WELLINGTON TRANSPORTATION MODELLING STEERING GROUP

SUMMARY OF INVESTIGATIONS

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1 Executive Summary

1.1 Outline

This executive summary covers the objectives, processes, achievements and suggestions for best practice relating to the Steering Group that the NZ Transport Agency requested be established to provide guidance for transport modelling associated with major projects in the Wellington Region, with the Petone to Grenada (P2G) project the first to benefit from this approach.

It should be noted that this report was undertaken after the multi-criteria assessment (MCA) and was not used as part of the decision making process that resulted in Option C (managed motorway) being selected as the preferred option to take forward to the next SAR stage of the project. The conclusions drawn from this report do, however, confirm that the MCA findings can still be considered robust.

1.2 Objectives

A Steering Group process was initiated by the NZ Transport Agency to understand the modelling work undertaken for the Petone – Grenada (P2G) link road, and develop a 'best practice' framework for modelling work going forward that could be applied to the P2G project and other projects within the region.

The objectives of the steering group were as follows:

- to create a forum within which ideas and concerns could be discussed in an open and collaborative manner
- to promote ongoing communication between key stakeholders – consultants, NZ Transport Agency, regional modellers– at all stages of the project lifecycle
- ensure that all stakeholders understand the functionality of the existing modelling tools in order that they can make most effective use of these tools
- develop, test and challenge the robustness of the assessment of transport schemes, with P2G the first project selected for this approach
- create a set of 'best practice' guidelines for undertaking transport modelling within the region associated with significant projects that have multiple stakeholders

1.3 Process

The Steering Group process was initiated with a workshop, attended by stakeholders across the Wellington transport modelling sector.

The workshop was run by an independent facilitator and the purpose was to provide a forum to discuss modelling work done to date, allow stakeholders to articulate ideas and concerns and to allow the independent modelling experts to pass professional judgement and opinion on a range of issues discussed.

The outcome of the workshop was a series of questions relating to:

- the robustness of the business case for P2G, particularly in relation to a range of possible scenarios
- the technical details relating to the modelling undertaken for P2G, given that the project is likely to come under public scrutiny during a board of inquiry or environment court

- a need to better understand levels of service on both P2G and the wider state highway network under a range of scenarios, and the implications that this might have for scheme design, interchange design and congestion on the wider network
- better understand the impact that public transport could have in terms of managing demand on P2G and the wider network

These questions were taken by the steering group – comprising Transport Agency modelling experts, Transport Agency appointed consultants, P2G peer reviewer and GWRC – and developed into a set of actions and investigations to be undertaken in a collaborative manner by members of the steering group.

The Steering Group agreed that the key outcomes from this process were as follows:

- a series of technical notes, summarising the investigations
- regular communication between steering group members, including bi-weekly meetings, to discuss progress and provide guidance
- a final report that:
    - summarises the investigations
    - provides a set of conclusions relating to the major questions
    - outlines recommendations going forward to the SAR stage relating to modelling risks, requirements and specifications
- a 'best practice approach to be used for future significant modelling projects within the region that include multiple stakeholders

A project modelling control group will also be setup to provide oversight and guidance during the next stage of modelling work for P2G, and will ensure that recommendations in report are adequately addressed and reported.

1.4 General conclusions and recommendations for future best practice

The overall conclusion from the steering group process was that it was valuable and worthwhile for the following reasons:

- it provided a forum within which work that GWRC had independently undertaken in relation to P2G prior to the modelling steering group being initiated, that informed GWRC views on the project, could be discussed, understood and incorporated into the P2G assessment
- it provided a forum within which modelling work undertaken by GWRC and Transport Agency consultants could be critically evaluated, with further investigations undertaken based upon these findings
- it drew all modelling stakeholders together, with the outcome being a common understanding of the functionality, strengths and weaknesses of the modelling tools
- it helped develop a better understanding of the business case for the P2G link road under a wide range of future scenarios

- provides recommendations for improvements and further investigations, to be undertaken during the subsequent SAR stage of modelling, to address identified risks

It is recommended that a steering group approach be adopted for future significant modelling projects within the Wellington Region, using the following 'best practice' guidelines:

- at the start of a project, a modelling team should be setup, including all relevant technical stakeholders and personnel in order to capture the range of experience that exists within the sector

- an open and collaborative ethos must be developed and embedded in the modelling team, to enable regular and constructive discussions to take place at all stages of the project and between all stakeholders

- targeted communication between the modelling team and the wider project team is also critical to the success and smooth running of the project

- at the start of a project, the existing modelling tools, their assumptions and their interdependencies should be critically evaluated and understood, with the focus placed upon the area of interest of the project and the suitability of the tools for answering the questions that are likely to arise during the project

- based upon these evaluations, any limitations with the modelling tools should be understood and addressed in the most practical manner

- the likely role, purpose and impact of a particular scheme should be understood by all modellers at an early stage, perhaps via a streamlined modelling workshop including stakeholders and selected modelling experts, with the role, purpose and impact being borne in mind during the remainder of the investigations

- in terms of the modelling programme:

    - it should deliberately begin at a high strategic level, looking at a range of scenarios representing optimistic and pessimistic views of the future regarding population and traffic growth

    - as the project progresses and the scheme gets refined, the modelling work will get more detailed. At this stage the appropriate modelling tools should be utilised, bearing in mind the need to look at a range of scenarios whilst ensuring consistency with strategic work which may have been previously undertaken

    - based upon the modelling work, a range of likely outcomes, the likelihood or them eventuating and their likely impact upon the transport network should be agreed by the modelling team and articulated to the wider project team in simple terms

- two-way communication and dialogue between modelling stakeholders is critical throughout the project lifecycle, in order to develop a robust piece of analysis that can be understood and supported by wider stakeholders through a hearings process

1.5 Conclusions and recommendations relating to P2G

In relation to the P2G link road, the substantive conclusions and recommendations are summarised in the remainder of this executive summary and are presented in detail in the main report.

At a very high level, the conclusions are as follows:

- the business case for the P2G link road remains very strong, with the scheme objectives met and significant benefits generated under a range of scenarios from pessimistic to optimistic
- levels of service on both the P2G link road and key stretches of SH2 and SH1 remain largely unchanged regardless of the assumptions made relating to levels of demand, with significant travel time savings and de-congestion benefits generated under all scenarios
- whilst areas where the modelling tools would benefit from some refinement have been identified, this should be placed in the context of a set of modelling tools that are generally suitable for the investigations that they have been used for to date, namely deciding between options
- the view of the steering group is that neither refinements to the modelling tools nor different assumptions would have resulted in an outcome other than Option C (managed motorway) being identified from the multi-criteria assessment and taken forward to the next SAR stage of the project

The high-level recommendations going forwards are as follows:

- results and outcomes should continue to be expressed as a range, with associated probabilities, to reflect uncertainty regarding input modelling assumptions
- minor improvements are suggested for the SATURN model to better replicate a new, comprehensive set of observed travel times that was not available during the model calibration and validation and thereby develop a more robust assessment of the impacts of P2G
- the S-Paramics model should be the focus of investigations during the SAR stage, particularly relating to:
    - the operational characteristics of the two interchanges – Petone and Tawa – and the requirement to design a safe layout that has the capacity to deal with forecast traffic volumes under a range of future scenarios
    - levels of service and travel times along P2G and critical sections of SH2 (Dowse to Ngauranga) and SH2 (North of Tawa)

1.6 Detailed P2G investigations, conclusions and recommendations

Below is a more detailed summary of the P2G investigations, conclusions and recommendations.

1.6.1 Model purpose and use

Three tiers of models listed below, in order of increasing level of detail but decreasing coverage, were used to understand the impacts of P2G on the wider transportation network:

- **Tier 1 -** Wellington Transport Strategic Model (WTSM); a traditional four-stage transportation model using land-use and demographic information to generate estimates of travel demand across the whole region
- **Tier 2 -** North Wellington SATURN Model (NWSM); a traffic-only model covering the North Wellington area and used to assess the strategic and road network benefits of P2G
- **Tier 3 -** S-Paramics Model; currently covers Tawa and Petone interchanges, a detailed simulation traffic model, used to assess operational performance and inform the design process.

The development and scoping of the S-Paramics model is still at an early stage; however, this model will be validated according to NZTA model validation guidelines and independently peer reviewed.

Outputs and assumptions are taken from the higher tier models (1 and 2) and fed into lower tier models (2 and 3). As part of this process, comparisons are undertaken between all tiers of models, focussing on the area of interest of a particular scheme, to understand differences between models and either update models accordingly or account for such differences as part of the project analysis in lower tier models.

As outlined in the Transport Model Development Guidelines[1] published by the NZTA, the validation requirements for each model differ, reflecting the level of definition which each model type provides.

Whilst WTSM and NWSM have both previously been independently peer reviewed, further assessment of the validation of WTSM and NWSM within the area of interest of P2G has now been undertaken against a new comprehensive set of travel time data that was not previously available. This analysis showed that the validation overall is satisfactory, although there are some differences between observed and modelled travel times at peak periods in both models on SH2.

WTSM 2011, which has been used for all P2G analysis to date, has recently been updated to a 2013 base year. Whilst initial analysis of the updated base and future year scenarios suggests that the resulting changes in traffic volumes within the area of interest of P2G are likely to be minimal, additional work is required to fully understand the implications of the updated base year model and updated forecast assumptions.

Project recommendations

- it is recommended by the steering group that differences between modelled and observed travel times in both WTSM and NWSM be understood and accounted for when updating NWSM and S-Paramics for the SAR stage of the project
- it is recommended that analysis be undertaken to fully understand changes in future year traffic volumes and levels of service between forecast models derived from WTSM 2011 and WTSM 2013 respectively, focussing on the area of interest of P2G
- based upon comparisons between WTSM 2011 and WTSM 2013, together with an understanding of P2G project time scales, a decision should be made regarding whether NWSM should be updated based upon new outputs derived from WTSM 2013

Wider recommendations

- it is important that the different tiers of models are used intelligently, with discussion between modellers at the early stage of a project important in order that everyone understands model functionality, assumptions and weaknesses
- this process may require targeted local validation improvements in lower tier models, or additional sensitivity tests, to address potential weaknesses in models at all levels

1.6.2 Assumptions and Information

Capacities on several key links (P2G, SH2 Ngauranga to Petone and SH1 North of Tawa) were calculated from first principles using the Highway Capacity Manual (HCM) methods, to provide a basis against which levels of service could be assessed consistently in this report.

[1] https://www.nzta.govt.nz/assets/resources/transport-model-development-guidelines/docs/tmd.pdf

HCM is but one method of estimating capacities, with the input capacities for WTSM and NWSM themselves developed from a combination of HCM data, Department for Transport UK (DfT) data and local information.

Whilst acknowledging the fact that NWSM capacities are expressed in passenger car units (pcus) and should therefore be higher than WTSM and HCM capacities (both expressed in vehicles), the comparisons undertaken for this report suggest that current capacity assumptions may not be consistent between models and with the HCM values, resulting in differences in the modelled traffic volumes, travel times, representation of bottlenecks / merge points, levels of service and route choice between the two models.

The volume / capacity (V/C) and level of service analysis presented in this report is based on data from average hour models (WTSM = 2hr, NWSM = 1hr), an appropriate level of detail for modelling tools of this nature.

Being average hour models, WTSM and NWSM do not fully reflect the profile of volumes and travel times within one-hour peak periods.

The 'peak of the peak' could result in V/C ratios between 5% to 10% greater than those quoted in the report for short periods of time within the longer time periods, and the corresponding effect that this might have upon travel conditions throughout the time period.

Project recommendations

- further analysis should be undertaken to review and verify capacities (links, merges, intersections) in all models, based on existing work undertaken when developing capacities for NWSM, together with US and UK research and recent local count data.
- based upon this further analysis, a decision should be taken regarding whether capacities used in NWSM should be updated in order to improve the travel time validation in NWSM
- whilst Jacobs undertook a range of internal sensitivity tests when developing NWSM to consider the effect of different capacity assumptions, stacking lengths, time slices and demand alterations, additional sensitivity analysis should be undertaken in NWSM at the SAR stage to determine the extent to which different capacity assumptions might affect levels of services, travel times and benefits specifically generated by P2G
- variations in traffic volumes within the peak hour (peak of the peak), and the corresponding impact on travel times, travel time variability and congestion, should be accounted for in the S-Paramics during the SAR stage to ensure that the interchange design can adequately cope with variability in traffic volumes

1.6.3 Land use

A number of alternative land use scenario tests were run in WTSM, to understand the impact that different land use patterns might have upon traffic volumes, travel times and levels of service on key parts of the network.

The results of the sensitivity tests showed that regardless of whether low, medium or high growth scenarios were chosen, levels of service at key locations on the network remained largely unchanged.

Project recommendations

- as the modelling suggests that levels of service would remain largely unchanged at key locations on the network regardless of the growth assumptions, combined with the fact that the region has followed a 'medium' population growth trajectory over the last 15 to 18 years, it is recommended that medium growth should remain the central case growth scenario

- further sensitivity testing to understand how any land use response to P2G might affect levels or service should be undertaken during the SAR stage of the project as the detailed design of the P2G link road and Tawa / Petone interchanges progresses

1.6.4 Comparison of WTSM and NWSM

A comparison of base year and future year traffic volumes and travel times was undertaken between NWSM and WTSM.

This analysis showed that there are differences in traffic volumes and travel time benefits due to P2G between the two models, with these differences traced back to different time periods definitions, networks, zone systems, capacity assumptions, software simulation capability and the travel time validation, together with the base year matrix adjustment / estimation processes that improves the validation of NWSM compared with WTSM.

Regardless of these differences, both future year models show that P2G itself delivers significant travel time savings for east-west trips and de-congestion benefits on SH1 and SH2.

Project recommendation

- differences in travel times and traffic volumes between the two models along SH2 and SH1 should be understood and accounted for when updating modelling tools for the SAR phase of the project

1.6.5 Comparison of NWSM and Bluetooth data

The NWSM 2013 model was calibrated against extensive travel time and count data available at that time and was deemed 'fit for purpose' by the peer reviewer.

For the review summarised in this report, a comparison of a new, more comprehensive dataset of observed Bluetooth travel speeds and the NWSM modelled travel speeds was undertaken, focussing on SH2 near Petone and Petone Esplanade, to better understand travel time variability and the level of model validation.

The analysis showed the following:

- significant travel time variability in the Bluetooth (observed) data, particularly at peak times / directions
- some statistically significant differences between the mean travel speed derived from Bluetooth and the mean travel speed derived from the validated SATURN model

Whilst Bluetooth provides an extensive source of data, limitations regarding sensor accuracy, particularly where the distance between sensors is short, means appropriate confidence margins should be attached to the data.

Notwithstanding these limitations, the comparison of SATURN travel times against this new dataset suggests that, in certain instances, the SATURN model is not adequately representing average travel times within statistically significant confidence intervals along SH2 and Petone Esplanade.

Project recommendations

- methods for updating NWSM to better represent the new dataset of travel times on SH2 should be investigated
- the development of an S-Paramics model, with an ability to model 5 minute time slices during the peak hour, should provide a tool that can account for the significant travel time variability that exists in the SH2 / Petone Esplanade area at peak times.

- similar Bluetooth analysis should be undertaken along SH1 between Porirua and Ngauranga Gorge, with the results used to update the NWSM along this corridor (if required)

1.6.6 Demand response to P2G

The P2G link road will deliver a shorter and faster journey for people wishing to travel between Lower Hutt and Porirua / Tawa / North Wellington, together with travel time improvements for persons heading to / from Wellington along SH1 and SH2.

These changes to the cost of travelling by car result in changes in behaviour and travel characteristics for certain users of the network.

Below is a list of changes in behaviour that could be expected from the P2G link road, together with the modelled changes in behaviour indicated by WTSM.

