Impacts of safer speed limits on road network operations
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Abstract

This paper presents the findings of an Austroads project carried out by ARRB investigating the impacts of road safety-based lower speed limits on network operations. There is a strong link between vehicle speeds and road safety, as recognised by the Safe System approach. Under speed management strategies implemented by Australasian jurisdictions, speed limits are sometimes lowered with the aim of producing lower vehicle speeds, and thus, quantifiable reductions in crashes.

The project provided an overview of the current state of research on the impacts of lower speed limits on the network operation indicators such as: travel speeds, journey times, traffic flow, air pollutant emissions, fuel consumption and the overall economic costs. These findings were extended by estimating the impacts of lower speed limits on urban arterial roads with interrupted traffic flow (signals, roundabouts). Microsimulation modelling of several arterial routes operating under peak-hour traffic conditions was used to quantify the changes in the network operation indicators.

The key finding of the project was that significant speed limit reductions on urban arterials operating under congested conditions would be unlikely to produce appreciable safety, operational, environmental or travel cost impacts. On the other hand, the identified literature suggested that impacts of lower speed limits on network operations would be greater outside of peak traffic times and under free-flow conditions. Specific estimates of these impacts remain to be investigated.

Keywords
Safe System, speed limits, speeds, travel time, casualty crashes, air pollutant emissions, fuel consumption, transport costs

Introduction

Assumptions are sometimes made about the impact that lower speed limits will have on traffic speeds, journey times, traffic flow, air pollutant emissions, fuel consumption and the overall economic impacts. While there were a number of recent studies in these areas, there was a need to consolidate and extend this research.

This paper presents the findings of an Austroads project carried out by ARRB investigating the impacts of road safety-based lower speed limits on network operations, as presented in Jurewicz (1). The project included an overview of the current state of research about the lower speed limit impacts on the above network operation indicators on different parts of the road network. Following this, consultation was carried out with Austroads stakeholders from different Australasian jurisdictions. Finally, microsimulation modelling was carried out to evaluate impacts of lower speed limits on urban arterial roads operating under peak-hour conditions.

Method

The literature review sought to quantify the lower speed limit operational impacts relating to various parts of the road network, e.g. freeways, arterials and local roads, focussing especially on urban road networks. The review covered four transport-related disciplines: arterial flow management, road safety, environmental impacts and transport economics. The following subjects were pursued in relation to various parts of the road network:

- speed-related network performance indicators
- impacts of lower speed limits on road safety
- impacts of lower speed limits on traffic performance (mean speeds, travel time, traffic flow)
- environmental impacts (air pollutant emissions, fuel consumption)
- economic cost of the impacts (unit costs)
available impact evaluation models.

In order to identify the relevant studies, a literature review was conducted using the resources of ARRB Group’s MG Lay Library. These resources included the library’s own comprehensive collection of technical land transport literature and information retrieval specialists with extensive experience in the transport field, as well as access to the collections and expertise of other transport-related libraries throughout Australia and internationally.

The consultation phase sought informed views from road authorities on the issues covered by the literature review and details about the state of the current knowledge. It also sought guidance on appropriate methodologies for addressing any gaps. The consultation was carried out by interviewing Austroads stakeholders drawn from the Road Safety Task Force and the Network Task Force.

The findings of the literature review and the consultation were extended by estimating the impacts of substantial speed limit reductions on performance of urban arterial roads. This was achieved by microsimulation modelling using VISSIM software. Five calibrated urban arterial road link models were donated by the road authorities for this purpose (three in New South Wales, one in Victoria and one in Queensland). The links varied in length from 1.8 km to 15 km. They represented a cross-section of single and divided urban arterials found in the outer metropolitan areas of Australasian cities. The existing speed limits on the arterial links ranged between 60 km/h and 100 km/h. Each link comprised of a number of road segments and intersections (signals or roundabouts). The stakeholder consultation process suggested that modelling the impacts of a 20 km/h speed limit reduction was of interest to road authorities. This speed limit reduction was applied to the existing speed limits on the modelled links.

