOV) on the journey to work, with the aim of reducing congestion. Whilst, a review of international experience reveals that demand-side strategies are often wider in scope than the journey to work, broader in aim than to alleviate congestion and may also involve supply-side aspects – these remain the dominant factors in policy making. The travel demand management matrix identifies nine categories of targeted demand instruments to improve transport network efficiency. These are aimed at reducing the demand for SOV trips or to redistribute these trips in space or in time.

The TDM matrix is an overview of instruments aimed at shifting demand away from SOV travel. The matrix identifies the specific travel demand instrument as well as the targeted trip purpose (e.g., journey to work, education, shopping, recreation) along with the anticipated behavioural response (mode shift, revise time of departure, shorter trips or trip reduction). In addition the instruments are classified as push (penalising travel by single occupant vehicle), pull (incentivising the use of alternative modes) or influencing travellers' attitudes or perceptions (behaviour modification programs). Finally the information sources and a brief description of any trials undertaken to test the instruments, are outlined.

1.2 The Structure of PART 1

Section 2 opens by defining TDM and TDM instruments, where instruments may be thought of as general policies or specific interventions aimed at modifying travel behaviour (section 2.1). The focus of this report is to identify and review cases of TDM instruments aimed specifically at easing congestion (section 2.2.1). However, any instrument that reduces the overall level of traffic may result in the complementary benefits of environmental quality or positive health outcomes (sections 2.2.2 and 2.2.3). Economic development and productivity (section 2.2.4) are somewhat more complicated because they are both complementary and competing objectives to congestion abatement.

In section 2.3 a distinction between supply-side and demand-side instruments is made. It is noted that it is not possible to maintain a strict adherence to 'supply-side' - being any policy that affect the level of service offered on the transport network, and 'demand-side'-– being how travellers weigh up or choose between existing transport options. This report relaxes the strict definitions by defining supply-side as any infrastructure or operational improvements to roads, including future planning by marking out reserves (Section 2.3.1). In addition, supply-side instruments include significant public transport investment in infrastructure (light or heavy rail, newly developed busways) or a substantial boost to public transport rolling stock. The report includes demand-side instruments that impose disincentives to SOV travel; provide incentives to switch to alternative travel options (mode, time of day, no-travel) and programs aimed to affect the traveller's perception of or attitude towards existing travel options (Section 2.3.2). Measures aimed to move people out of their cars (disincentives) are labelled as push instruments. Incentives to use alternatives to SOV travel are called pull alternatives. Programs aimed at educating or influencing travellers' perceptions of transport alternatives (behaviour modification programs) do not change the conditions in which travellers make their choice but aim to affect the way travellers evaluate their options.

Section 3 provides an overview of the conceptual framework informing the TDM matrix. Along with the classification of instruments based push, pull or behaviour modification programs, Section 3.1 introduces trip purpose and TDM instrument objectives. Following this, **Section 4** outlines eighteen categories and sub-categories of TDM instruments. Within each of these categories and sub-categories, common policy instruments are described and several case studies introduced in order to provide concrete examples of the instruments. There have been numerous other similar approaches to developing typologies of TDM instruments. Broaddus et al (2009) identified a number of TDM instruments for developing countries according to whether they provided incentives for alternatives to SOV use (Push), disincentives for SOV use (Pull) or a combination of incentives and disincentives. Rose (2007) developed a typology of TDM measures based on considering when travel demand problems occur, and where they occur or may where they may be targeted. Other overviews of a range of TDM instruments also have been developed (Austroads 1995; OECD 2002). Finally **Section 5** looks at four national and regional contexts where a range of TDM policies have been implemented: the Netherlands; Vancouver, Canada; London; and Singapore.

1.3 Terminology

A number of terms are used throughout the report, each with a specific meaning:

- **TDM instrument** is a general term for a *type of* TDM policy that could be implemented by way of a specific TDM project or program.
- **TDM Project** is the implementation of a TDM instrument for a particular purpose, having a dedicated budget and a predetermined scope and end date in mind. After the project is implemented funds are spent on monitoring. At some time the project will be evaluated against anticipated outcomes.
- **TDM Program** is the ongoing effort to manage travel demand. A TDM program may be thought of as a series of TDM projects that include a cycle of appraisal, implementation, monitoring, evaluation and updating. An example of a TDM program is *TravelSmart* which has an ongoing budget for delivering personalised marketing projects.
- **TDM Policy** is the strategic targeting of an instrument or portfolio of instruments.
- **TDM Initiatives is a** generic term including TDM instruments, projects, programs and policies.
- **Appraisal:** The determination of the anticipated impacts, effectiveness and value of a TDM project or program. An e*conomic appraisal* is the processes of calculating monetary equivalents to the benefits delivered by the TDM project and comparing these with the implementation costs.
- **Assessment:** The comparison of more than one appraisal with the aim of recommending which to implement when (prioritisation).
- **Decision:** A commitment of funds and other resources to implement the chosen projects or programs.
- **Evaluation**: The measurement of the actual outcomes of an implemented TDM project against the stated targets.

2 TRAVEL DEMAND MANAGEMENT

2.1 Defining Travel Demand Management

Contemporary understanding of TDM relates to the provision of competitive transport alternatives or maximising the opportunity available to travellers: *"Managing demand is about providing travellers, regardless of whether they drive alone, with travel choice, such as work location, route, time of travel and mode"* (FHWA 2012 p 10). Meyer (1999, p. 576) also views TDM as policies aimed at providing effective travel options: TDM "is any action or set of actions aimed at influencing people's travel behaviour in such a way that alternative mobility options are presented and/or congestion is reduced." Other views of TDM focussed on resource efficiency where travel demand management was seen as "… a general term for strategies and programs that encourage more efficient use of transport resources (road and parking space, vehicle capacity, funding, energy, etc.)" Litman (2003, p. 245). A key objective of TDM is to optimise the use of the current transport infrastructure so as to reduce or delay the need for road capacity expansion. As such, despite having other benefits, the principal reason for TDM policies is to abate congestion on existing road networks.

Current planning strategies in WA to reduce traffic congestion include a suite of instruments spanning supply-side approaches (investment in public transport, expanding the road network and optimising road network efficiency) and demand management defined implicitly as "supply" of active transport networks, limiting SOV opportunities (through parking management and road pricing) and travel behaviour change program. Integrated LU-T planning is considered as a separate initiative (Department of Transport, Moving People Network Plan for Perth and Peel Regions to 2031, 2013 (draft in confidence)).

For the purpose of this study on congestion abatement, **Travel Demand Management** is defined as any instrument or set of instruments aimed at reducing congestion, by means of influencing behaviour change, without having to supply additional road or public transport infrastructure. The range of instruments include financial instruments, stricter regulations on car use, travel behaviour change programs, improved active transport networks and improved connectivity of the public transport network.

2.2 Policy Objectives

2.2.1 Policy packaging

Policy packaging of TDM approaches has been recommended (Banister 2008; Givoni 2014). Policy packaging refers to the use of an integrated policy approach, where several policy instruments are designed and implemented in order to achieve common objectives. The rationale for selection of policy instruments in a package can be based on the mutually supportive relationships between policy instruments, whereby negative consequences of one policy may be counteracted by positive consequences of another. To develop policy packaging approaches it is important to first understand what policies instruments are available to use in addressing policy objectives. Policy packaging approaches to managing travel demand are ideally based on a mixture of disincentives for SOV and incentives for alternative travel behavior. Travel demand management approaches based on development market pricing of transport and increasing disincentives for SOV are widely viewed as the effective means to manage travel demand (Hensher and Puckett 2007). However, the issue of public acceptability is also viewed as the primary barrier to implementation of command and control type policies for TDM. The use of incentives to increase the attractiveness of alternative travel options is one way that issues of public acceptability can be mitigated and reduced.

2.2.2 Congestion and System Reliability

Travel demand management offers an alternative to road expansion to help relieve congestion and improve system reliability. Where TDM aims to provide competitive substitutes to car travel, the road system benefits from a more even spread of travel (and non-travel) alternatives being undertaken; meaning that there is less demand on one part of the network at a particular time of day.

- Congestion is generally attributable to the number of vehicles approaching the capacity of the road space. When this capacity is neared there is a breakdown in traffic flows leading to a slowdown in speed. At high levels of congestion there is also a reduction in vehicle throughput.
- System reliability refers to the day to day dependability of network conditions, rather than the natural rhythms experienced over the day. A transport network with a high degree of reliability means that travellers can anticipate journey times when making planned or routine trips. The reliability of the system is strongly dependent on the level of congestion, because at high levels of congestion a small variation in total demand on the route or a small incident can have a large and lasting effect.

Travel demand instruments aim to balance peoples' needs to travel a particular route at a specific time with the capacity to efficiently handle the level of realised demand.

2.2.3 Air Quality and the Environment (a complementary objective)

Private vehicle travel accounts for approximately 43% of the transport sector's greenhouse gas emissions and contributes a substantial proportion of other air pollutants (Department of the Environment, 2014). TDM instruments aimed at improving environmental outcomes typically seek to decrease the use of private vehicle travel. This may be achieved by shifting travellers to high occupancy modes (bus and rail) or active modes (cycle and walk); providing some advantage for low emission vehicles (e.g., free parking for electric vehicles – not covered in this review because it does not relate to congestion); or through alternative work arrangements (flexitime and telecommuting). TDM instruments aimed at alleviating congestion complement environmental outcomes in two ways. First any TDM aimed at reducing the overall volume of traffic reduces emissions. Secondly, emissions are higher under the stop and start conditions of congested traffic and easing congestion leads to lower emissions per vehicle kilometre.

Demand-side instruments specifically aimed at air quality and environment are not included in this review. Such instruments include incentives for purchasing cleaner energy vehicles or vehicle design regulations to reduce emissions. However, some TDM instruments aimed at abating congestion have positive environmental outcomes and others do not. Benefit calculations of TDM instruments need to account for broader objectives rather than their impact on congestion alone.

2.2.4 Health (a complimentary objective)

Demand instruments aimed at moving people out of cars and onto public transport or to take up walking or cycling have positive health benefits. Active travel, including public transport, provides opportunity to combine low to moderate aerobic exercise meeting the recommended level of 30 minutes a day for at least 3 days a week (Haskell et al 2007). Beyond the immediate health benefit of exercise, shifting transport to alternate modes has the potential to improve air quality and to reduce vehicle accidents. “Apart from encouraging a sedentary lifestyle, reliance on motor vehicle transport has a range of adverse health effects (traffic accidents, air and noise pollution, and greenhouse gas emissions)” (Manson 2001, p230).

As with the air quality and emissions, this report considers the health benefits of TDM instruments that are aimed at abating congestion, but does not consider any demand strategies that are specifically aimed at improving health.

2.2.5 Economic Development

Wider economic impacts are additional benefits not captured by the direct impacts of transport investment. Whilst being relatively new and requiring a greater investigation into the behavioural response parameters, these impacts feature in the UK appraisal guidelines (Guhnemann et al 2013). The effects include encouraging agglomeration and direct productivity gains in terms of reducing the marginal costs of production. In addition labour supply gains (new entrants into the labour market) and shift to higher taxable wages are considered. Apart from agglomeration effects, wider economic impacts appear to be relevant to significant transport investment (e.g., major highways or airport expansion). Agglomeration should be considered in TDM when considering integrated land-use and transport policies.

2.3 A Comment on Supply

Congestion can be alleviated though supply and/or demand strategies. Supply-side instruments include construction of new capacity as well as enhancements to existing transport network operations. Demand instruments aim to change the way people evaluate their travel options using the existing transport network. However such a strict definition poses some difficulty in framing the possible instruments for managing travel demand. Many of the existing TDM instruments presented in the TDM matrix aim to improve the level of supply offered by non-car alternatives. Extensions to bicycle lanes to improve cycling safety or improved connections between public transport modes are examples of supply instruments that affect alternate (non-car travel) modes. Integrated land-use and transport represent planning decisions, but the implementation of these decisions are necessarily supply initiatives as they guide the building or evolution of places and the transport function. Whilst it is impractical to define the scope of a TDM review by whether an instrument affects the supply-side or the demand-side of the transport function, it is necessary to specify the boundary of scope for the purpose of this review. Two broad areas of transport policy are disregarded from the analysis:

> ***Road building and improvements to road efficiency:*** Road capacity is the most important factor affecting the level of congestion. Municipal governments manage the level of congestion by way of transport investment in lanes (lane kilometres) and removing intersections along freeways and major arterial routes highways. The second supply instrument available to transport authorities is to improve operational efficiency. Smart intersections, controlled freeway on-ramps and other intelligent transport systems are used to improve the travel time on existing roads. The third supply instrument is the capacity of the network to manage and limit incidents. Intersection design, improved safety engineering, road management for special events and incident response are not considered to be demand management strategies in this report.
>
> ***Public transport infrastructure investment:*** Construction of urban rail, metro systems and light rail are not considered to be demand-side instruments. Major investment in public transport rolling stock is also considered to be a supply instrument. However, improvements to localised

public transport services may require additional staff or a redeployment of assets. For the purposes of this report such incremental changes are included in the 'pull instruments' that improve the quality of service of non-car modes.

Supply-side measures include delivery, efficiency management and planning of road infrastructure and investment in public transport infrastructure

- Expand the road network
- Optimise road network efficiency by way of intelligent transport systems
- Future planning of road hierarchy, key performance indicators, HR resourcing to deliver infrastructure and manage road network)
- Invest in public transport such as light rail construction, implementation of new rail links or purchase of additional rolling stock

2.4 Effectiveness of TDM instruments

Whilst several of the TDM instruments discussed in this report provide information on evaluations of selected case studies, the report does not propose a comparison of the effectiveness of each of the TDM instruments. Such an evaluation is outside the scope of this report for several reasons. Firstly, there is a general lack of consistent ex post evaluation of TDM measures in the literature. What evaluation is available lacks the methodological consistency needed to establish evidence of effectiveness. There is also variation in policy objectives that limits the utility of a comparative evaluation. For example, some TDM policies are intended to manage the efficiency of vehicle movements and address congestion, whilst others are intended to achieve change in travel modes. TDM policies are also often introduced as a policy package making it difficult to isolate influences on particular behavioural responses. Finally, the urban, cultural and political contexts in which TDM instruments operate are extremely varied limiting the reliability of evaluations of TDM in other contexts.

3 TRAVEL DEMAND MANAGEMENT MATRIX

3.1 Introducing the Travel Demand Matrix

Following the initial scan of literature, nine categories were established to organise the range of TDM instruments available. The categories are organised according to the extent that they provide incentives for alternative modes, or disincentives for SOV use. The categories (rows in the matrix) are:

1. Improving alternative modes
2. Integrated land use and transport
3. Workplace-based instruments
4. Travel behaviour change programs
5. Information and communication programs
6. Management of road space
7. Governance and administration
8. Parking
9. Taxes and charges

Of the nine categories, five have associated sub-categories. In total, eighteen broad categories and sub-categories help present TDM instruments for discussion. However, some instruments fit within more than one category; for example, parking instruments, a category of their own, can be applied at the workplace. Within the material discussed in this section and the additional material contained in the matrix, each TDM policy type is described in relation to a conceptual model (see Figure 1): the type of travel market the TDM instrument addresses; whether the instrument provides a disincentive or incentive to particular types of travel; and what type of objective the TDM instrument is aiming to achieve. One or more case studies that exemplify particular TDM instruments are introduced and their major characteristics described.

3.2 Conceptual model – columns in matrix

3.2.1 Push, Pull or Travel Behaviour Change Instruments

Push and pull approaches, can also be distinguished as 'carrots' and 'stick' (Meyer 1999), or 'command and control' and 'incentive based policy' (Santos et al 2010) approaches to TDM. Instruments are categorised as to whether they provide a *disincentive* for motorised modes during peak periods (push), whether they *incentivise* alternative modes or times of travel (pull) or inform/persuade individuals to change their perceptions of or attitudes to the existing travel alternatives (behaviour modification programs). Figure 1 illustrates the conceptual model developed to organise the nine categories of TDM instruments.

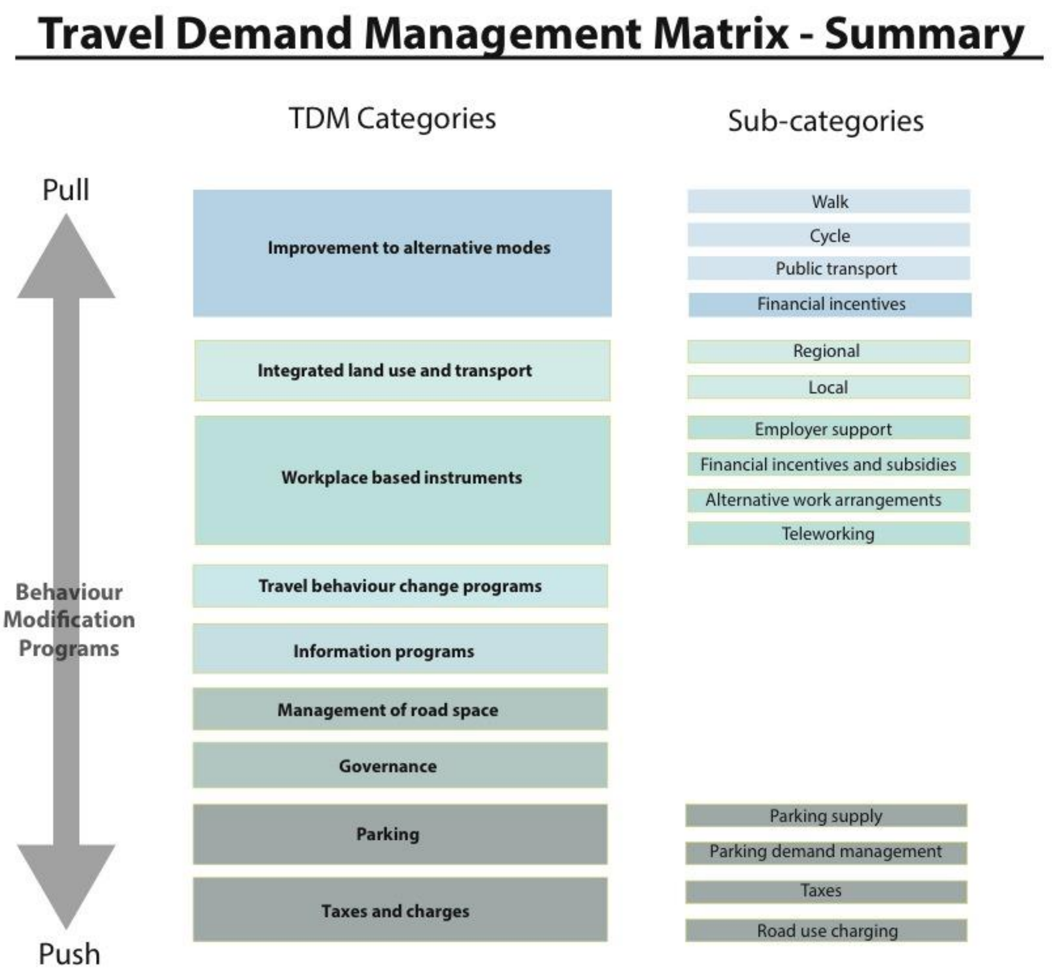

Figure 1: Conceptual model underpinning the TDM matrix

Push instruments aim to reduce the relative attractiveness of driving a SOV. For example, one type of push approach to TDM relates to an additional car use tax or a dedicated road user charge. Alternatively, instruments may aim to increase the cost of parking or limit the parking supply at a major destination. A third type of instrument is that of limiting the road space available to cars along certain routes or at specific time during the day. Push instruments are not designed to encourage any particular form of alternate travel (mode shift, travel less often, adjust time of departure, etc.).

Pull instruments represent incentives to encourage choices away from private vehicle by improving the availability or the quality of the alternatives. Reducing the cost of travelling by public transport may be achieved by direct reduction in fares. Alternatively, an improvement to the level of service in terms of headway frequency, multimodal accessibility (e.g., park and ride) or overall travel time may be implemented to shift travellers out of their cars. Improvements to active transport networks such as bicycle lanes or improved pedestrian conditions are also considered to be pull instruments.

Travel behaviour change and information programs may be achieved by informing the community of the travel outcomes by mode (i.e., by way of information on untested modes) or changes to attitudes (e.g., social norms around environmentally friendly travel). Travel behaviour change programs usually include a range of strategies including the provision of information, support and feedback, and incentives for sustainable travel. Travel behaviour change and information programs shift demand by working directly on the consumer's preference function. Where push and pull instruments change the levels of service on the transport network, travel behaviour change and information programs aim to alter the way travellers weigh up their transport options.

Travel demand management measures include incentives (pull measures) and disincentives (push measures) to enact travel behaviour change. In addition TDM measures may provide information or education to affect people's perception of or attitudes towards travel alternatives with intention being behavioural modification.

- Push measures are designed to make travel by SOV less attractive.
- Pull measures improve the competitiveness of alternate travel options, including no- travel.
- Behaviour modification programs rely on changing travellers' perceptions or attitudes toward alternate travel options

3.2.2 Transport Markets

Meyer (1999) separates instruments into categories of 'transport markets' such as work, shopping and tourism related travel. Different transport markets have differing demand responses to incentives and/or disincentives. We use the categories: commute (work based travel); shopping; recreational; educational; or multiple where the TDM covers a range of transport markets. Transport markets may have varying geographic scale and travel during the day or during the week. Individual's travel behaviour varies according to these different types of transport market.

3.2.3 TDM Objectives

There are different behavioural responses that may be the result of travel demand management. For the management of travel demand to reduce congestion, the behavioural responses may be reducing overall travel, shifting to an alternative mode to the SOV, or by changing the time of travel to limit demand in peak times. Four main TDM objectives were identified:

- Trip substitution – eliminate the necessity of some trips.
- Mode shift – shift to an alternative travel mode.
- Reduce travel distance – encourage shorter trips, or trip chaining.
- Peak spreading - manage the time of travel to avoid peak travel times.

4 Travel Demand Management Instruments

4.1 Improving alternative modes

Improving the quality of infrastructure, networks and services of alternative modes of transport to the car, such as walking, cycling and public transport, manages travel demand by increasing the attractiveness of alternative modes of travel to the private vehicle. Improving travel for pedestrians, cyclists and public transport users can have benefits beyond addressing the problem of congested roads. For example, the marginal social benefits of active transport – walking and cycling – may include less congestion through a decrease in demand for car travel, and increased health and wellbeing for individuals. Public opposition to road use pricing may manifest itself in arguments based on vertical equity concerns. For example, to shift the demand of peak hour commuters from SOV to public transport there needs to be adequate capacity of train and bus services and rolling stock. The improvement of alternative modes of travel to SOV is likely to be of critical importance to the successful planning and implementation of TDM instruments that create disincentives for SOV use, such as levies and road use pricing (Meyer 1999).

4.1.1 *Walking and cycling*

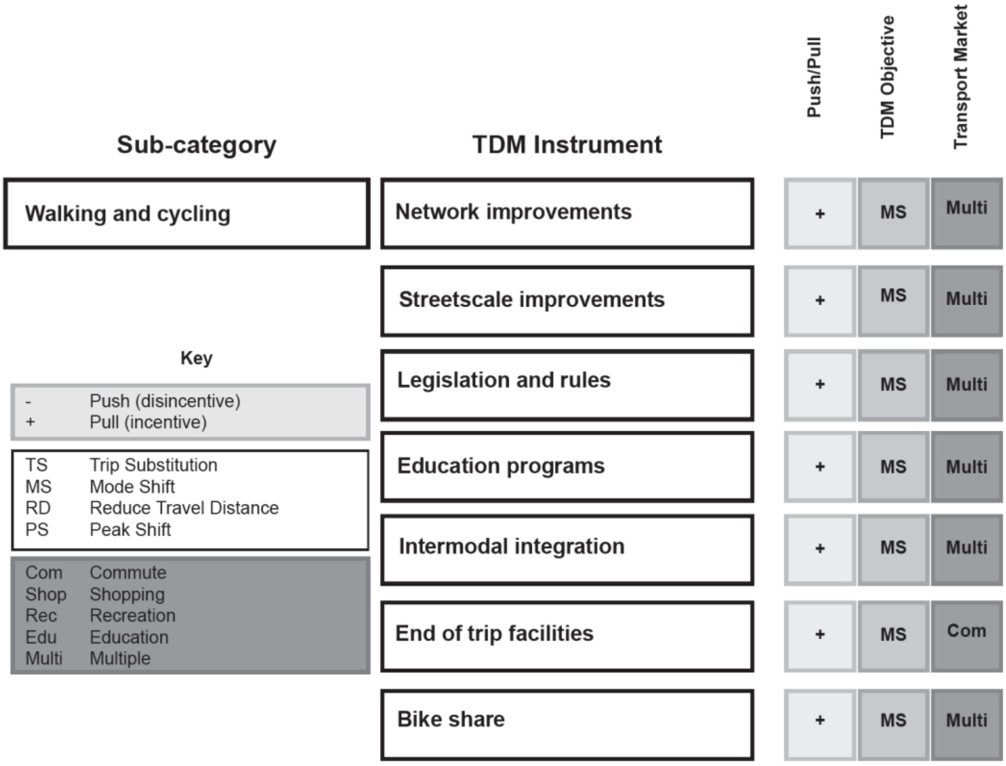

Figure 2: Improvements to alternative modes - walking and cycling

As illustrated in the TDM matrix in Figure 2, improving infrastructure, networks and quality of the places people walk and cycle offers an incentive for using alternative modes of travel to SOV. There are a number of ways conditions for pedestrian and cyclist travel may be improved in order to provide an incentive for people to switch away from motorised vehicle travel.

- Pedestrian or cycling **network improvements** can increase the connectivity of routes and provide greater accessibility for walking or cycling. This may involve providing missing links in networks, or increasing the quality and safety of critical links such as road crossings.
- Alternatively, improvements to the built environment for pedestrians and cyclists may be targeted across larger areas such as neighbourhoods or local government areas, through **street scale improvements**. Street scale improvements may improve the overall spatial quality for walking or cycling through lowering traffic speeds in busy streets or key activity nodes. The concept of area-wide street improvements is reflected in a number of related concepts; for example the woonerf (Netherlands), Home Zone (UK), Shared Zones and Shared Spaces (Australia and New Zealand – see **Case Study 1**) and Complete Streets (US).

Case Study 1: Shared space
Auckland, N.Z.

As part of recent planning for the Auckland central business district, a number of inner city streets have been designed according to the 'shared spaces' principle. One overall objective guiding the planning was to address congestion within the centre and increase the quality of the street environment for cyclists and pedestrians. 'Shared spaces' are improvements to the street, better integrating the needs of residents, pedestrians, cyclists and cars into the design of the street and is underpinned by a philosophy of 'shared responsibility' for safety and risk minimisation. 'Shared spaces' combine rather than separate the functions of the streets. Modifications typically include the removal of kerbs to create a continuous space; a reduction in parking space; and the minimisation of conventional road signage leading users of the street to reduce speed, raise awareness and minimise the risk of accidents (Karndacharuk et al 2014).