Induced (totally new) trips

- the fact that the same land use is assumed in WTSM for both the Do Minimum and Option and the trip rates are fixed means that the overall number of trips is the same between Do Minimum and Option scenarios for a particular year. By definition, this means that no true induction effect is assessed
- whilst the steering group consider that any true trip induction effects associated with the P2G link road (whilst not explicitly modelled) are likely to be small, compared to the more significant redistribution and reassignment effects (described below) and not lead to any significant change in assessed levels of service, it is recommended that sensitivity testing be undertaken at the SAR stage, particularly focussed on looking at the impact that land use changes resulting from P2G that might have in terms of additional (induced) trips on the network

Modal shift from PT to car

- negligible – minor shift from PT to car (SH1 corridor) broadly balanced by shift from car to bus along SH2

Trip-retiming between modelled time periods

- based upon modelled results from WTSM, no significant change in the proportion of peak period / inter-peak period trips occurs as a result of P2G
- whilst some peak spreading from peak shoulders (prior to 7.30am, post 8.30am) to the peak hour (7.30am to 8.30am) could in reality occur, the current modelling system cannot capture subtle behavioural changes like this

Split of traffic on P2G between re-assigned trips and redistributed trips

- around 2/3rd of trips forecast to use P2G are reassigned – existing trips that take a different route between their origin and destination
- around 1/3rd of trips forecast to use P2G are redistributed – existing trips where either the origin and/or destination changes, a result of opportunities (work, shopping, leisure) and improved accessibility generated by P2G
- a comparison of the traffic redistribution effects of P2G against guideline elasticities and projects of a similar nature in New Zealand suggest that the P2G response is at the upper end of the observed range

- whilst the steering group agreed that P2G would open up new opportunities for east–west travel, based upon extensive elasticity research and benchmarking against similar projects, 30% of daily trips using the link road being 'redistributed trips' is at the upper end of the range of responses that might be expected

- the steering group discussed and agreed that it is likely to take between 10 and 20 years for any redistributional response associated with P2G to be fully realised

- sensitivity testing in NWSM and WTSM, using the Do Minimum matrix assigned to the Option network and the Option matrices assigned to the option network, showed that future levels of service at key locations on the network would remain largely unchanged, regardless of what might be assumed relating to traffic redistribution

Project recommendations

- based on the conclusions drawn from this work and Steering Group discussions, the following core scenario for the assessment of P2G is proposed:

- ***2021*** *– assume no daily redistributional effects associated with P2G*

- ***2031*** *– assume that 50% of the daily redistributional effects generated by P2G would be realised*

- ***2041*** *– assume that 100% of the daily redistributional effects generated by P2G would be realised.*

- whilst initial indications show that varying the redistributional assumptions does not significantly affect levels of service and would not significantly change model outputs that were used during the recently completed multi-criteria analysis (MCA) , further sensitivity tests should be undertaken at the SAR stage of the project to verify these initial findings, particularly focussing on the Petone and Tawa intersections

- at the SAR stage, further research is required. combined with modelling to assess the potential impact of induced land use changes and any resulting increase in traffic volumes, to confirm and quantify the potential impact that true 'induced' trips, which may occur as a result of P2G but are not captured by the modelling system at present, could have upon levels of service

1.6.7 P2G and effects on wider network

1.6.7.1 Levels of service

Levels of service on the network were evaluated under a wide range of scenarios spanning different modelled years and different assumptions.

The analysis showed that P2G generally operates at an acceptable level of service (C or less along mid-block sections) regardless of the modelled scenario. Even elsewhere on the state highway network, changes in assumptions do not significantly change expected levels of service. The levels of service of the intersections will be determined through the pending S-Paramics work.

From solely a traffic volume perspective,, the case for crawler lanes only exists at peak times in peak directions under medium / high growth scenarios.

Project recommendations

- levels of service on P2G and the state highway should be assessed further during the SAR stage of the project, with expected outcomes expressed as a range rather than specific values to reflect uncertainty relating to transport model forecasts
- the justification for crawler lanes, from both a traffic volume and safety perspective, should be fully captured for a range of scenarios during the SAR stage of the project

1.6.7.2 HCV analysis

The recently completed WTSM 2013 model has an improved commercial vehicle (CV) component model, which results in 50% lower forecast HCV volumes on P2G under a hypothetical 2013 scenario compared with WTSM 2011. Analysis shows that HCV figures in the current 2013 version of NWSM are broadly reflective of the numbers in NWSM.

HCV growth rates in WTSM are based on historic trends showing that HCV growth is linked to GDP growth, with the implicit assumption that this historic relationship will be maintained into the future.

Project recommendations

- given the uncertainty relating to HCV growth rates it is recommended that observed data be collected to verify existing east-west HCV movements
- the sensitivity of traffic volumes and levels of service on P2G to different HCV growth assumptions should be understood in more detail during the SAR stage of the project
- utilising an extended S-Paramics model, the impact that HCVs have on levels of service on P2G under a range of scenarios, including a scenario with no crawler lanes, should be better understood
- all this analysis should be combined with relevant safety investigations to comprehensively outline the justification for crawler lanes

1.6.7.3 Interchanges

An S-Paramics model has been developed for the Tawa Interchange, with a Petone Interchange model being developed, to test and optimise interchange design at the SAR stage.

Project recommendation

- the S-Paramics models be developed further to assess operational aspects relating to the P2G link road and its impact on the interchanges and surrounding state highway network

1.6.7.4 SH1 North of Tawa

Observed traffic volume data on SH1 North of Tawa suggests that there is a peak prior to the peak hour between 7am and 7.30am, in the southbound direction, that is not currently captured by the modelling tools.

Analysis of levels of service on SH1 North of Tawa under a variety of future scenarios suggests that, based on the current modelling, a 4 lane solution might start experiencing significant delays sometime between 2021 and 2031

Project recommendations

- more travel time data (Bluetooth) and traffic counts are required to better understand variability and levels of service along SH1 North of Tawa
- additional data should be used to enhance the modelling tools, the understanding of future levels of service on SH1 North of Tawa, safety issues associated with weaving / merging and the assessment of project economics
- based upon this analysis, a clear recommendation should be made at the SAR stage regarding any future requirement for a 6 lane solution North of Tawa

1.6.7.5 SH2 Dowse to Petone

Levels of service between Petone and Dowse SH2 are forecast to reach 'E' between 2021 and 2031, under a scenario that includes P2G but excludes the Cross Valley Link (CVL).

The 2015 CVL PFR update suggests that CVL could result in worsening of levels of service on SH2 between Dowse and Petone.

Project recommendation

- P2G should be assessed with CVL in place and Petone Esplanade de-powered, to look at the impact on SH2 levels of services and the performance of Petone Interchange under a range of scenarios
- this analysis should build upon work undertaken for the 2015 Cross Valley Link PFR update

1.6.7.6 SH2 Ngauranga - Petone

This stretch of SH2 currently operates at capacity during peak times and is largely forecast to stay at capacity in the future, with peak hour traffic volumes largely unchanged as a result of suppressed (queued) traffic in the Do Minimum being released under the Option scenario.

Project recommendation

- further investigations should be undertaken at the SAR stage of the project, particularly focussing on interchange design and understanding the impact that traffic volumes during the 'peak of the peak' might have upon levels of service along SH2

Wider recommendation

- SH2 Ngauranga to Petone has been highlighted as both an existing and future problem, regardless of whether or not P2G is built
- further work, outside of the scope of the P2G project, is required to understand the problems in more detail and develop integrated network solutions involving all modes

1.6.7.7 SH1 Johnsonville to Ngauranga

Current observed data shows that AM peak travel times down Ngauranga Gorge are slow, the result of capacity constraint and blocking back caused by the Ngauranga merge.

P2G results in the re-assignment of some traffic that currently uses SH1/SH2 to travel between Tawa / Porirua / North Wellington and Lower Hutt to the alternative P2G route, resulting in de-congestion benefits southbound on SH1 between Johnsonville and Ngauranga, particularly in the AM peak.

1.6.7.8 Scope and coverage of S-Paramics

Based on the analysis presented in this report, the steering group recommended that consideration should be given to improving the S-Paramics model as follows:

Project recommendations

- extend to cover parts of Petone Esplanade and SH2 north / south of Petone Interchange and update to account for Bluetooth travel time analysis, in order to model the impact that variability in traffic volumes might have on levels of service and assist with interchange design
- extend to cover P2G from Petone to the crest to enable an operational assessment of crawler lanes to be developed to compliment the assessment of crawler lanes from a safety perspective
- extend to include SH1 North of Tawa and the Transmission Gully / SH1 interchanges at Linden, to model weaving / merging in more detail and provide additional information that can be used to assess the possible requirement and phasing for 6 lanes north of Tawa and assist with interchange design

1.6.8 Sensitivity tests

1.6.8.1 WTSM additional PT and tolling

Two sensitivity tests were undertaken in WTSM, to investigate how improvements to the PT network and tolling P2G might affect levels of service.

Additional PT improvements on the rail network included faster travel times, more 'Park and Ride' (P&R) spaces and more frequent services. Tolling was implemented at a level sufficient to reduce traffic volumes on P2G by 33%.

The results showed that:

- enhanced PT measures resulted in a small increase in PT patronage but no significant improvements in highway levels of service
- tolling P2G resulted in little change in PT patronage and increased traffic volumes / congestion on SH1 and SH2, with trips from North Wellington to Lower Hutt re-assigning via SH1 / SH2 to avoid paying a toll on P2G

1.6.8.2 NWSM zero growth sensitivity test

A (zero) growth sensitivity test, using 2013 demand to represent a future scenario where there is no growth in traffic volumes, shows that the P2G scheme still provides significant travel time savings and de-congestion benefits on SH1 / SH2 and generates an indicative BCR above 1.0.

Project recommendation

- that a more comprehensive, full BCR assessment be undertaken for the zero growth scenario

Wider recommendation

- that a zero growth test be undertaken as a matter of course to understand the level of benefits a project might deliver even under the most pessimistic of future scenarios

1.6.8.3 Effects of matrix estimation in NWSM

A sensitivity test was undertaken in NWSM to compare screen line crossing volumes between model runs using the prior (before matrix adjustments / estimation) and post (following matrix adjustments / estimation) matrices.

This analysis showed that, at a high-level, there are small differences between the 'prior' and 'post matrix estimation' model runs that are due to differences between the matrices as a result of different model time periods and the adjustment / estimation process.

Whilst at a local level some of the changes relating to east-west trips[2] are more significant in percentage terms, the absolute number of trips is relatively small and they comprise a relatively small proportion of trips within the region (compared with, for example, trips to / from Wellington CBD).

Project recommendation

- given the importance of east-west trips to the justification of P2G, combined with the lack of real data relating to existing east-west trips, it is recommended that additional observed data (Bluetooth data or ANPR surveys) be collected covering vehicle movements and travel times between Kapiti / Porirua / Tawa / North Wellington and the Hutt Valley, to provide a more robust and defensible evidence base and to verify and support the modelling work undertaken to date.

[2] Porirua to Lower Hutt, Upper Hutt to Porirua, Wellington North to Lower Hutt

2 Steering group purpose and report structure

2.1 Context

The Modelling Steering Group was established as a way to draw multiple project stakeholders together to ensure the application of a 'best practice' approach in transportation modelling and the development of a robust assessment for the project in question.

By following such an approach, it is intended that details relating to data, analytical techniques and assumptions can be resolved earlier in project assessments, reducing the requirement for these issues to be the subject of conferencing and hearing time.

The NZ Transport Agency has adopted the assessment approach detailed in the document 'Transport Model Development Guidelines[3]' (First Edition, Amendment 01), and this industry led collaborative approach is considered new best practice in this area.

2.2 Ethos

The purpose of the modelling Steering Group is to facilitate open and collaborative discussions regarding the modelling and assessment associated with regionally significant transport projects within the Wellington Region. P2G was the first project chosen for this new approach.

This approach was identified as a way to ensure early engagement between those in the transport sector who have a responsibility for the assessment and implementation of major transport projects. A number of different controlling entities have an interest in the network planning, and engagement between these organisations was co-ordinated through the establishment of the Steering Group. This approach has allowed the expertise, knowledge and experience of those in the partner organisations to be more effectively utilised for the benefit of the project.

Whilst the initial project to benefit from this approach has been the P2G Link Road, the process and indeed some of the outputs are expected to benefit a number of other upcoming project assessments in the region.

2.3 Workshop and steering group formation

A workshop was convened and attended by persons who have been involved in the modelling and assessment of P2G to date, together with a number of industry technical experts who were invited to join as a 'fresh set' of eyes.

Following the workshop, the Steering Group was established and tasked with addressing questions that arose from the workshop.

Those who were present at the workshop are listed in **Table 1**, together with the role in the project / workshop:

[3] https://www.nzta.govt.nz/assets/resources/transport-model-development-guidelines/docs/tmd.pdf
Effective 1 April 2014

Table 1 Workshop Attendees and Roles

Name	Organisation	Workshop Role
Julie Ballantyne	TDG	Modelling Expert – involved with WTSM Freight Model
Tony Brennand	NZTA	Steering Group – Transport Agency Principal Transportation Engineer
Roger Burra	41 South	Independent Facilitator
Geoffrey Cornelis	GWRC	Modelling Expert – WTSM Model Developer
Darren Fidler	Jacobs	Modelling Expert – NWSM Model Developer
Andrew Ford	GWRC	Steering Group – WTSM Model Practitioner
Tim Kelly	TKTPL	Steering Group – P2G Transport Assessment Peer Reviewer
Kesh Keshaboina	NZTA	Steering Group – Transport Agency Regional Office Principal Transport Planner
Peter McCombs	TDG	Observer - P2G Strategic Assessment Owner
Catherine Mills	TDG	Observer
Andrew Murray	Beca	Modelling Expert – previous experience at Board of Inquiry
Laura Skilton	GHD	Transportation Expert – Peer Reviewer: NWSM (2013 Version)
Eliza Sutton	Opus	Steering Group – P2G Transport Assessment Owner
Tim Wright	QTP	Modelling Expert – NWSM Peer Reviewer

2.3.1 P2G specific questions to address

During the course of the workshop, a number of P2G project specific questions were identified as needing to be answered.

These questions were summarised by the independent facilitator as follows:

- Business Case: How strong is the business case for the road? (e.g. transport costs & benefits, information to evaluate project effectiveness)
- Link Road Design: What is the most appropriate design for the road?
- which are the most appropriate options? (e.g. in terms of costs, benefits and effectiveness)
- how / whether to accommodate additional demand on SH1 north of Grenada /Tawa?
- how / whether to accommodate additional demand on SH2?
- Public Transport: What is the effect on and implications for public transport?
- Project Objectives: How well do alternative proposals for meeting the project objectives compare?
- Environmental Effects: Are the forecast environmental effects of the project acceptable?
- Regional Economic Effects: What are the effects of the project on the regional economy?
- Network Resilience: What are the effects of the project on network resilience?
- Petone Esplanade: What are the effects of the project on Petone Esplanade?
- Other Roading Projects: What are the effects of the project on other projects (and vice versa)?

2.3.2 Other questions to address

The steering group identified the following additional matters which should be addressed as part of the review:

- **Options Evaluation Framework / Process:** The options evaluation framework / process should be developed with an awareness of the capability / limitations of the transportation models used in the assessment

- **Travel Time Reliability:** One of the project objectives relates to travel time reliability – WTSM and NWSM are not designed to be able to forecast travel time reliability. The study team need to identify the extent to which each option will deliver on this objective

- **Passenger Transport:** Based upon analysis previously undertaken by GWRC, the study team need to work out how to communicate the passenger transport effects within the transport assessment and to identify the appropriate role for passenger transport in managing travel demand, either in the context of this project or as a recommendation for future investigations

- **Active Modes:** One of the project objectives relates to pedestrian and cyclists accessibility – WTSM and NWSM cannot capture these impacts. The study team need to think about the need / ability to forecast pedestrian/cycle demand

- **Operational Traffic Assessment:** The transport assessment will be complemented with an operational traffic assessment for HCVs and light vehicles

Conclusions

- the modelling workshop was useful as it enabled a free and open discussion of ideas and issues in a collaborative and non-confrontational manner

- the steering group has been useful as a means of guiding the investigations that arose from the workshop and subsequent analysis

- the overall outcome from the process is a more rounded and robust understanding of the likely impacts and effects of P2G scheme

Project recommendation

- it is recommended that a technical steering group is maintained during the SAR phase of the P2G project

Wider recommendations

- a technical steering group to guide the modelling work should be established at the outset of any future significant project that involves transport modelling

- the steering group should be of a manageable size and involve all key modelling stakeholders – such as consultants, peer reviewers, the Transport Agency, Regional / Local Government officers – and foster a collaborative ethos

- the aim of such a steering group should be to guide and advise the investigations to ensure that the modelling tools are being used intelligently and that the analytical system is able to appropriately inform project assessments

2.4 Report structure

The level of detail increases in terms of technical depth through the executive summary, the main body and appendices. This three-tiered approach is intended to cater for a range of readers.