VISSIM simulations were run for each link in the before scenario (existing speed limits) and in the after scenario (speed limits lowered by 20 km/h). The simulation outputs were produced at segment level and included operational parameters such as: mean speed, mean midblock point speed, average travel time, travel time standard variation and individual road segment delays during peak traffic period. The before and after parameters were compared to quantify the impacts of the speed limit reduction for every segment on each link. The simulation outputs were used to calculate expected changes in air pollutant emissions, fuel use and casualty crashes. The methodologies for calculation of these parameters were derived from Zito (2). Casualty crash changes were estimated from the changes in mean segment speeds using the revised Nilsson’s Power Model described by Cameron and Elvik (3). The changes in the key parameters (travel time, air pollutant emissions, fuel use and casualty crashes) were aggregated to link level and monetised using standard road user unit costs as provided by Luk, Kazantzidis and Han (4). The overall economic cost impacts of lower speed limits were thus calculated. Details of the exact methodologies used in this project are documented in detail in Jurewicz (1).

Results

Literature review

There was a substantial amount of information available on the impacts of lower speeds on different aspects of road network operation. Table 1 presents the key findings for different parts of the road network. A number of knowledge gaps were also identified. There was little available research on the operational impacts of lower speed limits on urban arterials, other than motorways. This was noted as a priority for further research in this field. Other specific knowledge gaps included:

- There was little information found specific to rural roads.
- Crash reduction benefits due to application of Variable Speed Limits (VSL) could be analysed in more depth to better understand the severity of the reduced crashes and crash types involved. How do different VSL systems and operation modes affect safety?
- There were no studies identified dealing with the effects of lower speed limits on performance of traffic signals and the role of signal coordination.
- There was lack of published, locally developed, speed-based air pollutant emission factors (curves) based on the composition of the Australian fleet.

1 VISSIM 5.10 is a microscopic, behaviour-based traffic simulation program capable of modelling traffic flow at individual intersections, road links and entire road networks.

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Table 1: Summary of key impacts of lower speed limits on operations of different parts of the road network, based on the review of published literature

<table>
<thead>
<tr>
<th>Part of the network</th>
<th>Traffic speed</th>
<th>Safety</th>
<th>Travel time</th>
<th>Traffic flow parameters</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorways</td>
<td>Greater mean speed reduction expected at high speed limits – approximately 4.0-4.5 km/h per each 10 km/h in speed limit reduction.</td>
<td>Reduced casualty crashes (including VLS applications); revised Nilsson’s Power Model suggests 10-15% casualty crash reduction for a 10 km/h speed limit reduction from 100 km/h.</td>
<td>Little or no consistent increase in the mean travel time for a given section. Increase observed only outside of the peak times. Mixed results for VSL applications.</td>
<td>Increased capacity at lower speed limits, e.g. 80 km/h; achieved through more homogenised traffic flow and less incidents. VSL applications very effective.</td>
<td>Air pollutant emissions and fuel consumption per km decrease with increasing speed up to about 80 km/h and then increase with increasing speed. Fuel consumption increases again at high speeds and increases by roughly 50% between 80 km/h and 120 km/h for passenger vehicles. Mean spatial speed reductions below 80 km/h will generally increase emissions and fuel consumption.</td>
</tr>
<tr>
<td>Urban arterials</td>
<td>Moderate mean speed reduction expected at medium range of speed limits – approximately 3.0-3.5 km/h per each 10 km/h in speed limit reduction; less if speeds are already low due to congestion.</td>
<td>Revised Nilsson’s Power Model suggests 5% casualty crash reduction for a 10 km/h speed limit reduction from 80 km/h.</td>
<td>Travel time increases expected, although studies provide different estimates; little evidence found in this area.</td>
<td>Little evidence; theoretically capacity improvement possible by reduction in mean speeds from 80 km/h towards 50 km/h (approximate peak capacity).</td>
<td></td>
</tr>
<tr>
<td>Local urban roads</td>
<td>Lower mean speed reduction expected – approximately 2.5-3.0 km/h if speed limit reduced by 10 km/h or more.</td>
<td>Revised Nilsson’s Power Model suggests 10-15% casualty crash reduction for a 10 km/h speed limit reduction from 50 km/h.</td>
<td>Travel time increases expected.</td>
<td>No evidence found – not likely to be an issue.</td>
<td></td>
</tr>
<tr>
<td>Rural roads</td>
<td>Higher mean speed reduction expected at high speed limits – approximately 4.0-4.5 km/h per each 10 km/h in speed limit reduction.</td>
<td>Revised Nilsson’s Power Model suggests 15% casualty crash reduction for a 10 km/h speed limit reduction from 100 km/h.</td>
<td>No estimates found; however, travel time increase is expected to be proportional to mean speed reduction.</td>
<td>No evidence found – not likely to be an issue.</td>
<td></td>
</tr>
<tr>
<td>General comments</td>
<td>Speeds during congested periods are not generally affected by the speed limit. Time-based speed limits and VSL appear to also reduce mean speeds. VSL was found to reduce speed dispersion.</td>
<td>Crash frequency is strongly dependent on traffic volume, so speed limit reductions on low volume roads will produce low absolute crash savings.</td>
<td>Individual travel time increases may not be significant, especially on urban networks. Lower speed limits are likely to have the greatest impact on roads where drivers can select speeds for significant proportion of the driving time. Travel time during congested periods is not generally affected by speed limit.</td>
<td>Lower speed limits are likely to have the greatest impact on traffic flow parameters on low-to mid-level traffic density roads, where drivers can select speeds for significant proportion of the driving time.</td>
<td></td>
</tr>
</tbody>
</table>