An example of 'shared spaces' in the CBD is the City of Auckland's Fort Street improvements. Planned improvements and the introduction of 'shared space' in the Fort Street area, which included a number of smaller streets in Auckland CBD, were set out in the City of Auckland city centre masterplan. The cost of the modifications was estimated to be $23 million and was funded through an additional rate targeted towards residents and business owners in the Auckland CBD. The street design features of the Fort Street 'shared spaces' are illustrated in Figure 2.

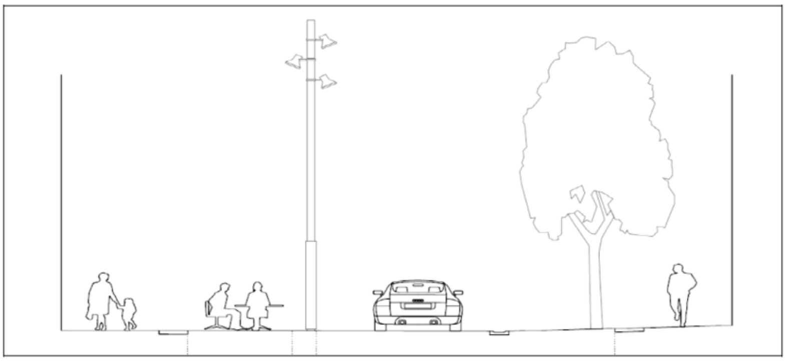

Figure 3: Shared space - Auckland City Council

A year following the implementation of the Fort Street 'shared space' the City of Auckland commissioned an evaluation of the improvements[1]. The evaluation included surveys of pedestrians and businesses; video observations of pedestrian and vehicle movement; vehicle counts; and indicators of economic activity. The evaluation found that the 'shared space' concept was well received and that, although there had been a few negative responses noted based on perceived safety issues, no accidents had occurred in the street.

- Changes to **legislation and rules** can improve the safety and quality of pedestrian and cyclist mobility in the streets. Changes to the road rules can better support the rights of pedestrians' and cyclists' mobility. For example, following a recent Queensland parliamentary inquiry into how to improve the interaction between cyclists and motorist on roads, changes have been made to the road rules in Brisbane, Australia, that require motorists to stay a minimum of 1 metre away when passing cyclists in a 60km/hour zone and 1.5 metres when the speed limit exceeds 60km/hour.
- **Education programs** may be provided by schools, local governments, advocacy groups or state agencies to provide training and information for safer walking and cycling. In the Netherlands, bicycling training for children is introduced in early years education.
- **Intermodal integration** refers to improved connections between walking, cycling and public transport. Integration may be facilitated by providing space for bicycles on trains, or through

[1] See: http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/ccmp/Documents/fortstareaevaluationfullreport.pdf

providing high quality infrastructure, such as paths or design features at stations in order to encourage walking and cycling to stations.

- **End of trip facilities** for cyclists, including secure parking, showers and change rooms, may be supplied at major public transport stations, workplaces or schools and universities in order to provide a more comfortable trip by bicycle (see **Case Study 2**).
- **Bike share** schemes enable short-term access to bicycles through a city-wide network of hire stations. These programs are increasingly popular in many international and national cities and have also been linked to an increased use of private bicycles and cycling rates (Fishman et al 2013).

Case Study 2: Dedicated bicycle facility
King George Square Cycle2City – Brisbane, Australia

The King George Square Cycle Centre is a jointly funded (Brisbane City Council and Queensland State Government) $7 million facility located at the King George Square train station in central Brisbane. The facility was provided for commuting cyclists whose workplaces did not provide adequate end-of-trip facilities. The centre includes over four hundred parking spaces for bikes, lockers, showers, laundry service, and bicycle maintenance service. The facility provides a range of membership options from casual to annual rates, and provides incentives for referrals.

An evaluation by Griffith University (Burke, Sipe and Hatfield 2010) was conducted a year after the opening of the facility in 2010. The key findings of the evaluation were:

- The facility had led to a reduction in approximately 56,000 VKT.
- 6% of members had switched mode of travel, from motorised vehicle to bicycle.
- Operating costs were not matched with revenue from membership fees in the first year. There was a tension between balancing operating costs and attracting new members through alternative pricing strategies.

4.1.2 Public Transport

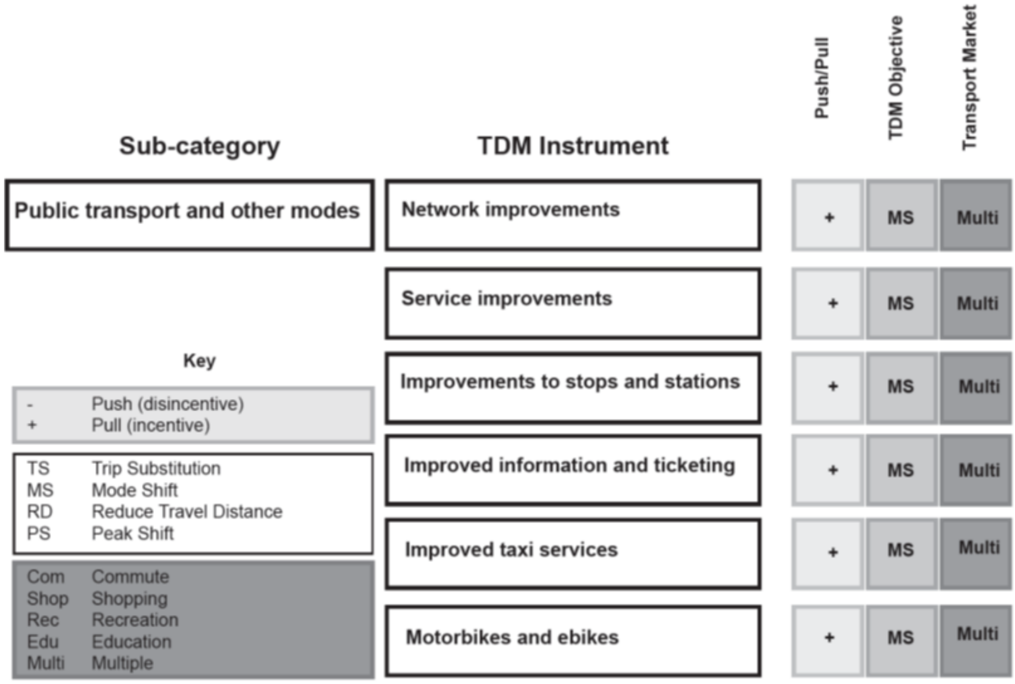

Figure 4: Improvements to alternative modes - public transport and other modes

Improving the quality and coverage of public transport networks and services is an important TDM instrument. Figure 4 indicates that improving public transport can support a range of transport markets by providing alternatives to SOV use. For TDM policies that impose a disincentive on SOV use, efficient, reliable and comfortable alternatives need to be available. Improving the capacity of public transport may be critical to the success of other TDM policies and mechanisms that may impose a disincentive for SOV use such as cordon pricing. There are several aspects of public transport networks that may be improved in order to manage travel demand.

- **Improvements to the public transport and the integration of different public transport modes or services.** For example, the introduction of the Joondalup and Mandurah railway lines in Perth was accompanied by a redesign of the bus network in order to better integrate feeder bus services with rail stations in order to improve the accessibility of stations to the surrounding residential catchment.
- **Improving public transport services** is a key factor in providing an alternative for SOV use and may include **improving the reliability** of existing services and **increasing the frequency** of services along routes. With travel by buses contributing to over half the public transport mode share for Perth, identifying improvements to bus travel has great potential to management travel demand through mode shift. In a synthesis of international evidence Currie and Wallis (2008) identified that increases in service frequency and greater reliability and speed, of the magnitude associated with Bus Rapid Transit, were the most effective means at increasing patronage on buses.
- **Improving the quality of stations and stops** contributes to the comfort and ease of access to public transport stops and can therefore contributes to the management of travel demand through improving the overall attractiveness of public transport modes. For example, stations may be improved with application of approaches such as Crime Prevention Through Environmental Design (CPTED).

- Better integration between transport modes may be achieved by the physical linking of modes and services. Better integration may also occur through **improved information and ticketing.** Perth, as well as cities such as Spain, London, and some German and Swiss cities, provides examples of urban public transport systems with successful integrated electronic ticketing systems. Moving from mode to mode, or service to service, is facilitated with efficient and convenient single ticket or card systems.

4.1.3 Taxi and motorbikes

Improvements to the taxi services can lead to a reduction in the need for car ownership and can support travel by alternative modes, such as walking and public transport. Improvements may derive from increased services and the improved quality or efficiency of services. Providing adequate parking or prioritising the on-road movement of small vehicles, such as motorbikes and e-bikes, can contribute to a reduction in congestion (although motorbike transport may not necessarily lead to a reduction or shift in travel demand on roads at peak hour).

4.1.4 Incentives and subsidies

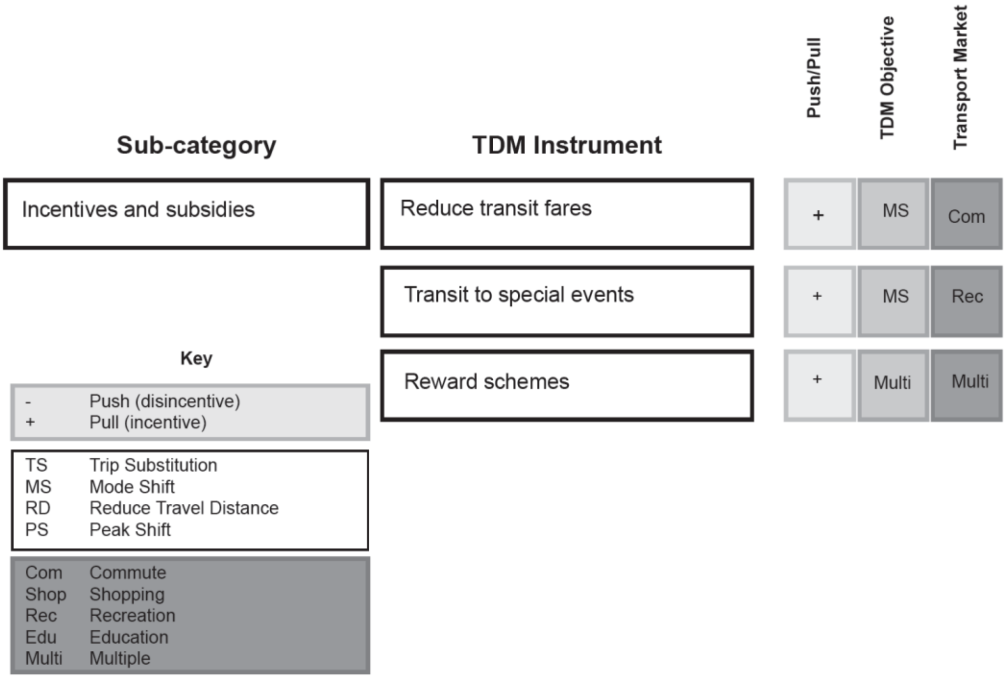

Figure 5: Improvements to alternative modes - incentives and subsidies

Financial incentives and subsidies may be provided for travel by alternatives to SOV, particularly public transport.

- The provision of **reduced public transport fares** for students and children is an example of subsidy used as a TDM instrument. Subsidising children's travel in this way provides an incentive for travel by bus and train and therefore may reduce the rate children are driven to school, a significant contributor to peak hour travel. Other subsidies that can manage travel demand include the lowering of public transit fees outside peak hours in order to manage the time of travel.
- **Free public transport travel to major events** provides an incentive for people to travel by bus and train, rather than SOV, to large events, where the movement of many people is likely to cause increased congestion.

- **Reward schemes** provide direct incentives to peak hour commuters who choose to travel outside the peak period, shift mode to public transport or choose not to travel and instead, telework. See **Case Study 3** below for an example.

Case Study 3: Peak avoidance incentives
'Spitsmijden', The Netherlands

'Spitsmijden' is the name of a program launched in 2006 in the Netherlands that provided an incentive for drivers participating in the program to avoid peak hour travel in certain locations (Tillema et al 2013). The scheme, a collaboration between government agencies, private companies and universities, was instigated as an alternative approach to counteract the acceptability issues associated with available road pricing instruments that worked by providing disincentives for car travel at peak times. The scheme used positive rather than negative pricing signals, rewarding volunteers in the scheme with a financial incentive if they chose to travel outside peak travel times in four locations in the Netherlands. The participants (500) were recruited through licence plate monitoring of the routes. The participants were regular commuters along the selected congested roadways and were rewarded for travelling on the roadway outside congested periods (7.30am – 9.30am), if they chose an alternative mode to commute, or if they chose not to travel by working from home. An evaluation of the scheme[2] was conducted following a preliminary trial and a reduction of approximately 50% in participant's peak hour trips was observed; primarily due to a shift towards travel outside the peak hour time period rather than a shift to alternative modes or working from home.

For more details see: Donovan (2011)

4.2 Integrated Land Use and Transport

The integration of transport and land use planning is an effective long-term TDM instrument. Most travel demand is derived from the need or desire to access activities associated with different places. The planning of land use that integrates existing and future planned transport networks and infrastructure, and vice versa, facilitates the development of urban forms and structures that may encourage travel by alternatives modes to SOV. For example, land use may be intensified and diversified in places served by good quality public transport in order to increase the diversity of opportunities for travel. TDM instruments based on integrated land use and transport can be used at different scales – a regional scale, such as a metropolitan region or growth area, or at a local scale involving individual developments or a smaller precinct scale.

[2] http://www.spitsmijden.nl/resultaten/english/Experimental_design_and_modelling_-_Spitsmijden.pdf

4.2.1 *Regional*

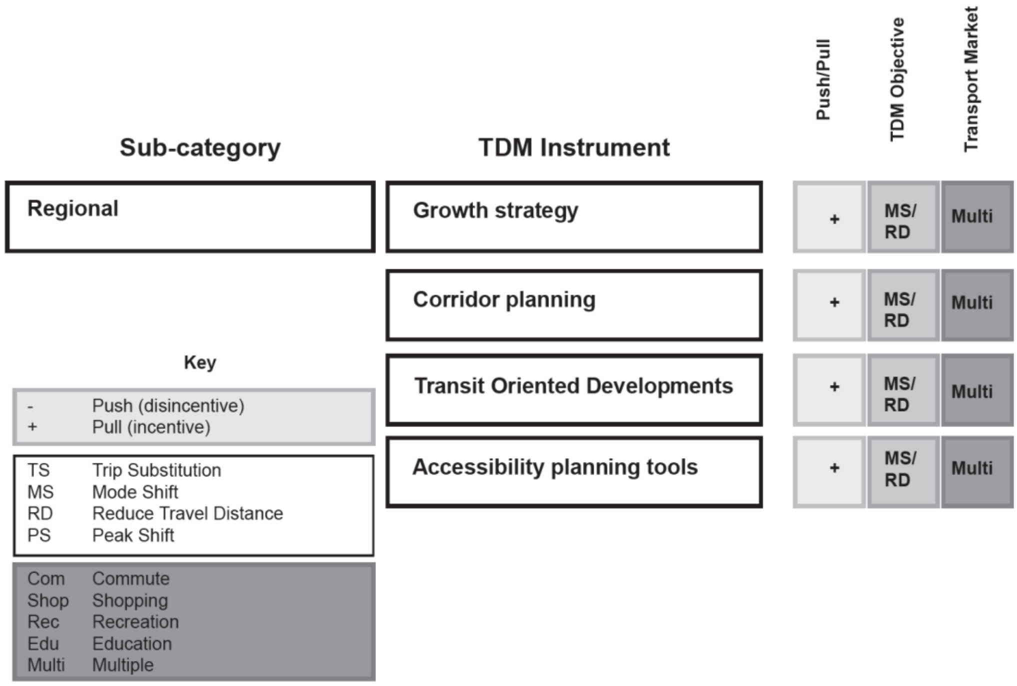

Figure 6: Integrated land use and transport – regional

- **Growth strategies** refer to long-term strategic land use and transport planning for regions or precincts experiencing rapid urban growth. Current regional growth strategies in Australian states are based on targets for a percentage of new dwellings to be within the existing urban boundary, therefore limiting the need for dispersed transport networks at the urban fringe. Growth strategies may take the form of broad strategic plans, or more specific regional urban policies such as the ABC location policy in the Netherlands (see **Case Study 4**)
- **Corridor planning** refers to the intensification of urban development along transport corridors, or 'spines'. Corridors are an effective urban form for high frequency and efficient public transport services. Increasing densities along corridors or at identified nodes along corridors can facilitate a shift in demand from SOV use to travel by public transport, walking and cycling.
- **Transit oriented development (TOD)** refers to developments located near good quality public transport stations and exchanges. Successful TODs cater for the needs of residents through a pedestrian oriented area and a mix of land uses reducing the need to travel outside the TOD area, as well as enabling connection to other places in the region through good quality public transport service and links. TODs need to be thought of as a regional strategy, with individual TODs interacting with other TODs within a broader regional context (Thomas and Bertolini 2014).
- From a regional perspective, accessibility refers to the ease of accessing activities (Hansen 1959). **Accessibility tools** enable planners to analyse the accessibility benefits of additional infrastructure or the services and plan land use development accordingly. SNAMUTS (Spatial Network Analysis for Multi-modal Urban Transport Systems), a tool developed by Curtis and Scheurer (2010) measures the accessibility of land use and transport systems via a range of indicators, enabling planners to better understand the accessibility implications for various growth scenarios.

Case Study 4: Integrated land use and transport
The ABC location policy, Netherlands

The ABC location policy in the Netherlands is an example of an integrated land use and transport policy instrument to better link the mobility needs of businesses to the accessibility of their location within the metropolitan regional area. The policy is applied through a metropolitan regional framework and therefore is a good example of a **regional integrated land use and transport TDM policy.** The policy is based on the simple objective of locating business types according to their accessibility needs. The ABC policy regulates the development of commercial land uses according to an evaluation of business access needs (a mobility profile) and an evaluation of the regional accessibility of the location (an accessibility profile). A business' mobility profile is based on the number of workers per development area; the intensity of car use for business activities; the visitor intensity; and freight or goods mobility needs.

- Locations that are most accessible to public transport such as the inner city and activity centres adjacent to public transport stations are deemed 'A' locations.
- Locations in areas adjacent to 'A' locations with reasonable access to public transport are deemed 'B' locations.
- Locations that have poor access to public transport and alternatively are well serviced by motorways are deemed 'C' locations.

The policy works in a number of ways. It is implemented through the land use planning system, primarily through locating car dependent business in areas most accessible by car (C locations), and for business that use public transport or active travel modes in areas accessible by these modes (A and B locations). The policy also operates through the regulation of the supply of parking – C locations have more generous parking requirements that A and B locations (for more parking supply TDM instruments see section 4.8.2). In addition, the policy provides signals to developers and businesses regarding future government infrastructure spending. For example, government can plan to improve the accessibility of areas identified under the policy as A-locations by investing in pedestrian and cyclist infrastructure. The policy therefore involves multiple levels of government in the Netherlands. At the national level, related ministries set the broad policy framework and organise the categories of business mobility needs and accessibility. The provincial government monitors broad demand and supply indicators and can intervene to adjust specific policy factors. The policy is directly implemented by local government through local planning and development assessment processes.

Although the broader strategic intent and design of the ABC location policy have been widely supported, Schwanen, Djist and Dielemen (2004) outlined a number of key criticisms of the policy. The nature of this criticism was based on the inability of the policy to address growth in the office sector. The increase in residential space in accessible locations created a shortage of spaces in urban centres and office based firms were unable to be located in A and B locations. There were other criticisms directed at the design of the policy including the mismatch between the simplicity of land use categories outlined in the policy, with the complex spatial arrangements of the places they were applied to. Furthermore, a mismatch between the types of travel behaviour associated with business types was identified. Differences between travel behaviour type (for example, between a car-dependent workplace and a workplace that has a more diverse travel mode share profile) may be related more so to individual level factors than related to business type.

4.2.2 *Local*

There are a wide range of TDM instruments that operate at a local scale to integrate land use and transport planning. These may involve evaluations of developments according to general integrated land use and transport principles; requirements for developers to provide financial contributions for transport infrastructure; and integrated land use and transport strategic planning at the local scale.

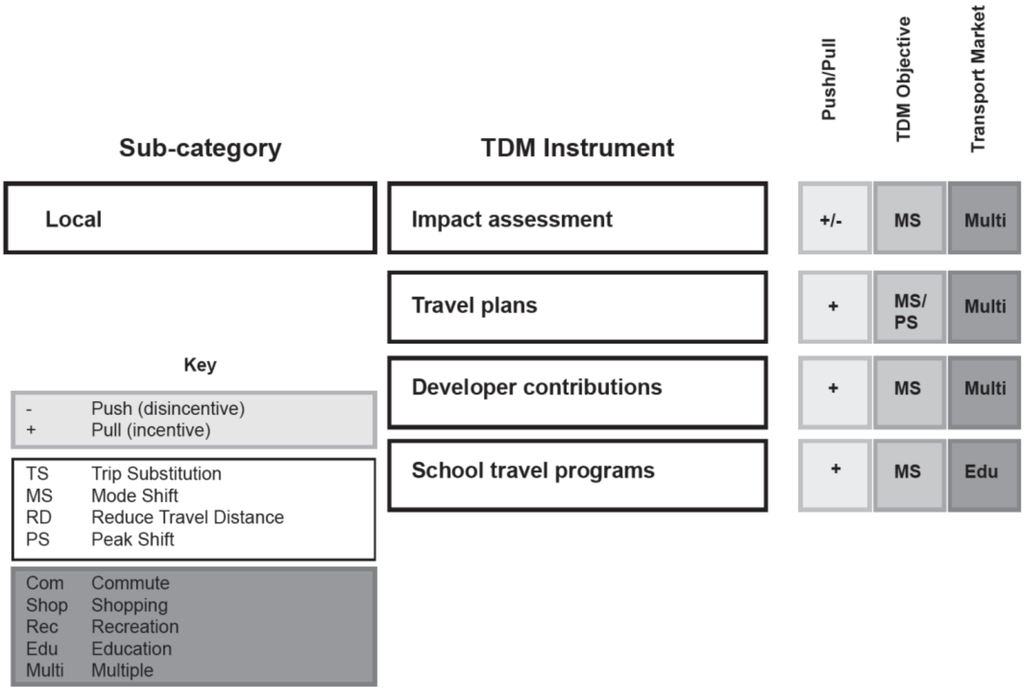

Figure 7: Integrate land use and transport - local

Examples of local scale TDM instruments include:

- **Impact assessments** at the development or precinct scale, such as social-cost and health impact assessments are used to identify potential consequences to the quality of urban life and travel, if the development were to go ahead. Impact assessments can use measures and indicators that draw attention to more sustainable outcomes for land use and transport systems. For example, developments near good quality public transport networks, or those that provide bicycle parking may be evaluated highly because of their potential to reduce car use and facilitate active travel. Specific **transport assessments** may be required for new developments (see **Case Study 5** for an example). These assessments evaluate potential impacts for developments that are likely to generate or attract large volumes of trips. The Perth Parking Policy (see **Case Study 10**) requires that, under the discretion of the responsible authority, a Transport Impact Assessment is carried out for developments within the Perth Parking Management Area for significant trip generating or attracting developments.
- **Travel plans** outline strategies to improve the ongoing travel behaviour of residents in urban precincts, large developments, workplaces or schools. Plans can be managed by a specific individual or small. Travel plans can be made a requirement for new developments as part of the development assessment process. Travel plans may include **trip reduction and travel distance ordinances**, which are requirements for new developments in particular, areas to commit to specific targets relating to number of trips and the distance of trips.
- **Developer contributions** are financial contributions made by developers to fund public infrastructure as part of approval of a development assessment.

- **School travel programs and investment in infrastructure around schools** may increase rates of children's walking and cycling to school and therefore contribute to a reduction in congestion around schools.

Case Study 5: Transport Assessments
United Kingdom

In the U.K. the National Planning Policy Framework requires that developments that will generate or attract a large amount of traffic be subject to a transport assessment. A transport assessment evaluates the likely impacts of a development on the existing and future travel activity and transport systems. The transport assessment is carried out in order to inform the assessment of a development. According to the U.K government guidance on transport assessments (2007), the following factors are to be incorporated into an assessment:

1. The local policy context
2. The scale of the development and its trip generation potential.
3. The existing transport networks and uses.
4. The potential environmental impacts.
5. A consideration of all modes, including walking and cycling.
6. The cumulative impact of current and future development in the broader area.

Transport assessments operate as a TDM instrument by either mitigating car dependent developments in areas that are accessible to alternative modes, or requiring compliance with best-practice standards for a range of mobility options. Transport assessments may also identify issues that can be addressed through ongoing travel management that can be incorporated into a **travel plan**. Transport assessments in the UK rely on associated databases to provide comparable impact assessments. The TRICs system (a national standard for trip generation analysis) uses extensive travel surveys based at a range of development types, in order to facilitate scenario planning and evaluation required by transport assessments.

In Perth, the WAPC has a number of transport assessment guidelines for development available on its website[3]. The assessments are provided for transport and land use planners as a guide for assessing the potential impacts of sub-division and development at the regional and local scale. However, unlike in the U.K., there are no statutory requirements to use the guidelines.

4.3 Workplace-based TDM

Workplace-based TDM include a range of instruments that are provided to employees to encourage travel to work by modes other than SOV. Although these instruments are administered by employers in the workplace, governments can play a facilitating role in the regulation and administration of employment based TDM instruments. Workplace-based instruments are often implemented as part of a package of instruments to manage the demand for commuter travel. Workplace-based instruments have been used extensively in the U.S. It is also important to note that the potential success of TDM workplace initiatives may be undermined by other workplace practises such as tax structures that encourage car use (Ker 2003).