The broad structure of the report is outlined below:

- **Section 3** outlines the main purpose of the three modelling tools – WTSM, NWSM and S-Paramics – and how they have been used for the P2G project
- **Section 4** outlines key assumptions relating to capacities and time periods
- **Section 5** outlines the range of land use scenarios developed for WTSM, together with results showing the impact that different land use assumptions might have upon levels of service on P2G and the state highway network
- **Section 6** provides a comparison of WTSM and NWSM, focussing on differences in travel times and traffic volumes between base and future versions of both models
- **Section 7** analyses and compares observed Bluetooth data with modelled travel speeds from NWSM
- **Section 8** summarises the likely effect that a range of different responses to P2G – modal shift, trip re-timing, induced trips, redistributed trips – might have in terms of demand using P2G and the state highway network
- **Section 9** focusses on the P2G link road and summarises levels of service under a range of different scenarios
- **Section 10** summarises results from a range of sensitivity tests undertaken in WTSM and NWSM
- **Section 11** outlines a set of recommended scenarios to be used for the next SAR stage of the project, together with current forecast levels of service on key links within the study area under these scenarios
- **Section 12** concludes and summarises the steering group recommendations that should be considered and discussed prior to undertaking the next SAR stage of the project

Throughout the document, conclusions, project recommendations and wider recommendations are provided where appropriate.

A significant amount of supporting documentation has been developed, both as part of this review process and prior to the establishment of the review process as the transport models have developed. This documentation, outlined in **Table 2**, contains more detailed analysis on the issues which this report summarises. The key documents identified below are included within the Appendix to this report, and have been summarised for the purposes of this review.

Note: **Appendix A1 and A2** refer to specific Steering Group and workshop details

Table 2 Supporting Documentation

Appendix	Title	Author	Date
A1	Steering group members	41 South	30th June 2015
A2	Workshop questions	41 South	30th June 2015
A3	WTSM validation in P2G area of interest	GWRC	27th August 2015
A4	Comparison of WTSM and NWSM traffic volumes and travel times	GWRC	27th August 2015
A5	WTSM 2013 assessment of P2G using 2013 demand – zero growth scenario	GWRC	27th August 2015
A6	Response to questions raised at workshop relating to WTSM modelling of P2G	GWRC	27th August 2015
A7	WTSM implied elasticities relating to P2G	GWRC	27th August 2015
A8	WTSM forecast assumptions relating to P2G	GWRC	27th August 2015
A9	P2G modelling in WTSM and WPTM	GWRC	27th August 2015
A10	Differences between WTSM and NWSM relating to SH1 North of Tawa	GWRC	27th August 2015
A11	Bluetooth comparison study	Opus	21st October 2015
A12	NWSM zero growth sensitivity test	Opus	26th August 2015
A13	Steering group capacity assumptions	Steering Group	15th November 2015

In addition to these attached appendices, the reports produced for the calibration and validation of WTSM 2011 can be found on http://www.gw.govt.nz/wellington-transport-models-technical-reports/. These reports are referred to, where relevant, in this report.

2.5 Glossary

Below is a list of commonly used words and terminology:

- **Induced traffic** –new trips, not currently made on the network, that are generated as a direct result of a particular scheme i.e. someone used to go shopping once a week, but now goes twice a week because the journey is quicker as a result of a new piece of infrastructure

- **Reassigned traffic** – trips that used to travel between A and B via a certain route but choose an alternative route to travel between A and B in response to a new piece of infrastructure i.e. someone used to travel though the city centre to get from A to B but re-assigns via a newly opened bypass

- **Redistributed traffic** – when trips that used to be made between origin A and destination B change their origin and / or destination in response to improved infrastructure i.e. someone who used to shop in the town centre but changes their travel patterns to shop in the city in response to a new road

- **Peak spreading** – this is when trips currently made in the inter-peak / peak shoulders, due to congestion during the peak period, may be re-timed to occur during the peak period as a result of improved travel times and reduced delays associated with a certain piece of infrastructure investment. Conversely, the opposite effect – worsening congestion during peak periods – can result in people re-timing their trips to occur in the less congested peak shoulders / inter-peak

- **Modal shift** – a change in travel behaviour due to changes in the relative cost of travelling by both modes which can be driven by travel time savings resulting from new infrastructure, road space reallocation or changes in economic parameters such as fuel price and PT fares i.e. modal shift from car to PT (or vice-versa)

- **Capacities** - the maximum throughput rate at which vehicles can reasonably be expected to traverse a point of a uniform segment of lane or roadway during a given period of time

- **Saturation flows** – the input mid-block / intersection capacities used in models such as WTSM and NWSM that form a starting point for the calculation of dynamic capacities

- **Volume / Capacity ratios** – the ratio of traffic volumes to capacity. The nearer the V/C ratio is to 100% (or above), the greater the congestion experienced

- **Levels of service** – a scale from A to F, related to corresponding V/C ratios, that is used as a means of providing a simple description of the extent of congestion that might be experienced under certain future scenarios (where A = free flow and F = totally congested).

- **Travel time variability** – the level of variation in observed travel times along a certain section of the network between one day and the next. In general, high variability is most common on congested parts of the network during peak periods

- **De-congestion benefits** – a term used to describe the benefits, derived from faster travel times and reduced travel time variability, that a scheme such as P2G might indirectly deliver along stretches of the highway network by removing traffic (re-assigned to P2G) and reducing congestion

- **VKT** – Vehicle Kilometres Travelled, is the product of distance travelled per vehicle over all the vehicles travelled for a road segment, corridor or network. **VKT per capita** – a measure of how much car travel, per person

- **WTSM** – the 'Wellington Transport Strategy Model' is a strategic, 4-stage model (trip generation, trip distribution, mode split and trip assignment) covering the whole of the Wellington Region

- **EMME** – the software package in which WTSM is based

- **NWSM** – the 'North Wellington SATURN Model is a more detail highway assignment model that provides an improved representation of intersections compared to WTSM and is used as the main tool to assess the traffic effects of P2G

- **SATURN** – the software package in which NWSM is based

- **S-Paramics** – the software package that is used to develop detailed micro-simulation models to design and optimise components of a scheme such as intersections and interchanges

3 Model Purpose and Use

The comprehensive assessment of a transportation project requires a consideration of wider network effects as well as the detailed operation of specific intersections. For this reason, assessments make use of linked models at a number of levels.

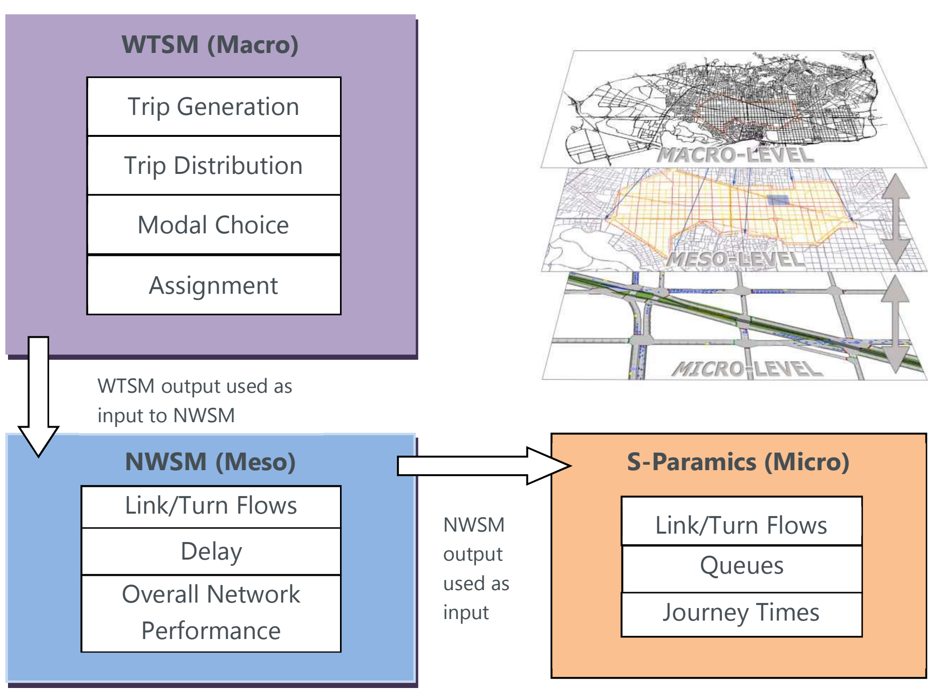
In New Zealand, and elsewhere in the world, a hierarchy of models is commonly used, with each model having a different structure and purpose. When using these models for transport analysis, it is important that the transport modeller understands the purpose, provenance and limitations of each model and uses appropriate outputs from each model in the correct context.

The three tiers of models are shown below:

- **Tier 1** – macro-level strategic model (WTSM) provides a high-level representation of the highway and public transport network and is a tool used to estimate travel demands through the processes of trip generation, distribution and modal split
- **Tier 2** – meso-level model (NWSM) provides a more detailed representation of road network, intersections and traffic conditions and is the tool used for highway assignment and the general operational assessment of the scheme and the wider network
- **Tier 3** – micro-level model (S-Paramics) provides a detailed representation of the road network, including the simulation of linked traffic signals; an operational tool to assist with network optimisation

Figure 1 below shows the specific functionality of each modelling tool, together with the data flows and feedback loops / checks used to ensure consistency between the three tiers of models.

Figure 1 Model dataflow



3.1 WTSM

3.1.1 Model history

The Wellington Transport Strategy Model (WTSM) is a 4-stage transport model covering the Wellington Region.

WTSM is a high-level, strategic tool that can be used to understand the potential impacts of policy decisions and provide inputs (matrices) to more detailed project models that are developed to assess schemes such as the P2G link road.

WTSM uses the following as the basis for generating estimates of trips across the region:

- land use inputs – population, households, employment
- information from household travel surveys
- economic data relating to car ownership, GDP, CPI, cost of parking, PT fares

The trips estimated by the model are then split between the appropriate modes – car, PT and active modes – depending on the relative difference in costs between these options, with these differences driven by the characteristics of the highway and public transport networks and the input economic parameters.

The final step is the assignment of the highway and PT demands to respective networks representing these modes.

WTSM was initially developed in 2001, to coincide with the 2001 Census, and subsequently updated in 2006 and 2011. It is the 2011 version of WTSM that has been used for the P2G analysis.

The suite of model development, validation and forecasting reports associated with each update can be found on the GWRC website:

http://www.gw.govt.nz/wellington-transport-models-technical-reports/

The 2011 version of WTSM was peer reviewed and confirmed as 'fit for purpose' by John Bolland Consulting.

WTSM 2011 still uses historic underlying household interview survey (HIS) data, in this instance from 2001, as the basis for estimating trip rates. Household travel surveys are generally undertaken when a model is initially developed, due to the significant cost involved.

Whilst high-level household travel patterns are unlikely to have changed significantly across the region between 2001 and 2011, local and small scale changes are possible due to changes in land use and changes in travel behaviour (i.e. increasing popularity of working from home or WCC CBD living).

It is for this reason that both base and future year versions of WTSM are analysed and understood to ensure that recent trends are being picked up by the models.

3.1.2 WTSM 2011 review for P2G

The Transport Agency has published guidelines for the validation of transport models. These differentiate between higher level/coarser models such as WTSM (for which validation requirements are looser) and more detailed models such as NWSM and S-Paramics (with tighter validation requirements).

https://www.nzta.govt.nz/assets/resources/transport-model-development-guidelines/docs/tmd.pdf

Under these guidelines, WTSM is categorised as "(A) – Regional model".

When outputs from WTSM are used as inputs to other models, it is important to understand the level of WTSM validation in the area of interest of the scheme in question (in this case P2G) so that any potential weaknesses can be documented and taken into account in subsequent and more detailed modelling.

A review of the validation of WTSM within the P2G project area was undertaken. The analysis focussed on the count and travel time validation, using the same dataset that was used when originally calibrating and validating the model in 2011, and is included in **Appendix A3** of this report.

The broad findings of the review are summarised below, with more detail available in **Appendix A3**:

- the AM peak validation of screenline data within the area of interest is good, and exceeds NZTA guidelines (which stipulate that 60% of screenlines have a GEH value of less than 5)
- the inter-peak and PM peak validation within the area of interest does not meet the same guideline criteria, but when considered against other criteria stated in the NZTA guidelines - GEH less than 7, 10 and 12 - these periods are considered acceptable
- in general, there is a good correlation between observed and modelled volumes in the AM and IP periods, but observed volumes exceed modelled volumes in some locations, particularly along SH1 in the outbound direction, during the PM peak period
- observed volumes exceed modelled volumes in the peak direction on SH2 in the PM peak (between Upper and Lower Hutt) as well as northbound on SH1 between Porirua and North Wellington in both the inter-peak and PM peak. This was raised and noted in the 2011 calibration and validation report as an issue that project modellers should bear in mind when using outputs from WTSM
- based upon the 2011 travel time dataset (obtained from bi-annual moving car travel time surveys), the travel time validation is generally good, with most modelled travel times within the range of observed travel times, although there are a number of areas of relevance to the P2G project where travel time validation could be improved:
    - slight over-estimation (model too slow) of AM peak (SB) travel times between Ngauranga and Petone, driven by the difficulty of modelling dynamic capacities and slow moving traffic associated with the Ngauranga merge in a strategic model
    - under-estimation (model too fast) of AM peak (SB) travel times between Johnsonville, Ngauranga and Aotea Quay, for similar reasons to those outlined above with reference to Ngauranga to Petone
- whilst these differences between modelled and observed travel times could imply that WTSM would over-estimate car trips and under-estimate PT trips on both corridors, in terms of the generalised cost of travel the differences are relatively small meaning that the impact is likely to be minimal
- furthermore, the car and PT validation actually shows an acceptable fit between modelled and observed values at a high level

In summary, the overall level of validation of WTSM in the area of interest is generally good, with the purpose of **Appendix A3** being to provide a point of reference for the subsequent application of outputs from WTSM.

3.1.3 2013 WTSM update

WTSM is updated following each new Census to reflect the latest available Census and other information, with the latest update – from 2011 to 2013 – having currently been completed.

Whilst WTSM 2013 has not been used for any analysis relating to P2G, it is important going forward that the P2G project team understand if there are any trends arising from the WTSM 2013 update that might have implications for the assessment of P2G that has to date been undertaken using WTSM 2011.

The 2013 WTSM update focussed on the following key areas:

- updating the heavy commercial vehicle component of WTSM, using GPS vehicle tracking equipment to create partially observed matrices
- updating the population, employment and household inputs to account for Census 2013 population and employment estimate.

A high-level comparison of annualised light vehicle and HCV demand between the base year 2011 and 2013 versions of WTSM was undertaken and is presented in **Appendix A6**.

This analysis can be summarised as follows, with reference to WTSM 2013:

- there is a 1% increase in region wide annual[4] light vehicle trips between WTSM 2011 and WTSM 2013
- at a TA to TA level, most changes in annual trips between WTSM 2011 and WTSM 2013 are small in absolute and / or percentage terms
- annual HCV trips decrease by 18% between WTSM 2011 and WTSM 2013, whilst HCV trips to / from Porirua, Kapiti and Upper Hutt are between 40% to 60% lower
- HCV trips solely within the same TA account for around 75% of all HCV trips, a figure broadly similar to WTSM 2011
- analysis of sector to sector demand between Porirua / North Wellington and Lower Hutt in WTSM 2013 suggests that annual HCV demand for these movements is 60% lower than in WTSM 2011
- changes in HCV volumes are due to improvements made to the HCV model in WTSM 2013 resulting in an improved understanding of freight movements within the region

Whilst changes in light vehicle demand between WTSM 2011 and WTSM 2013 appear to be negligible, the significant reduction (18%) in HCV demand between WTSM 2011 and 2013 could have implications for traffic volumes in NWSM.

