

# Efficient transportation networks

## A multi-modal perspective

*(Michael Parker)*

The traditional approach to roadway network planning has been to undertake a travel demand model analysis, identify the links that are predicted to experience congestion, and widen them to increase their capacity. While this may improve the operation of the section of road that is being widened, the release of that bottleneck frequently attracts more traffic to the area. As a consequence, other parts of the corridor or connecting roads, which may otherwise be expected to operate well, may become congested themselves.

Where roadway improvements lead to an increase in network efficiency, drivers may simply choose to commute further instead of banking the travel time savings. This effect actually increases the overall demand on the network in terms of vehicle kilometres travelled, which may negate some or all of the benefits achieved from the roadway improvements.

Efficient use of the limited funds available for roadway improvements means encouraging more efficient use of the network itself. The majority of vehicles on the road have only one occupant, and each driver requires much more roadspace than they would if they were sitting on a bus or riding a bike. Transit and active transportation also have wider benefits in creating more livable, healthier and more sustainable communities. When deciding which sections of roadway to improve, potential enhancements for these non-auto modes should be considered.

It is also important to remember that roads are conduits for the transfer of freight. Congested or otherwise inadequate goods movement corridors increase the overheads incurred in bringing products to stores and supermarkets, and this is often reflected in higher prices for the consumer. The direct cost of roadway improvements, in both financial and environmental terms, should be considered too.

This paper and the accompanying presentation will provide more detail on the incorporation of the aforementioned factors into the analysis of the network to identify the transportation improvements that can get the most “bang for the taxpayer’s buck” by building a more efficient network. It also describes some of the tools that have been developed to effectively undertake the calculations and to present the inputs and outputs in a clear, graphical manner for inclusion in Transportation Master Plan studies.

The performance of existing and future transportation networks can be evaluated by the use of macro-modelling software such as EMME or TransCAD. The study area is broken down into transportation analysis zones (TAZs) and, for each horizon year, the level of population and employment for each zone is input into the model. The zones are then connected by links which are assigned a throughput capacity in terms of vehicles per hour based on factors such as the number of lanes and operating speed. Finally, the software determines the most likely travel patterns associated with that combination of infrastructure and land use, and assigns traffic volumes (in both directions) to each of the links in the roadway network.

To determine the performance and potential for congestion for an individual link, it is necessary to compare the traffic volume assigned with the assumed capacity of that link to process those vehicles. This is known as the volume/capacity (v/c) ratio; a value of 1.0 indicates that the assigned volume is precisely matched by the capacity, and the link would be operating optimally under steady, consistent traffic flow conditions.

In practice, there is variability in the timing of vehicles entering a link, hence the link would oscillate between being under capacity when there were gaps in the traffic flow, and over capacity at other times when there are more vehicles arriving than the link capacity can accommodate. In the latter situation, a 'snowball effect' may occur where the lack of spare capacity to absorb fluctuations in traffic flow can lead to the rapid formation of queues and the deterioration in the operation of the roadway. To avoid this, it is recommended that the maximum hourly volume on a link be between 80% (v/c=0.8) and 90% (v/c=0.9) of its capacity, with the remainder acting as a buffer.

As part of the Transportation Master Plan (TMP) process, macro-models are typically developed for the following scenarios:

- Existing: typically based on population and employment data collected in the most recent census (e.g. 2011), along with the roadway network that was present at that time;
- Do Nothing: using population and employment projections for a future horizon year (e.g. 2031) assuming that the existing roadway network will still be in place along with improvements that are already under construction or otherwise committed;
- Future scenarios comprising the structure of the 'Do Nothing' case plus a select basket of improvements. While several scenarios may be modelled, it is not feasible to analyze every single permutation, even with a relatively small basket of projects.

The transportation of people serves no purpose in and of itself; rather, it enables us to participate in activities at different locations. The most popular such activity is employment, hence overall travel demand is the highest during the weekday morning and evening rush hours, when the majority of office workers are driving from, and to, their homes. The other 158 hours of the week, the volume of traffic is typically lower and, in some cases, significantly so. However, this is the "worst case scenario" that is generally considered in modeling. If the network is able to manage the demand at these times, then it should operate acceptably the rest of the time.