[3] See: http://www.planning.wa.gov.au/publications/1197.asp

4.3.1 *Employer support*

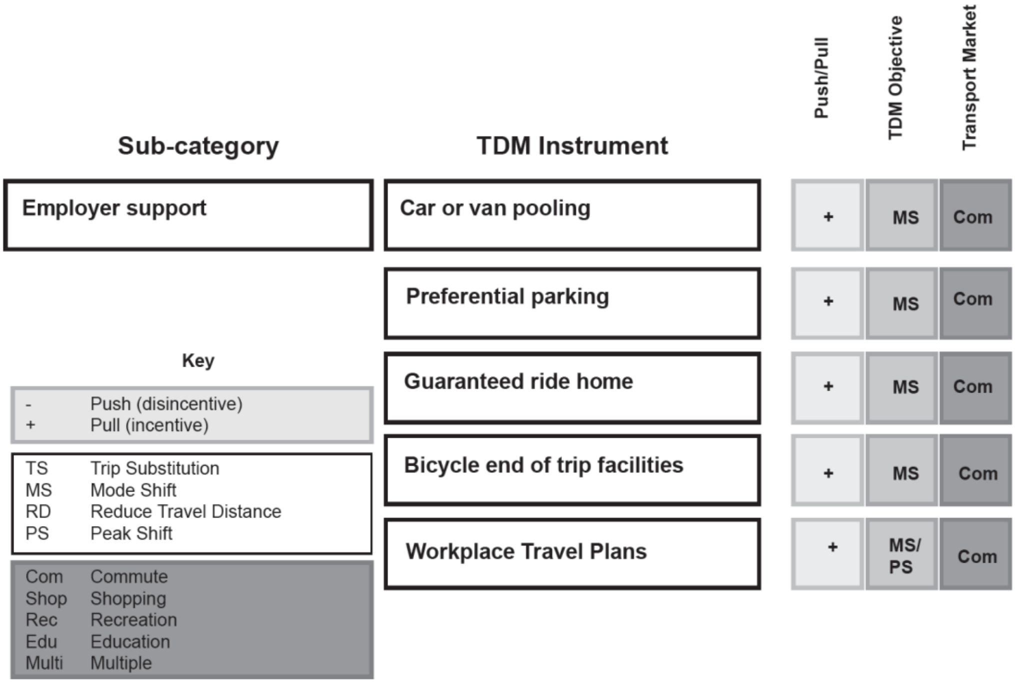

Figure 8: Workplace-based TDM - employer support

- **Carpooling (Ridesharing)** involves employees sharing a ride to their place of employment. The employer can use a range of strategies to facilitate compatible commuters sharing rides to work. **Vanpooling** differs from carpooling in that employer subsides a small van or bus transport service. This TDM instrument is usually implemented when employees live long distances from their place of employment.
- **Preferential parking** provides reserved parking spaces for employees who carpool. The spaces provided are usually the best quality spaces (for example, sheltered) or where parking is limited.
- **Guaranteed ride home** is a service provided to employees who carpool, or use alternative modes to SOV to travel to work, where a 'ride home', usually by taxi, is subsidised by the employer in the case of an emergency.
- **Bike storage, loan schemes and end of trip facilities may be provided** at the place of employment in order to increase the attractiveness of cycling to work. Bike loan schemes may be used to provide bicycles for employees who do not have access to bicycles.
- Many of these specific instruments may be encompassed within **workplace travel plans**. Travel plans are often developed for large workplaces such as universities, hospitals, in order to communicate and organise strategies to reduce travel by SOV.

4.3.2 *Financial incentives/disincentives*

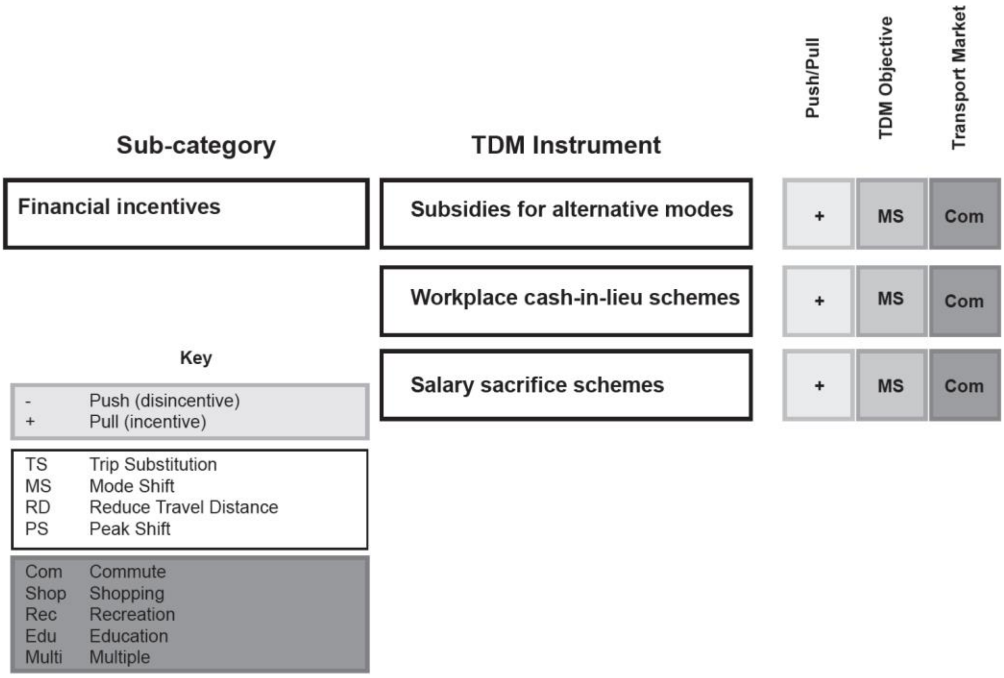

Figure 9: Workplace-based TDM - financial incentives

- **Subsidies for public transport or car share schemes** may be provided by employers in order to increase the attractiveness of alternative modes of travel to SOV.
- **Workplace parking schemes and levies** are pricing mechanisms that allow the employer to disclose and recover the cost of the provision of parking spaces at workplaces. Parking schemes and levies encourage a shift in the demand away from commuter travel by SOV through disclosing the real costs of parking and therefore making driving less attractive (see **Section 4.8** for more details on parking as a TDM instrument).
- **Salary sacrifice schemes** allow employees to receive part of their remunerations in the form of concessional tax benefits. Although salary sacrifice schemes may incentivise SOV use, alternatively they may be designed to incentivise travel by alternative modes of transport (**see Case Study 6**).

Case Study 6: Salary sacrificing for bicycles, Cyclescheme – UK.

Salary sacrificing schemes have been linked to incentivising car travel by providing tax relief instruments for car ownership. However, salary sacrificing may also be used as means to incentivise alternative modes of travel. As part of a 'green transport plan', the U.K. government introduced legislation allowing employers to offer bicycles and related safety equipment as tax-free benefits for employees. The tax-benefits are accessed by a typical salary-sacrificing scheme. The salary-sacrificing scheme allows employees to forego part of their salary for a loan of bicycle and safety equipment. The reduction in an employees' gross salary leads to a decrease in taxable income and therefore provide employees with an incentive to loan or purchase a bike. Typical savings from participating in the scheme can range of 30-45% of the usual cost of the hire of the bike and equipment (University of Cambridge 2013). Cyclescheme, a private company, was established to assist workplace employees, their employers and cycling retailers in accessing tax incentives.

4.3.3 *Alternative work arrangements*

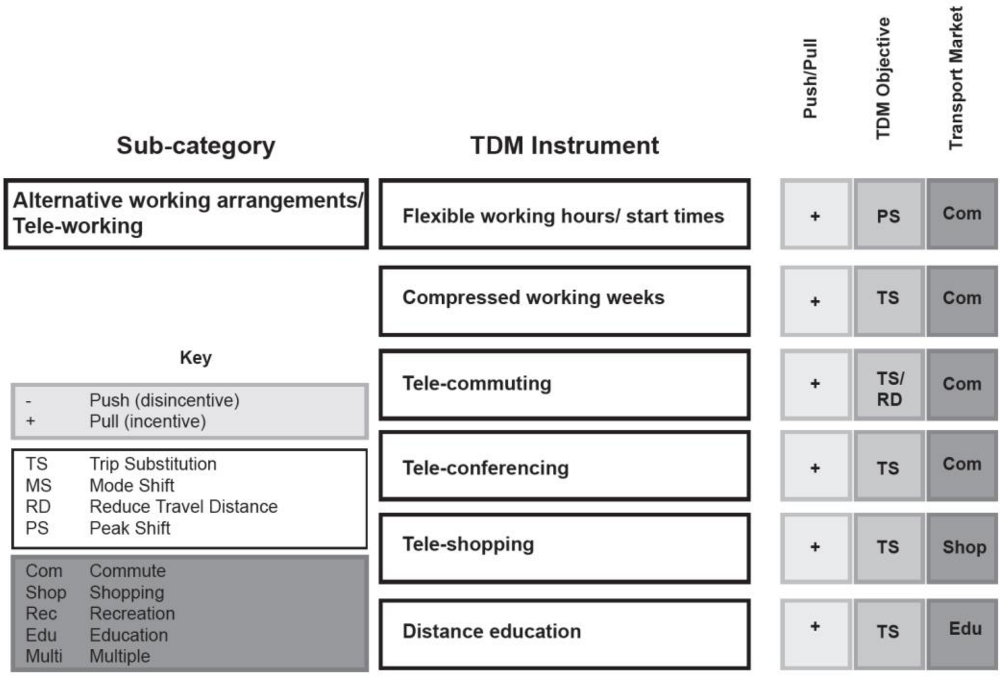

Figure 10: Workplace-based TDM - Alternative working arrangements and teleworking

- **Flexible working hours** provide employees with more flexibility in when they chose to start and finish work. This provides greater opportunities for employees to travel outside peak hours. **Staggered working hours** are varied start and finished times usually set by employers for different groups of employees, and provide more certainty for employers but less freedom for employees than flexible working hours.
- **Compressed working week** result from arrangements between employers and employees regarding the length of the working day. Employees can work an extra hour per day in order to take a regular day off; for example working an extra hour per day for nine days, to take the tenth day off. Compressed working weeks can lead to the spreading of peak demand and the reduction of travel to work on the allocated day off.

4.3.4 *Tele-working*

- **Telecommuting** involves employees working at places other than the workplace through the use of communication technology. Telecommuting allows home-based work, thereby eliminating the need for commuter travel. Shared, centralised office space may be hired by individuals, providing access to office facilities, teleconferencing spaces and social interaction for remote and home-based workers.
- **Teleconferencing** similarly uses communication technologies to allow meetings and conferences to be conducted from a range of locations. Travel to meetings can contribute a significant number of trips during the working day. Teleconferencing reduces the need for travel to and from meetings.
- **Teleshopping**, whilst technically not a workplace based TDM instrument, can reduce the need for smaller 'additional' trips on the way to and from work.
- **Distance Education** involves the reduction in the need for students to travel to school through the use of telecommunications. Whilst, distance education is prominent in regional areas of

Australia, post-secondary school education institutions are increasingly employing web-technologies to allow students to work from places other than universities, for example.

4.4 Travel Behaviour Change Programs

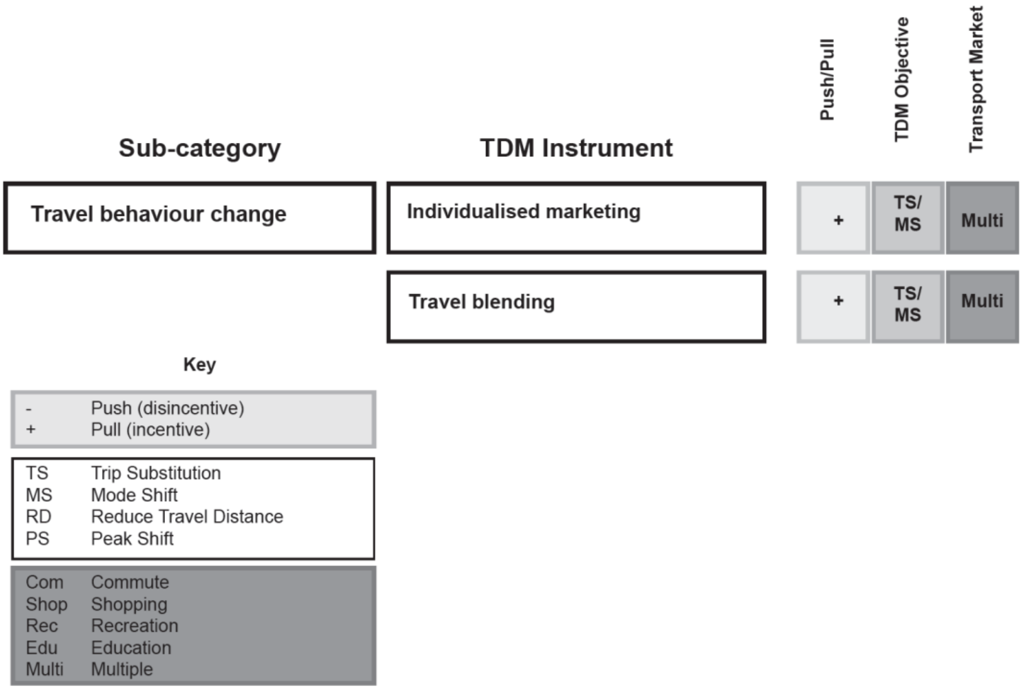

Figure 11: Travel behaviour change

Travel behaviour change can occur when individuals initiate change towards more sustainable travel behaviour and habits without coercion from government through 'push' policies. Travel behaviour change programs are targeted towards changing the decision-making and behaviour of individuals, households or workplaces usually through a range of strategies including the provision of information, support and feedback, and incentives for sustainable travel. Decisions regarding travel are made at different scales: individual travel behaviour; household travel behaviour; and workplace travel behaviour. Travel behaviour change programs are targeted at behaviour at each of these scales, often at different types of travel including the commute to work and school travel. Australia, and Perth in particular, have been at the leading edge in travel behaviour change policy over the last twenty years (See **Case Study 7** for more details). A couple of examples of travel behaviour change programs are:

- **Individualised marketing** refers to travel behaviour change programs that are specifically designed for individuals. The programs involve targeting individuals and households with information regarding sustainable travel options and benefits. **Indimark™** is a travel behaviour change program that targets individual travel mode change through providing information regarding existing services and infrastructure. The objective of this approach is, not necessarily to change the amount of travel but rather the mode of travel, away from SOV use to more travel by public transport, cycling and walking.
- **Travel blending** is a program that has the objective of increasing households blending of travel modes and blending of activities in order to reduce travel (Ampt 2003). The program involves households keeping diaries of travel behaviour in conjunction with the provision of information and education about such factors as the rates of emissions and costs. Travel

blending programs can incorporate a wide range of participant organisations including transport service providers, local governments, businesses in the community, schools as well as households and community groups.

Case study 7: Travel Behaviour Change Program
Travel Smart in Australia

In the late 1990's growing concerns over urban traffic congestion and the environmental impacts of increasing motorisation led to a new TDM strategy used by the Australian federal and state governments. Travel behaviour change programs were incorporated into the suite of most state government transport policies and resulted in Australia becoming an international exemplar for the use of travel behaviour change programs as a strategy for demand management. Travel behaviour change programs have now been used by several Australian State Government agencies for over a decade. Some examples of travel behaviour programs developed and implemented by state government agencies in Australia include:

- An **individualised marketing** program was trialled in South Perth, WA in 1997 involving 380 households. The program was followed up with a larger program in 2000. The program involved marketing travel behaviour change through personalised information and incentives. The program was evaluated through before and after surveys and found to be an effective in managing travel demand, with decreases in the percentage individual car trips and increases in the percentage of trips by all other modes (Roth et al 2003), although these findings have been disputed (Stopher 2003).
- A t**ravel coaching** program was implemented in in Adelaide, SA (Roth 2011) involving the individual coaching of fifty volunteers at the University of South Australia.
- A **travel blending program** was undertaken in Adelaide, involving 96 households (Rose and Ampt 2001). Information regarding 'blending' household activities was provided to the participating households and travel diaries captured before and after travel behaviour. The program also involved a range of neighbourhood scale service providers, including local government and community organizations.

A **Travel Smart Local Government Program** saw the WA State Government provide seed funding for local government travel smart officers. The officers were involved in the implementation of household and community travel behaviour change programs, helped liaise between local and state government, and were change agents within the local government organisation (Murphy 2012). Evaluations of travel behaviour change programs suggest that they are an effective means of managing key types of demand for travel. Stopher et al (2004) identified four issues that evaluations of travel behaviour change programs need to address. These are 1) a survey of the travel behaviour of participants before and after program implementation; 2) data on the number of trips, distance and time travelled and travel mode; 3) the necessity of a large sample in order to detect small changes to travel behaviour; and 4) the need to evaluate social, heath and community benefits of travel behaviour change.

4.5 Information and Communication Programs

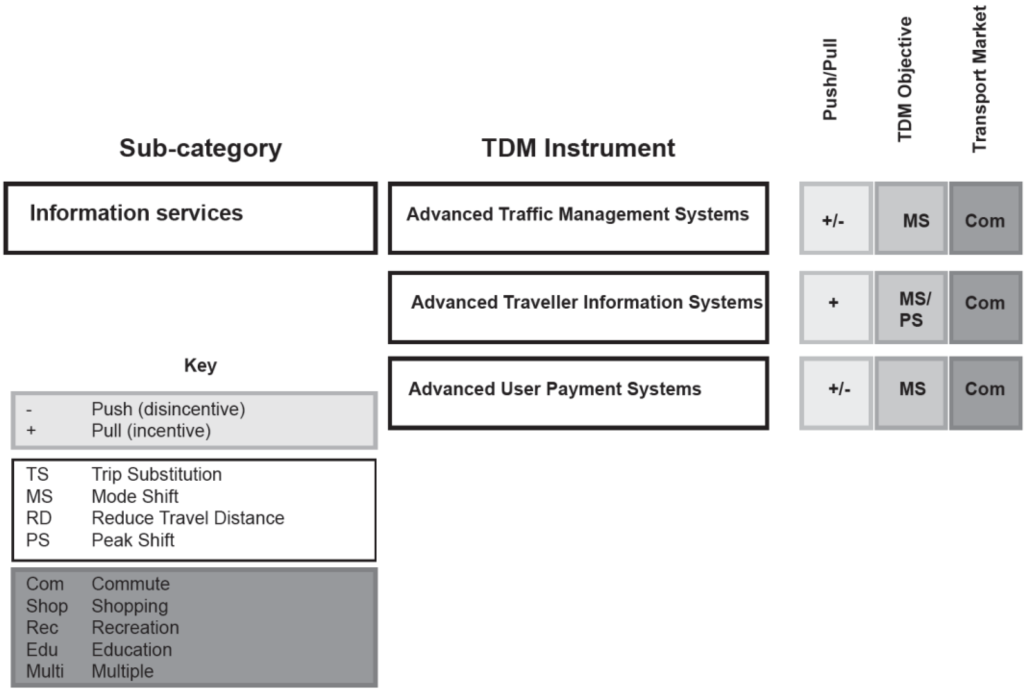

Figure 12: Information and communication programs

The use of communication information better informs potential drivers' decision-making with regard to travel. Although many information programs are utilised in the management of movement of existing traffic on the road system (lane choice) and therefore are outside the scope of this report, there are a number of examples of the use of information programs to manage decisions regarding route and mode choice and the time of travel.

- **Advanced Traffic Management Systems (ATMS)** involves the use of communication and sensory technology to manage traffic flow. ATMS may be used as a TDM instrument by improving the travel time and reliability of vehicles other that SOV through traffic signal priority and responsive lane restrictions to encourage high occupancy vehicles, PT and or/freight vehicles and discourage low occupancy vehicles (Rose 2007).
- **Advanced Traveller Information Systems (ATIS)** are systems that provide information to potential drivers in order to influence departure time, mode or route choices (Rose 2007). ATIS may use radio, wireless or mobile phone technology in order to communicate real-time transport services and conditions of congestion on routes. ATIS may be useful as a TDM instrument for non-recurring congestion; for example pre-trip information on congested routes may allow travellers to select a different route or time of travel. Alternatively, ATIS may also be utilised in communications regarding the real-time information of public transport services and may contribute to higher overall rider satisfaction with alternative modes to SOV.
- **Advanced User Payment Systems (AUPS)** are integrated payment systems that improve the efficiency of transport systems that require payments. AUPS may be used for public transport systems, enabling users to better integration between modes. AUPS may also be used for integrated payment with parking and tolls along with broader pricing initiatives such as congestion pricing (Rose 2007).

4.6 Management of Road Space

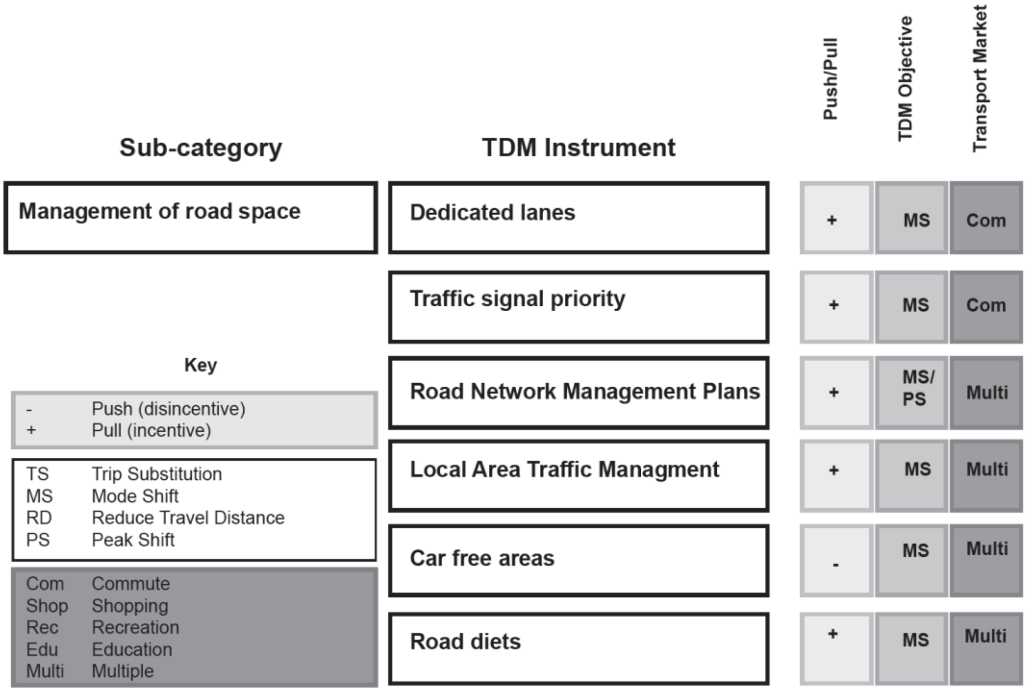

Figure 13: Management of road space

Management of road space can manage travel demand through the restriction or prioritisation of particular modes in areas or road lanes, or alternatively by managing the impact (speed and volume) of motorised vehicles in order to improve other modes of travel such as cycling and walking. It is important to note that some objectives of the management of road space may not necessarily relate to TDM. In many cases the management of road space is used to better facilitate the movement of motorised vehicles within transport systems. Management of road space becomes a TDM instrument when the focus is on switching from Single Occupancy Vehicles (SOV) to High Occupancy Vehicles (HOV), and therefore decreasing the demand for road space per traveller. Examples of the management of road space for TDM are:

- **Dedicated lanes** may be provided for buses or HOV vehicles in order to allow these vehicles to travel unimpeded along congested roads. Dedicated lanes are usually located adjacent to lanes for general traffic and they may be permanent or operate in peak travel periods (see **Case Study 8**).

Case Study 8: High Occupancy Toll (HOT) Lanes
San Diego, U.S.

The U.S. Federal Highway Administration (2001) introduced a three-year demonstration project of High Occupancy Toll (HOT) lanes on the I-15 in San Diego in 1998. Volunteer SOV were charged for use of the HOT lanes. Two types of pricing structures of HOT lane use were used during the demonstration program. The first involved a fixed monthly fee for participants in the program and the second involved a variable charge according to the level of congestion on the road. Revenue raised by the program was partly hypothecated and redirected into public transport improvements along the corridor. An ex-post evaluation of the program involved traffic studies including traffic volume, mode, speed and time, as well as panel surveys gathering attitudinal responses of HOT lane users. The evaluation found that during the demonstration program use of the HOT increased and SOV users of the HOT lanes reported travel timesavings. The variable charge for HOT use resulted in a greater spread of peak traffic volumes in HOT lanes as SOV drivers responded to higher prices during congested periods and chose not to use the HOT lane, or chose to travel at less congested times when prices were lower. Furthermore, the variable price was more acceptable to the program participants than the fixed monthly fee. Part of the revenue raised from HOT lanes was used to fund a bus service along the transport corridor. The evaluation found that there were modest increases to ridership of the bus service; however the increase in ridership did not meet the original objectives of the program.

- **Traffic signal prioritisation** gives road-based public transport, such buses and trams, priority at traffic signals in order to maintain or improve reliability of public transport vehicle flow. Approaching buses and trams may automatically or manually prompt traffic lights.
- **Road network management plans** are integrated tools for monitoring and managing the functioning of road networks. The plans use a range of land use and transport network indicators to inform policy decisions relating to the management of travel demand, the reallocation of road space and guidance on future infrastructure investment. Two examples are illustrative of the application of road network management plans as travel demand management tools. Firstly, the Link and Place approach (Jones and Boujenko 2009) is based on the recognition that streets serve both functions as links for transport journeys, and as places for conducting activities. Streets are identifying according to a matrix of link and place values with twenty-five potential types of streets. The matrix can inform trade-offs between link and place functions in future planning for changes to adjacent land uses and for the functioning of the transport system. The second example is Melbourne's road networking operating plan Smartroads. Smartroads identify a road hierarchy based on the intended priority modes, land use activity and the time of day road use is generally higher. The road hierarchy is then subject to network operating analysis, effectively evaluating Level of Service, relative priority and relative efficiency, and then identifying operational gaps in the network (Wall 2011). The Victorian Auditor General's report (2013) into managing traffic congested found that the SmartRoads initiative has significant potential to address congestion issues in Victoria but lacked a clear implementation plan in order to fully leverage network wide benefits.
- **Local area traffic management (LATM)** refers to the use of traffic calming infrastructure to reduce vehicle speeds and consequently improve the safety of local streets for pedestrians and cyclists. LATM shares similarities with other street scale improvements (See Section 4.1.1. above).
- **Car free areas** are used to restrict vehicles from roads in designated areas permanently or at different times of the day or week. Car free areas are used in many European cities such as Rome and Oxford in the U.K and are usually located in city centres, commercial districts, or where there is a high volume of pedestrian activity. City centres can also have restrictions for some vehicles and not others. For example vehicles with licence plates ending in odd (even) numbers may be restricted on odd (even) days. Examples of cities that have area restrictions based on licence plate numbers include Athens and Mexico City. However, such schemes have been found to lead to perverse outcomes such as households purchasing additional cars in order to avoid restricted travel (Eskeland and Feyzioglu 1997).
- **Road diets** involve the reduction of road space for vehicles and the reallocation to other modes of travel. Road diets work as a demand management tool by removing the supply of existing road capacity. Typically, road diets involve the conversion of four lane roads to three lane roads – one lane for each direction and a central turning lane. This reallocation of road space can be achieved through repainting the road surface, or through the installation of road infrastructure such as raised medians. Typically, road diets can contribute benefits in three ways (Tan 2011). They can improve the operational efficiency of vehicle traffic by separating

turning vehicles and limiting the need to merge. They also improve the safety of the road conditions reducing the likelihood of rear-end collisions, limiting speeding and provide refuges for pedestrians. Road diets also increase the space on roads for streetscape improvements like trees and lights.