This issue is discussed in more detail in **Section 9.1.2**.

Revised forecast versions of WTSM 2013 will also be produced as part of the WTSM 2013 update. Whilst these models are not currently complete, the Statistics NZ projections that are inputs to the models show similar trends to the projections used for WTSM 2011, with population growth of around 10% forecast between 2013 and 2043, with growth focussed on Wellington City and the western coast (Kapiti and Porirua). As in WTSM 2011, employment growth is likely to still be focussed on Wellington City.

Given these broad similarities between the demographic inputs to WTSM 2011 and 2013, the GWRC modelling team believe that using any revised land use projections developed for WTSM 2013 as a basis for an assessment of P2G is unlikely to result in substantial changes to traffic volumes and levels of service that would result in different conclusions being drawn to what has already been presented as part of the current P2G assessment (based on WTSM 2011).

[4] AM peak, Inter-peak and PM peak trips, annualised

Project recommendation

- comparisons between the current WTSM forecasts (derived from the 2011 model) and final revised forecasts (derived from the 2013 model) be undertaken, to provide a basis for discussions regarding whether NWSM should be updated from using WTSM 2011 to using WTSM 2013 for the SAR stage of the P2G project, especially given that NWSM has already been updated to 2013 using WTSM 2011

3.2 NWSM

The Northern Wellington SATURN model (NWSM) was updated in 2013 by Jacobs NZ Ltd on behalf of the Transport Agency. This model was used as a basis for scenario testing for the P2G link scoping stage phase.

Following a review of the scoping stage process, the Transport Agency commissioned Jacobs to update both the base and future year forecasts for the purpose of the P2G scheme multi-criteria assessment process. This update involved the collection of additional data to inform the understanding and calibration of travel times in the Petone and Ngauranga areas, as well as turning and link volumes along the Esplanade and at Ngauranga.

The model has the following time periods (principal model time periods in bold)

- AM pre-peak (07:00 – 07:30)
- **AM peak (07:30 – 08:30)**
- AM post-peak (08:30 – 09:00)
- Inter-peak (1 hour average of 11:00 – 13:00)
- PM pre-peak (16:00 – 16:30)
- **PM peak (16:30 – 17:30)**
- PM post-peak (17:30 – 18:00)

The peak periods were determined based upon analysis of traffic count data, to ensure that the peak hour models represented the busiest average hour during the time period across the extent of the model. It is accepted, however, that the busiest hour might vary between certain specific areas in the wider model, something that should be accounted for during project specific analysis.

The updated base year validation report concluded that, in general, "NWSM provides a suitable basis for future year forecasting for the purpose of assessing the likely impacts and travel time benefits of the proposed P2G link".

A note of caution was raised regarding specific details of the validation of Lower Hutt and Upper Hutt City centres. Whilst the preliminary assessment by Jacobs (confirmed by the peer reviewer) was that issues should not significantly affect the assessment of P2G, it is important that they are understood further in the context of P2G and any potential future upgrades of NWSM.

WTSM models an average 2hr time period and does not have the functionality to account for changes in traffic volumes within this time period.

Whilst NWSM does have the functionality to model 5 minute time slices, with any residual queues / traffic volumes passed to the next time period, in practical terms this approach would be complicated due to variations in count data and trip length across a wide modelled area (where travel times for many trips would be greater than 5 minutes).

Of the modelling tools, S-Paramics is the only platform that has the functionality to deal with differences in demand by 5 minute time slice for small areas of the network.

3.3 S-Paramics

Two separate and small models, outlined in **Table 3**, were developed in S-Paramics for the Tawa and Petone interchanges, where P2G ties into the existing state highway network, with their primary purpose being to enable preliminary operational assessments of alternative interchange configurations at each site to be undertaken.

Table 3 Summary of S-Paramics Interchange Models

Model Location	Stage 1 – Scoping/MCA (complete)	Stage 2 – SAR (next stage)
Tawa	Completed in 2014 using NWSM 2013	To extend and update based upon Steering Group recommendations
Petone	Completed in 2014 using NWSM 2013	To extend and update based upon Steering Group recommendations

As highlighted above, these models will be further developed to assist with investigations relating to the more detailed SAR stage of the project.

4 Assumptions and information

This section provides some context around the reporting of results and outlines assumptions relating to levels of service and capacities that will be used throughout this report

4.1 Reporting of results

4.1.1 Scope of analysis

This report summarises detailed investigations that have been undertaken looking at a range of issues identified during the modelling workshop and subsequent steering group discussions.

The majority of the data presented in this report has drawn upon analysis previously undertaken in WTSM and NWSM, together with analysis of new Bluetooth data (not used in the calibration and validation of NWSM).

Limitations with the analysis to date are outlined, with a general recommendation being that additional analysis be undertaken at the next SAR stage to address these limitations.

4.1.2 Usage of WTSM and NWSM

The results presented in this report are largely drawn from two sources – the strategic model, WTSM, and the project model, NWSM, supplemented by the Wellington Public Transport Model (WPTM) for selected public transport analysis.

Table 4 outlines which models are used to provide data for which section, together with the rationale.

Table 4 Sections and models used for analysis

Section	Model(s)	Comment
Section 5: Land Use	WTSM (2011)	Land use is an input into WTSM, with the resulting output matrices used as inputs to NWSM
Section 6: Comparison of WTSM and NWSM	WTSM (2011) and NWSM (2013)	Both models used to compare differences
Section 8: Demand Response	WTSM (2011) and NWSM (2013)	WTSM models behavioural change resulting from changes in travel costs, with NWSM used to verify changes
Section 9: Petone to Grenada Link Road	WTSM (2011), NWSM (2013) and S-Paramics (2015)	Both WTSM and NWSM used to assess strategic / economic case for P2G, with S-Paramics used for operational assessment and refinement
Section 10: Sensitivity Testing	WTSM (2011), WPTM (2011) and NWSM (2013)	WPTM used for understand impact of P2G on public transport

4.1.3 Peak periods

The models cover the following peak periods:

- WTSM
  - AM peak – average two hour period between 7:00 am to 9:00am
  - PM peak – average two hour period between 4:00pm to 6:00pm
- NWSM

- AM peak hour – average hour between 7.30am to 8.30am, with pre/ post peak periods also modelled to transfer residual queues / traffic volumes from one time period to the next
- PM peak hour – average hour between 4.30pm to 5.30pm, with pre/ post peak periods also modelled to transfer residual queues / traffic volumes from one time period to the next

The WTSM time periods cover the AM peak and PM peak periods. The NWSM time periods were defined based on analysis of traffic count data across the extent of the model to identify the peak hours within each period, with pre-peak / post peak half hour periods also modelled to transfer residual queues / traffic volumes between one time period and the next.

Both models are average hour(s) models and do not account for micro-level variability in traffic volumes and traffic conditions, generally referred to as the 'peak of the peak'.

Therefore the volume-capacity ratios and levels of service presented in this report describe average conditions during each peak period / hour.

Depending on the location, traffic volumes can be up to 10% greater in the 'peak of the peak' compared with during the average hour / two-hour period.

This is a limitation of the analysis to date and will be addressed during the SAR stage as a result of additional data collection that will be used to help develop an S-Paramics model that has the ability to consider demand by 5 minute time slice.

4.1.4 Inter-peak

The analysis presented in this report generally focusses upon the AM and PM peak periods for the following reasons:

- most current issues / congestion on the network occur in the AM and PM peak periods; the Inter-peak traffic conditions are generally free flowing (barring any incidents, maintenance and/or weather events)
- in the future, it is likely that any issues / congestion on the network will firstly present themselves (and largely be confined to) in the AM and PM peak periods
- solutions that address AM peak and PM peak problems on the network should also benefit the Inter-peak

For these reasons – and for brevity – the Inter-peak is omitted from most of the analysis presented in this report.

4.1.5 Confidence range

Analysis presented in this report focusses on the extent to which levels of service and capacities vary at key points on the state highway network, including P2G, under different scenarios and sets of assumptions. The purpose of this approach is to determine the extent to which the benefits delivered by P2G are dependent upon certain assumptions.

A level of uncertainty and variability is attached to any forecasts, given that they will often relate to a point 20 or 30 years in the future and be dependent upon a given set of assumptions being realised.

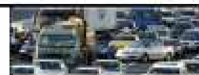
Whilst the 'central case', a term used regularly within this document, is regarded as a 'most likely' future scenario, in reality the future outcome is likely to sit within a range of 'low', 'central' or 'high' scenarios, with an associated likelihood of each of these scenarios being realised.

4.2 Levels of service and capacity assumptions

4.2.1 Levels of service

A key measure of congestion is Level of Service (LoS). The LoS definitions are summarised in

Figure 2 below and are referred to throughout this report.

LOS	Traffic Flow				
	Description		Operating Speed	Volume/ Capacity	Density (pc/mi/ln)*
F	Gridlock		≤ 10% Free Flow Speed	100%	40
E	Significant Delays		10% - 20% Free Flow Speed	88%	35
D	Moderate to Significant Delays		20% - 30% Free Flow Speed	65%	26
C	Stable Operating Conditions		30% - 50% Free Flow Speed	45%	18
B	Relatively Unimpeded Flow		50% - 80% Free Flow Speed	28%	11
A	Free Flow		≥ 80% Free Flow Speed	0%	0

* Exhibit 14-4, HCM 2010 - (pc/mi/ln = passenger carrier/mile/lane)

Figure 2 Level of Service definitions (HCM)

As a means of reference, the Steering Group agree that LoS E or above generally constitutes severe congestion. Typically in such situations, authorities would consider ways to manage this congestion.

Levels of service quoted in this report refer to **mid-block** levels of service rather than intersection levels of service.

4.2.2 Capacities

The Highway Capacity Manual (HCM, 2010) defines capacity as "the maximum throughput rate at which vehicles can be reasonably expected to traverse a point of a uniform segment of lane or roadway during a given period of time".

Capacities are generally quoted in terms of 'number of vehicles per hour' and can relate to the following:

- intersection capacity – what is the maximum number of vehicles that can get through a particular movement at an intersection (signalised or priority), and is governed by the saturation flow for a particular movement, the signals timings and / or gap acceptance

- mid-block capacity – what is the maximum number of vehicles that can be accommodated on a stretch of road (in each direction)

Capacities depend upon a number of variables:

- quality and safety of the road – lane width, shoulder width, curve radii, frontage activity, frequency of accesses

- the posted speed limit (generally 100kph on SH1 / SH2 and 80kph design speed for P2G)
- the geometry of an intersection
- the gradient
- the mix of HCVs (slower vehicles) and general traffic (faster vehicles)
- signalised green times

Furthermore, capacities are 'dynamic'. Whilst a theoretical capacity might be assumed for an intersection or mid-block section, variations in traffic volumes and behaviour can change the effective capacity particularly after flow break down, as outlined in the two scenarios below:

- if demand exceeds capacity, this can cause congestion that will lower average speeds and, in certain situations, lower the effective capacity of a section of road / interchange until demand drops and the congestion dissipates
- the capacity for minor movements at priority intersections is often dependent upon main line traffic volumes – during peak periods, high main line flows will limit the number of gaps available for minor movements, thus reducing the effective capacity

WTSM, NWSM and S-Paramics use input capacity assumptions (sometimes referred to as saturation flows) for all intersection movements and mid-block capacities.

During the model assignment process, the input capacities at intersections are refined by model feedback loops depending upon traffic volumes, whilst mid-block capacities are used as a basis for estimating delays based on the relationship between speed, flow and capacity.

Given the strategic nature and extent of WTSM, input capacities were developed in broad terms based upon road categorisation, speed limits, number of lanes and limited local data.

Whilst NWSM capacities were developed by Jacobs (with input from the peer reviewer) from a combination of HCM and DfT research together with an understanding of local count data, quality / type of road and gradient, they are not derived using the same level of local detail and on a specific link by link basis as is the case when input capacities are developed for S-Paramics or other intersection design tools such as SIDRA and LINSIG.

However, the level of detail underpinning the development of capacities for NWSM is considered reasonable for a meso-model such as NWSM.

In order to estimate levels of service for this report, agreed reference capacities were calculated for three key links on the network – SH2 between Ngauranga and Petone, SH1 North of Tawa and P2G – based upon the HCM methodology and factors such as geometry, speed limit, safety, characteristics of interchanges and the mix of HCVs.

Table 5 below shows the input capacities in WTSM and NWSM for key links within the area of interest of P2G, together with agreed reference capacities that are used for analysis presented in this report. Note that the NWSM capacities have been converted into vehicles from pcus (in which are used in NWSM) using the observed number of heavy vehicles on each link and the pcu adjustment factor of 2.

Table 5 Model capacities for key links

Section	Current NWSM (veh/hr/lane)	Current WTSM (veh/hr/lane)	Assumed for analysis in report (veh/hr/lane)
P2G	1,850	1,800	**1,700**
SH1 North of Tawa	2,050 (1,900 on one southbound stretch in Option)	2,000	**1,950**
SH2 Ngauranga to Petone	2,050 (1,850 at the merge point)	2,000	**1,900**

Table 5 shows that there are some slight differences in input capacity assumptions between the two models.

The agreed vehicle capacities, developed by the steering group and used henceforth in this document to provide a consistent basis for reporting V/C ratios, are slightly lower than both the WTSM and NWSM capacities. They have been calculated based upon observed data (traffic volumes and delays) and information relating to the relationship between capacity and gradient derived from the HCM. More detailed rationale behind the derivation of these capacities can be found in **Appendix A13**.

Of equal importance to capacities, however, is both the shape of the speed-flow curves used on motorway standard roads such as SH1 and SH2 – these govern the rate at which delays increase and speeds decrease as volumes reach capacity - and the ability of the modelling tools to capture delays and blocking back associated with merge bottlenecks such as the SH2 Petone on-ramp.

Whilst it is acknowledged that significant work has been undertaken when developing NWSM to calibrate the capacities and speed-flow curves to replicate observed travel times and to represent merges such as SH2 / Petone on-ramp, it is recommended that this be reviewed during the SAR stage, drawing upon new Bluetooth travel time data and updated count data, to determine whether the current travel time validation on SH2 and Petone Esplanade can be improved.

4.2.3 Volume / Capacity ratios

Volume over capacity (V/C) ratios are a measure of how close to its maximum capacity a section of road (a mid-block section for the purpose of this report) is operating. The V/C ratio is calculated by dividing the actual traffic volume, expressed in passenger car units (pcus), by the capacity.

This report assumes that each HCV is equivalent to 2 passenger car units, meaning that on average one HCV takes up the same amount of road space as two cars.

All reported volumes in this report relate to **vehicles**, whilst all V/C ratios are calculated based on **PCUs**.

Conclusions

- the capacities in both WTSM and NWSM at the three key locations – SH2 Ngauranga to Petone, SH1 North of Tawa and P2G – differ slightly from one another and are slightly higher than the capacities that have been measured or calculated from the Highway Capacity Manual, with these difference due to the different level of detail used when developing capacities for both WTSM and NWSM
- data collected for SH2 Ngauranga to Petone shows that peak period flows are not constant but have demand peaks within the peak period, which affects network delay and the onset of flow breakdown

Project recommendations

- the capacities agreed for this piece of work should be developed in more detail at the SAR stage, drawing upon existing work undertaken when developing NWSM and aided by additional data collection that should deliver a better understanding of existing traffic volumes and delays during peak periods, particularly along SH1 North of Tawa
- a further review of capacities, speed-flow curves and the modelling of merges should be undertaken to determine if scope exists to improve the travel time validation on SH2 and Petone Esplanade for the SAR stage of the project
- the demand profile that exists on the current network (SH1 and SH2) should be carefully investigated to understand the shape and existence of peaks within peaks, drawing upon analysis undertaken by Jacobs when developing NWSM.
- this analysis should be used in the modelling process to correctly understand the onset of flow breakdown and the project economics be enhanced with reference to additional benefits as outlined in the EEM A3.18 and A3.19

Wider recommendations

- at the commencement of any significant project that may involve multiple tools (generally models), it is suggested that discussions regarding current bottlenecks within the area of interest, existing network performance and the suitability of general modelling assumptions such as capacities take place amongst the modelling steering group

5 Land Use

5.1 Land use scenarios

Land use data – population, households and employment – is the basis from which trips are generated in WTSM. The magnitude and spatial location of any growth through time will affect travel patterns and the overall number of trips on both the highway and PT networks.