Figure 1 shows example link structures representing a road network across three future scenarios. In the figures on the left, the number of parallel lines signifies the number of lanes in each direction, and proposed lanes are highlighted in blue. On the right, the colour figures show the link volume/capacity ratios in the peak direction for each scenario, with red indicating that a link is expected to be congested.

The traditional approach to identifying the recommended network improvements is to run the 'Do Nothing' model to identify the links with a high v/c ratio. The improvement projects will be aimed at reducing the v/c ratio by widening those congested links to increase their capacity, or constructing new links that provide alternative routing options and thus reduce the traffic volume on the affected links.

This logic considers the roadway network to operate like plumbing. When a pipe becomes blocked, the standard course of action is to locate the blockage and clear it. The expected result would then be a system that flows as well as it did before the problem arose. However, there is a key behavioural difference between the water molecules flowing through pipes and traffic flow on a highway. The former is governed by the laws of physics, whereas the latter is directed by human decision making.

The significant investments associated with facilitating the movement of transportation network users are typically justified by the benefits that will result, sometimes in terms of safety but more often in terms of travel time savings. The assumption is that travel time is wasted and that commuters will always adjust their behaviour to minimize it. However, the logical extension to this is that workers would prefer to live as close to their work as possible, in which case everybody's commute would involve only a short walk, or even a gentle roll out from under their desk. This is clearly not the case, hence the reality must consist of a balancing act between the competing desires to keep travel time as low as possible and the benefits that may be achieved from living some distance from work.

Like any product or service, demand for travel (and the activities to which it allows access) is sensitive to the associated costs incurred. Such costs can be measured not just in terms of travel time, but also comfort, safety and actual financial expenditure. Improving the quality of transportation facilities affects the relationship between cost and demand. It is not necessarily the case that the travelling public will realize the associated savings in terms of travel time alone.

Marchetti, Zahavi and others have hypothesized that there may be a fixed tolerance, or even a preference, for a certain quantity of travel time. This concept is known as a 'travel time budget', and it can be leveraged so as to minimize other costs, such as those associated with accommodation. In the case of toll roads, a financial cost may be incurred in order to increase average speed and hence the distance that may be travelled within a fixed time, rather than reducing the time required to travel a fixed distance. The wider network may experience greater demand in terms of vehicle kilometres travelled, partially or even fully negating any benefits that may have been expected from the roadway improvements and the associated public investment.

Figure 1: Induced demand affecting network performance following roadway improvements