4.7 Governance and Administrative

Sub-category	TDM Instrument	Push/Pull	TDM Objective	Transport Market
Governance and administration	Vehicle quotas	-	TS/ MS	Multi
	Tradeable driving rights	+/-	TS	Multi
	Area wide transport plans	+	TS/ MS/ PS	Multi
	Transportation partnerships	+	TS/ MS/ PS	Com
	Travel/public health campaigns	+	MS	Multi
	Car share schemes	+/-	TS/ MS	Multi
	Shuttle bus services	+	MS	Multi
	Carbon reduction or air quality targets	+/-	TS/ MS	Multi

Key

-	Push (disincentive)
+	Pull (incentive)
TS	Trip Substitution
MS	Mode Shift
RD	Reduce Travel Distance
PS	Peak Shift
Com	Commute
Shop	Shopping
Rec	Recreation
Edu	Education
Multi	Multiple

Figure 14: Governance and administration

Governments can use regulatory mechanisms to manage travel demand. Governance based TDM instruments may involve the direct intervention into travel markets to provide disincentives for SOV use or incentives for alternative modes. Alternatively, they can be regulatory mechanisms that facilitate relationships between public and/or private organisations and local businesses. These instruments strengthen existing, or create new opportunities, for communication and collaboration. Governance based TDM instruments usually are based on legal or statutory mechanisms.

- **Vehicle quotas** are TDM instruments that ration vehicle ownership and sometimes the use of vehicles at particular times or places. There are a number of different methods that can be used to organise the quota system, including a public auction of a quota number of licences to own vehicles, or through the use of allocating quotas to access city centres by licence plate numbers. For an example of a vehicle quota system see **Section 5.5** on Singapore.
- Vehicle quotas can be incorporated into **tradeable driving rights/ permit schemes.** These schemes involve the introduction permits or quotas to access roadways. Such schemes allow

the pricing of scarce resources according to market mechanisms. The cost of access to roadways at peak times is driven by the exchange of driving rights permits.

- **Area wide travel plans** are plans that outline actions to limit travel or shift demand to public transport, walking and cycling within a neighbourhood or precinct area. Sometimes area wide transport plans may incorporate travel co-ordinators; usually professionals who provide individualised or group advice and assistance to business-owners, employees or residents regarding transportation options (see **Case Study 9**).

Case Study 9: Area wide travel plan
Rouse Hill, N.S.W.
Source: Wiblin et al. (2012) see also Premier's Council for active living (no date)

Planned since the early 1980's, the Rouse Hill Town Centre is a transit-oriented development located in an urban growth area, 40km north west of Sydney. When completed, the 122 ha development site is planned to accommodate 4,500 new residents, 1,800 dwellings and generate 12,000 permanent jobs (Premier's Council for Active Living 2010). Travel demand management was planned into the development. Through a developer contribution, $3 million were allocated specifically for TDM and a further $16 million for other sustainable transport instruments.

One TDM developed for managing travel demand in the Rouse Hill Town Centre was an area wide travel plan. A number of key features were incorporated in the Rouse Hill Area Wide Travel Plan. These included:

- A dedicated transport co-ordinator.
- A Green Travel Club for employees of the Rouse Hill development. The club provided opportunities for networking, rideshare information, social events and incentives for sustainable transport to and from and within the development.
- A shop-front for 'green travel' information within the Rouse Hill Town Centre.
- Events and promotions.
- An advocacy body for the development's sustainable transport objectives.

In an evaluation of the early-stages of the TDM initiative, Wiblin, Mulley and Ison (2012) conclude that area-wide travel planning is more complex than workplace-based travel planning. The experience at Rouse Hill Town Centre demonstrates that area-wide travel planning must address the travel behaviour for a range of different groups and individuals – employers, employees, residents, commuters, and shoppers.

- **Transportation partnerships or transportation management associations** involve the collaboration of public, private organisations and local businesses in addressing travel issues over a precinct or regional scale. The purpose of partnerships may range from providing information and networking opportunities for sustainable mobility programs, through to allocating grants and funds for transport improvement projects. TDM may occur through travel planning, behaviour change programs or the provision of infrastructure for pedestrians, cyclists or public transport users.
- **Travel safety, public health or environmental awareness campaigns** may be used to communicate messages to the public regarding the health, wellbeing and environmental benefits of active travel or reducing SOV use.
- Businesses or workplaces may have **car share schemes** that provide short-term hire of cars. By providing opportunities for households and individuals access to a car when travel by car is essential, the cost of vehicle ownership may be reconsidered.
- **Shuttle bus services** may be provided by government agencies in order to provide small-scale transport options that are responsive to the needs of some community members. Shuttle buses can be used for travel to shopping centres, places of education such as universities and technical colleges, or public transport stations and exchanges.

- **Carbon reduction or air quality targets** are indirect TDM instruments, providing organisations and workplace specific carbon reduction or air quality targets that may instigate other travel reduction or sustainable mobility policies and mechanisms.

4.8 Parking

Parking is an influential factor in shaping demand for travel. As cars spend most of their time parked, the availability and cost of parking spaces at origins and destinations plays an important role in shaping the decision to own and use motor vehicles. Applying a price for parking increases the total cost of travel and therefore can lead to a decrease in demand for travel by private vehicles. Parking as a TDM instrument may be used in two ways: managing the demand of the existing parking supply, or adjusting the supply of parking.

4.8.1 Parking Demand Management

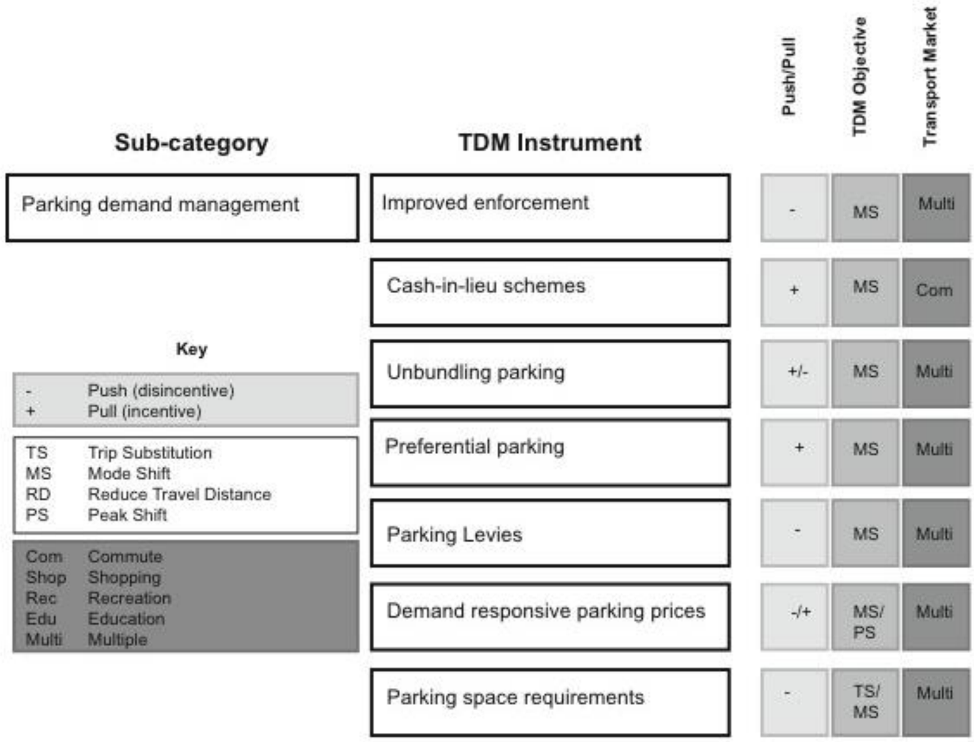

Figure 15: Parking demand management

The management of demand for existing parking spaces enables a more efficient use of both land resources and road spaces. Drivers cruising for parking can contribute significantly to the congestion on roads (Shoup 2006). Managing the demand for car parking spaces can therefore influence the level of congestion on roads. TDM parking policies and instruments are often based on creating efficient markets by revealing the hidden costs of parking spaces. The correct pricing of car parking space influences both the level of demand for vehicle travel and the duration that the car is parked. However it should be noted that the management of demand for parking influences vehicles driving to destinations within areas where parking is priced. Parking demand management instruments do not influence arterial traffic passing through a parking area, and the effectiveness of parking policies in limiting congestion may be undermined by the price of parking in adjacent areas outside of parking policy areas that may attract drivers.

A number of instruments are identified in the TDM matrix related to the management of parking demand.

- **Improved enforcement** means that existing on-street parking restrictions are better monitored and enforced. Improving enforcement can contribute to the successful operation of other parking policies and therefore may have an indirect influence on the management of travel demand.
- **Cash-in-lieu of parking schemes** offer employees the option of receiving cash as an alternative to employer provided car-parking spaces. The option allows greater flexibility for employees who can commute to work by modes of transport alternative to SOV to forego parking spaces that they may never use.
- **Unbundling parking** refers to the process where parking is separated from individual dwellings (usually apartments and units) in order create a distinct market for car parking spaces. Unbundling parking spaces allows the cost of parking spaces to reflect land values therefore creates its own market conditions – i.e. residents may choose not to purchase or rent an additional parking space, and instead substitute car travel with public transport use.
- **Preferential parking spaces** may be provided to HOV in order to provide an incentive for people to car pool to work or events. Preferential parking spaces may be used when parking supply is limited and there is excess demand for parking space, or they may be provided in attractive locations (i.e. the closest space to destinations). Discounted rates may also be provided for preferred travel types. For example, in the Perth CBD, three car parks currently provide discount rates for carpool vehicles.
- **Parking levies** are area wide pricing strategies that impose a levy on existing parking spaces. Many Australian cities currently use levies as a means to reduce congestion into central business districts, provide more desired types of parking (for example, applying the full levy to long-stay parking and reduced levy or exemptions for short-stay parking) and as a source of revenue, often to fund alternative travel options (See **Case Study 10**).

Case Study 10: Parking Levies
Perth and Melbourne, Australia

Perth: Following a doubling of central Perth's parking supply from 1975 to 1995, the City of Perth and WA State Government responded by implementing the Perth Parking Policy in 1999 (Richardson 2014). The policy provided guidance on the administration of the Perth Parking Management Act 1999, with the objective to create a more balanced mode share for travel to the Perth CBD. It sought to do this with a number of key strategies: the setting of maximum requirements of parking spaces for non-residential developments within the city, based on floor space ratios; imposing an annual licence fee (parking levy) for non-residential parking hypothecated to fund the Central Area Transit (CAT) service; matching the supply of parking to complement the broader function of the streets; and the identification of parking zones (pedestrian priority, short stay and general parking zones) in the city to manage the duration of parking. The annual licence fee in 2014 ranged from $630 to $730 per parking space.

Melbourne: The Victorian Government introduced a parking levy for central Melbourne and adjacent areas in 2006. The levy is applied to "off street" parking spaces within the levy area. The levy area is divided into two sections, the Melbourne CBD where the full levy is charged annually ($1300 in 2014), and adjacent areas to the CBD where a reduced levy is charged ($950 in 2014). Hamer et al (2011) evaluated the impacts of the levy, finding that the effectiveness of the levy was hindered by parking providers not passing on the full costs of the levy to drivers. The authors suggest that the actual price of parking, not the amount of the levy, is the critical determining factor in the effectiveness of levies to reduce congestion.

- **Demand responsive parking prices** are schemes that allow the cost of parking spaces to vary according to the time of day. In a study of the effects of demand responsive pricing in Seattle, U.S., Ottosson et al (2013) concluded that price elasticity does vary at different times of the day and can be used to determine pricing for parking during peak and non-peak periods. The outcomes of such market based instruments for parking, as illustrated by demand responsive pricing, is that the costs of travel by car (for example, the opportunity cost of land taken up by parking spaces) are incorporated into individual decision-making regarding travel, and that there are less individuals 'cruising for parking' and therefore less congestion on roads (see **Case Study 11**).

Case Study 11: Demand Responsive Parking Price Schemes
SF Park, San Francisco, U.S.

In 2011 the City of San Francisco introduced an innovative performance-based parking program. SF Park is a citywide parking program that used parking sensors and metres to allow parking prices to respond to demand for parking. The price of street parking spaces varied based on occupancy rates, informed by research by Shoup (2011). In other words, the more demand for on street parking at particular times and in particular places, the higher the price of parking spaces, and therefore a responsive lowering in overall demand for spaces. The program was justified on the basis that it would reduce congestion, create safer streets and improve the economic viability of the streets, neighbourhoods and the city centre. The ambitious program was partly funded by a U.S. Department of Transportation grant.

An evaluation of the program is currently under way. The evaluation will be based on an extensive database informed by the ongoing monitoring of occupancy rates. SF Park (2014) identifies four expected outcomes of the evaluation.

1. Increased parking availability.
2. Reduced parking search time.
3. Reduced cases of double parking
4. Decreased long-term on street parking.

- A regulatory approach to parking demand management is the use of **parking space requirements** for developments. Requirements for developments to supply certain amounts of parking spaces are set out in town planning schemes. Through a better understanding of the potential level of demand for parking spaces in an area, a maximum parking supply may be define and parking space requirements may be adjusted to reflect the desired level of parking. Maximum rates of required parking spaces (rather than minimum requirements currently defined in town planning schemes) may be defined to cap supply in certain areas.

4.8.2 *Parking supply*

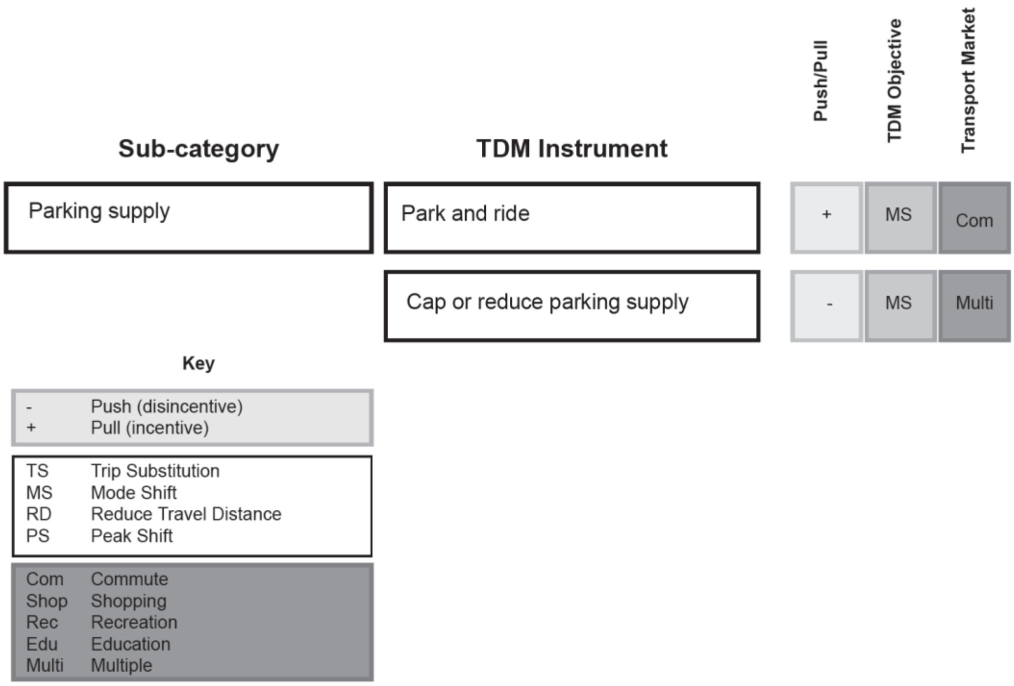

Figure 16: Parking supply

Travel demand may also be managed by adjusting the supply of car parking spaces. TDM may occur by either increasing or decreasing supply. For example, car parking may be increased at public transport stops in order to facilitate the use of public transport to access activity centres. Alternative, car parking may be decreased in areas that are sufficiently serviced by public transport in order to shift demand to alternative modes of travel to SOV.

- **Park and ride** involves the increase of parking supply at public transit interchanges in order to facilitate inter-modal connections. Park and ride is used extensively in Western Australia, as well as the U.K., Sweden and the U.S., as a means of providing access to public transport for large urban catchments of low-density residences. Park and ride facilities may also be provided for bicycles.
- **Parking caps** involve the decrease or limitation of parking space supply in activity centres in order to facilitate a shift in demand to other modes of travel. Parking caps have been used in the Perth central business district since the 1980's and there are now parking caps at Murdoch and Curtin activity centres. The parking caps are determined by modelling of the regional road network at peak conditions and are allocated based on bays per hectare of site area.

4.9 Taxes and charges

Taxes and charges are pricing mechanisms that create a disincentive for SOV use and encourage a shift in demand for alternative modes. The use of tax and charges is often justified by the assumption that the incorrect pricing of transport services and infrastructure results in over-consumption and that the means to address this is through the use of pricing signals. There is widespread support among transport economists and increasingly among transport bureaucrats, that some form of pricing of congestion would be the most effective means to manage the demand of use of urban roadways (King, Manville and Shoup 2007; Hensher and Bliemer 2014). However, the acceptability of pricing mechanisms aimed at decreasing peak-hour congestion amongst the public, is often raised as a significant barrier. There have been innovative approaches to addressing this barrier (see **Case Study 12**) but it remains that political factors are a significant factor in the planning and implementation of taxation and road use charging schemes.

4.9.1 Taxes

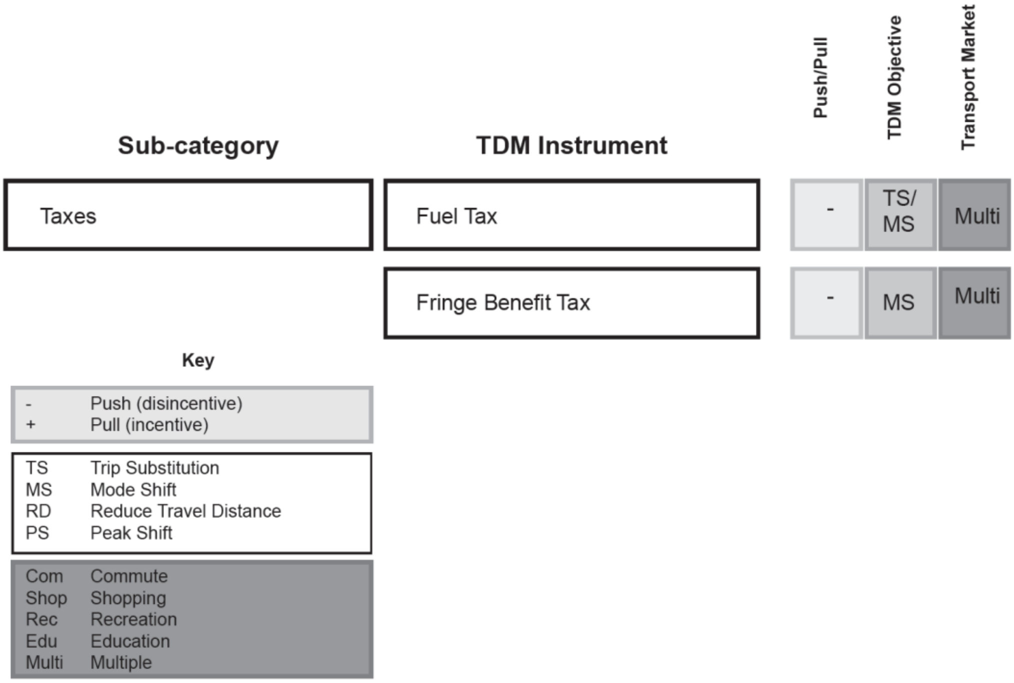

Figure 17: Taxes and charges - taxes

- **Fuel taxes** increase the marginal cost of kilometres driven and can be used to reduce overall demand for travel by private motorised vehicles. However, as fuel taxes are usually broad-based and not targeted towards travel along particular routes or at the busiest times, they are not particularly effective in the management of demand to reduce congestion.
- Workplace taxation schemes may be designed in such a way that incentivises SOV use. The **fringe benefits tax** (FBT) is an example where the design of the tax incentivises car ownership as part of a salary package and promotes car use as a means of lowering taxation rates. TDM may also address the redesigning of taxation schemes in order to avoid incentivising car ownership and use.

4.9.2 *Road user charges*

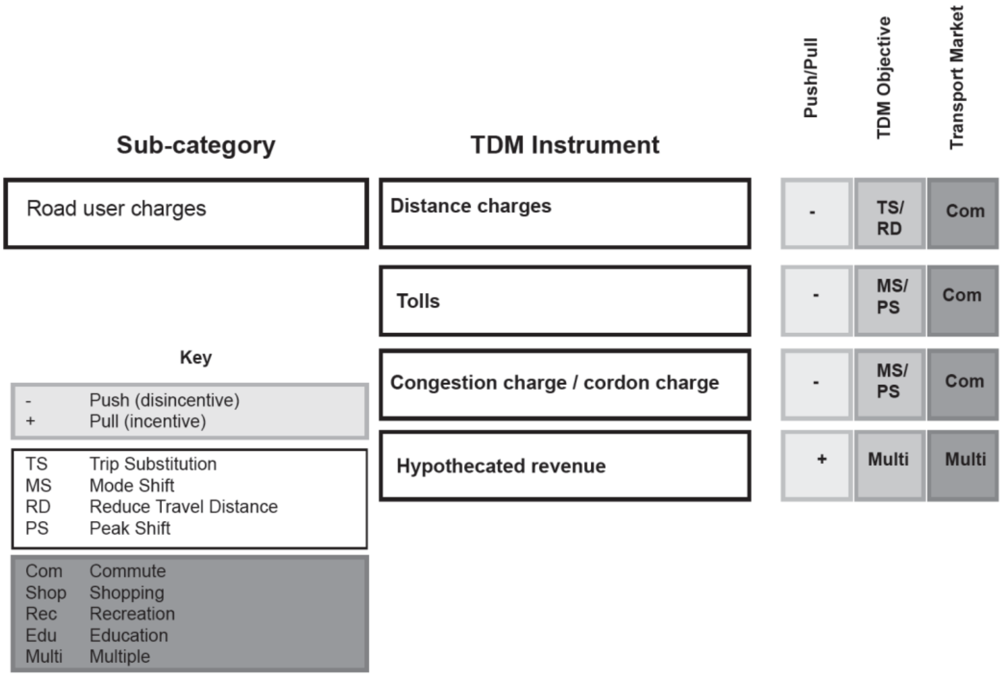

Figure 18: Taxes and charges - road user charges

Three types of instruments illustrate road use charging as a demand management mechanism

- **Distance based charges** allocate road use prices according to the overall distance vehicles travel. Distance based charges are often collected once-a-year, through insurance or vehicle registration transactions. Annual distances travelled are usually recorded by odometer readings. In Germany, the LKW-Maut is a road user charge for freight vehicles based on the distance driven in addition to the vehicle type (number of axels and emission category of the vehicle). However, it is important to look at the design and overall objectives of charges in order to appraise their potential to manage travel demand. In the case of LKW-Maut, it is arguable whether TDM was the intended outcome of the design of the charge, as revenue raised by the charges is directed towards expanding and maintaining the road system – hence supply factors. The use of **time-based charges** as well as distance-based charges may allocate prices for road use more effectively. Road use is charged at varying peak and non-peak rates. The cost of travel for the road user is based on the overall use of the road at that time.
- **Tolls** are charges for the use of various transport infrastructure such as roads, bridges and tunnels. Tolls can be used as a TDM instrument if the toll charge is based on a variable pricing structure and higher prices are set during periods of high congestion. Although tolls are often used to fund transport infrastructure, often this is usually road infrastructure and therefore reduces their effectiveness as a demand management tool.
- **Cordon charging** involves charging drivers when they enter a cordon area, usually a city-centre. The cordon charge may make other modes more attractive, shifting demand away from private vehicle to public transport, for example. The cordon charge also works as a disincentive for vehicles moving through the cordon area, as opposed to vehicles travelling to a location within the cordon (Ker 2003). In this way the cordon charge has the effect of freeing space in congested city roadways for consumers and employees of city firms improving economic efficiency of city centres. Lower volumes of vehicles may also improve inner city environments for walking and cycling. London, Stockholm and Singapore provide examples of

cities that have implemented cordon charging (See **Case Study 12** for an overview of the Stockholm congestion charge).

Case study 12: Cordon Pricing
Stockholm, Sweden.

The public's acceptance of TDM instruments is a critical factor for the successful implementation of TDM policy. For example, whilst road pricing is widely accepted as a sound and effective way of managing travel demand, as Zhu, Du and Zhang (2013) note, there are major barriers in the form of public acceptability based on the perception that road pricing is an additional tax on congestion, the additional transaction fees, the welfare and distributional costs, and concerns over privacy. Ubbels and Verhoef (2005) distinguish between public, political and business acceptability issues, although these are often interdependent.

In 2006 the city of Stockholm in Sweden introduced a **congestion charge** for motorists travelling into the inner urban core of the city. The congestion charge provides a useful case study of how TDM policies can be designed in order to improve the acceptability The congestion charge was initially introduced as a trial, followed by a referendum on whether the charge should be permanent. The initial trial ran for six months from January to July 2006. The cordon area was approximately 30km². Unlike the London cordon scheme which charged £5 (later £8) per day, the Stockholm scheme used a range of prices throughout the day. Higher prices were charged at peak hour in order to manage excessive demand and congestion. Concerns regarding the equity of the scheme were addressed through the use of exemptions to the cordon charge. Efficient fuel vehicles, vehicles owned by disabled drivers, taxis, buses and emergency vehicles were exempt from the charge.

The 'trial followed by referendum' model was a key factor contributing to the success of the scheme. The City of Stockholm articulated the intent of the congestion charge as a "test" to improve the efficiency of the transport system and stated an objective of a 10-15% reduction in vehicle traffic into the cordon area. Public acceptance of the charge increased substantially during the trial period. The trial was presented as part of a package of policies targeted to reducing congestion in the inner city. The two other primary policies that supported the congestion charge were increased public transport services (primarily buses into and out of the city at peak times) and increased park and ride facilities on public transport links to the city. Forecasted traffic studies revealed differing rates of reduction of traffic volumes as a result of the scheme, yet some evaluations indicate that the targeted reductions in volume of 10-15% were surpassed (Eliasson 2009).

- The public acceptability of TDM instruments, in particular 'push' mechanism that impose a disincentive on travel that leads to congestion, can be shaped by the strategic use of revenue generated by the instrument (Ubbels and Verhoef 2005). The use of **hypothecated revenue from a tax or road user charge** effectively commits the revenue for a specific purpose, in particular funding options that counteract direct effects of the tax. For example, the revenue raised by road use charges may be directed into improving public transport infrastructure and services to provide better alternatives to drivers who may want to avoid the additional cost associated with the road use charge.

5 TDM: Case Study Cities, Countries and Regions

5.1 Overview

The following section highlights some cities and regions that provide examples of the implementation of TDM policy instruments. Whilst international examples provide opportunities for policy learning, lesson about the practical implementation of TDM policies and insight into the capacity of TDM instruments to address travel demand, it is important to keep in mind that cultural, spatial and institutional contexts play an important role in the success and failures of TDM policies.