Areas where population is forecast to grow will generate an increased number of trip productions / attractions throughout the day, whilst areas where employment growth is likely to be focussed will attract more trips in the AM peak, generate more trips in the PM peak and likely generate an increase in employer's business / service trips in the Inter-peak.

In common with all projections, land use projections are dependent upon assumptions relating to a multitude of factors such as birth rates, death rates, economic initiatives, migration, the location of development (often sourced from Territorial Authority (TA) plans) and the likelihood that a particular land development might be fully realised over a certain timeframe.

All forecasting is subject to a degree of uncertainty, especially when looking across long time horizons.

Best practice in transport planning is to acknowledge such uncertainty with sensitivity testing relating to key input assumptions such as land use and economic parameters.

Work undertaken for the P2G scoping assessment and multi-criteria analysis largely focussed on versions of this model derived from WTSM 'medium growth' scenarios which are, in turn, based on Statistics NZ medium projections.

Medium growth is considered the 'central case' growth scenario in WTSM, with observed population and employment growth between 1990 and the present day having broadly followed a medium growth trajectory and recent projections also based upon 'medium' growth assumptions.

Some concern was expressed at the modelling workshop that alternative land use scenarios had not been analysed, resulting in little understanding of the sensitivity of P2G to different assumptions.

Prior to these steering group investigations, GWRC had in fact run a number of sensitivity tests in WTSM, using different land use assumptions. The underlying assumptions for these model runs are documented in **Appendix A8**, with the processes and more detailed resulting included in **Appendix A6** and **Appendix A9**.

Following discussions amongst the Steering Group, it was agreed that these existing 2031 sensitivity tests, details of which are in **Table 6**, should be summarised and presented in this report.

Table 6 WTSM land use scenarios used for P2G

Scenario	Description
Medium growth	Core medium growth scenario, TA and regional growth totals equivalent to Statistics NZ 'medium' growth
Low growth	Regional and TA growth totals equivalent to Statistics NZ 'low' growth projections
High growth	Regional and TA growth totals equivalent to Statistics NZ 'high' growth projections
Western expansion	Kapiti, Porirua growth equivalent to Statistics NZ 'high' projections, growth elsewhere equivalent to 'medium'
Eastern expansion	Lower Hutt, Upper Hutt and Wairarapa growth equivalent to Statistics NZ 'high' projections, growth elsewhere equivalent to 'medium'
Wellington City expansion	Wellington City growth equivalent to Statistics NZ 'high' projections, growth elsewhere equivalent to 'medium'
Medium growth + more intensive Lincolnshire Farm development	Medium growth plus additional housing equating to overall growth in population at Lincolnshire Farms of 10,000

5.2 Lincolnshire Farms assumptions

Lincolnshire Farms is a significant residential growth area, as identified in the Wellington City Structure Plan.

Due to its proximity and connectivity with the P2G link road, it has the potential to generate a significant number of trips that might use the P2G link road, and therefore the sensitivity of the P2G link road to land use assumptions relating to Lincolnshire Farms is important.

Analysis presented later in this report, showing the results of an assessment of P2G using base year demand, demonstrates that P2G would still deliver significant benefits regardless of any development assumptions (including Lincolnshire Farms), demonstrating that P2G is not dependent upon Lincolnshire Farms.

Conversely, Lincolnshire Farms is not dependent upon P2G as the development area would still connect into the local road network at Newlands and Grenada in the absence of P2G.

However, increased traffic volumes likely to be generated by Lincolnshire Farms could cause some congestion in the absence of P2G. When combined with the opportunities generated by having the P2G link road close to the development, it is likely that without P2G, the Lincolnshire Farms development might not be able to grow to its full extent.

Figure 3 below shows the WTSM model zones covered by the Lincolnshire Farms development, together with the broad proposed alignment of the P2G link road. As part of the most recent plans for the link road, there would be a connection to Lincolnshire Farms approximately half way along P2G. The section of zone 84 south-west of the link road is likely to be the area where most residential development would be focussed.

Figure 3 WTSM zones relating to Lincolnshire Farms development

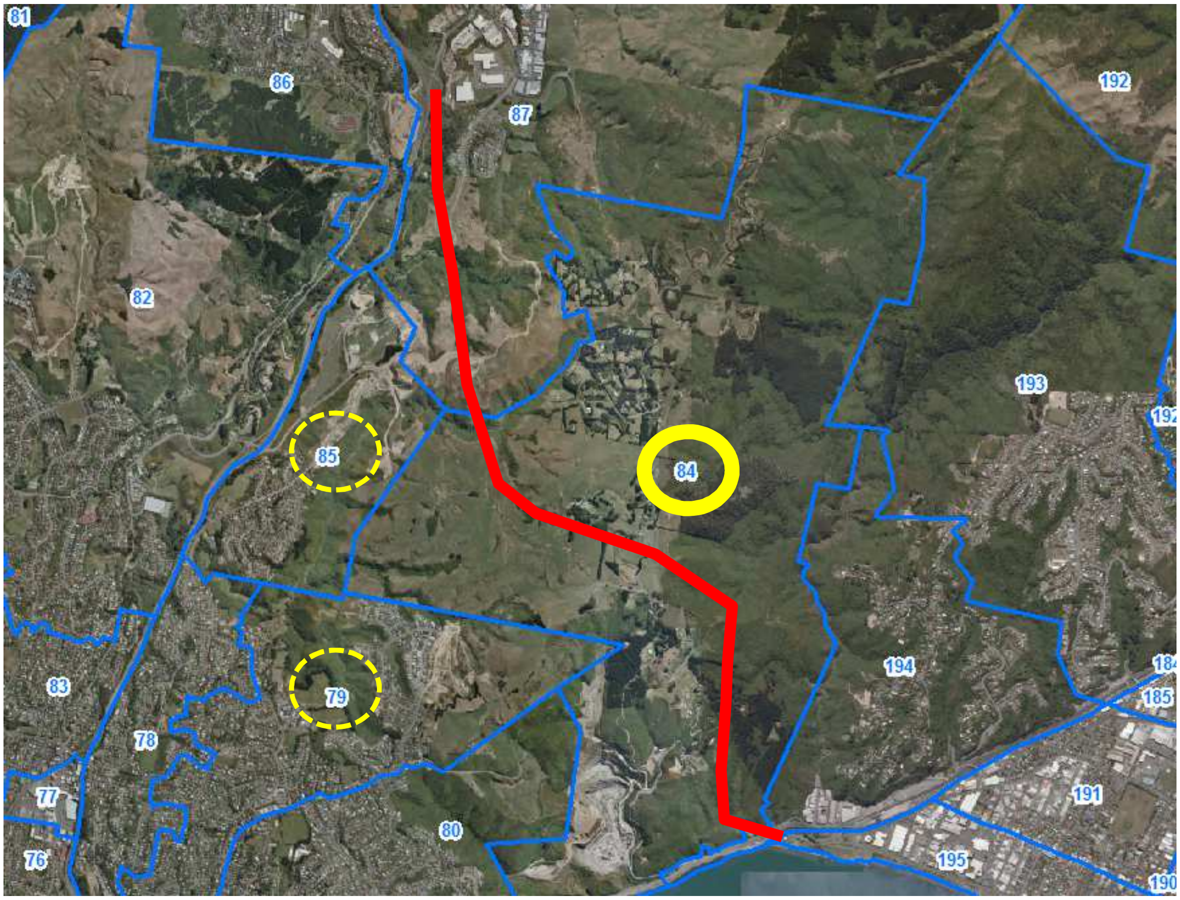


Table 7 below shows the population growth by scenario that is assumed in WTSM for the Lincolnshire Farm development areas, covering zones 79, 84, 85[5]. The development area and scale of development is described in more detail in the Wellington City Council Urban Structure Plan[6]

Table 7 Lincolnshire Farms development assumptions in WTSM

	Population growth in Lincolnshire Farms area			
Scenario	2011 to 2021	2021 to 2031	2031 to 2041	Total growth
Low	1,300	600	600	2,500
Medium	1,500	600	600	2,700
Eastern expansion	1,500	600	600	2,700
Western expansion	1,500	600	600	2,700
Wellington expansion	2,200	1,000	900	4,100
High	2,200	1,000	900	4,100
Medium + more intensive Lincolnshire Farms growth	1,500	4,600	600	6,700

[5] The majority of the Lincolnshire Farms development is assumed to occur in Zone 84

[6] http://wellington.govt.nz/~/media/your-council/projects/files/linc-structureplan.pdf

The land use information shows that the Lincolnshire Farms development is significant and likely to generate a significant number of trips, many of which will use the P2G link road.

The assumptions relating to the Lincolnshire Farms development can be summarised as follows:

- medium growth assumes population growth of around 2,700 between 2011 and 2041
- the Wellington expansion and High growth scenarios assume growth of 4,100
- the medium growth plus more intensive Lincolnshire Farm development assumes growth of 6,700

5.3 Results of land use sensitivity tests

The resulting traffic volumes, volume / capacity (V/C) ratios and travel times at several key points on the strategic network were compared, to give a broad indication of the impacts of alternative land use scenarios.

Table 8 shows mid-block WTSM 2031 (with P2G) traffic volumes and V/C ratios for the following scenarios

- the lowest growth scenario
- the current central case medium growth scenario
- the highest growth scenario

As stated earlier in this report, traffic volumes and V/C ratios are averages across the 2 hour modelled WTSM time period. Based on limited observed data, it is possible that V/C ratios and resulting levels of service at 'peak' times during the peak periods may be between 5% and 10% greater than those stated below.

Table 8 Variation in forecast traffic volumes and mid-block V/C ratios according to land use scenario

	P2G Link Road - assumed capacity = 1,700 per lane[7][8]					
	AM 2031, EB			PM 2031, WB		
	Volume	V/C		Volume	V/C	
Lowest – 'Low growth'	1,900	58%		1,900	58%	
Medium Growth	2,200	67%		2,200	67%	
Highest – 'Medium + LF'	2,400	73%		2,500	76%	
	SH1 North of Tawa with P2G- assumed capacity = 1,950 per lane					
	AM 2031, SB			PM 2031, NB		
	Volume	V/C (2 lane)	V/C (3 lane)	Volume	V/C (2 lane)	V/C (3 lane)
Lowest – 'Low growth'	2,800	74%	49%	2,500	66%	44%
Medium Growth	3,100	82%	55%	2,800	74%	49%
Highest – 'High growth'	3,400	90%	60%	3,100	82%	55%
	SH2 Ngauranga to Petone with P2G - assumed capacity = 1,900 per lane					
	AM 2031, SB			PM 2031, NB		
	Volume	V/C		Volume	V/C	
Lowest – 'Low growth'	3,500	96%		3,700	100%	
Medium Growth	3,700	101%		3,800	104%	
Highest – 'High growth'	3,800	104%		3,900	107%	

[7] Note: V/C ratios are calculated for a 4-lane section of P2G at the crest, therefore not accounting for any capacity benefits that crawler lanes on uphill / downhill sections might provide

[8] Note that in WTSM, HCVs are modelled as running in with and at the same speed as general traffic on P2G. If HCVs were in dedicated crawler lanes, the documented V/C ratios would be 1 or 2 percentage points lower

Source: WTSM 2011, data presented above assumed full 100% demand response associated with P2G

The results show the following:

- even under the highest growth scenario, only moderate delays are forecast for P2G, equivalent to a level of service in the middle of the LoS D definition
- under the medium growth scenario, the forecast level of service on P2G is at the LoS C/D boundary
- under a 4 lane option on SH1 North of Tawa, WTSM forecast that a LoS D would be experienced during all time periods / scenarios except under the highest growth scenario in the AM peak when it would operate at LoS E, suggesting that significant delays may be experienced
- under a 6 lane option, the volume / capacity ratios on SH1 North of Tawa would experience stable operating conditions (LoS C) under all land use scenarios
- SH2 between Ngauranga and Petone is forecast to operate at LoS F in both the AM peak (southbound) and PM peak (northbound) under all scenarios

Conclusions

- different land use scenarios do not result in significantly different forecast level of service on P2G, SH1 North of Tawa and SH2 between Ngauranga and Petone in 2031
- whilst V/C ratios on the P2G link road are 74% under the highest growth PM peak scenario in 2041, this highest growth scenario is unlikely to be realised
- it is clear that whilst P2G significantly improves network efficiency and provides some relief to SH1 and SH2, congestion particularly on SH2 will still remain a problem in the future

Project recommendations

- based upon the analysis presented in this section, combined with the fact that since the early 1990s the Wellington Region has generally seen ‘medium growth’, the medium growth scenario should remain the central case growth scenario
- further sensitivity testing to be undertaken during the SAR stage of the project, to look at the impact that induced land use change associated with P2G might have upon levels of service on both the P2G link road and the operation of the Petone / Tawa interchanges under different future scenarios
- capacity issues on SH2 that remain unchanged as a result of P2G should be investigated further, outside of the scope of the P2G project as part of the SH2 PBC

Wider recommendations

- for future large modelling projects, it is suggested that a range of future land use scenarios are understood and developed during an early stage of the project through collaboration between project stakeholders including the consultants, GWRC and modelling steering group
- whilst one scenario may be chosen as the central scenario, the sensitivity of the scheme in question to different future scenarios should be evaluated at an early stage in the project

6 Comparison of WTSM and NWSM

WTSM and NWSM have been developed for different purposes and have different functionality / specification, relating to:

- level of network detail
- representation/definition of peak periods
- capacity assumptions
- representation of intersections
- required level of validation, as specified in the NZTA validation guidelines

By their very nature and purpose there are likely to be differences in traffic volumes and network characteristics between the two models.

It is important is that significant differences are understood and accounted for by the modelling practitioner when developing and using any of the lower tier models for transport analysis.

This chapter outlines the findings of a comparison of the WTSM and NWSM models, focusing on both base year and future year versions of the models. This analysis is documented in further detail in **Appendix A4.**

The analysis purposefully focuses on differences between the two models rather than differences between each model and the observed data, as the base year validation reports for both models contain detailed summaries of validation against observed data. A summary comparison of WTSM demand and NWSM demand is also presented in Chapter 7 of the NWSM Calibration and Validation Report.

Notwithstanding this focus, the analysis provides limited commentary against new observed datasets where there are significant differences between the two models, to demonstrate which model is more accurately representing reality.

6.1 Base year comparisons

The base year version of WTSM is validated to a 2011 modelled year, with the resulting car and HCV demand matrices used as inputs to the 2013 version of NWSM.

The process of converting demand from WTSM to NWSM involves a number of steps, such as factoring from a 2011 to 2013 reference year[9], splitting 2hr WTSM demand into peak hour and pre/post peak demand segments in NWSM, adjusting demand on a sector to sector basis and then applying matrix estimation techniques in order to better match observed and modelled traffic volumes.

As a result of these adjustments, some differences between the two models are expected.

6.1.1 Base year traffic volumes

Analysis of differences in base year traffic volumes between WTSM and NWSM focussed on screenline and link comparisons within the area of interest, rather than comparing each model with observed data (this is contained in the relevant validation reports).