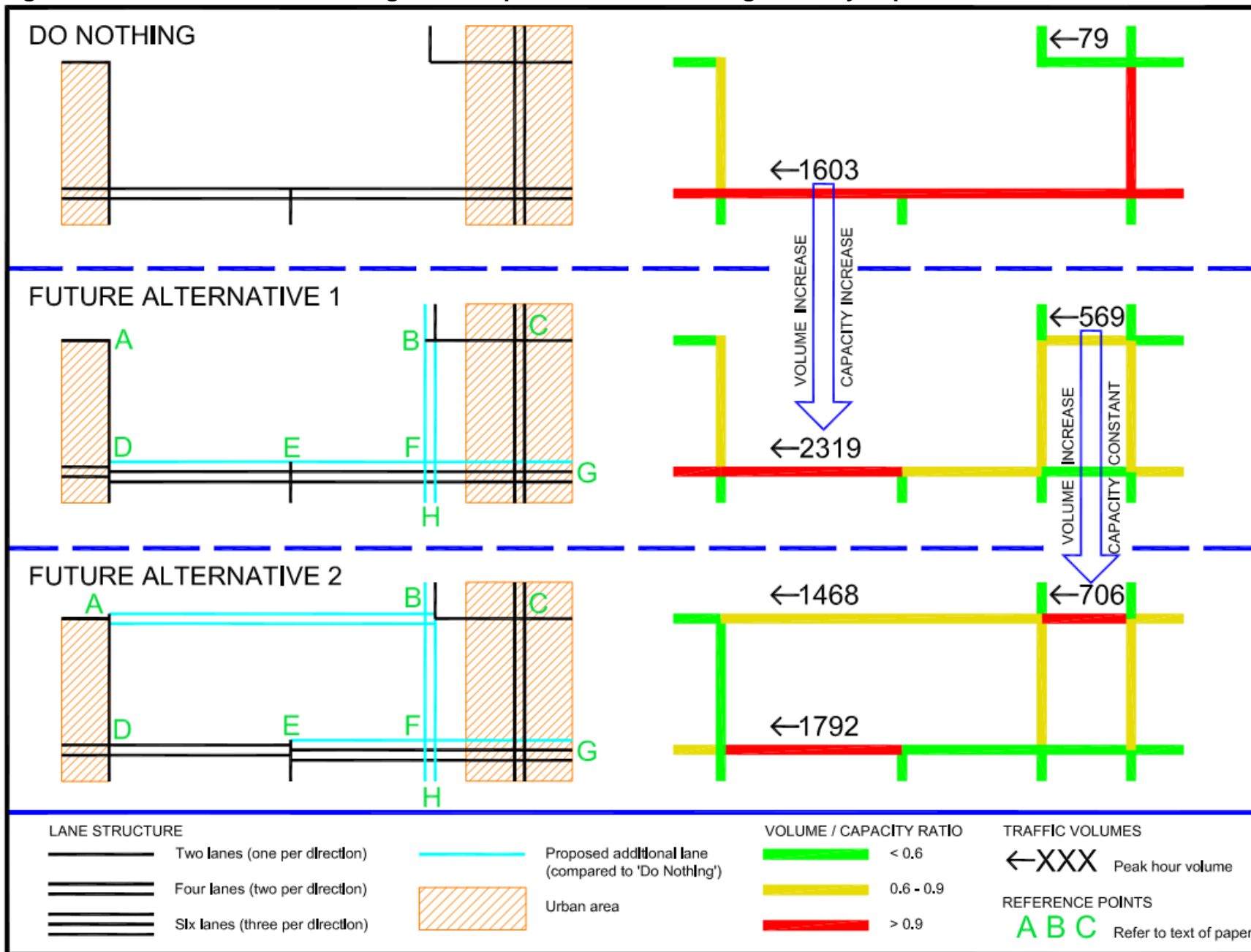


Figure 1 demonstrates how travel demand may be induced by highway improvements. The top row shows the aforementioned Do Nothing future baseline scenario.

In Future Alternative 1, an existing highway connecting two urban areas is proposed to be widened from two to three lanes in each direction between points D and G on the figure. Since it is the only direct inter-city connection, the highway is expected to be congested in the Do Nothing scenario; however, following the proposed widening, parts of the roadway, EF and FG, will experience an improvement in performance and are respectively shown in yellow and green in the volume/capacity (v/c) plot on the right. On section DE, this 50% increase in lane capacity, when combined with the construction of a perpendicular four-lane road BH, induces a 45% increase in volume from 1603 to 2319 peak hour vehicles. More people will attempt to drive further within their travel time budget, filling the majority of the additional capacity.

In Future Alternative 2, part of the existing inter-city highway, EG, is proposed to be widened. This leads to a significant improvement in performance on that widened section, with the v/c ratio dropping below 0.6 from a ratio in excess of 0.9 in the Do Nothing case. Although section DE is not proposed to be widened in this scenario, the additional demand attracted to the inter-city corridor results in a volume increase on section DE from 1603 in the Do Nothing scenario to 1792 in Future Alternative 2. This adds to a v/c ratio that is already above 0.9 in the Do Nothing scenario.

A second inter-city highway, AB, is proposed for construction and the model shows that, similarly, the through traffic pushes section BC, which would otherwise operate with a volume/capacity ratio below 0.9, into the red in Future Alternative 2. Summing the inter-city volumes, it can be seen that there is more than double the demand (3260) than in the Do Nothing case (1603). Therefore, the new road AB in Future Alternative 2 will encourage more and longer commutes by car, requiring yet more infrastructure.