5.2 Vancouver

Over the past thirty years the greater region of Vancouver has become an exemplar city for a sustainable model of urban land use and transport (Punter 2003). The transformation began in the early 1990's where, supported by an extensive public participation program, a series of policy and plans and the creation of a regional scale of urban governance led to an integrated approach to land use and transport planning and infrastructure development. The management of urban travel demand has been a key objective in Vancouver's transformation. In the 1990's there was a planned increase in the supply of housing supply in the downtown Vancouver area. This increase in the capacity of centrally located housing was supported by improvements to the regional transport network with additional public transport infrastructure, such as the Skytrain, and support for other alternative modes of travel. In addition to improving the accessibility of the downtown area, Vancouver's regional growth strategy identified **transit oriented developments** (TOD) as a strategy to reduce car travel and urban sprawl in the greater Vancouver region. TODs are developments that integrate land use and transport objectives and manage travel demand through providing accessible alternative to SOV use and through reducing the need to travel great distances by containing activities within a higher density urban precinct. An example of a successful TOD is Collingwood Village located at the Joyce-Collingwood station on the Expo line of Vancouver's elevated rail, the Skytrain. Collingwood Village is part of corridor of connected TODs. Some of the development's features include high quality public spaces, extensive bicycle parking, underground car parking and a variety of housing types.

Vancouver has also implemented other policies supportive of managing travel demand. There have been a number of regulatory changes to the **supply of parking** in Vancouver. For example, the municipality of Vancouver, including the central business district, has maximum parking requirements. New developments with access to good quality public transport stops and stations are occurring with unbundled parking. The TOD Marine Gateway is an example of a development that has unbundled car parking spaces from the sale of apartments. Another example of innovative TDM approach is the **car share schemes**, MODO. The scheme was established in 1997 and allows long or short-term hire of a range of vehicle types. The scheme has grown in popularity and is now being integrated with developments in the Vancouver area. For example, a development at Oakridge in Vancouver provides priority car park spaces for MODO co-op vehicles, similar to disabled access parking.

Vancouver's reputation as a leading region for innovative transport policy has much to do with the governance of its planning and transport functions. Governance refers to the spatial and institutional relationships between public, private and civic governing agents. Fragmented governance of transport systems impedes the implementation of TDM policy (Rietveld and Stough 2007). Metro Vancouver (formerly the Greater Vancouver Regional District) is the regional governing body representing twenty four local authorities. The objectives of the authority are to plan and deliver key urban utilities and service and provide democratic governance that enables greater participation from the public.

Translink is the regional transportation authority that plans, finances and manages all transportation infrastructure and services in the Vancouver region. Translink is controlled by local governments yet operated within a regional policy framework and is funded by revenue generated by fare and levies from the transport sector – charges, tolls, fines, fare, and fees. Although services are contracted, Translink was the first regional governing body in North America that had authority over all transport modes and systems.

5.3 The Netherlands

The Netherlands has a strong tradition of spatial planning and since the 1960's urban growth within the Netherlands has been shaped by a number of policies that integrate land use and transport planning (Schwanen et al 2004). From the 1960's until the late 1980's, **urban growth policies** were directed towards growth areas and sub-centres on the fringe of the urban centres, under a strategic directive of concentrated decentralisation. In the 1990's a policy shift towards consolidation saw urban growth channelled into existing urban centres. The urban centres of Netherlands including Amsterdam, The Hague, Utrecht, and Rotterdam are considered amongst the most successful exemplars of compact city policies (Hull 2011). These policies include subsidies for housing improvements in city centres and the **ABC location policy** (see Case Study 4).

The cities of the Netherlands, as well as many other northern European and Scandinavian cites, in particular Copenhagen in Denmark, are exemplars of **cycling friendly cities**. Pucher and Buehler (2008) evaluated the policies and approaches in these countries in order to provide an example of best practice planning for cycling, and founded the reasons these cities provide practicable alternatives to travel by motorised vehicles was through:

- dedicated bike lanes along busy routes, with good signage. In 2004 Copenhagen and Amsterdam had approximately 400km of dedicated cycle lanes each;
- area wide traffic calming in local streets;
- intersections designed to accommodate safe cycling;
- provision of bike parking;
- integration of cycling and public transport;
- bike education – for cyclists and motorists;
- traffic laws;
- promotional events; and
- a range of complementary taxation, parking and land-use policies.

The Netherlands has also produced a number of approaches to **street scale improvements** that have managed travel demand by making walking and cycling more attractive (Hamilton-Baille 2008). The woonerf or 'living streets' are streets that integrate pedestrian paths and the road into a singular surface. The streets often had entrances creating the feeling that one was entering a distinct area. The concept of the 'living street' has been revitalised in the broader 'shared space' movement that is based on the elimination of signage and visual cues for cars, requiring drivers to slow down and exercise caution in streets that are shared with pedestrians and cyclists.

5.4 London

In recent years London has introduced a number of innovative policies and schemes with the intention of managing travel demand and improving the urban quality of the city centre. The London **cordon**

charge provides an important international example of congestion pricing. The planning of the congestion charge began in 1998 as part of Mayor Ken Livingston's election campaign. Following a period of public consultation and debate, the charge was introduced in February 2003. Ison and Rye (2005) identify three factors that contributed to the successful implementation of the cordon charge.

1. Consensus that congestion was a problem.
2. The objectives of the charge were clearly articulated by policy makers.
3. The design details of the charge were simple and some degree of flexibility was evident to respond to implementation challenges.

The cordon area covers 21km² of central London, bound by an inner ring road with 174 entry and exit points. Motorists entering the cordon area between the hours of 7am and 6.30pm between Monday and Friday are required to pay a congestion charge. The cordon charge can be paid through multiple transaction points (internet, phone and shops) and is enforced through the use of 700 cameras. There is ongoing monitoring of traffic along the boundary road as it was highlighted that the road that could become highly congested as a result of the cordon charge. In order to address equity issues exemptions to the charge were granted to residents, private hire vehicles, alternative fuel vehicles, breakdown vehicles and emergency vehicles. The revenue raised by the cordon charge was reinvested in **improving London's public transport network and services**, contributing to the ease in which the policy was accepted and ultimately implemented (Ison and Rye 2005). In 2004, London also moved from requiring minimum off-street parking to imposing **maximum standards for off-street parking**, leading to a reduction of 40% in the parking supply (Guo and Shuai 2014).

London is also making changes to improve the quality of its streets for pedestrians and cyclists. An example of a **streetscape improvement scheme** is Kensington High Street, an important shopping precinct in London. The streetscape improvements, which began in 2000, involved the 'decluttering' of the streetscape and included the widening of pedestrian paths, provision of bicycle parking, additional pedestrian crossing and the simplification of street signage (Hamilton-Baille 2008). The improvements were based on the 'shared space' concept, where vehicles respond to the lack of visual cues such as signage and curbs and therefore reduce speeds and are more aware of pedestrians and cyclists who share the road space. A more recent example of a shared space street scheme is Exhibition Road in Kensington, the site of many key cultural institutions.

5.5 Singapore

Singapore has attracted much attention from transport policy makers and researchers due to its strong regulatory approach to managing travel demand of SOV. Singapore was an early adopter of policies that directly managed demand for SOV use. Singapore has used a **cordon charge**, the **Area Licencing System**, since 1975 charging drivers to enter the CBD. In 1998 the original system was changed from a paper based system charging cars to enter restricted zones per day, to an electronic system that charged cars each time they crossed the area boundary. Due to the success of the congestion charge, the scheme has been extended to additional congested major roads. In 1990 Singapore introduced a **Vehicle Quota System**, capping the number of vehicles permitted to use the road system. The quota is organised according to a competitive bidding process that allocates vehicle use entitlements for ten years. The vehicle quota system works is supplemented with vehicle purchase and ownership fees and taxes. However, it is important to note that car use has increased and the average distances travelled by cars in Singapore are high given the size of the island, possibly due to the ongoing expansion of road and highway capacity and little congestion (Lam and Toan 2006).

Singapore has also planned and invested in land use development and alternatives to SOV in order to manage travel demand. Singapore has an extensive rail system (Mass Rapid Transit), a smaller light rail system, bus system and a highly regulated taxi-cab service. To facilitate the movement of road based public transport and to better integrate travel between modes Singapore also uses additional TDM instruments including bus priority signalling, park and ride and integrated public transport networks and fare system. Since the 1970's land use planning in Singapore has resulted in increased densities in areas well supported by public transport.

6 Conclusion

This report presents the first part of an initial investigation into the potential TDM response to the issue of traffic congestion in Perth, Western Australia. The literature review informing this report was initiated in response to a question identified by the Transport Portfolio during the development of the PATREC Strategic Business Plan 2013-2016: *What are the key demand management instruments available for managing transport congestion in Perth?* To address this question this report presents a matrix of TDM instruments and provides a range of case studies illustrating concrete examples of a selection of TDM instruments and details on their implementation and evaluation in Australian and international contexts. A conceptual model guiding the categorisation of instruments was outlined, organising instruments according to the objective of travel demand management instrument, the relevant transport market, and whether the instrument provided an incentive to change mode from SOV, or provided a disincentive for SOV use. Accompanying this report on the range of TDM instruments available to policy makers is a second report that provides an overview of the possible appraisal tools, evaluation procedures, performance measures and congestion measures that may be used as the basis for selecting, implementing and reviewing TDM initiatives. Together, the two reports present the first stage in a broader inquiry into critical questions regarding the capacity of TDM to address congestion in Perth.

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APPENDIX

The Travel Demand Management Matrix

Improving alternative modes: **Improving modes of transport, such as walking, cycling and public transport, manages travel demand by increasing the attractiveness of alternative modes of travel to the private vehicle.**						
Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
Walking and Cycling	Network improvements	Providing or improving infrastructure, such as dedicated or shared paths, in order to extend the existing cycling and pedestrian network.	Pull	Mode shift	Multiple	In Bogota, Colombia the Ciclorutas is a city wide network of over 300 km of pedestrian and cyclist dedicated pathways. The Ciclorutas is supported by a secondary network, linking residential areas to activity centres such as Bus Rapid Transit stations.
	Street scale improvement	Programs that improve the quality and safety of local streets and major activity streets. Lowering traffic speeds in residential areas and around high trip attractors such as schools, shopping centres and main streets.	Pull	Mode shift	Multiple	An example of a main street improvement project is the recent development of 'shared space' approach in Kensington High Street, London. The Dutch concept of the 'woonerf', the UK 'home zones' and the US 'complete streets' are examples of approaches to streets scale improvement at the neighbourhood scale.
	Legislation and rules	Adapt laws and rules that improve the rights, safety and priority of cyclist and pedestrians in the transport system. For example rights of way, minimum clearance laws, and priority at crossings and intersections.	Push/ Pull	Mode shift	Multiple	The recent introduction of new cycling laws in Queensland requiring drivers give cyclists a 1.5 metre clearance is a relevant example.
	Education programs	Education and awareness programs for cycling and for road safety can develop confidence and skills for active	Pull	Mode shift	Multiple	Education programs for cyclists and pedestrians are common throughout the world, however the Netherlands and Germany have innovative

		travel. These are particularly effective with children and young adults.				travel education programs. The Netherlands 'traffic garden' built in the 1950's is an education centre featuring miniaturised streets where children can learn skills to navigate safely in city streets.
	Better integration with other modes	Providing transport infrastructure and/or services that facilitate inter-modal trips. This includes providing space for bikes on public transport, parking for bikes at stations, and locating public transport stops in close proximity.	Pull	Mode shift	Multiple	The Denmark Park and Bike Terminal in the City of Aarhus is a good example of a drive-ride intermodal project, where a commuter can drive a car with their bicycle to a terminal with sufficient parking space that is located on the main cycling network.
	End of trip facilities	Providing facilities such as bike-parking and showers for cyclists and pedestrians at key activity nodes, such as workplaces and stations.	Pull	Mode shift	Commute	The Netherlands and Denmark lead the way in cycling parking. An example is at the Utrecht Central Station.
	Bike share	Bike share programs provide short-term access to bicycles through a city-wide network of hire stations.	Pull	Mode shift	Multiple	Many international and national cities have bike share programs including New York, Paris, London, Melbourne, Melbourne and Brisbane.
Public Transport	Network improvements	Improving and/or increasing public transport infrastructure, routes or rolling stock in order to enhance the capacity and intermodal connections of the public transport network.	Pull	Mode shift	Multiple/ commute	In the early 1980s Portland transformed its transport system by reconfiguring its 'hub and spoke' bus lines that focused on the city centre, into a grid of frequent bus lines. The network plan improved connections and accessibility for city. See www.humantransit.org "Portland: the grid is 30 years old…thank a planner".
	Service improvements	Improving public transport services including the frequency and reliability of services. This may be achieved through integrating services and timetabling of different modes or through providing priority to public transport modes, such as priority lanes, dedicated lanes and signalling.	Pull	Mode shift	Multiple/ commute	Zurich in Switzerland uses 'pulse timing' to better integrate bus and rail transfers. Buses and trains are timed to arrive at transfers stations at half-hourly intervals, allowing better integration between inter-modal travel.
	Improved quality of stations and stops	Improving the quality of stations can lead to a more comfortable experience for public transport users and therefore increase its attractiveness as a mode of travel. Improvements may be better shelter at public transport stops, more lighting or safe road crossings adjacent to stations.	Pull	Mode shift	Multiple/ Commute	Many international and national examples.

	Improved information and ticketing	Improving useability of public transport timetables and ticketing information – online, at stops, on board – increases the legibility and ease of moving from mode to mode.	Pull	Mode shift	Primarily commute	There are many international and national examples of integrated public transport ticketing systems, such as the Oyster Card in London and Perth's Smart Rider. Tri-Met in Portland U.S., has introduced a mobile app ticketing system.
Other modes	Improved taxi services.	Improvements to the taxi services can lead to a reduction in the need for car ownership and can support travel by alternative modes, such as walking and public transport. Improvements may derive from increased services and the improved quality or efficiency of services.	Pull.	Mode shift	Multiple.	Many examples.
	Motorbikes and e-bikes	Providing adequate parking or prioritising the on-road movement of small vehicles, such as motorbikes and e-bikes, can contribute to a reduction in congestion (although motorbike transport may not necessarily lead to a reduction or shift in travel demand on roads).	Pull	Mode shift	Commute	North Sydney Council has provided electric bikes to council workers for work travel as a substitute for cars.
Financial incentives and subsidies	Reduce public transport fares	Providing subsidies or incentives for particular types of travel or travellers can contribute to modal shifts in peak hour.	Pull	Mode shift	Primarily commute	The use of fare concessions for student travel is widespread.
	Public transport to special events	Provide transport subsidies (like free PT travel) to major events in order to reduce congestion.	Pull	Mode shift	Recreation	An example of a major travel demand management strategy for a major event was Transport for London's plan for the London 2012 Olympics.
	Reward schemes	Reward schemes may be used to provide direct incentives to peak hour commuters who choose to travel outside the peak period, shift mode to public transport or choose not to travel and instead, telework.	Pull	Time of travel/ reduce travel/ mode shift	Commute	'Spitsmijden', a Dutch program launched in 2006, provided an incentive for drivers participating in the program to avoid peak hour travel in certain locations.

Integrated land use and transport: **The planning of land use that integrates existing and future planned transport networks and infrastructure, and vice versa, facilitates the development of urban forms and structures that may encourage travel by alternatives modes to SOV.**						
Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
Regional	Growth strategy	Growth strategies can enable better integration between land use and development planning and transport planning and policies.	Pull	Reduce travel/ Mode shift	Multiple	Many cities and regions have growth strategies. Portland, U.S. is frequently used as an example of a city with a growth strategy that successfully integrates land use and transport.
	Corridor planning	The integration of land use and transport planning for activity corridors -higher density; frequent PT service; linear transport networks; nodes of activity centres along corridors.	Pull	Reduce travel/ Mode shift	Multiple	There are many examples of corridor planning that integrates land use and a range of transport modes. Arlington in the U.S is one example.
	Transit Oriented Development	Increased residential density and mixed uses around public transport stations.	Pull	Reduce travel/ Mode shift	Multiple	Transit Oriented Developments are used in many city and regional approach to integrating land use and transport. Cities that have good examples include Portland, Vancouver, the Netherlands and Copenhagen.
	Accessibility and land use planning tools	Greater accessibility means that people can get to the activities they need or want to travel to easier. Measures of accessibility incorporate both land use and transport systems. Tools that measure accessibility can better inform planning for land use and transport.	Pull	Reduce travel/ Mode shift	Multiple	A tool developed by Curtis and Scheurer (2010), the Spatial Network Analysis of Multi-modal Transport Systems (SNAMUTS) is currently being used to evaluate the quality of urban transport networks in a number of national and international cities, as well as Perth.
Local	Impact assessment	Impact assessments are formal evaluations of developments, precincts or policies that can manage travel demand by incorporating assessment criteria that focus on improving outcomes for alternative modes of travel to the SOV.	Push/pull	Mode shift	Multiple	The UK has recently required developments that are likely to be large trip generators and attractors to be subject to a Transport Assessment.
	Travel plans	Travel plans consist of a package of strategies and instruments that promote alternatives to SOV use.	Pull	Mode shift/ reduce travel	Multiple	Travel plans are used extensively in the U.K. In London, the O2 (formerly the Millennium Dome) has an example of a best practice travel plan.

	Developer contributions	Financial contributions made by developers to fund public infrastructure, such as pedestrian or cyclist infrastructure, as part of approval of a development assessment or subdivision.	Pull	Mode shift	Multiple	Developer contributions are widely used by Australian planning authorities to provide transport infrastructure.
	School travel programs	Schools generate a large amount of travel activity. School travel programs may include improvements to the built environment, traffic safety, travel behaviour or flexible school start times in order to reduce vehicle congestion around schools and increase sustainable mobility.	Pull	Mode shift / time of travel	School	Many national and international cities, including Perth have examples of school travel programs. Many European countries such as the Netherlands, Germany, Denmark and Switzerland, have high rates of children walking and cycling to school.

Workplace-based instruments:

Workplace-based TDM instruments include a range of instruments that are provided to employees to encourage travel to work by modes other than SOV.

Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
Employer support	Car or van pooling	Employers can provide support for carpooling, or the shared use of commuting vehicles amongst two or more individuals. Also larger employers may rent small buses and vans to provide a vanpool commuter service.	Pull	Mode shift	Commute	Carpooling (or ridesharing) is commonly used in the U.S. Commuter Connections in Washington State is an example of a carpool scheme. Also see the San Diego iCommute Program.
	Preferential parking	Employers can provide parking to preferred modes of travel, for example carpool vehicles.	Pull	Mode shift	Primarily commute	Examples of the use of preferential parking are widespread. However, several Californian cities provide best practice examples as a travel demand management strategy. The City of Gardena has ordinances for workplaces to provide 10% of the parking to be located closest to workplace entries and to be reserved for carpool or vanpool vehicles.
	Guaranteed ride home	Guaranteed ride home is a service provided to employees who carpool, or use alternative modes to SOV to travel to work, where a 'ride home', usually by taxi, is subsidised by the employer in the case of an emergency.	Pull	Mode shift	Commute	Guaranteed ride home schemes are common in workplaces in the U.S.
	Bike storage/ end of trip facilities	The provision of good quality, end-of-trip facilities for active modes of travel. These can include lockers, showers, and parking spaces for bikes.	Pull	Mode shift	Commute	See 'End of trip facilities' in Improving Alternative Modes above.
Financial incentives/ disincentives	Subsidies for alternative modes	Employees may subsidise alternative modes to SOV including free public transport travel passes and subsidies for car-share schemes.	Pull	Mode shift	Commute	Eco-passes are used in the United States as a workplace travel demand management subsidy. Public transport agencies sell to employers the right to free travel for a group of their employees.
	Workplace cash-in-lieu schemes.	Commuters who are offered subsidized parking are also offered the cash equivalent if they use alternative travel modes.	Pull	Mode shift	Commute	The City of Nottingham in the U.K. has introduced a workplace parking levy that requires employers to provide a fee for the provision of car parking spaces at workplaces. The implementation of this controversial levy

						was facilitated by public consultation and the hypothecation of the generated revenue towards public transport improvements.
	Salary sacrifice schemes	Salary sacrifice schemes allow employees to receive part of their remunerations in the form of concessional tax benefits. Salary sacrifice schemes may incentivise either SOV use or alternative modes of transport depending on the agreements in place.	Pull	Mode shift	Commute	As part of a 'green transport plan', the U.K. government introduced legislation allowing employers to offer bicycles and related safety equipment as tax-free benefits for employees.
Alternative work arrangements	Flexible working hours or staggered start and finish times	Flexible starting and ending work times.	Pull	Time of travel	Commute	Flexible working hours are widely used (for example the Fair Work Ombudsman in Australia has guidelines).
	Compressed working week	Providing the option for employees to work more hours over fewer days.	Pull	Reduce travel	Commute	An example of a compressed working week policy used to manage travel demand is provided by Washington State Department of Transport: http://www.wsdot.wa.gov/choices/compressed.htm
Tele-working	Tele-commuting	Telecommuting involves employees partially or completely working at places other than the workplace through the use of communication technologies.	Pull	Reduce travel	Commute	Hub Australia (http://hubaustralia.com/) provides shared work and learning spaces in Melbourne, Sydney and Adelaide.
	Tele-conferencing	Tele-conferencing involves the use of communication technologies to allow meetings and conferences to be conducted from a range of locations.	Pull	Reduce travel	Commute	There is a wide range of companies that provide tele-conferencing technologies and support.
	Tele-shopping	Use of communications to purchase goods	Pull	Reduce travel	Shopping	Tele-shopping is now widespread.
	Distance Education	Partial or complete substitution of telecommunications for the attendance at primary, secondary or tertiary education sites.	Pull	Reduce travel	Education	Increasing in Australia and US.

Travel behaviour change programs: **Travel behaviour change programs usually include a range of strategies targeted towards changing the travel behaviour choices of individuals, households, schools or workplaces including the provision of information, support and feedback, and incentives for sustainable travel.**						
Categories	TDM Instrument		Push/Pull	TDM objective	Travel purpose	Example
	Individualised marketing	Individualised marketing of travel behaviour change programs use information, incentives and education in order to reduce or change the mode of individuals' travel. Participation is usually voluntary and programs are adapted for the relevant contexts.	Pull	Mode shift/ reduce travel	Multiple	There are many examples of individualised marketing of travel programs in Australia cities, including several interventions as part of Perth's Travel Smart program.
	Travel Blending	Travel blending approaches aim to improve the blending of travel activities in order to reduce travel. Programs usually involve travel diaries and monitoring of everyday travel activity.	Pull	Mode shift/ reduce travel	Multiple	There have been a number of examples of Travel Blending programs in Sydney and Adelaide (see Rose and Ampt 2001).

Information and Communication Programs:

The use of communication information in road transport better informs potential drivers' decision-making with regard to travel.

Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
	Advanced Traffic Management Systems (ATMS)	Use of communication and sensory technology to primarily manage traffic flow, not manage travel demand of SOV. However ATMS may facilitate other demand management measures including signal priority and linking, lane restrictions to encourage HOV, PT and or/freight vehicles and discourage low occupancy vehicles (Rose 2007).	Push/Pull	Mode shift	Commute	ATMS is well established across the US. Australian cities have adopted ATMS
	Advanced Traveller Information Systems (ATIS)	These systems use a range of telecommunications, wireless and visual technology to provide information to travellers in order to influence departure time or mode choice before the trip is undertaken (Rose 2007).	Pull	Time of travel/ Mode shift	Commute	The Pugent Sound Regional Council in North Western U.S. has incorporated a comprehensive ATIS system in their regional transport planning in order to support the management of travel demand.
	Advanced User Payment Systems (AUPS)	Managed payment system includes integrated payment and smart charging across modes and/or with parking and tolls along with broader pricing initiatives such as congestion pricing (Rose 2003).	Push/pull	Time/ Mode shift	Commute	There are few examples AUPS, but these systems may become more evident with technological innovations and in cities with multiple transport system transactions.

Management of road space: **Management of road space can occur through the restriction or prioritisation of particular modes in areas or road lanes, or alternatively by managing the impact (speed and volume) of motorised vehicles in order to improve other modes of travel such as cycling and walking.**						
Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
	Dedicated lanes	Providing road space for alternative modes, either by preferential treatment (HOV lanes) or by physical exclusion of vehicles (dedicated bus or bike lanes), increasing the efficiency and therefore attractiveness of these modes.	Pull	Mode shift	Commute	California in the U.S. has a large number of HOV lanes. For dedicated bus or bike lanes, cities such as Copenhagen, Amsterdam and Vancouver provide examples.
	Road Network Management Plans	Road network management plans are integrated tools for monitoring and managing the functioning of road networks.	Push/ pull	Multi	Commute	SmartRoads is a road network management plan used in Melbourne, Victoria (see section 5.6).
	Traffic signal priority	Enables buses/ light rail to control traffic signalling on roads in order to enhance the reliability and efficiency of the service.	Pull	Mode shift	Commute	Traffic signal priority for public transport is widely used including in Singapore, Calgary and Portland.
	Local Area Traffic Management (LATM)	The planning and management of local area road space to reduce vehicular traffic speeds and volumes, and improve amenity and safety for walking and cycling.	Pull	Mode shift	Multiple	Many Australian local governments have Local Area Traffic Management plans. For international examples of LATM see the Complete Streets and woonerfs discussed in 'Street scale improvements'.
	Car free areas	Cars and motorised vehicles are restricted in locations, such as alleyways or heavily pedestrianized city centres either permanently, temporarily or routinely.	Push	Mode shift	Multiple	Widespread including central Copenhagen, Oxford, Melbourne, and central Perth.
	Road Diets	Road diets involve the reduction of road space for vehicles and the reallocation to other modes of travel. Road diets work as a demand management tool by removing the supply of existing road capacity.	Push/Pull	Mode shift	Multiple	There are many examples of road diets in the United States.

Governance and administration: **Governments can use regulatory mechanisms to manage travel demand. Governance based and administrative TDM instruments may involve the direct intervention into travel markets, or regulatory mechanisms that facilitate relationships between public and/or private organisations and local businesses.**						
Categories	TDM Instrument	Description	Push/Pull	TDM objective	Travel purpose	Example
	Vehicle quotas	Vehicle quotas are TDM instruments that ration vehicle ownership and sometimes the use of vehicles at particular times.	Push	Mode shift / reduce travel	Multiple	Singapore has used a vehicle quota scheme since 1990. The quota is organised according to a competitive bidding process that allocates vehicle use entitlements for ten years.
	Tradeable driving rights/ permits	These schemes involve the introduction of permits or quotas to access roadways. The cost of access to roadways at peak times is driven by the exchange of driving rights permits.	Push/pull	Reduce travel	Multiple	An example of a tradeable driving right scheme is proposed by Raux (2004) in an issues paper published by the OECD and the International transport Forum.
	Area wide transport plans	Area wide transport plans are plans that outline actions to limit travel or shift demand to public transport, walking and cycling within a neighbourhood or precinct area.	Pull	All	Multiple	Rouse Hill in NSW is an example of a planned TOD with an area wide transport plan (see Case Study 9)
	Transportation partnerships	A non-profit, member controlled organisation that provides information, co-ordinates and manages demand in specific transport systems – for example a Transport Management Association.	Pull	Mode shift/ time.	Commute	A Green Travel Club was established as part of the Rouse Hill Town Centre in NSW. The club provided a travel coordinator, information, incentives and advocated for the travel needs of its members.
	Travel, public health or environmental awareness campaigns	Campaigns that raise the awareness of the costs of increased motorised transport and the benefits of non-motorised modes of travel.	Pull	Mode shift	Multiple	The Greater Wellington Travel Demand Management Plan contains a public awareness strategy.
	Car share schemes	Car share schemes allow members to reserve cars for short term use. Car share operators store and maintain vehicles.	Push/pull	Reduce travel	Multiple	An example of a well-developed car share scheme is mobil.punkt in Brenham, Germany. See: http://www.mobilpunkt.info/
	Shuttle bus services	Government may provide small vehicle shuttle services to provide public mobility – for example, demand responsive transport; special shuttle services; circulating shuttles.	Pull	Mode shift	Commute or shopping	There are many examples of shuttle bus services. For a list of TDM shuttle service case studies in U.S. cities see: http://www.vtpi.org/tdm/tdm39.htm

	Carbon reduction or air quality targets	TDM strategies may share synergies with carbon reduction or air quality targets. Such targets may require vehicle use restrictions in particular locations and at certain times.	Push/pull	Reduce travel/ Mode shift	Multiple	The European Union has regulated for Low Emission Zones that restrict vehicles or types of vehicles in many European cities.