[9] Minimal traffic growth was experienced between 2011 and 2013

To summarise the screenline analysis:

- there is a relatively good correlation between modelled and observed traffic volumes in both the AM peak and Inter-peak between WTSM and NWSM screenline crossing volumes
- in the PM peak, NWSM has 23% more traffic crossing the north-south screenline (SH1 North of Tawa, SH2 South of Haywards) and 13% more traffic crossing the CBD screenline (SH1 and Hutt Road, south of Ngauranga), due to matrix adjustments that result in an improved level of validation in NWSM compared with WTSM

At a link level:

- in the AM peak, NWSM traffic volumes southbound down Ngauranga Gorge are 12% higher than WTSM traffic volumes, with the difference due to time period definitions and the impacts of matrix adjustment / estimation
- both models show similar traffic volumes on SH2 between Ngauranga / Petone and Dowse / Petone for all time periods / directions
- PM peak traffic volumes on SH1 at Tawa and SH1 at Ngauranga Gorge are substantially higher in NWSM compared with WTSM, due to matrix adjustment and time period differences
- the WTSM validation technical note[10] acknowledges that PM peak modelled traffic volumes on SH1 at Ngauranga Gorge and SH1 North of Tawa are low compared with observed traffic volumes
- PM peak modelled traffic volumes on SH1 in NWSM correlate much better with observed traffic volumes than WTSM, demonstrating the project model is addressing matters identified in the WTSM validation

Whilst in general terms traffic volumes compare well between WTSM and NWSM, differences at specific locations can be explained by:

- differences in route choice between the models
- a more detailed representation of intersections in NWSM compared with WTSM
- differences in network descriptors such capacities between the two models
- time-slicing implemented in NWSM to better reflect the variation in demands throughout the modelled time periods
- matrix adjustment and estimation processes in NWSM
- more sophisticated simulation capabilities of the NWSM software

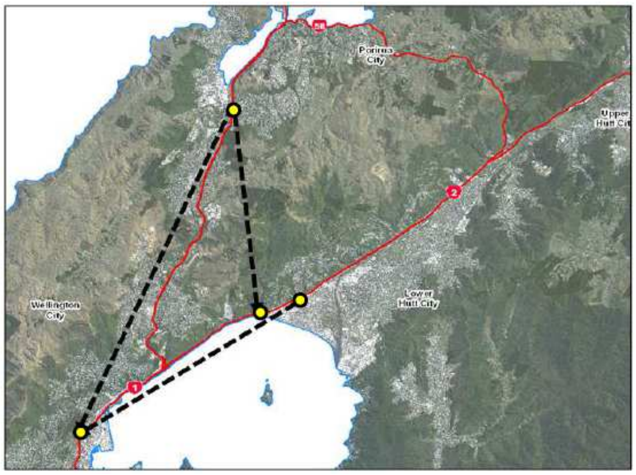
Overall, the matrix adjustments in NWSM improve the validation (compared with the WTSM-sourced ‘prior’ matrix and also improve the validation within the area compared with WTSM.

[10] http://www.gw.govt.nz/assets/Transport/Transport-models/TN18-WTSM-Calibration-and-Validation-FINAL.pdf

6.1.2 Base year travel times

A comparison of base year modelled travel times between WTSM and NWSM focussed on six routes shown in **Figure 4** - Porirua to Wellington (SH1), Dowse to Wellington (SH2), Porirua to Petone (SH1/SH2) - for both peak directions – AM peak (SB) and PM peak (NB).

Figure 4 Travel times routes



The analysis can be summarised as follows:

- there is a good correlation between WTSM and NWSM travel times for three routes – Porirua to Wellington (AM), Porirua to Petone (AM) and Wellington to Dowse (PM)
- Wellington to Porirua (PM) travel times are 6 minutes longer in NWSM compared with WTSM, a direct result of WTSM under-representing traffic volumes on this stretch of SH1 and consequently not adequately reflecting travel times, with NWSM better reflecting observed traffic volumes and travel times
- conversely, WTSM travel times between Dowse and Wellington in the AM peak (SB) validate acceptably and are 6 minutes greater than comparable NWSM travel times, suggesting that NWSM may not be adequately capturing slow moving traffic on this stretch of SH2
- based upon comparisons presented in the respective NWSM and WTSM model calibration and validation reports, NWSM more accurately represents observed travel times on SH1 whilst WTSM more accurately represents observed travel times and delays on SH2

6.2 Future year comparisons

Future year NWSM matrices are derived by applying the base year NWSM screenline and matrix estimation adjustments to future year WTSM matrices. Given the methodology used, it is reasonable to expect that at a screenline level, both models should show similar changes in traffic volumes.

Changes in travel times between base and future year are driven by relative changes in traffic volumes, the shape of the demand profile, link capacities and how additional traffic might alter traffic conditions.

Therefore differences in base year travel times / congestion between WTSM and NWSM, driven by factors such as differing levels of network detail and different capacity assumptions, could result in future year versions of WTSM and NWSM responding differently to a similar increase in traffic volumes.

6.2.1 Traffic volumes

6.2.1.1 Base year to 2031 Do Minimum

At a screenline level, traffic volume growth rates are very similar between the two models (as expected) with the difference in growth between both models no more than 2% to 3%.

Consequently at a link level, traffic volume growth rates are similar between WTSM and NWSM.

The most significant difference in response between the two models occurs on SH2 between Ngauranga and Dowse, where WTSM shows relatively low growth between 2011 and 2031 in both peak periods (~7%) whilst NWSM shows higher growth of around ~20%. More detailed analysis of this significant difference shows that it is driven by higher growth rates for counter-peak direction traffic in NWSM compared with WTSM, a result of base year matrix adjustments and the process of applying NWSM base adjustments to WTSM future year matrices.

Capacity constraint on SH2 between Ngauranga and Petone in both WTSM and NWSM effectively limits any increase in peak direction traffic volumes in both models.

While the same growth rates might be expected between the two models, differences in network characteristics and the base year matrix adjustments made to improve the level of calibration and validation in NWSM results in different growth rates.

The technique of applying matrix adjustment techniques in the base year project model (NWSM), with appropriate constraints / monitoring of outcomes, and then applying growth from the strategic model (WTSM) to these adjusted base year matrices is a common technique that has been used for similar models and schemes that have successfully passed Board of Inquiry scrutiny.

6.2.1.2 2031 Do Minimum to 2031 Option

Both models show very similar traffic growth rates when assessed at both a screenline and individual link level, with the only real differences occurring on SH2 between Dowse and Petone, probably driven by differences in route choice within the Petone area between the two models.

6.2.2 Travel times

6.2.2.1 Base year to 2031 Do Minimum

The main difference in response between the two models relates to SH1 between Porirua and Ngauranga in the AM peak.

Whilst travel times deteriorate by 5 minutes in WTSM, the corresponding deterioration is 10 minutes in NWSM. This is due to NWSM better reflecting the limited spare capacity, resulting in future year travel times in NWSM being more sensitive to relatively small changes in traffic volumes compared with WTSM.

6.2.2.2 2031 Do Minimum to 2031 Option

There are some differences between the response of both models to the P2G link road and associated de-congestion on the state highway network:

- NWSM forecasts more significant travel times savings on SH1 between Porirua and Wellington (5 minutes) than WTSM (1 minute), due to the point made in 5.2.2.1
- travel time savings between Dowse and Petone in the AM peak southbound (and vice-versa in the PM peak northbound) are forecast to be around 2 minutes greater in WTSM compared to NWSM, a result of WTSM operating nearer to capacity that NWSM, thus generating more significant de-congestion benefits

- whilst WTSM suggests that P2G will improve Porirua to Petone travel times by 10 minutes, NWSM suggests that travel times might improve by 15 minutes

Differences in travel times between forecast versions of both models are due to differences in traffic volumes, the shape of the demand profile and capacities between the respective base models that are carried through to the future year models.

Looking at the P2G link road itself, whilst the forecast travel time savings are higher in absolute terms in NWSM compared with WTSM, in percentage terms both models suggest that P2G will improve east-west travel times by between 50% and 60%.

Conclusion

- most of the differences between NWSM and WTSM can be explained and traced back to differences in the base year models that relate to a number of factors such as matrix adjustment factors in NWSM, different time periods, different networks, capacity assumptions and different validation requirements

- overall, however, NWSM is more accurately reflecting observed conditions than WTSM, which is the reason for using a more detailed project model in the first instance

Project recommendations

- improvements are made to the lower tier NWSM traffic assignment model (if justified) to improve the travel time validation, focusing on SH2 but also considering SH1 to maintain consistency across the modelled area

- whilst a recommended approach for future projects (outlined below) would be to update the higher tier WTSM model at the start of a project, based upon the considerable work that has been undertaken to understand differences between WTSM and NWSM in relation to P2G, the most pragmatic and sensible approach for the next stage of the P2G project is to focus attention on updating the lower tier NWSM and S-Paramics models (if required) rather than developing a project model at this late stage in the project

- the focus of this update will be on better replicating a new, more comprehensive dataset of observed travel times by adjusting both mid-block and intersection capacities across the network

Wider recommendations

- a recommended approach for future projects would be to investigate the need to update the higher tier strategic WTSM at the start of the project, based upon comparisons between the various models and the scale and nature of the project in question, to improve travel time and traffic volume validation in WTSM, with these results and changes fed into the respective lower tier models

- for future projects of a similar size and scale, involving multiple tiers of models and multiple partner agencies, a full understanding of the validation of all available modelling tools, focussing upon the area of interest, should be undertaken at an early stage in the process

- the results of these investigations could be used to refine the tools (if required) to provide the basis for consistent analysis across the range of modelling tools

7 Comparison of NWSM and Bluetooth Travel Times

The collection of detailed travel time information from Bluetooth systems was used to gain a better understanding of average travel times and travel time variability on SH2 and Petone Esplanade, and determine the extent to which NWSM replicates these observed travel times.

In common with other analysis presented in this report, the focus of the Bluetooth analysis has been the AM peak and PM peak periods as these contain the greatest levels of variability.

It should be noted that this updated and more comprehensive dataset differs from the 2012 and 2014 data that was used to calibrate and validate NWSM 2013.

7.1 Comparison of travel speeds between Bluetooth and NWSM

Bluetooth data was collected from the NZTA Acyclica system for the period 1 August - 28th September 2015 and compared against modelled travel speeds. The analysis focused on observed speeds as opposed to travel time as there are slight differences between NWSM modelled link lengths and distances between Bluetooth detectors for the route sections for which comparisons are provided below.

The data is not available in its most raw and disaggregated format – the processing and cleaning of this data is detailed in Appendix A11. The highest level of detail available was average travel times during each 5 minute periods in the AM peak (7am to 9am) and PM peak (4pm to 6pm), Monday to Friday, for the stated date range. Overall, this method provides 984 data points for each section of route – 24 five-minute time slices within each 2hr time periods, multiplied by 41 weekdays.

From the range of observed average speeds, an average across the data set was calculated for each time period / route section, together with the standard deviation. It should be noted that during both the AM peak and PM peak, the observed 2hr data range is greater than the modelled AM peak hour (7.30am to 8.30am) and PM peak hour (4.30pm to 5.30pm).

In order to compare modelled and observed travel speeds, the 95% confidence interval (2 standard deviations) was also calculated.

A summary of the observed average travel speed and variability, together with modelled travel speeds, is shown in **Table 9**. An indication of the goodness of fit between modelled and observed travel speed is also provided, by assessing whether modelled travel speeds are within 2 standard deviations of the mean observed travel speed.

More detailed analysis of this data can be found in **Appendix A11** of this report.

Table 9 Bluetooth speed comparison summary

		Observed Data (Bluetooth)			Modelled Data	Comparison
Route section	**Time**	**Mean (km/hr)**	**Weekly Average Standard Deviation (Km/hr) (σ)**	**2 Standard Deviation (σ)**	**Modelled Speed (km/hr)**	**Within 2σ?**
Esplanade (WB) (~1.8km)	AM	23	7	9 to 37	40	within 5km/hr
	PM	51	5	41 to 61	40	within 5km/hr
Esplanade (EB) (~1.9km)	AM	50	2	46 to 54	34	No
	PM	36	8	20 to 52	32	Yes
Petone to Ngauranga (SB) (~3.5km)	AM	38	7	24 to 52	34	Yes
	PM	71	5	61 to 81	56	within 5km/hr
Ngauranga to Petone (NB) (~3.5km)	AM	75	2	71 to 79	85	within 5km/hr
	PM	59	6	47 to 71	51	Yes
Melling to Petone (SB)[11] (~4.4km)	AM	42	16	10 to 74	89	No
	PM	87	1	85 to 89	99	No

The analysis against this new dataset shows that:

- peak period / direction travel speeds are generally slower than counter-peak / direction travel speeds
- travel speeds on SH2 between Melling and Ngauranga are slow in the AM peak (average ~40kph)
- travel speeds on Petone Esplanade are slow in the AM peak (westbound) and PM peak (eastbound)
- routes with slow travel speeds, such as the Esplanade and SH2 between Petone and Ngauranga at peak times, have high standard deviations, showing that considerably travel time variability exists both within the observed time periods and from one day to the next
- using 2 standard deviations (95% confidence interval), the results show that:
    - modelled travel speeds are within the 95% CI for only 3 of the 10 routes
    - modelled travel speeds are narrowly outside the 95% CI for a further 4 routes
    - modelled travel speeds lie significantly outside the 95% CI for the remaining 3 routes
    - routes where modelled travel speeds lie outside of the 95% CI are evenly split into routes where modelled travel speeds are too fast and modelled travel speeds are too slow

More detailed analysis of the data, presented in **Appendix A11**, shows that some of the observed variability within the data is driven by:

[11] Melling to Petone (NB) is not present as there are no detectors on this stretch of SH2

- different travel patterns and characteristics between Monday / Friday and Tuesday / Wednesday / Thursday
- differences in travel speeds within the two hour long time periods, themselves determined by changes in traffic volumes at a micro level and associated changes in congestion / delays

Whilst Bluetooth systems generate huge amounts of data, the data can lack accuracy over short distances as sensors can detect vehicles anywhere within a 100m radius of the sensor location.

Therefore the results in this section, together with the conclusions and recommendations, should be placed in this context.

7.2 Review of NWSM travel time validation

As an average hour model, NWSM cannot account for the effects of travel time variability but should have modelled travel times that lie within an acceptable range of observed values.

Further to the investigations highlighted above, Jacobs undertook additional analysis and confirmed that the NWSM model is not replicating the latest Bluetooth information to an acceptable level for some route sections in certain time periods.

To place the existing validated and peer reviewed version of NWSM in context, during the calibration process different speed-flow curves (SFC) were tested, with the chosen SFCs based upon a set of agreed coding conventions that were initially developed for the Christchurch SATURN Model (CAST). These SFCs and capacities were developed from consideration of US (HCM), UK (DfT) and Australian (Acelik) research, with some adjustment based on local data in Wellington.

Whilst different speed-flow curves in different time periods would improve the travel time validation, this approach is not considered best practice in New Zealand (nor globally) as it implies that physical road characteristics governing capacities and speed-flow relationships change between time periods (which is not that case) and does not give you a consistent / robust basis for estimating the future dynamic relationship between traffic speeds and traffic flows.

The observed travel time variability in the Bluetooth data appears to arise from queuing on the SH2 on-ramp blocking back onto the Esplanade and SH2 (past Petone), resulting in delays and a reduction in capacity until demand levels decrease and queuing traffic dissipates.

Speed-flow curves model mid-block delays but do not in themselves trigger upstream queue propagation; such delays are triggered by the dynamic capacities at bottlenecks such as the Petone on-ramp / SH2 merge point.

The implication of the current situation, where NWSM over-estimates travel speeds (and under-estimates congestion) under a Do Minimum scenario, is that benefits from a scheme such as P2G which is forecast to reduce congestion are likely to be understated.

For the next SAR stage, it is suggested that further investigations be undertaken to assess the merits of different techniques for better replicating observed travel times and queues on Petone Esplanade and SH2.

This work, including any previous work that has been undertaken in this regard but is not captured in this report, should be documented in a technical note together with any conclusions and refinements (if appropriate) to NWSM and S-Paramics.