So, if projects are not to be selected exclusively on the basis of volume/capacity ratios, then what criteria should be applied? The answer is to incorporate upgrades that make better use of the roadway by increasing its ability to move people. This means improving the infrastructure for transit and cycling, modes where each travelling person occupies a smaller area of roadspace than a solo driver. This also frees up the roads for other important functions such as freight movement. As well as the benefits of more efficient roadways, it is important to consider the true costs of improvement works in financial and environmental terms.

A scoring system can be developed to rate projects based on multiple accounts, with criteria may include the following:

- **Support for Transit:** In rural communities, density and intensification targets can make the provision of express transit service between major settlements more feasible, in which case this account can recognize improvements on direct routes between primary settlement areas. In urban environments, where roadway and transit improvements overlap, points can be awarded to reflect potential running time savings along transit routes.

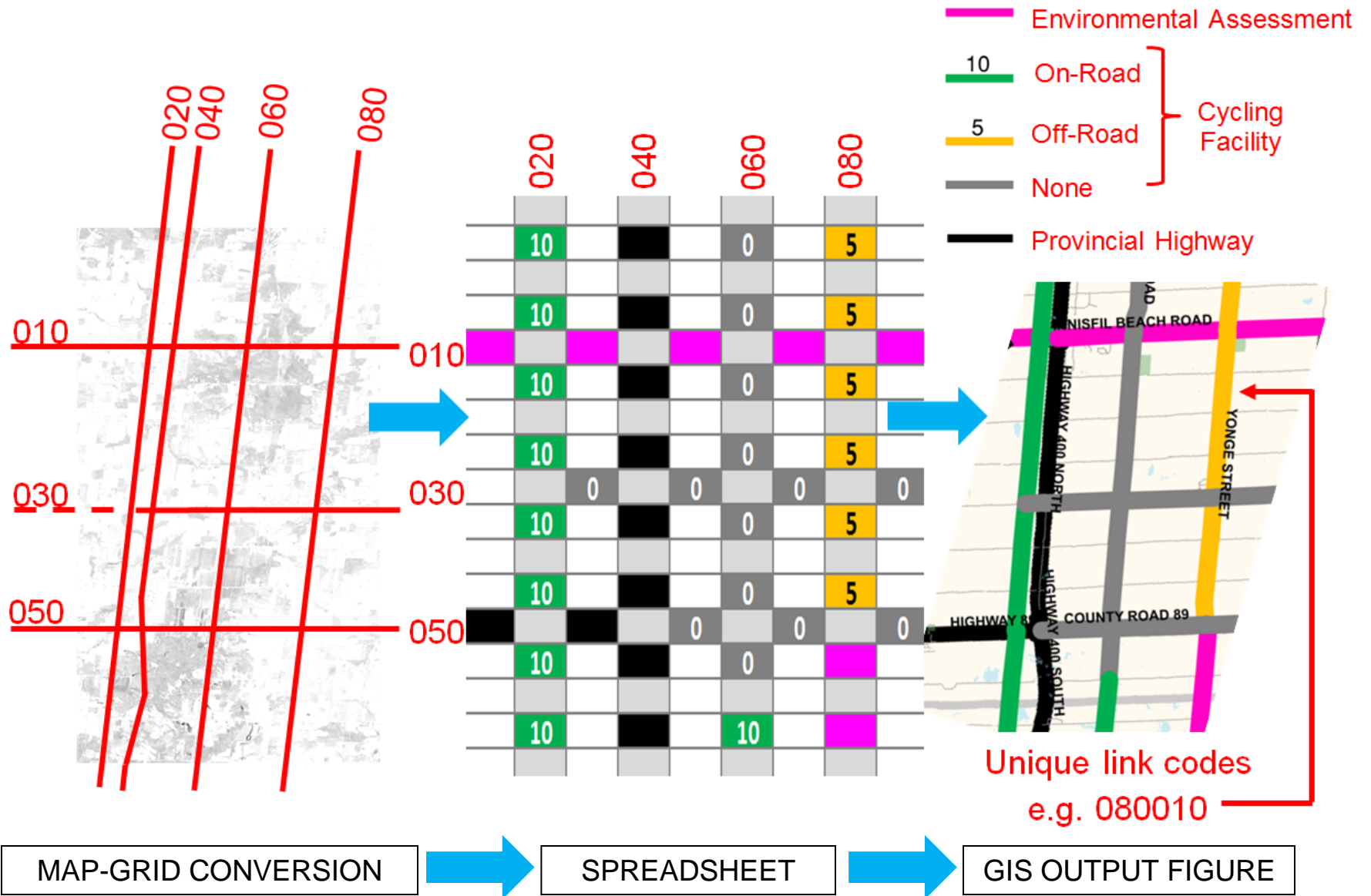
- **Active Transportation:** This identifies overlaps between road network improvements and active transportation projects, recognizing potential synergies by giving preferential scoring to road projects that have the scope to incorporate active transportation facility upgrades. Benefits may be found where on-road bicycle facilities are proposed and can be implemented at the time of the road widening, although these economies of scale may also exist for certain off-road sections.
- **Goods Movement:** This recognizes improvements that are proposed on roads identified as goods movement corridors, roads linking major settlements, or bypasses around smaller communities. Lower travel times for freight mean reduced overheads and benefits for the wider economy.
- **Environmental Impact:** This identifies the land use designations adjacent to the proposed improvements which may be affected by them. This may include, in decreasing order of environmental impact: settlements, economic/employment districts, rural/agricultural lands, areas that may carry a 'greenlands' or similar designation, and conservation areas.
- **Cost Effectiveness:** This is based on the implementation costs per kilometre. Although this will be a high level estimate, consideration should be given to the need for structures, large-scale earthworks and other aspects that may increase construction costs for certain routes.