Parking: **Parking is an influential factor in shaping demand for travel. Applying a price for parking increases the total cost of travel and limit demand. Alternatively, controlling the supply of parking can lead to a decrease in demand for travel by private vehicles.**						
Categories	TDM Instrument	Description	Push/ Pull	TDM objective	Travel purpose	Example
Parking demand management	Improved enforcement	Increased enforcement of parking restrictions to address problems such as parking spill over.	Push	Mode shift / time of travel	Multiple	Improved enforcement was used as a means to manage travel by the University of California, Berkley in their Parking Travel demand management Strategy.
	Cash-in-lieu of parking schemes	Cash-in-lieu schemes allow developers to reduce on-site parking for a fee. Revenue of the fee can be used to fund the provision or management of on-street parking. Cash-in-lieu schemes may be included in the land use planning systems or at the workplace.	Pull	Mode shift	Primarily commute	There are many local, national and international examples of cash-in-lieu schemes, however there are good examples in California and also Toronto.
	Unbundling parking	Unbundling parking refers to the process where parking is separated from individual dwellings (usually apartments and units) in order create a distinct market for car parking spaces.	Pull	Mode shift / reduce travel	Multiple	Soma Residences in San Francisco, a 278 unit development in an city area well served by public transport, provided 200 unbundled parking spaces. The use of parking is coordinated by a parking manager. The unbundled parking allowed the development to meet affordable housing objectives.
	Preferential parking	Prioritised parking spaces may be provided for preferred modes of travel (HOV) at workplaces (see above: Workplace-based instruments), shopping centres, public car parks or public transport stations.	Pull	Mode shift	Primarily commute	The City of Perth currently has three city car parks that provide discounted rates for carpool vehicles.
	Parking levies	Parking levies are area wide pricing strategies that impose a levy on existing parking spaces.	Push	Mode shift	Primarily commute	Perth, Melbourne and Sydney are examples of Australian cities that have implemented parking levies in their CBDs.
	Demand responsive parking prices	Demand responsive parking price schemes enable parking prices to adapt to the supply of parking in the system. Often demand responsive parking price schemes use communications and information technology to monitor	Push/Pull	Mode shift / time of travel	Multiple	SF Park in San Francisco is a good example of a large demand responsive parking price scheme (see Shoup's book *The High Cost of Free Parking* (2011)). Also Seattle, U.S., has recently introduced a performance based parking

		parking spaces, forecasts of travel times and enabling parking space reservation.				pricing. For a detailed report on the implementation of the policy see: http://www.seattle.gov/transportation/parking/docs/SDOT_PbPP_FinRpt.pdf
	Maximum parking requirements	A regulatory approach to parking demand management is the use of parking space requirements for developments. Maximum rates of required parking spaces (rather than minimum requirements currently defined in town planning schemes) may be defined to cap supply in certain areas.	Push	Mode shift	Multiple	Various maximum parking requirement schemes are used in central business districts in Australian cities including Melbourne and Perth.
Parking supply	Park and Ride	Park and ride involves the increase of parking supply at public transport interchanges in order to facilitate inter-modal connections.	Pull	Mode shift	Commute	There are many national and international examples of 'park and ride' schemes and Perth uses 'park and ride' in order to facilitate access to public transport stations.
	Parking caps	Intervening in parking supply can be used to manage the demand for SOV use by reallocating existing parking space, imposing maximum parking space regulations, or eliminating parking space altogether	Push	Mode shift	Multiple	Examples from San Francisco, U.S. are the Rincon Hill Plan (2005) and the Market and Octavia Neighbourhood Plan (2008). Perth has a parking cap on specialised activity centres such as Curtin University and the Murdoch Activity Centre.

Taxes and charges: **Tax and charges are pricing mechanisms that create disincentives for SOV use and can shift demand to alternative modes.**						
Categories	TDM Instrument	Description	Push/ Pull	TDM objective	Travel purpose	Example
Taxes	Fuel tax	A fuel tax works as TDM for aggregate travel but it is not well targeted towards demand related to geographic areas, different parts of the road network, and time.	Push	Reduce travel	Multiple	Fuel taxes are widely used to manage aggregate travel demand, however Australia is ranked as one of the lowest countries in the OECD in terms of the rate of fuel tax behind most EU countries (Bureau of Resource Economics 2014).
	Fringe Benefit Tax	Fringe benefit tax (FBT) exemptions may be granted to particular types of travel for company cars. The structure of FBT concessions may provide perverse incentives for car use. Alternatively, FBT can be redesigned in order to provide incentives for alternative modes of travel.	Push	Mode shift	Commute/ Workplace-based	In 2009, Pedal Power, a non-profit Canberra based cycling group made a submission to the Australian Tax Review, suggesting a repeal of FBT concessions for cars, the introduction of FBT concessions cycling and public transport, and corporate tax concessions for the provision of cycling friendly infrastructure and programs at the workplace.
Road user charges	Distance-based charges	Distance-based charges allocate road use prices according to the overall distance vehicles travel. In order for distance-based to address congestion, some incorporation of the time of travel, as well as overall distance travelled, is important.	Push	Reduce travel	Commute/ freight	Examples of countries with distance-based charges include New Zealand, Switzerland, and Germany (LKM-MAUT).
	Tolls	Tolls on roads, bridges and tunnels are often used to fund transport infrastructure. However this is usually road infrastructure and therefore reduces their effective as a demand management tool. Variable toll charges may be implemented in order to reduce demand for travel at congested times.	Push	Time of travel/ Mode shift	Commute	Oslo, Norway uses a toll tax to partly fund public transport infrastructure, although the large proportion of the revenue raised goes to funding road infrastructure.
	Congestion charge / cordon charge	A charge on travelling that is higher under congested conditions than uncongested conditions. An example of a congestion price is a cordon charges. Cordon charges are fees for motorists that enter a cordoned area, usually a city centre.	Push	Reduce travel/ Mode shift	Commute	Singapore, London and Stockholm have cordon-charging schemes in place. There are similarities and differences between the schemes but they are generally viewed by the public, policy-makers and academics (King et al 2007; Hensher and Puckett 2007) as effective

						programs to reduce inner urban congestion and provide a revenue source for alternative transport modes.
	Hypothecated revenue	The allocation of revenue, often raised by a toll or tax, for a specific purpose, in particular funding options that counteract direct effects of the tax.	Pull	Multi	Multi	The revenue raised through the Perth Parking Levy is hypothecated to fund the Perth Central Area Transit (CAT) service.

PART 2: REVIEW OF TDM APPRAISAL AND EVALUATION TOOLS

1 PURPOSE

The purpose of this part of the report is to give an overview of the possible appraisal tools, evaluation procedures, performance measures and congestion measures that may be used as the basis for selecting, implementing and reviewing TDM initiatives. This report provides an international review of the tools used to appraise the potential effectiveness of employing a particular TDM instrument (or suite of instruments) to a specified market, route or area. In addition, the report examines a number of evaluation cases where the actual performance of a TDM instrument was reviewed after its implementation.

This part of the report report concludes with an overview of congestion indicators and congestion measures used in TDM appraisal and evaluation to measure performance against the objective of congestion reduction. The report does not recommend an appraisal tool or an evaluation strategy, nor does it indicate which congestion indicator is appropriate to guide assessment of TDM projects.

2 AUSTRALIAN NATIONAL GUIDELINES FOR TRANSPORT SYSTEM MANAGEMENT

2.1 The Eight Process Decision Model and Transport performance procedure

The *National Guidelines for Transport Systems Management in Australia* (ATC[4], 2006) set out a decision framework which is top-down or strategy led. The guidelines aimed to provide a consistent framework and procedures to assist and guide transport planning. The eight process model can be broadly segmented into three stages of a top-down decision process:

Strategy and Policy

1. *Strategic Objective Setting* identifies the broad societal goals along with the contribution of transport objectives towards achieving god social outcomes. By setting targets and transport indicators the decision makers create a map between transport outcomes and the broadly defined objectives.
2. *Policy Choices* – perhaps not appropriately named -- refers to the development of strategic priorities. For example are non-infrastructure investments preferred to infrastructure investments or 'is private funding of transport infrastructure a priority?'. These policy directions guide assessment of transport initiatives at later stages in the decision making process.
3. *System Planning* is a long term vision of the way any investment will fit into the transport network. In general it is a strategic decision on what links, corridors or areas should take priority.

[4] The Australian Transport Council no longer exists. In December 2013, the Council of Australian Governments (COAG) agreed to a new Council System, the Transport and Infrastructure Council.

4. *Identifying Infrastructure and Non-Infrastructure Initiatives* is a process in which possible transport investments are brought to the table. The TDM review - Report A - is an example of identifying possible policy instruments which can be developed further to be proposed TDM projects.

Appraisal and Assessment

5. The *appraisal* process has three stages. At first a strategic merit test is used to identify projects that align with the strategic policy priorities (formed at the policy choice phase). This is a filtering process whereby some proposals are rejected without advancing to an elaborate and often expensive business case appraisal. The rapid appraisal stage is a preliminary cost benefit analysis with rough estimates of the costs, behavioural responses and the social benefit valuations. If a project is advanced beyond this phase a full cost benefit analysis should be undertaken and a business case is developed.
6. The *assessment* of the project proposals is a formal prioritisation of the projects by reviewing each case. Smaller initiatives may only include the strategic merit test. A schedule of investments takes into account urgency, budgets and funding opportunities.

Implementation and Review

7. The *project delivery* phase requires detailed planning. The planning should address the resourcing and funding of the project. The guidelines do not provide advice on project implementation.
8. *The review* of the project is a formal process of measuring the outcome of the project against the stated aims and forecasts. Whilst a review may look at the decision and implementation process, this is not the focus of this report. Reviewing the impact of a TDM initiative means measuring the observed outcomes against the strategic targets and transport indicators set in phase 1.

The review of TDM appraisal tools (Section 4) concentrates on the appraisal and assessment stages of the overall decision framework. However, policy support is considered (Section 5) and – based on the external review undertaken by Graham Currie – it is suggested that qualitative tools may support policy setting. A short review of monitoring and evaluation (Section 6) and the valuation of benefits and congestion indicators (Section 7) complete the report.

3 A GENERIC TDM DECISION FRAMEWORK

The primary focus of this report is to review a number of tools used to appraise TDM initiatives. However, the appraisal component sits within a broader decision-making framework that commences with the identification of priorities for the transport system framed as strategic or policy directions. These directions set the agenda for the appraisal and assessment efforts and inform the appraisal team of what nature of TDM projects are to be considered. At the appraisal stage an estimate of travel behaviour response is used to determine an anticipated effect on the performance of the transport system and subsequently the value of any benefits incurred. The assessment compares projects and helps prioritise projects in terms of their net benefits. While the assessment is limited to a recommendation, the decision is a commitment of funds to implement the project.

The effect of the TDM project is played out in the transport system in much the same manner as is modelled by the TDM appraisal. At the primary level travellers respond to the incentives or penalties introduced by the TDM instrument, in turn these choices affect the performance of the network and this change in performance yields the benefits to the affected parties. Whether or not the TDM project has the desired effect – meets the anticipated targets forecasted at the appraisal stage – is only known through some form of measurement in the change of the system's performance. At the appraisal stage, specific metrics to be monitored need to be considered. Post implementation a monitoring phase needs to be undertaken. Evaluation is a comparison between the anticipated benefits and the realised benefits.

The generic TDM decision framework is presented in Figure 1 and its components are discussed below.

Setting the agenda through broad policy directions

Travel demand management instruments are implemented through particular projects. A TDM project involves a commitment of resources to either change the transport and land-use system or to affect travellers' decisions through a marketing or information initiative. Proceeding the implementation phase there needs to be a policy commitment to employ one or more TDM instruments. For example a policy agenda may be to restrict parking supply in the CBD or to encourage cycling.

Examining the expected benefits through project appraisal, assessing the proposals and selecting projects

Following setting policy priorities, projects that contribute to the policy directions are identified. Each project is **appraised** by estimating the impact on the transport function. Firstly, the implementation of a travel incentive, disincentive or behavioural change intervention will cause some – a very small proportion in most instances – to change their travel patterns. Whilst the number of people affected may be a small proportion of the targeted community, their changes will have an effect on the overall performance of the system. If the response should be to cut one or two car trips per week, the system benefits from reduced emissions, noise, accident rates or congestion. The size of the impact depends on two things. Firstly, the magnitude of impact is due to the number of people that choose to change their travel behaviour (the demand response) and, secondly, the value of each behavioural change (the valuation of benefits). The aggregated benefits are compared to the implementation costs (cost-benefit analysis).

Assessment of the *appraised* projects may support a go/no go decision. In this case a single project is assessed and based on the project appraisal a judgment is cast on whether to implement the project. Alternatively, a number of potential projects drawn from the same policy direction (e.g. parking supply restrictions) may be assessed with the view to choosing the most cost effective alternatives. Finally, the assessment may aim to compare projects across policy directions. In this case, assessment may be thought of as allocating a finite budget to competing alternatives or TDM instruments. Assessing the projects provides a recommendation of which project to implement, or in which order to implement (prioritisation). The **decision** is a commitment of funds to implement projects.

Project Implementation

The implementation of the project is to deliver the TDM incentives, taxes and charges or behaviour change and information program. From an appraisal and evaluation standpoint, this represents the cost of implementation.

Response, System Effects and Benefits Realisation

TDM initiatives foster behaviour change, shifts in departure time, change of mode, shorter trips or telecommuting. In the longer term a TDM initiative may change vehicle ownership or workplace and residential location choices. Changes at the level of the individual lead to system performance improvements through the effect on aggregate travel. For example, the implementation of a TDM instrument may increase public transport ridership, improve the level of congestion in a part of the network or foster economic development at activity centres. The measurement of the direct physical effect support evaluation of the project, but they are not the benefits. The benefits are realised through improved economic outcomes to travellers (e.g., reduction in travel time and an improvement to transport system reliability), health outcomes (e.g., improved fitness levels and lower incidence of cardiovascular disease or type 2 diabetes), environmental outcomes (e.g., noise, pollution and greenhouse gas reductions) or wider economic impacts (e.g., improved business productivity). Economic appraisal is based comparing benefits and costs after converting benefits into monetary equivalents. However, quantifying benefits is an involved investigative process on measuring peoples' willingness to pay. TDM appraisal may sometimes proceed without quantifying benefits and using subjective assessments or setting priorities.

Monitoring and Evaluation

Appropriate performance metrics are established prior to program implementation and monitoring is the mechanism of measuring the performance of the network in relation to those metrics. Evaluation is the comparison of the observed performance with the expected outcomes reported at the appraisal phase. Feedback to strategy and policy direction setting and appraisal is critical to reinforce or alter TDM approaches on the basis of evidence of actual achievements of TDM initiatives on the ground.

The following section provides a review a range of tools developed to support different critical stages of the Generic TDM Decision Framework - strategic policy direction setting, appraisal and evaluation tools.

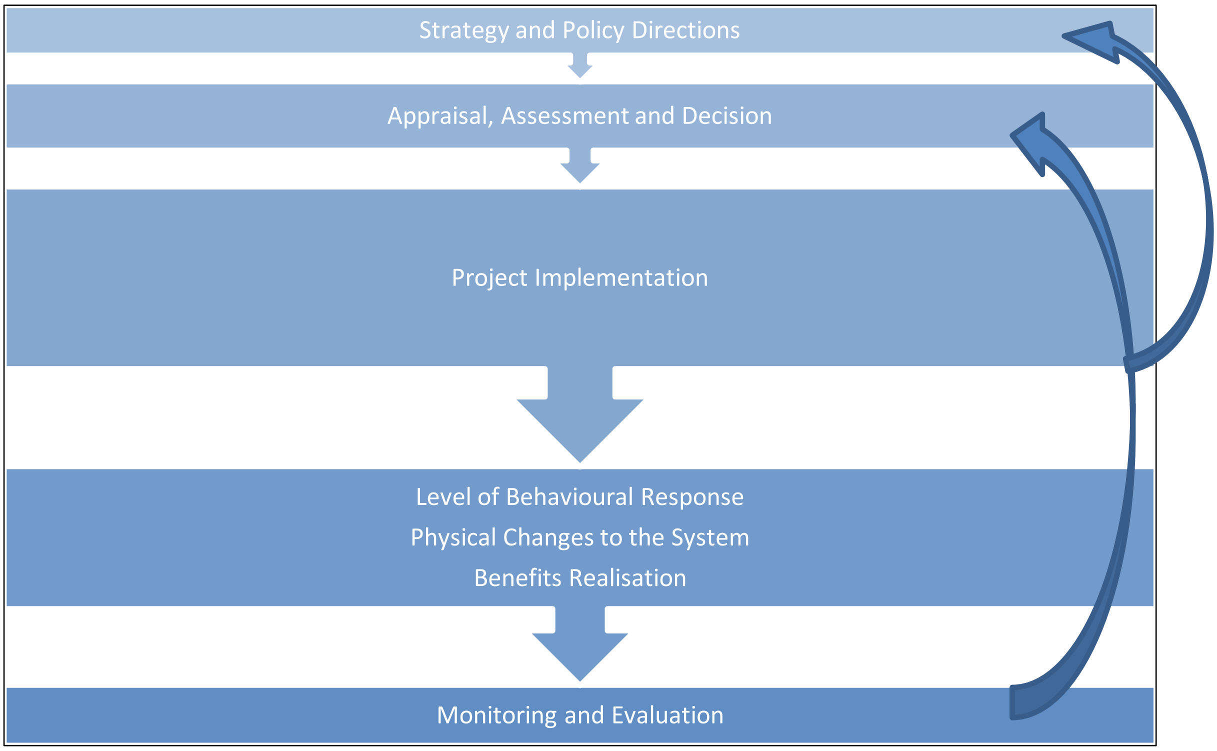

Figure 1: Generic TDM Decision Framework

4 TDM APPRAISAL TOOLS

The descriptions of these tools are ordered by their level of sophistication in terms of estimating the impact of travel behaviour response and changes to the performance of the network. Participatory models and subjective assessments (Section 4.1) that apply subjective assessment are not evidence based tools. The impact on behavioural change and transport network effects is based on the opinions of the group of stakeholders brought together to assess the potential TDM projects. However, as is discussed when presenting short listing and rapid appraisal, the method can be coupled with evidence-based tools. Sketch models (Section 4.2) are evidence based, but most rely on elasticities from literature reviews or from locations other than the one in being analysed in the appraisal. Two of the sketch models only provide estimates for the number of targeted individuals that adjust their travel (**behavioural response)** and the other two models go onto compute the associated benefits in terms of emission reductions or monetary equivalents. Sketch models do not investigate the effects on the performance of the transport system. Two further models – 4 step transport model and activity based model -- are considered in Sections 4.3 and 4.4. Each model imbeds the TDM benefits calculations into existing transport models for the site of the analysis. These models are superior to sketch models in two important ways. The first is that the behavioural responses are calibrated to data collected in the location under review and each computes any network affects, which takes into account congestion at the traffic assignment step.

Valuation of TDM benefits: Most of the TDM appraisal tools reviewed here do not provide a full cost-benefit approach which is most commonly employed for road and rail investment; the exception being TRIMMS which includes valuations for emissions, congestion abatement, health impacts and noise. That is not to say that the benefits due to the estimated travel behaviour change cannot be calculated in a subsequent phase. However, the conversion of benefits into monetary equivalents is not part of the models. The review extends to identification of benefits as well as some monetary values for the more commonly used benefits identified for transport investment appraisal (**Section 4**). The review covers nine benefits in which appraisals may be based.

Cost-Benefit analysis in TDM appraisal: Cost-benefit analysis quantifies and then compares the cost and benefits of the TDM project. The analysis incorporates non-market benefits and costs such as safety improvements, environmental pollution and increased accessibility. The monetary equivalents are estimated using marginal willingness to pay (WTP) measures – usually derived from discrete choice models. A review of the relevant willingness to pay measures is given in Section 4. The cost-benefit approach makes use of appraisal tools as described earlier to estimate the behaviour change and its impact on the network performance. This impact is then converted into dollar amounts using marginal WTP values.

As benefits accrue at different rates for each project a present value for costs and benefits is calculated. The present value (PV) or present worth of a future benefit or cost is its discounted value at the present day. The discount rate used for economic appraisal by state governments in Australia is around 7%.

Cost-benefit discounting is a way of organising and reporting the value of the project. On its own it is not a TDM appraisal tool as the full analysis needs to provide estimates of behaviour change and the impact on the transport network. The NZ Transport Authority requires cost-benefit analysis and provides agencies with a sketch model similar to (New Zealand Transport Agency 2010).

Assessment and decisions: The review does not extend to detailing and comparing transport authority manuals on appraisal. However, should Phase 2 of the project extend to suggesting a decision framework, the most advanced appraisal manuals are Volume 2 of the Economic Evaluation Manual, New Zealand (New Zealand Transport Agency 2010) and the Transport Business Case, United Kingdom (Department for Transport, UK 2011). The Australian Transport Council issued a set of decision framework recommendations (ATC, 2006 Vol 2) and appraisal standards (ATC 2006 Vol 3). The national standards for New Zealand, the United Kingdom and Australia follow the generic decision framework as outlined in Figure 1.

It must be noted that some of the tools included in this section on appraisal tools, are actually named as "evaluation" tools. In accordance with the terminology used in this report, clarified in Section 1.2, if the tool is aimed at determining the anticipated impacts, effectiveness and value of a TDM project or program, it is considered an appraisal tool.

4.1 Community Participatory Models and Subjective Assessments

4.1.1 Importance-Performance Analysis (IPA)

Selection of relevant TDM instruments may be performed through subjective assessment of the importance of the attributes delivered to the community by a specified TDM instrument (Ko et al., 2009), i.e. experts and citizen groups rate the importance of the instrument components. Whilst the survey instrument does not explicitly relate travel behaviour change with importance, it can be reasonably argued that the transport expert group would equate *importance* with effectiveness (to induce travel behaviour change) and the community respondents would see importance as being a measure of desirability. Performance refers to the current assessment with a particular aspect of the transport network (e.g., the level and distribution of congestion charges). The IPA tool appears to rely on a notion of satisfaction in which the community express their desire to see improvement in an aspect of the transport system (this may be loosely thought of as expectations) and their assessment of the current performance of that aspect (related to experience). Satisfaction is equated to the difference between expectations and experience.

The importance-performance analysis (IPA) highlights that TDM effectiveness is sometimes explored by asking stakeholders (transport experts and citizens alike) their opinion on what TDM they consider to be most effective. In the Seoul case study (Ko et al., 2009) it is clear that investment in improving the transport services or reducing the cost of public transport were preferred by experts and the community. Conversely, the provision of cycling facilities was the lowest on their list of priorities.

4.1.2 Short-Listing

In a similar way to IPA, Rose (2007a, b) suggested an approach to short-list the possible solutions to a transport problem. The assessment technique asks stakeholders to identify TDM instruments that they believe to be effective (at creating the desired travel behaviour change or achieving a specified benefit). The tool is not strictly evidence based as they rely on expert opinion and community priorities. However, it is thought that the short listing tools can be a first step in the process in that it identifies a number of TDM candidates that warrant further analysis by way of rapid appraisal (or rough cut cost benefit analysis). Short listing and rapid appraisal approaches differ from the top down approach outlined in Figure 1, as problem identification rather that policy guidance is the starting point for the use of the tool.

Short-listing potential TDM projects requires a subjective rating of the potential outcome from employing the instrument, as well as their confidence that implementation will be achieved. While the method is a subjective appraisal, it is meant to *'reveal a number of candidates that warrant further analysis'* (Rose 2007b, p. 11). The outcome criteria is scored at two levels, firstly at how effective the TDM instrument is at managing demand (e.g., shifting car travel to other modes or time of the day, or optimising existing infrastructure). At the second level the contribution of the initiative towards achieving economic, environmental or social aims is queried. For example, improving traffic efficiencies by means of an active traffic management initiative may score highly on the economic scale, but poorly on the environmental and social scales.

The shot listing method outlined by Rose (2007) does not detail a way to prioritise social, environment and economic outcomes in order to provide the rankings of alternative TDM projects. It is assumed that decision makers are relying on subjective weights to prioritise the broadly specified goals (social, environmental and economic outcomes) as well as subjective assessments on how well each alternative performance on each goal. The branch of decision science that details this method into a mathematical model of priorities and performance is known as multi-criteria analysis (MCA) and is outlined below in Section 4.1.3. Rose's (2007) paper suggests that each of the short listed alternatives could be examined further by a rapid appraisal analysis. The rapid appraisal approach makes us of a **cost benefit analysis.**

4.1.3 Normative Group Techniques and Delphi

The normative group technique (NGT) and the Delphi method are group decision tools that aim to improve inclusive decision making. For each technique participants are offered the opportunity to contribute their ideas without having to speak up in a group setting.

NGT sets aside time for participants to write their ideas or solutions before these are shared with the group. Anonymity is encouraged. The individual contributions are discussed and general themes or solutions are formed. The themes are prioritised by way of voting. Currie and Tivendale (2010) applied NGT to intermediate stakeholder engagement exercises within a broader effort to reorganise Melbourne's 330 bus routes. The engagement exercises helped set policy priorities, such as providing public transport services in the evening and on the weekend. However, analytical and demand forecasting techniques were used to establish the revised bus routes.

The Delphi method uses repeat questionnaires to gather considered opinions and forecasts from a panel with expertise in a particular field. After each round of survey responses, panellists may adjust their opinion based on their reading of other panel members' contributions. The panellists are usual not identified and the responses in each round can be the unedited versions of all contributions or a moderated summary of the responses. The process aims to reach a consensus between the experts. Unlike NGT, short listing or IPA, the participants in the Delhi panel are not necessarily part of the decision making organisation or within the community affected by the decision.