Conclusions

- there is a high level of variability in the average travel speeds during the AM and PM peak experienced by traffic along the Esplanade and SH2 in the vicinity of Petone Interchange – this variability is most pronounced at peak times

- for some route sections and time period, modelled travel times from NWSM (calibrated / validated against 2014 Bluetooth data) do not sit within an appropriate range of observed travel times as derived from the 2015 Bluetooth data.
- whilst considerable analysis of modelled and observed travel times had been undertaken on SH2, no similar analysis has been undertaken on SH1

Project recommendations

- the new Bluetooth data used for this analysis should be reviewed by the NWSM peer reviewer, with the model builder (Jacobs), peer reviewer (QTP) and practitioners (Opus) developing a consensus view regarding an appropriate travel time range for each route sections / time period, which should provide the basis improving the travel time validation in NWSM
- Steering Group to develop scope of work required to improve the robustness of the NWSM model in its application to the P2G project, in liaison with Jacobs and the Peer Reviewer
- additional Bluetooth data to be gathered for the SH1 corridor to understand travel times and travel time variability to the same level of detail as has been undertaken on SH2
- investigations to focus on merge and link capacities, speed-flow curves, levels of demand along Petone Esplanade, the Petone on-ramp / SH2 merge and the potential for reinstating a 'pre pre peak' to NWSM as implemented in an earlier version of the model to reflect a 2012 dataset
- updates to NWSM relating to SH1 and SH2, together with issues for consideration when developing the S-Paramics model, should be justified based upon this analysis
- given that NWSM in its current status may underestimate the benefits from P2G, develop an approach for capturing the full level of benefits associated with P2G

Wider recommendations

- more extensive use should be made of Bluetooth data to understand baseline travel times and travel time variability both when calibrating / validating models and when commencing project specific evaluations, whilst also improving our understanding of limitations and margins of error associated with this data

8 Demand response to P2G

8.1 Introduction and context

Highway and public transport infrastructure improvements generally lead to a reduction in the cost of travel – defined as a combination of travel time (car and PT), fuel costs (car) and PT fares (PT).

Depending on the nature of a particular highway scheme, the dominant response is likely to be the re-assignment of traffic from parallel existing routes to the new route (e.g. a new bypass) that provides faster travel times.

Likewise for public transport, the dominant response to a BRT corridor providing express services would be re-assignment from existing stopping services.

Highway and public transport infrastructure improvements can, however, stimulate changes in travel behaviour other than re-assignment, as outlined in the examples below:

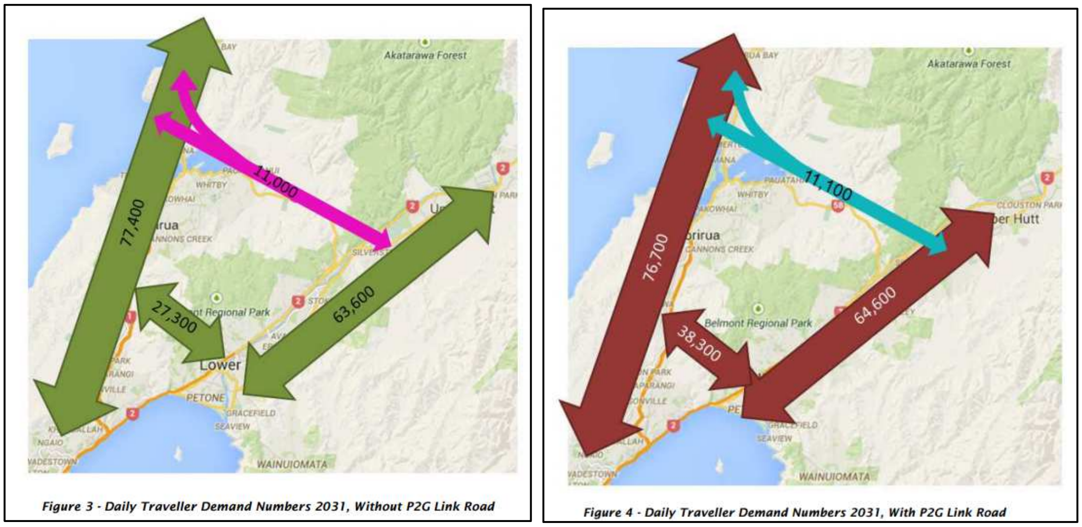
- if peak period highway congestion is severe, some people may re-time their trip to take place during the less congested inter-peak period. Conversely, relieving such congestion can result in trip re-timing from the inter-peak to the (now less congested) peak periods
- if the widening of an existing road provides more highway capacity and improved travel times for a particular journey, yet the relative cost of travelling by public transport for the journey in question remains unchanged, some modal shift from PT to car may occur
- conversely, if PT travel times improve yet highway travel times remain unchanged, some modal shift from car to PT may occur
- the widening of an existing road or a new link road might generate entirely new trips; e.g. improved accessibility to a shopping centre may encourage people to go shopping more often as previously they restricted the number of journeys they made due to high travel costs (congestion, slow travel times, etc.)
- a new link road that improves accessibility and reduces travel costs between two areas could result in a redistribution of existing trips. This might occur immediately (e.g. shopping trips made to one area in preference to another) or over a longer time period (e.g. people changing their place of residence or employment or a warehousing facility locating to an area with improved accessibility)

The nature and extent of any demand response will vary depending upon the nature of the scheme in question, the distribution of trip purposes, the travel costs on the network prior to the new scheme being implemented and the impacts of the scheme in terms of improved travel times, reduced travel costs and improved accessibility.

8.2 P2G context

Figure 5 below is a schematic showing forecast daily WTSM traffic volumes between key origins / destinations in 2031 under 'without' and 'with' P2G link road scenarios

Figure 5 Daily traveller demand numbers, 2031, with and without P2G link road, medium growth



Source: WTSM 2031

It clearly shows that east-west and west-east trips increase from 38,300 to 49,400 as a result of P2G.

More detailed WTSM analysis of forecast traffic volumes on the P2G link road itself suggest that around 1/3rd of trips using P2G in 2031 are ‘additional’ trips (largely east-west trips) not present in the Do Minimum, with the remaining 2/3rd being trips (largely east-west trips) that exist in the Do Minimum but re-assign to P2G from existing routes such as SH58 and SH2/SH1.

These additional trips are generated by WTSM in response to changes in travel times and costs. The purpose of this section is to establish whether these additional trips using P2G are due to the redistribution of existing trips, modal shift, trip re-timing or true trip induction.

The following is a summary of the findings, with more detail provided in **Appendix A6**. Unless otherwise mentioned, the analysis focuses on 2031 scenarios with the P2G option being Option C.

8.3 Modal shift

Analysis of differences in PT volumes between the Do Minimum, Do Minimum Cross (Do Minimum matrix assigned to the Option network) and Option assignments was undertaken to determine the extent of any modal shift generated by P2G.

For all the modelled P2G option scenarios, a bus service with a 30 minute frequency provides a direct connection between Porirua, Tawa and Lower Hutt via the P2G link road.

In summary, modal shift resulting from P2G is small, the net effect being:

- a 2% decrease in peak period public transport trips down the SH1 corridor at Ngauranga Gorge, the result of a small degree of modal shift from rail to car (from Tawa and Porirua area) and bus to car (from Johnsonville), driven by de-congestion benefits on SH1 down Ngauranga Gorge
- a 1% increase in peak period PT trips from the Hutt Valley to Wellington, the result of modal shift from rail to bus (Lower Hutt to Wellington) and rail to car, driven by de-congestion on SH2 between Ngauranga and Petone benefiting both private vehicle and bus trips

8.4 Trip-retiming

Analysis was undertaken in WTSM looking at the percentage of daily trips that occur within each time period – AM peak, Inter-peak, PM peak – to determine if any trip-retiming takes place as a result of P2G.

This analysis showed that the effect of trip-retiming between the off-peak and peak periods as represented in WTSM is negligible, with the percentage of all daily trips occurring in peak periods increasing from 22.0% to 22.2% as a result of P2G whilst the proportion of daily trips made during off-peak periods decreased from 78.0% to 77.8%.

Whilst this implies that peak spreading is not likely to be a significant issue as a result of P2G, an element of trip re-timing could occur within peak periods, as some people may change their trip patterns from travelling in the peak shoulders (7.00am to 7.30am, 8.30am to 9am) to travelling during the peak hour (7.30am to 8.30am) in response to improved levels of service delivered by P2G.

The modelling tools and techniques do not currently have the functionality to capture the potentially small impact the trip re-timing from the peak shoulders to peak hour might have, with the implications of this discussed below in section 8.6.

8.5 Reassignment of trips

Trip reassignment is the re-routing of existing trips in response to opportunities and improved travel times arising from a project.

Analysis of the Do Minimum and Do Minimum Cross assignments in the AM peak 2031 shows that the two-way re-assigned traffic volumes of 4,800 vehicles (7am to 9am) on P2G can be apportioned as follows:

- 1,450 (35% of total) re-assign from SH58
- 3,100 (65% of total) trips re-assign from SH1/2

8.6 Induced trips

At the workshop it was agreed that it was important that the Steering Group, as part of their investigations, differentiated between:

- induced trips - entirely new trips generated as a result of P2G
- redistributed trips – existing trips where the origin and / or destination changes in response to P2G

The number of daily trips (car and PT combined) generated by WTSM is related to the input land use (population, household and employment), with fixed trip rates then applied according to household category.

As the land use is fixed between the P2G Do Minimum and Option scenarios, the number of daily trips on the network is also fixed between the Do Minimum and Option assignments.

This means that WTSM does not generate any new daily trips (induced trips) under any future scenarios where the input land use assumptions are the same.

WTSM does, however, redistribute existing trips, for example, shopping trips made to one area in preference to another or someone changing their place of residence or employment in response to improved accessibility.

In relation to true induced (new) trips, there is limited evidence in New Zealand regarding the likely magnitude of such a demand response. The steering group believe that the likely magnitude of such a response is low, and likely to sit within the upper bound of sensitivity tests already undertaken for the P2G project.

Analysis of the P2G link road under a 2041 AM peak or PM peak scenarios suggests that an additional 1,000 vehicles would be required to result in a V/C ratio greater than 85% that would likely result in significant delays.

This confirms that levels of service on P2G would not change significantly if small numbers of true 'induced' trips were generated.

8.7 Land use and transport interaction

In WTSM, the likely land use and transport impacts of the P2G link road are assessed independently.

Initially, one variable (the highway network) is changed between the Do Minimum and Option in order to identify the direct benefits associated with the scheme in question rather than changing multiple variables (land use and the highway network) and being unable to identify what is driving the benefits.

Secondly, the land use assumptions are changed to independently model the sensitivity of the scheme to different land use scenarios, as documented in Section 5.

Whilst a land use transport interaction (LUTI) model would dynamically model the links between a particular scheme and possible changes in land use, no such model currently exists for Wellington.

With the development costs associated with such a model likely to be significant (over $1 million dollars), the steering group believe that the most appropriate approach to modelling the likely interaction between transport and land use is the approach that has been taken for P2G, namely modelling transport and land use independently with appropriate sensitivity tests and ranges of scenarios.

8.8 Redistributed trips

Analysis of the WTSM Do Minimum and Option assignments in the AM peak 2031 show that two-way traffic volumes of 6,700 vehicles (7am to 9am) on P2G can be apportioned as follows:

- 4,800 reassigned trips, as detailed above (~70% of total)
- approximately 1,900 redistributed trips (~30% of total)

The daily Do Minimum and Option matrices were compared at a sector level, to better understand the origins and destinations of these redistributed trips.

This analysis showed that P2G results in a reduction in the number of shorter distance trips solely within areas such as Tawa, Porirua and North Wellington (Johnsonville / Newlands) and a corresponding increase in longer distances trips between Tawa / Porirua / North Wellington and Lower Hutt (and vice versa).

These changes in WTSM are a response to improved accessibility and improved travel times delivered by P2G, resulting in new opportunities for east-west travel.

WTSM responds to these improvements by redistributing, for example, a small percentage of existing home to work trips solely within Tawa, replacing the workplace within Tawa with a workplace in Lower Hutt, with the redistributed trips using the P2G link road.

The magnitude and scale of this redistributional effect is small when compared with the number of trips on the network as a whole.

For example, focussing on Tawa itself, of the 24,700 daily trips that are internal to Tawa in the Do Minimum, only 1,300 (5%) are subject to the redistributional effects of P2G, still leaving 23,400 daily trips within Tawa in the Option scenario. The majority of the these 1,300 daily trips are shorter distance trips between Tawa and Porirua that are replaced by longer distance trips between Tawa and Petone, Lower Hutt and Seaview.

The net impact of the redistributional effects highlighted above is an increase in east-west trips and an increase in VKT, with shorter distance trips being replaced by longer distance trips using P2G.

A number of sensitivity tests were run in NWSM, by taking a certain proportion of 'redistributed' trips, adding them to the Do Minimum matrix and assigning this matrix to the network, to understand how different assumptions relating to the level of redistribution that may occur could affect traffic volumes and travel times at key locations on the network.

The scenarios that were modelled were as followed:

- 1 - Do Minimum matrix assigned to Do Minimum network
- 2 - Do Minimum matrix assigned to Option network (0% redistribution) – Do Minimum cross assignment
- 3 - Do Minimum matrix + 50% of redistributed trips, assigned to Option network (50% redistribution)
- 4 - Option matrix assigned to Option network (100% redistribution)

Table 10 below shows AM peak and PM peak levels of service on P2G, SH1 North of Tawa and SH2 Petone to Ngauranga in 2031 under the scenarios outlined above, to give an indication of how different redistribution assumptions might affect LoS.

Table 10 Variation in levels of service according to traffic redistribution assumptions

	Volume / Capacity ratios, 2031					
Scenarios	P2G		SH1 North of Tawa		SH2 Ngauranga to Petone	
	AM (EB)	PM (WB)	AM (SB)	PM (NB)	AM (SB)	PM (NB)
1 - Do Min	N/A	N/A	43%	57%	96%	97%
2 - Do Min Cross (0%)	47%	49%	50%	67%	93%	101%
3 - Do Min + 50%	55%	56%	52%	67%	96%	101%
4 - Option (100%)	64%	65%	54%	69%	98%	102%

The data shows that regardless of the assumptions relating to the level of redistributed traffic, peak period levels of service on key links within the area of interest remain largely unchanged.

8.9 Realism of the WTSM demand response

As summarised above, the redistribution of existing trips is the main WTSM demand response to P2G.

Whilst there was a general consensus at the modelling workshop in June 2015 that some redistribution associated with P2G should be expected, the question was raised about whether 30% of traffic using P2G being redistributed traffic, as is currently predicted by WTSM, is reasonable.

This section discusses the realism of the WTSM demand response and is structured as follows:

- benchmarks the redistributional impacts of P2G against the modelled redistributional effects of similar projects across New Zealand
- outlines the time period over which any redistribution might be expected to occur

- outlines implied elasticities calculated from WTSM
- outlines elasticity modelling sensitivity tests undertaken in NWSM

8.9.1 Benchmarking of demand response

A piece of work was undertaken looking at a number of major roading projects in New Zealand to determine the level of demand response that the modelling work forecast for these projects.

It is acknowledged that by looking at model predictions rather than any out-turn realities that the predictions could be subject to the same errors as the modelling techniques used.

Ideally such an assessment would focus on observed 'before and after' data for large projects to gain a better understanding of how accurately modelling tools forecast changes in traffic volumes. However, no such observed information is available, particularly relating to the induced traffic / redistributional impacts, meaning that it is necessary to rely on comparisons of model predictions, with appropriate caveats placed around uncertainty.

Notwithstanding these limitations, looking at three similar large infrastructure projects provides an indication of how the P2G demand response would rank.

Table 11 below lists the projects, provides a description of the major benefits associated with each and documents the demand response (% of overall increase in traffic volumes that is due to effects other than re-assignment).

Of the projects, three – TG, M2PP and P2G – have been assessed with WTSM whilst the other – Waterview – has been assessed with the Auckland 4-stage model that is built using the same EMME software platform as WTSM.

Table 11 Demand response for significant roading projects in New Zealand

Scheme	Description / Beneficiaries	Demand Response
Waterview	Provides an alternative shorter route to SH1 / SH16, from Manukau to Albany, allowing traffic to bypass the inner city motorway junction	7% of trips on route
M2PP	Road from MacKays Crossing to Peka Peak, allowing through traffic to bypass Waikanae / Paraparaumu and improving connections between Paraparaumu Beach / Waikanae Beach and the south. Runs broadly parallel to SH1	12% of trips on Expressway
P2G	Link between Tawa and Petone, providing alternative route for east-west movements instead of SH58 and SH1/2, connecting two areas currently poorly connected	30%

Looking at the projects above, the P2G demand response is the most significant.