The choice of accounts will vary according to the local context and, before aggregating the scores, certain variables can be weighted in line with stakeholder priorities.

A basket of improvements can then be evaluated based on these accounts. Candidate roads may be scored in blocks between major intersections, with values averaged across the length of the proposed project. A threshold can be set for the total score across all accounts, and those projects with a tally greater than that can be prioritized for implementation. It should be noted that roads where Environmental Assessments (EAs) have been undertaken or are underway should be excluded from this evaluation, with decisions based upon the outcome of the more detailed EA progress.

To assist with calculating the scores, a spreadsheet template can be set up. Lines can be drawn across the road map in two directions, predominantly horizontal and vertical, and grid reference numbers can be attached. This will enable the road network to be translated into a grid, and for each horizontal or vertical section of roadway to be identified by a unique six-digit code. Scores for each link in the network can be input on separate tabs, which can be weighted, summed and exported along with the unique code. The GIS network can be drawn with numbered links that are consistent with the grid, and colours can be matched with point scores. The table of codes and values can be imported into the GIS file, which will then be populated automatically. This process is illustrated in Figure 2.

Figure 2: Score calculation and map production process (example: active transportation)



The projects selected by the aforementioned methodology can be incorporated into the Do Nothing model to create an alternative future scenario. This model can then be run to identify the links whose operation has improved, and those that will still experience congestion.

As previously described, the traditional approach to mitigating those red links would be to simply widen the affected roads or construct new ones. The alternative methodology can be adapted to subject those red links to the multimodal evaluation. Those that score highly are recommended for widening. For those that score poorly, alternative improvements are investigated on nearby or parallel roads. Those alternatives that score highly can themselves be recommended for implementation in order to divert traffic away from the congested links while also improving the road network for all users.

In summary, the common practice of trying to relieve congestion by widening roadways or building new ones can be self defeating, encouraging people to drive further in order to meet their broader lifestyle objectives while maintaining a tolerable commute time. This paper and the accompanying presentation demonstrate these effects and show that it is possible to make more efficient use of roadways by considering synergies with transit and active transportation improvements, freeing up capacity for freight movement and considering financial and environmental costs. The result will be effective and targeted investment in the development of sustainable transportation networks that operate efficiently for all modes.