Note: economic impacts were omitted from this table due to lack of information specific to different parts of the road network.
The literature review also identified four different types of models for the estimation of the impacts of lower speed limits on network operations. Analysis of the model methodologies and results highlighted that there was no one approach which could estimate the full range of network operation and economic impacts. The effects of non-recurrent congestion (minor incidents, roadworks, special events, etc.) could not be adequately modelled by any of the approaches. Nevertheless, microsimulation modelling technique provided a viable platform for estimation of lower speed limit impacts on mean speeds and travel time. It was shown that the model outputs could be then used to estimate safety, environmental and economic impacts of lower speed limits.

Consultation

Consultation with the Austroads stakeholders confirmed that more information was required about the impacts of lower speed limits on the operation of urban arterial roads with interrupted flow. The majority of stakeholders agreed that this should be the priority for the reminder of the project. Use of traffic microsimulation models was confirmed as the preferred methodology to bridge this knowledge gap. Other areas of interest included the impacts of lower speed limits on: CBD areas, major rural town centres, rural roads and major freight routes.

Modelling of lower speed limit impacts

The key finding from the modelling task was that at link level (an entire arterial route), all impacts of a 20 km/h speed limit reduction on network performance parameters were insignificant on urban arterials in peak traffic conditions. Mean speeds changed very little in absolute terms at link level: -1.3 km/h to 1.5 km/h. Midblock mean speeds changed by between -0.5 km/h and 1.1 km/h. The most appreciable speed reductions were noted on one segment which had the lowest congestion, 100 km/h original speed limit and uninterrupted traffic flow (start of a freeway).

Travel time, air pollutant emissions, fuel consumption and expected casualty crash numbers also did not show significant changes at link level. There was no evidence of changes in the reliability of travel time either (this result does not account for the expected reduction in flow disruptions due to minor traffic incidents). Analysis of the segment travel time and delay information suggested that travel time and speeds were controlled by congestion at the intersections rather than by driver speed choice. The modelling confirmed the previous literature which states that speed limits have limited impact under congested conditions.

On the basis of the modelling, it can be concluded that reductions in speed limits would have no appreciable effects on urban arterials during times of congestion. Limited data constrained further analysis of the impacts at off-peak times and should be pursued through future research.

The methodology developed under this project offers an opportunity for road jurisdictions to provide evidence-based evaluation of speed limit reductions across a range of operational factors, including the social cost impacts. Proposed speed limit reductions can be evaluated at link or network level using microsimulation modelling technique, as done in this project. Past speed limit reductions can be evaluated using the collected before and after traffic data.

References

4. Luk, JYK, Kazantzidis, G & Han, C, in press, Estimating Road Network Congestion and Associated Costs, Austroads project NS1203, Austroads, Sydney, NSW, Australia.