Delphi is often used in long term decision contexts where the outcomes are ambiguous and not easily modelled by quantitative techniques, such as land-use feedback to transport infrastructure (Schuckmann et al., 2012). However, Still et al. (1999) found that planners were unconvinced by the outcomes of the Delphi method and trusted the output of a land-use transport interaction model. It was also noted that the Delphi panel exhibited personal bias against certain policies. Despite the drawbacks of community engagement or expert opinion approaches, Lemp et al. (2008) concede that these techniques have a place in settings where the analytical models are based on weak behaviour evidence or the planning horizon is for the long term.

4.1.4 Multi-Criteria Decision Analysis

Multi-Criteria Analysis accounts for the trade-offs inherit in complex decisions. The methodical contribution of MCA tools is to elicit priorities from decision makers with the aim to uncover **decision weights** that accurately reflect the decision maker's priorities. A number of methods have been proposed to elicit priorities and to score alternatives. The simplest being the additive utility method. Whilst being easily understood by decision makers the additive utility model is often criticized because the both the priority weights and the performance measures are subjective. However, despite their overwhelmingly complex mathematical presentation, the advanced decision models – like analytical hierarchical processing, **AHP** – calculate the decision scores using subjective priorities and performance measures. Berrittella et al (2007) report the use AHP to the prioritisation of TDM policies aimed at addressing climate change. The policy alternatives, such as "tax schemes aiming at promoting environmental-friendly transport modes", are too broad for appraisal. The outcome of the exercise is to identify which policy areas require further investigation.

Multi criteria decision tools – including short listing and importance performance analysis – rely on subjective assessment and expert opinion. These are not evidence based tools and should not be used to appraise individual TDM projects. Currie and Tivendale (2010) show that the group decision techniques are appropriate tools to facilitate stakeholder engagement, but these exercises would fit into a wider assessment of transport alternatives. The brief review of community participation models and subjective assessment indicates that these tools may play a role when identifying decision makers' policy priorities (i.e. at the upper level of the decision framework in figure 1.) but are not necessarily appropriate to appraise individual travel demand management initiatives.

4.2 Sketch Models

For TDM instruments that have a low cost of implementation (when compared to road or rail expansion), a sketch model may be appropriate. Sketch models aim to provide decision makers with a rough estimate of travel behaviour change in response to the implementation of a TDM instrument. The models import behavioural parameters from reviews of TDM studies. In many cases these parameters are transferred from other settings, and as such, have not been calibrated to the region in which the model is to be applied. Whilst all sketch models provide estimates of travel behaviour responses, they vary in the level of detail used for the base case. The TDM Evaluation Model (section 4.2.1), COMMUTER (4.2.2), and The Trip Reduction Impacts of Mobility Model (TRIMMS, Section 4.2.4) were developed primarily for workplace TDM project and usually require the baseline data of current commuter pattern of affected employees. The TDM Evaluation Model may be extended to local area analysis, in which case, zone-to-zone trips by mode split describe the base case. Washington State's TDM Effectiveness Estimation Methodology (TEEM, Section 4.2.3) incorporated integrated land-use and transportation initiatives, in which case the base case scenario required information about land-use patterns (employment density, provision of parking etc.).

The second difference between models is the extent to which the benefit calculations are embedded into the models. The TDM Evaluation Model and TEEM provide estimates of behavioural response, leaving it to the user to compute any benefits associated with this change using another platform. COMMUTER imputes the reduction of total emissions for a number of pollutants based on travel behaviour change estimates. TRIMMS provides the most flexible platform for including benefit calculations. However, it does require the user to import the benefits (negative costs as savings per vehicle trip).

The development of sketch models appears to have been principally undertaken in the US and the tools are tailored to workplace incentives for employees to choose alternate commuting modes to the car. The earliest of such models is the US Federal Highway Association's TDM Evaluation Model.

4.2.1 Rapid Appraisal

The rapid appraisal method is adopted from a part of the three-stage filtering process as outlined by ATC (2006). At the first stage the ***strategic merit test*** determines whether a proposed TDM project aligns with the strategic priorities of the relevant decision authority. A rapid cost-benefit analysis (CBA) is applied to the alternatives that pass the strategic merit test. Whilst not stated it appears that Rose's (2007) short-listing of alternatives acts as the strategic merit test and TDM candidates that pass onto the next phase can be analysed using rapid CBA. At the time of the article Rose indicated that there had been little experience with applying CBA to TDM projects. However, sketch models as described below could be used to undertake rapid CBA.

4.2.2 US Federal Highway Association's TDM Evaluation Model

Developed by the COMSIS Corporation in 1993, the TDM Evaluation Model provided support to employers to appraise workplace TDM project such as carpooling programs or flexitime. The model was also designed to support local government decision on instruments such as parking regulations, HOV lanes or improvements to public transport.

The model used a baseline travel matrix. For local government the baseline travel data would be traffic generated from a specified origin arriving at a particular destination (O-D pairs) by mode. Workplace baseline matrices record the commuting trips made by employees to the site. Strategies that affect either travel time or travel cost are examined by way of logit pivot tables. These make use of the current trip times and cost for all travel modes and estimate the mode shift due to the changes in trip conditions that are attributable to the TDM instrument. Responses to workplace initiatives that do not directly affect travel times or costs are computed by way of a look-up table that matches the type of TDM instrument with an appropriate response parameter (elasticity).

Summary information for the TDM Evaluation Model

Strategies Addressed - Improved transit; HOV lanes; carpooling and vanpooling promotion; telecommute and work hour strategies; pricing and subsidies.

Methodology - Strategies that affect the time and/or cost of travel are evaluated using a "pivot-point" mode choice model. It requires information on baseline mode shares and changes in travel time or cost. Other strategies, such as employer-based support programs and work hour shifts, are evaluated using lookup tables based on empirical evidence.

Data Requirements - Baseline travel data requirements include zone-to-zone person and vehicle trip tables for the analysis area. Default parameters model impacts TDM instruments. The user has the option to change default parameters affecting strategy effectiveness.

Outputs - Changes in modal share, vehicle-trips, VMT, average vehicle occupancy and ridership.

Limitations – Transferability of parameters are not tested. Program does not provide valuations of terms business, social or environmental benefits.

Level of Effort - The TDM model is easy-to-use, off-the-shelf software. Some effort is required to develop inputs in the form of matrices showing the number of trips by mode and the distance between each pair of zones.

Source:
http://www.fhwa.dot.gov/environment/air_quality/conformity/research/transportation_control_measures/emissions_analysis_techniques/descriptions_tdm_evaluation_model.cfm

4.2.3 COMMUTER

The US Environment and Protection agency's (EPA) COMMUTER model is designed to evaluate workplace or local government area TDM programs. The model provides an estimate of the behavioural shift away from SVO commute resulting from the implementation of a TDM instrument, as well as a calculation of emission reductions. The model does not take into account any network effects – such as induced traffic – and is generally applied to a single worksite or an employment centre.

The model is based on broad categories, considering whether the instrument/strategy affects employees' travel costs or travel times or refers to 'soft' (non-financial) changes. For changes to travel times or costs the model uses a logit pivot table and for 'soft' changes the model uses look-up tables:

- Logit pivot table: is a multinomial logit model based on imported parameters. The travel cost or travel time changes are applied to each commute and probabilities of choosing a new mode or other travel arrangement are computed.
- Look-up-tables: The change associated with a particular intervention. The response parameter is also dependent on the level of intensity.

The model applies at the work setting whereby the decision maker:

- Provides the current commuting information, such as mode split;
- Chooses a TDM from the available menu;
- Computes the expected behavioural change based on the logit model or the look-up table parameters;
- Calculates the benefits associated with this change (i.e. change in emissions).

Summary information for the COMMUTER Model

Strategies Addressed - Improved transit; HOV lanes; carpooling and vanpooling promotion; bicycle and pedestrian programs; telecommute and work hour strategies; pricing and subsidies.

Methodology - The data and methodologies used to estimate travel impacts are similar to (the same as) those in the TDM Evaluation Model. Emission changes are based on changes in trip s, vehicle miles travelled (VMT), and speed, using lookup tables derived from MOBILE5a.

Data Requirements – baseline population and trips by mode. Estimated changes in travel time and cost by mode; and description of other (non-time/cost-based) TDM programs. The user has the option to change default parameters.

Outputs - Changes in modal share, vehicle-trips, VMT, and emissions.

Limitations - Transferability of parameters are not tested. The software does not address a portfolio of TDM's. The ability to manage scenarios is also limited.

Level of effort – Relatively easy to use.

Source/Availability - The EPA TCM/Commuter Choice Model was developed in 1998. The COMMUTER 2 was released in 2002. It appears that the model is no longer supported. The model was interfaced with EPA's current MOBILE6.2 emission factor model.

4.2.4 TDM Effectiveness Evaluation Model

TDM Effectiveness Evaluation Model (TEEM) was developed by the Washington State Department of Transportation as an analytical tool to assess the impact of TDM and land use strategies in the Central Puget Sound Region (Winters, Hillsman et al. 2010). The TEEM model uses local data sources and is able to assess the effectiveness of 20 TDM and land-use strategies applied to activity centres in a corridor of planned highway reconstruction. Potential changes in vehicle trips due to these strategies are separately estimated by different methodologies. Using the assumption of interaction the model is capable of evaluating the combined impacts of different strategies. However, this has to be done by incrementally applying the sensitivity factors to the base mode shares. This elasticity-based spreadsheet model is very simple and user-friendly tool. However, it can mask real complexities of some inter-related strategies and therefore the users of the model need to be aware of when such interaction may be occurring and readjustment in the base mode shares are needed.

Summary information for the TEEM Model

Strategies Addressed – It measures the effectiveness of 20 TDM and land-use strategies applied to activity centres in a corridor of planned highway reconstruction.

Methodology - TEEM is a post-processor spreadsheet-based model, which includes price and service point elasticities of demand to estimate potential changes in vehicle trips from the TDM measures.

Data Requirements – It uses elasticity parameters from case studies.

Outputs - Potential changes in vehicle trips.

Limitations – The evaluation of joint impacts of different strategies has to be done by incrementally applying the sensitivity factors to the base mode shares.

Level of Effort - Very simple and user-friendly tool. However, the users of the model need to be aware of interactions between strategies and readjust the base mode shares.

Source: http://www.wsdot.wa.gov/research/reports/fullreports/746.1.pdf**.**

4.2.5 Trip Reduction Impacts of Mobility Management Strategies (TRIMMS)

The National Centre for Transit Research and the Centre for Urban Transportation Research at the University of South Florida developed the TRIMMS (Trip Reduction Impacts of Mobility Management Strategies) model to evaluate the full benefits and costs associated with the TDM projects that particularly focused on mobile source ozone reduction strategies (Concas and Winters 2012). The TRIMMS development project was funded by the Florida Department of Transportation and the US Department of Transportation to enable transit agencies and location communities to quickly estimate the impacts of TDM projects, including support initiatives such as rideshare matching services, employer-based subsidies to promote public transport (alternative work schedules), parking pricing, pay-as-you-go pricing, and other financial incentives.

TRIMMS estimates changes in mode share, trips, VMT, and changes in relevant cost externalities associated to a TDM project (noise and air pollution, added congestion, excess fuel consumption, global climate change, health and safety). Changes in mode share, trips, and VMT are estimated using constant elasticity of substitution parameters obtained from past empirical evidence. However, the social costs associated with the changes in the externalities are estimated using a spreadsheet-based sketch-planning model. In order to evaluate the cost effectiveness of the project, TRIMMS produces a benefit-cost ratio (BCR). The total annual benefits from a TDM project are calculated by summing the daily reductions in the social costs over the number of working days (235 days) in a year. To transfer all input costs in current dollars TRIMMS uses the Consumer Price Index (CPI) and a discount rate of 4%.

The NZ Transport Authority has adopted a sketch model similar to TRIMMS (New Zealand Transport Agency 2013). However it is not always clear that the spreadsheets offered provide an estimate of travel behaviour change or whether the user must import these estimates from another analysis. The spreadsheets do provide benefit valuations and a cost benefit analysis.

The latest version of the TRIMMS has functionality to conduct a sensitivity analysis. TRIMMS uses a Monte Carlo simulation technique to provide more robust estimates of the benefit-to-cost ratio. Using the simulation technique, TRIMMS is able to provide statistical confidence of obtaining a certain benefit-to-cost ratio in case the project is repeated over and over again.

Summary information for the TRIMMS Model

Strategies Addressed - Alternative work schedules include compressed workweek, flexible working hours, and telework. The rideshare and vanpool initiatives offers a guaranteed ride home. Worksite amenities refer to the provision of childcare facilities and the presence of sidewalks connecting transit stops to the worksite. Further policies for analysis include employer-based subsidies to promote public transport use, parking charges, pay-as-you-go pricing, and other financial incentives.

Methodology – From entering the year of analysis and the metro statistical area, TRIMMS updates all input cost parameters in time and based on the geographic area of the project. Users have to select one of the 85 metropolitan statistical areas from the U.S. census region. Next, the users define the project characteristics, the baseline mode shares and trip length. American Community Survey three-year average (2005-2007) and trip length by mode from the National Household Travel Survey offers the default values but users can input their own values. Users select any employer support instruments and if public transport access and changes to travel times. The behavioural response level is estimated monetary equivalent benefits are computed. The cost effectiveness of the project is evaluated using a benefit cost ratio: the sum of the daily benefits for 235 working days over the project costs. The Consumer Price Index (CPI) and a discount rate of 0.4% is used.

Data Requirements – The changes in mode share, trips, and VMT are estimated using trip demand functions that rely on constant elasticity of substitution parameters. The elasticity parameters were obtained from past empirical evidence. The social costs associated with the changes in the externalities are estimated using standard unit cost of those externalities that were obtained from different sources.

Outputs - TRIMMS provides three different output tables. The first output is about the changes in travel behaviour due to a project: changes in mode shares, the number of round trips, miles of travel between baseline and final values. The second output table shows changes in social costs generated by a project and its impacts on single occupancy vehicle (SOV) travel behaviour. Finally, it provides annualised costs, benefits, net program benefits, global climate change, and BCR to evaluate project's cost effectiveness.

Limitations – Like other sketch-planning tool, TRIMMS has limitations. One limitation is the use of elasticities to measure travellers' responsiveness to price and travel time changes. Another limitation is in the estimation of global climate change impacts. It only considers the marginal damage costs associated with CO_2 emissions, while other authors provide more comprehensive estimates of greenhouse emission costs.

Level of Effort - TRIMMS simplifies the quantification requirements for TDM programs by making careful simplifications, as well as enhancements.

Source: http://ntl.bts.gov/lib/43000/43600/43635/77932-final.pdfs.

4.3 Four-Step Travel Modelling

The sketch planning tools presented above (TDM, COMMUTER, TEEM, and TRIMMS) do not use the full advantage of four-step transport planning models within their frameworks. However, it was recommended by the TRIMMS developers that four-step models should be incorporated into the assessment process to assist transportation planners in estimating the impacts of TDM on traffic flows and traffic congestion in corridors where TDM is to be implemented (Concas and Winters 2012). Following this recommendation, Winters, Hillsman et al. (2010) developed Transportation Demand Management Assessment Procedure (TDMAP) that integrate four-step model with TRIMMS to produce estimates of changes in travel behaviour at the traffic assignment stage. TDMAP does so with the following steps:

- First it extracts the origin/destination (O-D) tables by modes from the modal split model of the four-step regional travel demand model and then aggregates the modes with compatible modes in TRIMMS (Car–Drive Alone, Car–Rideshare, Vanpool, Public Transit, Cycling, Walking, and Other);
- In the next step, TRIMMS estimates the mode shares in the TDM affected zones and calculates the changes in mode shares in the zones;
- Finally, the estimated changes in mode shares are distributed over associated origin zones and initial O-D tables are updated. The updated O-D tables are then fed back into the regional travel demand model to be used for traffic assignment (Winters, Hillsman et al. 2010).

4.4 Activity-Based Models

Activity-based models showed a significant improvement to the traditional four-step travel demand model by providing a deeper insight into individual decision-making process. These models consider travel as being derived from the demand for personal activities. Travel decisions, therefore, become part of a broader activity scheduling process based on modelling the demand for activities rather than merely trips. Past studies have shown that these models have a significant advantage in analysing the impact of TDM strategies as they predict a wider range of impacts, including secondary and synergistic effects of the strategies under consideration (Jones 1983; Shiftan and Suhrbier 2002; Shiftan 2008). For example, a commuter may shift from use of car to public transit for the trip between home and work because of an employer trip reduction strategy. The shift in travel mode is the direct effect of the TDM strategy. As the person stopped driving to work he/she might not stop on way home to buy groceries as he/she used to do while driving to work. Therefore, he/she returns home by transit and then takes car to go nearby grocery stores, which is a secondary effect of the strategies. Activity-based modelling is capable of account for such secondary effect.

Using Portland's activity-based transportation models Shiftan and Suhrbier (2002) evaluated the impact of three TDM strategies (pricing of automobile travel, telecommuting, and public transport improvements) separately and their combined impacts. While adding up the reduction in drive alone trips for the three individual policies show a reduction of 1.89% trips, the combined policy shows a reduction of 1.86% drive alone trips which indicates the marginal interaction effects of the three strategies. Shiftan (2008) assessed the impacts of several land use policies using a residential choice and activity-based models within the Washington County Urban Growth Area boundary. The policies include improvement in land-use by providing bicycle paths, upgrading the level of local shops, and providing a community square; improvement in transit service; and increasing safety and school quality in the city centre. With the stated improvement in land uses, the residential choice model showed an increase in the number of households in the Urban Growth Area by 13%. Moreover, 4.2% of the total metropolitan households moved from the suburb to the urban growth area reducing the suburban population by 6.1%. The activity-based model showed that public transport tours increased by 5.2%, walking tours by 7.2%, and bicycle tours by 7.8% with a slight increase in car tours by 2.5%.

5 STRATEGIC POLICY ASSESSMENT TOOLS

Strategic and policy direction setting is supported by tools such as the abatement tool, which does not target a particular problem or area in the network but is rather focussed on predicting aggregate effects of alternative portfolios of TDM instruments at the transport systems level. Reports of these quantitative, strategic policy decision-support tools, as oppose to project appraisal tool, particularly in relation to transport, let alone TDM, are less evident in the literature and present a substantial opportunity for innovation. They are not, however, unrelated to project appraisal tools. Learning from a review of the wider application and reporting of experiences in developing and using project appraisal and evaluation tools can be brought to bear in developing an appropriate strategic TDM policy assessment tool for Perth. The learning is twofold: firstly, continuous project monitoring and evaluation will yield a database of evidence in terms of TDM elasticities and secondly, project appraisal tools or components of tools together with impacts and effectiveness measures and project-level valuations, provide inspiration for upscaling to the strategic policy level.

In the emission context, the Marginal Abatement Cost Curve (MACC) is a function that shows the cost of implementing an emission abatement measure per unit reduction of emissions. The approach may be used for evaluation of technology adoption (e.g. electric vehicles).

Adopting this method for the problem of congestion will require an appropriate measure of congestion. For example annualised congestion cost – being the additional travel time due to congestion multiplied by the value of time plus additional fuel expenditure. The MACC approach is a cost-benefit calculation of identifiable projects aimed at achieving lower congestion at some time in the future. A base case projection of congestion (i.e. traffic growth on the existing or planned network) is compared to a variety of TDM projects. The need to identify how the measure is implemented (i.e. what projects will be undertaken) is essential for calculating the cost and benefit of the TDM. For example “improve public transport” is an identified TDM instrument, but analysis on its effectiveness would require scoping a project. A TDM project is a defined policy intervention with an implementation budget and an identified target population.

MACC approach to evaluating TDM:

1) Base projections of population and distribution/cost of transport system. It may need to take into account the strategic direction papers for 2031.
2) Cost TDM projects (capital and operating) as well as any social welfare savings (i.e. could include externalities).
3) Measure the behavioural response to TDM – reduction of private or commercial vehicles on road at time of day (i.e. the where and the when). Calculate the impact on congestion (or other criterion).
4) MAC = $ / unit reduction in congestion measure.

Note: Using abatement curves to analyse congestion differs substantially from emissions. This is due to step 3. The technology (TDM measure) potential is due to the behavioural response. In emissions the technology potential is the reduction in pollutant or GHG if the technology is adopted.

5.1 Marginal Abatement Tools for Policy Analysis: Reviewing Evidence

A possible way to use marginal abatement cost curve to support policy is to use a rough estimate based on a review of programs. The review would need to identify the costs of each program as well as a measure of congestion reduction. A source for these cases is the review of Congestion Mitigation and Air Quality Improvement (CMAQ) program, United States (Transportation Research Board, 2002).

The Congestion Mitigation and Air Quality Improvement (CMAQ) program was allocated $14.1 billion for programs other than vehicle technology improvement to reduce emissions: *"while congestion mitigation was a goal of CMAQ, the primary policy focus since the program's inception has been on achieving the air quality goals"* (Transportation Research Board 2002, p.1). As a consequence the report did not provide an impact measure on congestion. Figure 2 is extracted from the report and shows the range of marginal costs for abating one ton of emissions. The figure is added here to illustrate an exercise that could be undertaken should the data, on which the CMAQ review was based, still be available.

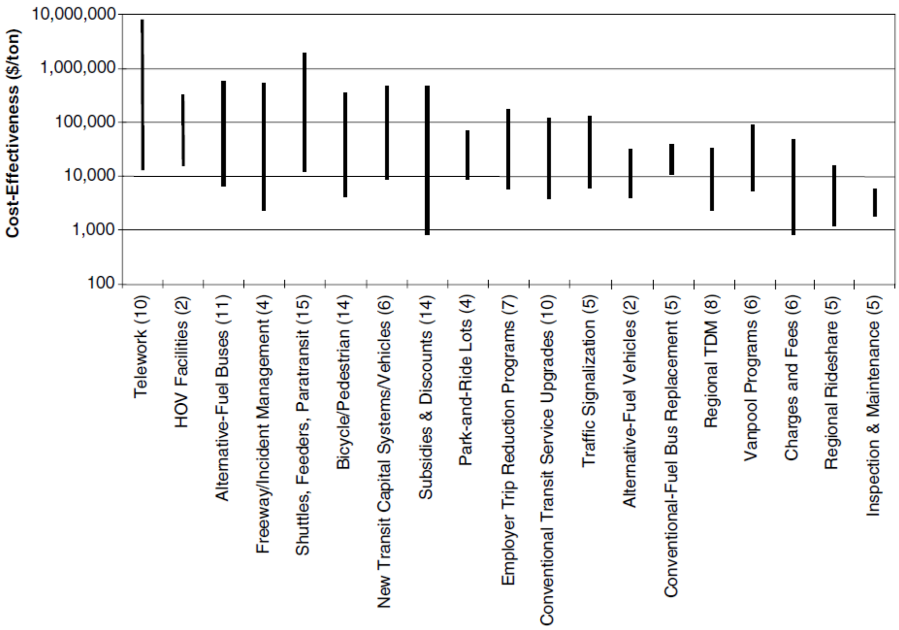

Figure 2: Range of Marginal Costs to remove one ton of emissions. Source: Transportation Research Board 2002, p. 127

5.2 Marginal Abatement Tools for Policy Analysis: Generating a database of TDM project appraisals

An alternative strategy to create a marginal congestion abatement cost curve is to build an appropriate sketch model for Perth. The tool would be based on TRIMMS as it includes a number of benefit measures, whereas the other sketch tools only report changes in travel behaviour or the reduction in emissions. To generate a marginal abatement cost curve a database of TDM projects could be generated by applying the tool to suggested projects and programs.

Over time monitoring and evaluation records could be added to the database to provide more accurate accounts of the effects of the projects. Whilst the development of the tool would take many years it would be in addition to the implementation of TDM projects and an effective monitoring and evaluation process.

5.3 Concerns Expressed by External Reviewer

The Marginal Abatement Cost Curve (MACC) represents a start of the art tool. However, the emphasis on quantitative policy support tools may be overly optimistic. It is considered misguided to emphasise quantitatively strong methods in a field which has very little detail and performance data available. This is why many of the 'practical' tools available emphasise broad estimation methods. This review suggests PATREC re-orient towards tools with less quantitative rigour where broad estimations can be made. In our view this reorientation will become essential when the quantitative data from actual performance of TDM measures is assembled.

PATREC will investigate a decision making process whereby participatory tools and subjective assessment may help set the policy agenda. However, phase 2 will pursue appraisal tools that are evidence based.

6 MONITORING AND EVALUATION

Monitoring and Evaluation is more than an afterthought or a post project review. Evaluation is an integral part of TDM projects and programs. Each project has specific policy objectives and appropriate performance measures should be developed in order to decide project's achievement towards the policy objectives. Establishing appropriate performance measures prior to program implementation will provide practitioners with consistent and accurate results. Depending on the chosen performance measures and supply of data through project monitoring, the evaluation can take many forms from simple calculations to complex transport models. It is however essential that practitioners allow an adequate amount of time for the project to fully develop before they evaluate the possible changes in individual travel behaviours or impacts on the existing transport system as a result of its implementation. The cyclic nature of TDM projects indicates that once a project is evaluated, the practitioner should go back to planning stage to either improve or alter the TDM project using the information gathered during the evaluation stage or use the information for future TDM projects.

The European Union developed the MOST-Monitoring and Evaluation Toolkit MOST-MET to provide guidance to practitioners to measure the impact of various Mobility Management (MM) programs (e.g. mobility centres, mobility management for companies, schools, leisure sites and tourist destinations) against the program's goals and objectives, using carefully chosen indicators. Changes in the target group members due to the project are measured by the indicators. MOST-MET follows a seven-step methodology as follows:

- Formulation of objectives;
- Specification of target groups;
- Choosing Mobility Management instruments and services;
- Applying of assessment level;
- Specification of indicators;
- Monitoring;
- Evaluation.

Sweden developed its own evaluation framework, namely SUMO (System for Evaluation of Mobility Projects) (Hyllenius, Ljungberg et al. 2004). SUMO is also based on MOST-MET that was adapted to Swedish conditions to evaluate the impact of transport projects on individual attitudes and behaviours. However, SUMO is unique in how its targets, indicators, and results can be specified at different levels (e.g. number/percentage of people aware, people that show an interest, people satisfied with the services offered). Campaign Assessment Guidance (CAG) is another evaluation tool developed under the TAPESTRY (2003) of European Union. CAG offers an ex-post comparison of the situation before and after the implementation of a campaign. Nonetheless, the European Union is now using a new tool for systematic evaluation of mobility projects and programs, which is known as Max-SUMO. This new tool was developed under the project MAX - Successful Travel Awareness Campaigns and Mobility Management Strategies and is based on the existing tools (SUMO, MOST-MET, and CAG) where it uses the concepts of travel awareness aspects from CAG, the empirical research conducted within the MAX project, and practical hands-on experience learned from the application of SUMO and MOST-MET (Trivector 2009).

Canada has recently developed a new evaluation framework based on the above two approaches, namely TDM Measurement Toolbox (Transport Canada 2012). The strength of this Canadian Toolbox is that it contains detailed evaluation indicators for 46 TDM measures along with their possible data collection tools at different assessment levels.

In general, the impact of TDM initiatives is evaluated by measuring the change in travel behaviour, for instance a reduction in vehicle miles travelled, modal shift from the solo car driving to the use of sustainable transport (public transport, walking, and cycling) and/or increase in the share of multi-occupant vehicles (e.g. carpool and vanpool). These changes are measured by counting traffic on the target area and by surveying individual’s travel behaviour before and after implementation of the initiatives. In order to avoid high cost of data collection, MOST suggests combing the data collection program with existing surveys, by adding some additional questions, instead of carrying out an extra survey. Moreover, in case data were not collected before the implementation of the project, retrospective questions about people’s travel behaviour at a point of time before the implementation may at least provide the general idea of the changes and gives hints about the reasons for these changes.

7 MEASURING IMPACTS ON THE TRANSPORT SYSTEM

Appraisal of TDM initiatives involves measures relating to two components. Firstly, a TDM project is appraised on its effectiveness in enacting travel behaviour change. The second component of TDM appraisal models is measuring the value or benefit of the behaviour response with four broad classes of impact having been identified: travel time and reliability, environmental benefits, fitness and well-being and wider economic impacts. With a primary objective of TDM being to reduce levels of congestion, measurement of congestion impacts is pivotal in TDM appraisal. A range of congestion indicators have been developed but are all essentially some form of a composite measure using travel time savings

7.1 Effectiveness

Effectiveness of a TDM initiative is measured by the level of travel behaviour change. Often the impact is measured as the reduction of SOV car trips during peak hour – essentially with the view that the TDM outcome is to reduce congestion. However, other objectives such as air quality and environment may not necessarily focus on trips during peak hour, but rather on total travel (aggregate vehicle kilometres, VKT). Alternatively, when focusing on health and fitness, TDM effectiveness may be measured in terms of increased public transport use or increased travel by active modes. The dimensions of TDM effectiveness listed below form a truncated list of that given in Rose (2007b):

- Reduction in car use: A primary measure of TDM effectiveness. If the TDM is aimed at commuting trips, the measure may be in terms of reduced number of SOV trips. If the application for the TDM instrument is for a school, the effectiveness may be determined by the reduction of service trips by car;
- Increased public transport ridership: Whilst this is a complement to reduced car dependency, the measure is relevant to public agencies interested in the impact of cost recovery from public transport initiatives;
- Increased travel by walking or cycling: Most commonly used metric if a principle aim of the TDM is to promote health and fitness.

7.2 Valuation of Benefits

The second component of TDM appraisal models is measuring the value or benefits of the behaviour response in terms of one or more measures. Whilst effectiveness indicators are useful for monitoring, any appraisal based on cost-benefit analysis will need to make use of economic indicators. The performance of the network is summarised as the economic values of travel time savings, system reliability, vehicle operating costs, improvements to air quality and greenhouse gas emissions and noise. The marginal willingness to pay values for each are reviewed in the next section. In addition, the review includes public transport measures of crowding and comfort because these outcomes may be affected by TDM's that shift car travellers onto mass transport. Finally, the benefits related to health, fitness and safety are viewed as complimentary benefits.

7.2.1 Travel Time Savings

Values of travel time savings (VTTS) dominate benefit calculations used in assessing transport policy and infrastructure projects. Monetary valuations are often differentiated by the travel purpose (work vs. non-work), transport modes (car, bus, rail, walking, cycling), length and/or duration of the travel. The components of the total (door-to-door) travel time, such as access/egress, transfer, in-vehicle and waiting time, have been found to have different VTTS, reflecting the different utilities/disutilities experienced by travellers between the origins to the destinations of their trips. Additionally, the method of calculation may depend on the transport setting.

- Time savings valuations are generally based on whether the trip is within the 'working hours' or outside them (Mackie and Worsley 2013). Empirical evidence shows that VTTS within working time vary substantially across countries and continents: VTTS was estimated as £34.12/hour in UK in 2010; €23.50 in Germany in 2008; 247 SEK for trains and 291 SEK for all other modes in Sweden; $23 for car, bus, and train and $57 for air, and high speed rail in USA; A$44 in NSW Australia;

- In contrast, VTTS for commuting shows some similarities: was £6.46 per hour in UK; €9-10 in the Netherlands; $12 for local commute and $17 for intercity commute in USA; 87 SEK for car, 53 for bus, 69 for train, and 108 for air in Sweden for trips shorter than 100km.

- Evidence from revealed and stated preference work showed that people are willing to pay more for reductions in waiting time and walk time than for in-vehicle time (Gühnemann, Kelly et al. 2013). As a result, the value of wait time is factored by 2.5 of in-vehicle time saving and walking time by a factor of 2 in the UK, however, the factors are slightly lower for USA and NSW, Australia.

- Using a behavioural model that accounts for income differences, in the UK it was found that the time saved on commuting was 10% more 'valuable' than the time saved on non-work related travel; the percentages are even higher in The Netherlands and Sweden.

- Whilst Mackie, Wadman et al. (2003) suggest that a lesser value of travel time savings for small time savings should apply, the UK appraisal did not differentiate between small and big travel time savings. Sweden and Germany however, have taken some steps in this direction. For instance, in Germany, in case of savings below 5 minutes, VTTS are calculated at 70% of the 'nominal' value.

- New Zealand and Sweden apply mode-specific estimates for VTTS (Eliasson 2013, Mackie and Worsley 2013). When evaluating VTTS for commercial travel, the driver's time and vehicle operating cost changes are accounted for in the UK (Guhnemann et al. 2013). In addition, Swedish appraisal standards consider the interest payable on the value of goods in transit (Mackie and Worsley 2013). The Netherlands use a stated preference survey of shippers and carriers to determine their willingness to pay for any delay (de Jong 2013).

7.2.2 Reliability

Reliability has recently been included as a performance measure in some transport policy manuals, based on evidence that showed willingness of trip makers to pay for decreasing the travel time variability in addition to travel time savings (Hensher 2001, Bhat and Sardesai 2006). Reliability is studied based on the repeated journeys along a route and hence it is usually measured by the variance (or standard deviation) of travel time (Li, Hensher et al. 2010). Travel time variability can be categorised into three types: i) day-to-day variability (due to weather condition, fluctuations in traffic, accidents, road construction, events and so on), ii) day-of-week variability (weekdays versus weekends), and iii) inter-vehicle variability (due to personal driving behaviours and traffic signals) (Bates, Dix et al. 1987, Bates, Polak et al. 2001). However, incorporating reliability or travel time variability in appraisal (more generally) within cost-benefit analysis (CBA) is yet to become a common practice and appropriate methods for valuation of reliability are still considered in the state-of-art sphere (Batley, Grant-Muller et al. 2008). In UK, reliability impacts are not directly taken into account in the initial benefit-cost ratio (BCR) i.e. BCR at the time of project appraisal, rather they are added in the final BCR calculation i.e. BCR at the time of project evaluation.

Reliability Ratio (RR) is a widely used valuation approach in practice in UK and USA for incorporating reliability into the appraisal. RR represents the ratio of standard deviation of travel time over value of travel time, or for rail, RR = value of standard deviation of lateness/value of lateness, where value of lateness = factor (3-4)* value of in-vehicle travel time. By contrast, in Sweden, standard deviation of travel time variability for car is valued by 0.9*VTTS and long unexpected delays on car and average delays on public transport are valued at 3.5*VTTS. A 25% surcharge is added on the time benefits in the Netherlands. In NSW, Australia, the value of travel time reliability is equal to the value of in-vehicle time savings.

7.2.3 Vehicle Operating Costs

A review of valuations for vehicle operating costs is not offered because of the differences between countries due to technical and engineering standards. Any TDM tool developed for Perth will need to use local standards. The Cost Benefit Appraisal manual published by Austroads does not include valuation of vehicle operating costs however RTA Road Evaluation Manual includes a set of economic parameters that provide values on vehicle operating costs (Douglas and Brooker 2013).

7.2.4 Air Quality and Climate Change

Both local and regional pollutants are quantitatively measured to assess the impacts of air quality in transport project appraisal. Particulate matter (PM_{10}) and nitrogen dioxide (NO_2) are the primary sources of local air pollution and road transport is one of the major generators of the pollutants (Department for Transport 2014). Changes in concentrations of the pollutants in local areas as a result of a transport scheme have been quantified. In the UK, a combination of two approaches is used for monetary valuation of changes in PM_{10} and NO_2 concentrations. A damage cost approach is used when the changes in concentrations are within the European Union (EU) limits and a marginal abatement cost approach is used when it is expected that the proposed scheme would exceed EU limits on NO_x (nitrogen oxides NO and NO_2) concentrations. NSW, Australia uses the damage cost approach for the valuation, incorporated in the Air Quality Appraisal Tool (AQAT) for the valuation of air quality impacts of transport and land use development. The AQAT estimates hot running emissions, cold-start emissions and non-exhaust $PM_{2.5}$ (particulate matter with diameter of 2.5 micrometres or less) emissions for the damage cost calculation. In addition to quantification and valuation, the tool also accounts for other planning measures that are designed for trading-off negative impacts i.e. improvement in air quality. Unit damage cost (in A$ per tonne of $PM_{2.5}$) was calculated as a function of population density at Significant Urban Areas (SUA) across Australia (NSW Environment Protection Authority 2013). In a recent study by the OECD (2014), the cost of 2010 health impacts (both deaths and illness) due to air pollution from road transport was estimated at about USD 1 trillion across OECD countries. Table 1 shows the estimated cost of location pollution across four countries.

Table 1: Costs of Local and Global Pollution in Four OECD Countries

Country	Costs
England	Global pollution €420 per tonne for NO_x in 2008 Local air quality €3.37 per resident equivalent
Sweden	Costs for $PM_{2.5}$, Volatile Organic Compounds (VOCs), SO_2, NO_x per exposed person varies with the ventilation zone
NSW, Australia	Pollution cost = 0.001 * change in PM_{10} concentration due to the project * population exposed * normal death rate * value of life
New Zealand	Same as NSW Australia

For the valuation of the impacts of climate change, the UK uses marginal abatement cost approach for the non-traded sector (as defined by the EU Emissions Trading System). A cost of £53.58 per tonne of CO_2 was estimated in 2010 in UK, whereas it was €70 per tonne in Germany and €62.66 per tonne in The Netherlands. The estimated cost in the USA and New Zealand was much lower than the European countries, at $19-21/tonne in USA and $40/tonne in New Zealand.

7.2.5 Noise

Transport-related noise pollution produces 'a feeling of displeasure' to individuals (WHO 2007). It brings discomfort by interrupting communication, concentration and activities (Miedema 2007). It is therefore necessary to assess the level of noise causing annoyance to people. The UK has clear guidelines for valuation of transport-related noise, based on a study by Bateman, Day et al. (2004). A hedonic pricing approach was used in the study to estimate willingness-to-pay for a peaceful and quiet environment in the housing market in Birmingham. The Birmingham based model was then updated by Nellthorp, Bristow et al. (2005) to be used across UK; the model was included in their WebTAG toolkit (Transport Analysis Guidance). There is no monetary value placed for noise level below 45 decibels (dB $L_{Aeq,\,18h}$) and the value remains constant above 81dB $L_{Aeq,\,18h}$. Annual value of a 1dB change in noise level between 45 and 81dB is estimated from £10.91 to £127.24 per household. In Germany, the willingness-to-pay to achieve low noise levels at night (<37dBA) was estimated at €67.68 per resident in 2008. In the USA, the valuation of noise annoyance is based on the cost of sound barriers or land value impact, whereas in NSW, Australia, it is calculated based on a prediction of change in property values (0.9%) by a 1dB increase in noise level above 50 dB $L_{A10,\,18h}$. However, hedonic pricing method for the valuation of noise annoyance has been questioned on several grounds, including multicollinearity of explanatory variables, spatial heterogeneity, or other market imperfections. Therefore, there has been an increasing interest in the use of stated preference methods for valuation of traffic related noise annoyance (Wardman and Bristow 2004).

7.2.6 Crowding and Comfort

Crowding and comfort are important factors in project appraisal for public transport. Whereas crowding can be measured quantitatively (density of passengers on vehicles, access ways and stations) (Tirachini, Hensher et al. 2013), comfort reflects several qualitative aspects of a journey including the quality of seats, and the smoothness of the ride. Occupancy rate or load factor is the most common metric for measuring crowding. It is measured as a ratio of actual in-vehicle passengers and the number of seats (Whelan and Crockett 2009) or as the ratio of in-vehicle passengers and the nominal capacity of the vehicle (seating and standing capacity) (Jara-Díaz and Gschwender 2003). A load factor over 80% is indicative of overcrowding and, in most countries, multipliers (1.03-3) are used to adjust for in-vehicle travel time and whether the person is sitting or standing. For instance, in the UK, a multiplier of between 1.03 and 1.16 is used for someone sitting in a crowded train, whereas the multiplier is increased to 1.65 for short distance and 2.11 for long distance standing. Sweden uses a 'comfort' multiplier of 1.5 for driving on a congested road and a factor of between 1 and 3 for public transport, depending on the level of crowding. New Zealand uses a different valuation where they increase the value of travel time by 40% for standing passengers compared to sitting passengers in public transit. A recent study by Tirachini, Hensher et al. (2013) found that a model that ignores crowding overestimates the VTTS for low occupancy rates and underestimates VTTS in case of substantial crowding.

7.2.7 Complementary Benefits

Despite travel time being considered the first benefit of any TDM measure, in recent times, safety, health outcomes and regeneration impacts, have been highlighted as integral part of TDM benefits.

8 Fitness and Health

Fitness and health is a relatively newer addition to transport appraisal. The World Health Organization (WHO) pioneered the approach by incorporating the health effects of transport interventions or infrastructure projects into CBA. It is easier to estimate the cost of infrastructure provided to increase the level of walking and cycling, than the direct benefits of walking and cycling. WHO (2007) provided guidance in the form of an harmonised method for the economic appraisal of health effects. Although their Health Economic Appraisal Tool (HEAT) was particularly developed for cycling, the method also allows for assessment of the health benefits of walking. The tool helps to answer the question *"If x people cycle y distance on most days, what is the value of the improvements in their overall mortality rate?"* (WHO 2007, p13). Most of the European countries use HEAT for their economic appraisal of cycling. New Zealand uses their own developed tool (New Zealand Economic Evaluation Manual) for the valuation, with separate estimates for walking and cycling (New Zealand Transport Agency 2010). Past studies also estimated the monetised benefits of active transport to health and found that each additional cyclist may add a benefit of £22 to £498 per year depending on a number of factors including age (Fishman, Garrard et al. 2011). Boarnet, Greenwald et al. (2008) developed a methodology to quantify monetised values of increased walking. Most evaluation approaches, for either TDM or construction projects, use improvements in mortality rate as the primary indicator of health performance. The Active Transport Quantification Tool developed by the International Council for Local Environmental Initiatives (ICLEI), however incorporated additional factors in their valuation including savings from reduced driving and consequently decreased congestion, pollution, and crash risk, along with increased fitness and wellbeing (ICLEI 2010).

9 Safety

Appraisal of transport safety deals with monetised value of a statistical life (VSL) to estimate total benefits and then uses the valuation in the appraisal of investments aimed at preventing road accidents. Total direct and indirect costs of accidents are considered (Milligan, Kopp et al. 2014). VLS in general is the amount of money individuals are willing to pay for improvements in safety (i.e. to avoid the risk of fatalities) with the expectation of saving a life (Miller 2000). Different ways of determining the willingness to pay WTP were put forward: USA uses a hedonic wage model for their estimation of VSL. From empirical analyses by a panel of expert economists, $9.1 million was determined as the value of a statistical life in 2012 and is being used by the US Department of Transportation with an annual growth rate of 1.07 over the next 30 years (2013-2043). They are also using relative disutility factors (Table 2) based on injury severity level (AIS).

Table 2: Relative Disutility Factors by AIS

AIS Level	Severity	Fraction of VSL
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Fatal	1.000

Source: U.S. Department of Transportation (2013)

Other monetary values used for transport project appraisals are provided in Table 3.
Table 3: Monetary Values in Five Countries

Country	Value
England	VLS £1.65m, Serious injury £0.186m, Light injury £0.014m
Netherlands	Fatal €2.744m, Serious injury €0.282m, Light €0.005-0.009m
Sweden	Fatal 23.7m SEK, Serious injury 4.4m SEK, Light 0.02m SEK
NSW Australia	Fatal A$6.3m, Serious injury A$0.467m
New Zealand	Speed limit 50km/hour: Fatal NZ$3.798m, Serious injury NZ$0.401m, Light NZ$0.021m Speed limit 100km/hour: Fatal NZ$4.560m, Serious injury NZ$0.486m, Light NZ$0.029m

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11 Regeneration

Regeneration by transport improvement projects may affect the economy of the whole area of the project and its surroundings. The impacts include: changes in employment/labour market and impacts for business activity. Therefore, the purpose of the assessment of regeneration impacts under transport project appraisal is to show how a proposed transport project will influence the economy in the regeneration area (Department for Transport 2014). For instance, improvement in accessibility by means of improved transport networks and connectivity will change travel time, cost, and reliability. The improvement would probably attract more businesses, and/or expand existing businesses and hence create more employment opportunities in the area. However, there are no general guidelines across countries on how to incorporate the regeneration impacts in transport appraisal. In the UK, local benefits associated with changes in target areas (i.e. regeneration areas) are considered as a regeneration impact. The UK Department for Transport (2014) proposed that potential regeneration impacts of transport should comprise: *'Impacts for business activity via such changes in travel conditions such as costs of access to customers and costs of access to supplies;* Labour market impacts through access to a larger pool of labour, and access of workers to a wider range of jobs; Access to and from the regeneration area by visitors' (Department for Transport 2014, pp. 3-4). The USA however does not include regeneration impacts in its CBA, instead, regeneration is considered as a separate entity in a multi-criteria analysis in which projects are ranked based on a variety of qualitative and quantitative factors. An overall score is calculated for each project and the project with highest score is selected. In NSW, Australia, changes in population and employment at corridor level are attributed to the regeneration impact of transit-oriented development (TOD).

12 Wider Economic Impact

There are broader benefits and costs related to transport projects that are not incorporated in traditional evaluation frameworks. These additional potential sources are grouped under as the "Wider Economy Impacts" of transport projects (Joint Transport Research Centre 2008). A recent guideline provided by the Department for Transport, UK (2014) identified three sources of impact – agglomeration impact, output change in imperfectly competitive markets and tax revenues arising from labour market impacts (from labour supply impacts and from moves to more or less productive jobs). Agglomeration impact occurs when a transport project affects the cost of trips to, from or within the locations of agglomeration and hence is measured as a function of elasticity of total productivity with respect to the job density, change in the effective job density and GDP in the area (Department of Transport 2005; UK Department of Transport 2005). Output change in imperfectly competitive markets occurs when firms can increase their profit due to a reduction in unit cost of transport (to business and/or freight), as those firms frequently require the use of transport in their production and distribution. A simplified approach is used to estimate the impact of this benefit in the UK. *'It is estimated as a proportion of total user benefits for business journeys, calculated as a 10% uplift to business user benefits'* (Department for Transport 2014, p.4). Finally, tax revenues arising from labour market impacts occur when a transport scheme influences labour market decisions. The change in tax revenues as a result of labour market impacts is estimated as a function of the change in GDP from the labour supply impact, and from the move to more or less productive jobs impacts. In UK practice, it is estimated that the change in GDP from the labour supply impact is 40%, and the change in GDP from the move to more or less productive jobs impact is 30% (Department for Transport 2014).

The New Zealand Transport Agency published a detailed report on quantifying and estimating the wider economic impacts of transport investments in 2011 which is somewhat similar to the UK approach where they divided wider economic impacts relating to: imperfect competition benefits, increased competition benefits, labour supply benefits, and job relocation benefits (Kernohan and Rognlien 2011). Other approaches include: input/output models, used in The Netherlands and the USA

(Netherlands: REMI; USA: TREDIS). In the USA, the logistics and supply chain impacts are also considered.

12.1 Congestion Impacts

Three broad definitions of congestion exist in the literature. The first two are engineering based: throughput or demand/capacity relationships; and travel delay. The economic perspective relates to the impact imposed on other commuters by additional vehicles sharing a congested link. It is recognised that no single definition of congestion applies. The European Conference of Transport Ministers (2007, p.10) acknowledges this by offering three broadly different definitions based on:

- The demand capacity relationship: congestion is a situation in which demand for road space exceeds supply,
- The travel delay or impedance: congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches capacity and
- The user's perspective "congestion is essentially a relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the system actually performs.

The gap between user expectation and system performance is a measure of user satisfaction. In order to report an indicator of user satisfaction policy agencies would need to survey the road users. User surveys may be undertaken after the implementation of a TDM instrument. Phase 2 aims to develop a tool to appraise the effectiveness of a proposed TDM initiative. Any survey undertaken would be aimed at eliciting perceived effectiveness or determining the community's level of acceptance rather than to gauge the level of satisfaction and, as such, user satisfaction is not considered further.

Measurements of traffic congestion are usually based on a traffic volume to road capacity ratio (V/C). A V/CR of 1.0 or more indicates that the traffic level has exceeded the design capacity of the road at this point. However, the point in which vehicles slow each other down occurs around a V/C of 0.75 to 0.80 (Boarnet et al., 1998). Litman (2012, p. 3) suggests that a *"V/C less than 0.85 is under-capacity, 0.85 to 0.95 is considered near capacity, 0.95 to 1.0 is considered at capacity, and over 1.0 is considered over-capacity"*. As indicated in Figure 1 as V/C approaches 1.0, small changes in traffic volume lead to large changes in congestion delays. For V/C greater than 1.0 not only is there a slowdown in the speed of vehicles on the congested link or route, there is also a reduction in vehicle throughput.

To calculate the impact due to a time delay, a reference travel time is needed. The reference travel time is the anticipated time a vehicle would take to complete its journey is conditions were uncongested (Luk et al., 2009). It is also valid to make the comparison between congested and uncongested conditions by referring to speed. However, to calculate the economic impact, speed needs to be converted back to travel time by taking into account the distance travelled. It is generally thought that Free-Flow and posted speed limits overvalue the delay, and therefore the benefits of congestion relief. Socially optimum travel time is favoured. The socially optimal travel time correlates with a vehicle to capacity ratio of about 85-90 per cent or to travel times that are 65-80 percent of the free flow speed (van den Bossche, Certan et al. 2001).

Selection of reference travel times:

1) Free-Flow time: travelling at speeds that are considered to be safe if conditions mean that no vehicle interacts with another vehicle.
2) Signed speed limits: approximately equal to Free-Flow time.

3) Social optimum: if a tax was imposed such that the private costs = the social costs (i.e. efficient charging).
4) Pre-congestion levels: approximately 85% volume to capacity ratio or 70% free-flow speed.

Economic indicators of congestion convert the travel delay into a monetary amount either by way of value of travel time savings or as a direct calculation of additional fuel costs incurred due to congestion. Table 4 details the broad classifications of congestion indices. For a complete list of indices see Litman (2012).

Table 4: Broad Categories of Congestion Indicators

Indicator Classification	Description and Measurement	Reference
Delays	Compare the congested travel time to a reference travel time. Indicators include annual hours of delay, delay per capita, delay per road user. The indicators are sensitive to the choice of a reference travel time.	Litman (2012) Grant-Muller and Laird (2006)
Ratios	Measure the ratio of congested periods to uncongested periods. Travel time rate and travel time index measure the proportion of time a route, link or area is in congested condition. The proportion of road mile under congestion indicates what fraction of the network is under congestion during peak times.	Litman (2012) and Grant-Muller and Laird (2006)
Economic	Convert delays into a generalised cost of congestion. Annual or per capita costs of congestion sum time money value of travel time losses and are dependent on the measure used to compute the loss. The travel time valuations are often split between private and commercial travel. Excess fuel costs compares running cost under congested conditions to the running costs under non-congested conditions using standards.	Litman (2012) and Grant-Muller and Laird (2006)

13 CONCLUSION

PART 1 presented a review of the various TDM instruments that are available to policy makers. PART 2 complements the review by presenting the typical tools used for appraising TDM initiatives at various stages of the generic TDM decision framework. TDM project and program appraisal are the most commonly described tools presented in the literature. Sketch tools developed in the United States dominate the findings. The most commonly used tools were developed to assess workplace TDM projects. However, the general approach of estimating the effect of behaviour change and its impact on the transport network is a common theme throughout all the models reviewed. Whilst cost-benefit analysis is a preferred appraisal methodology in transport appraisal in general, it has not been widely adopted in tools designed specifically for TDM appraisal, although its potential for this has been recognised. The most promising of the appraisal tools reviewed is TRIMMS because it extends the basic estimation of behavioural response to include a calculation of the private benefits as well as externalities. Also, TRIMMS has a cost-benefit analysis module. Tools can be used in combination to improve efficiency. Subjective assessment tools such as short-listing and rapid appraisal (Rose 2007a,

b) offer a method whereby short-listing limits the number of initiatives to be appraised and a sketch model such as TRIMMS can be used for the rapid appraisal.

At the level of support for strategic and policy direction setting, where portfolios of TDM initiatives need to be assessed, there are fewer tools reported in the literature, particularly in relation to transport and TDM, presenting a substantial opportunity for innovation. Marginal abatement cost curves are borrowed from climate research. These tools cannot be readily transferred to congestion analysis because the basis of the change is behavioural; in climate science the basis of the change is usually an improvement in technology. However, marginal abatement is effectively another way of reporting a cost-benefit result. In addition to the learning from cost abatement curves applied in other field such as in climate science, learning from this review of the wider application and reporting of experiences in developing and using project appraisal and evaluation tools, can be brought to bear in developing an appropriate strategic TDM policy assessment tool for Perth. The learning is twofold: firstly, continuous project monitoring and evaluation will yield a database of evidence in terms of TDM elasticities and secondly, project appraisal tools or components of tools together with impacts and effectiveness measures and project-level valuations, provide inspiration for upscaling to the strategic policy level.

Travel demand management is the application of demand strategies to improve the efficiency of the transport system. A primary focus of demand management is to encourage alternatives to the use of single occupancy vehicles on the journey to work, with the primary aim of reducing congestion. In addition to reviewing TDM appraisal tools, this review has considered the range of impact measures used to determine the expected and actual effects of TDM on the transport system and benefits to travellers. Key measure of TDM effectiveness on the transport system are: reduction in number of car (in particular, SOV) trips; increased public transport ridership; and increased number of trips by walking or cycling. Whilst indicators that measure change in aggregate number of trips per mode per time of day are useful, any appraisal based on cost-benefit analysis will need to make use of economic indicators which considers the economic value of the benefits to travellers. Key indicators of value are the marginal willingness to pay for: travel time savings, system reliability, vehicle operating costs, improvements to air quality and greenhouse gas emissions and noise. Public transport measures of crowding and comfort can also be included because these outcomes may be affected by TDM's that shift car travellers onto public transport. Benefits related to health, fitness and safety can be included as complimentary benefits.

With a primary objective of TDM being to reduce congestion levels, this review specifically considered measures of congestion used to monitor change. A range of congestion indicators have been developed but are all essentially some variation of a composite measure using travel time saving.

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