Comparing P2G with the M2PP expressway, both of which were modelled using WTSM, there are a number of reasons for the difference in the demand response between the two schemes:

Nature of road

- M2PP is effectively a bypass for a stretch of the state highway that experiences congestion at peak times, and is forecast to deliver travel time savings of around 5 to 7 minutes for a trip travelling along its entire length[12]
- P2G is a new link, rather than a bypass, providing an alternative route for east-west traffic instead of SH1 / SH2[13], potentially generating east-west travel time savings of between 10 to 15 minutes

Accessibility improvements

- M2PP improves accessibility to a number of small areas, such as Waikanae Beach, and connectivity within the Kapiti Coast area, likely to result in new opportunities for trips and thus some trip-redistribution
- P2G significantly improves connectivity and accessibility between the major centres of Tawa, Porirua, North Wellington and Lower Hutt, linking major areas of residential development with major employment areas, and creating many new opportunities for trips

In summary, the P2G link road is a transformational transport project within the region when compared against a selection of other roading projects. It is not primarily a bypass but a new link road that connects two areas that are currently poorly connected and consequently generates new opportunities and choices regarding where people might choose to live and work.

Therefore it is reasonable to expect that the redistributional response associated with P2G might be more significant in than for other major roading projects within the region and across New Zealand.

Notwithstanding this comment, the scale of the demand response (30% redistribution) is considerably greater than what has previously been forecast for other large road infrastructure projects in New Zealand.

Whilst the steering group believe that there are good reasons why P2G might generate a significant demand response, it is best practice to undertake sensitivity tests to see how levels of service on P2G and other key links might change should the demand response not be fully realised. This is documented in section 8.13.

8.9.2 Timeframe for redistributional response

The time frame during which changes in traffic volumes associated with P2G might take place depends upon the nature of the response.

The re-assignment of existing trips to P2G is likely to occur over a relatively short time period, with drivers soon becoming aware of the travel time savings that P2G can deliver.

Any true redistributional response, however, would occur over the medium to long term as follows:

- a demand response associated with discretionary trips, such as shopping trips, could occur almost immediately but might take months or even years to develop to its maximum extent. These trips, however, comprise a relatively small proportion of total trips

[12] M2PP Traffic Modelling Report http://www.nzta.govt.nz/assets/projects/mackays-to-peka-peka-application/docs/technical-report-34.pdf

[13] SH1 – congestion down Ngauranga Gorge (AM), SH2 – congestion from Petone to Ngauranga (AM and PM)

- a demand response related to persons changing their place of residence or employment as a result of opportunities delivered by the new P2G link road could take much longer, perhaps several years
- longer term redistributional impacts will to a certain extent be dependent upon changes in land use that may occur as a result of opportunities generated by the link road

When looking at international research, there are differences of views regarding how long it might take for any trip redistribution response to reach equilibrium; some studies suggest that equilibrium is reached after 4 years, whilst others suggest that the response is still ongoing greater than 10 years after the scheme opening date[14].

In relation to P2G, given the scale of the scheme and the significant accessibility benefits it is likely to deliver, the steering group believe that growth in traffic volumes due to redistributional effects is likely to occur incrementally, perhaps taking a period of 10 to 20 years until the network reached an equilibrium state again and the response reached its maximum extent.

8.9.3 Current residential mobility within Wellington Region

A significant amount of residential mobility currently exists within the Wellington Region, driven by many factors such as employment opportunities, increasing wealth, increasing family size, down-sizing, etc.

The Census showed that in both Porirua and Lower Hutt, around 35% of residents in 2013 were living at a different address to where they lived 5 years previously (2008).

At a more detailed level, the 2013 the Census showed that 5% of residents in Porirua and Lower Hutt (7,000 persons in absolute terms) were living elsewhere within New Zealand in 2008. Whilst the data is unable to be disaggregated further, it is likely that a significant proportion of these persons will have moved to Porirua / Lower Hutt from elsewhere within the region (i.e. Lower Hutt to Porirua) between 2008 and 2013.

This data demonstrates that the residential population is highly mobile even without the impact of infrastructure projects that might improve accessibility and opportunities to travel.

8.9.4 Principles of elasticity modelling

The previous sub-section has outlined that any demand response to P2G is likely to be gradual and occur over the medium to long term.

In terms of assessing whether the demand response seen in WTSM is realistic, many authorities and research institutes have published guideline 'elasticities' regarding the possible nature and extent of any demand response that might occur under certain future scenarios.

The guideline elasticities outlined and used below are sourced from Australian and European studies and vary according to:

- Trip purpose – commute, leisure, employer's business
- Income – high, medium, low
- Mode – car, PT

[14] https://www.nzta.govt.nz/assets/Planning-and-investment/docs/implications-of-road-investment-201211.pdf, Section A3.6, pg 120

- Time period – peak, off-peak
- Time frame for response – short run (1 to 2 years) to long run (5+ years)

In summary, there is a large degree of variation in relation to the reported elasticities, with long run (long term changes) elasticities for car trips / car VKT with respect to travel time varying from -0.2 to -1.0 depending on the purpose / time period, resulting in the following range of demand response:

- an elasticity of -0.2 implies that a 10% increase in the cost of travel would result in a 2% decrease in demand (or vice versa)
- similarly, an elasticity of -1.00 implies that a 10% increase in the cost of travel would result in a 10% decrease in demand (or vice-versa)

Published elasticities are generally lower for peak periods (-0.2 to -0.6) compared with the off-peak (-0.4 to -1.0) and are to some extent affected by location-specific factors. It is for this reason that these have been used simply to provide context for the modelling of conditions in Wellington.

This work is summarised in more detail in **Appendix A7.**

8.9.5 WTSM implied elasticities

The P2G demand response in WTSM was assessed by looking at the percentage change in demand for certain sector to sector movements together with the percentage change in average travel time for this movements, from which implied elasticities were calculated.

The analysis suggests that the implied elasticities were around -0.8 in both peak periods – i.e. a 10% decrease in travel time generates a 8% increase in trips on P2G – whilst it was higher in the Inter-peak (-1.9). At a daily level the implied elasticity is around -0.9 to -1.0.

On this basis, WTSM appears more responsive to P2G (higher elasticities, greater demand response) than might be expected when looking at the guideline elasticities. However, in the absence of 'before/after' surveys relating to projects originally assessed with WTSM, the steering group are unable to conclude whether the P2G response is a 'real' issue (due to the transformational nature of the P2G scheme) or a result of modelling tools.

The steering group concluded that this uncertainty should be dealt with in terms of understanding levels of service on the P2G link road, SH1 and SH2 under a range of possible future scenarios, to determine the extent to which the design of the link road and levels of service are dependent upon assumptions relating to traffic redistribution.

This work is summarised in more detail, including tables, in **Appendix A7.**

8.9.6 NWSM elasticity modelling

A further piece of analysis was undertaken using the NWSM Do Minimum matrices and assigning these to the NWSM Option network in 'elastic mode', with elasticity parameters of -0.2, -0.5 and -0.8 specified to represent different elasticity scenarios.

When SATURN is run in this way, changes in costs between the Do Minimum and Option networks are combined with the input elasticity value to generate revised trip matrices, providing a broad comparison in SATURN of the responses already modelled in WTSM (modal shift, trip redistribution, trip re-timing).

There are inherent limitations to using the SATURN elasticity method:

- trips are allowed to grow un-constrained in SATURN (i.e. the number of trips increases) whereas in WTSM the total number of trips remains the same and changes in traffic volumes are a result of redistribution approach
- in SATURN, changes in trip patterns are driven by changes in travel costs (there is no land-use component)

Despite these acknowledged limitations, this method provides an indication of the changes in traffic volumes along P2G that could be expected as result of changes in costs in the SATURN model under a number of elasticity scenarios.

Table 12 shows AM peak (EB) and PM peak (WB) trips on P2G in 2031 for the Do Minimum Cross, -0.2, -0.5 and -0.8 SATURN scenarios and the Option C scenario that is derived from WTSM.

Table 12 Forecast P2G traffic volumes under a range of elasticity scenarios

Scenario	Flow (2hr)	% change wrt Do Minimum
AM peak, P2G, Eastbound		
NWSM DM Cross	1,500	
NWSM -0.2	1,560	4.0%
NWSM -0.5	1,780	18.7%
NWSM -0.8	1,970	31.3%
NWSM Option C	1,950	30.0%
PM peak, P2G, Westbound		
NWSM DM	1,600	
NWSM -0.2	1,640	2.5%
NWSM -0.5	1,840	15.0%
NWSM -0.8	1,970	23.1%
NWSM Option C	2,010	25.6%

Table 12 shows that the NWSM model run with an elasticity of -0.8 (result highlighted in red) generates a 23% to 31% increase in traffic volumes on P2G itself. This is similar to the 30% increase in traffic volumes on P2G between the Do Minimum and Option C generated by WTSM (section 8.7).

Whilst not presented above, comparisons for other key links within the area of interest – SH1 North of Tawa, SH2 Ngauranga to Petone and SH2 Dowse to Petone – suggest a similar relationship, with the demand response from the SATURN -0.8 elasticity test broadly aligned with the full WTSM demand response for Option C.

When compared to the guideline elasticities outlined in section 8.8.3, the peak period elasticity value of -0.8 required for the NWSM demand response to align with the WTSM demand response is slightly higher than the guideline range of long run peak period elasticity values (-0.2 to -0.6) as obtained from international research.

This reaffirms the findings presented in Section 8.8, namely that WTSM appears to be slightly more responsive to P2G (higher elasticities, greater demand response) that might be expected when looking at the guideline elasticities.

8.10 Recommended scenarios for next project phase

Based on the information presented in this section, the Steering Group decided that the recommended approach would be to use the following 'medium redistribution' scenario as the core scenario for the assessment of P2G:

- 2021 – assume no redistributional effects associated with P2G
- 2031 – assume that 50% of the redistributional effects generated by P2G (as estimated by WTSM) would be realised
- 2041 – assume that 100% of the redistributional effects generated by P2G (as estimated by WTSM) would be realised

These scenarios will be applied equally to the AM peak, Inter-peak and PM peak, as the WTSM demand response already shows that, as expected, re-distributed traffic as a percentage of total traffic volumes is greater in the Inter-peak compared with the AM peak or PM peak.

Given the inherent uncertainties regarding land use and the demand response to P2G, the steering group recommend that alternative scenarios should also be used to represent 'zero' and 'higher' redistribution scenarios.

The scenarios are summarised below in **Table 13** and reflect the following:

- a zero redistribution scenario (effectively the Do Minimum demand)
- a medium level of redistribution, as outlined above
- a higher level of redistribution in 2031 and 2041

Table 13 Proposed scenarios for SAR modelling

Year	Zero growth redistribution scenario	Medium redistribution scenario	Higher redistribution scenario
2011	2011 Demand, Option network		
2021	2021 Do Min demand, Option network		
2031	2031 Do Min Demand, Option network	2031 Option demand (50% of redistributed trips), Option network	2031 Option demand (100% of redistributed trips), Option network
2041	2041 Do Min Demand, Option network	2041 Option demand (100% of redistributed trips, Option network	2041 Option demand (150% of redistributed trips, Option network[15]

Initial results from these scenarios, detailing levels of service and V/C ratio at key locations on the network and undertaken using the modelling tools that were used for the multi-criteria analysis, are presented in **Section 11** of this report.

[15] Note that the 2041 higher redistribution scenario has not yet been run

Conclusions

- the functionality of the modelling system does not implicitly enable the generation of any totally new trips, referred to as 'induced trips', because land use and daily trip rates that are applied remain the same between the Do Minimum and Option scenarios and WTSM assumes that same number of daily trips under each scenario
- whilst it is likely that the impact of any induced traffic effects associated with P2G would be small and within the standard range of uncertainty associated with any traffic forecasts, a method should be developed during the SAR stage to quantify the level of induced trips that might be expected and the impact that this might have on levels of service
- modal shift and trip re-timing associated with P2G is negligible, although a limited amount of trip re-timing that cannot be currently captured by the modelling system could occur between the peak shoulders and peak periods
- around 2/3rd of traffic forecast to use P2G reassigns from alternative routes such as SH58 and SH1/SH2
- the remaining 1/3rd of traffic forecast to use P2G is redistributed trips, whereby a person's origin and / or destination changes in response to changes in costs, improved accessibility and opportunities delivered by P2G
- P2G is a unique and transformational transportation project, and as a result it is difficult to benchmark the demand response as there very few schemes of a similar nature currently being assessed in New Zealand
- it is likely that any redistributional traffic response resulting from P2G would take between 10 and 20 years to be fully realised
- guideline elasticities, sensitivity testing in SATURN and comparisons against similar projects suggests that the current full WTSM demand response to P2G sits at the upper end of the range within which it is expected the response should lie

Project recommendations

- the 2041 high redistribution scenario should be run during the SAR phase of the investigations
- the range of recommended scenarios highlighted above should be used in order to refine the assessment of P2G itself and to develop and assess the operation of the Petone and Tawa interchanges during the SAR stage of the project
- additional work should be undertaken to confirm the likelihood and scale of any true induced traffic effects that might accompany the P2G scheme
- this analysis should include testing of induced land use effects associated with P2G, and the impact that increased traffic volumes associated with induced land use might have upon levels of service
- any future analysis and interpretation should bear in mind that the WTSM modelled demand response to P2G (mainly due to trip redistribution) sits at the upper end of the range within which the response would be expected to lie

Wider recommendations

- future project teams, including GWRC, should understand how WTSM might account for trip re-timing, peak spreading, true induced trips and trip redistribution on a project specific basis
- detailed analysis of the demand response in WTSM associated with any large infrastructure interventions should be undertaken towards the start of any project, with the level of effort and investigation proportionate to the size of the project and its likely impacts
- results of this analysis should be benchmarked and discussed, with the steering group and project team coming to an understanding regarding a range of possible responses and the accompanying likelihood of these responses occurring
- that project teams should understand that any demand response is unlikely to occur immediately and could take between 10 and 20 years to be fully realised
- future project teams should liaise with GWRC at the project scoping, initiation or Programme Business Case (PBC) phase to understand how WTSM might account for trip re-timing, peak spreading, true induced trips and trip redistribution on a project specific basis

9 P2G design and effects on wider network

9.1 HCV analysis of the P2G link road

The P2G link road as designed, modelled and assessed for the multi-criteria assessment (MCA) consists of four lanes for general traffic along its entire length, together with crawler lanes for heavy commercial vehicles along steep sections of the route.

This section of the report provides a brief summary of HCV assumptions and levels of service on the P2G link road and is structured as follows:

- analysis of levels of service based on the NWSM SATURN central scenarios
- commentary regarding changes in HCV volumes between WTSM 2011 and WTSM 2013, HCV growth assumptions in WTSM and how these might affect the P2G assessment
- the sensitivity of this analysis to the modelling assumptions

9.1.1 NWSM – sensitivity of P2G level of service to crawler lanes

Table 14 presents AM peak (EB), PM peak (WB) and Inter-peak (average of EB and WB) traffic volumes, V/C ratios and levels of service along P2G under the following core central case scenario that was agreed by the steering group and outlined in **Section 8.9**:

- 2011 (current)
- 2021 Option (0% redistribution)
- 2031 Option (50% redistribution)
- 2041 Option (100% redistribution)

The breakdown of vehicles – cars and HCVs – is provided, together with the volume / capacity ratio under **'with'** and **'without'** crawler lane scenarios, assuming a capacity of 1,700 vehicles per lane.

The **'with'** crawler lane scenario assumes that all HCVs use crawler lanes, while the V/C ratios assume 2 lanes in each direction, a capacity of 1,700 vehicles per lane and only considers light vehicle volumes – HCVs are effectively separated from the 2 normal lanes of traffic.

The **'without'** crawler lane scenario assumes a simplistic scenario where all HCVs use the two general traffic lanes, thus the V/C ratios are calculated assuming 2 lanes in each direction, a capacity of 1,700 vehicles per lane and considers light vehicles and HCV volumes combined. This approach is likely to ignore the detrimental impact upon capacity that a small number of slow moving HCVs might have, with the results likely to overstate performance (LoS).

Table 14 V/C and LOS of P2G link road

Year	Direction	Traffic volumes			V/C Ratio		Implied LoS	
		Car	HCV	Total	Crawler lanes	No crawler lanes	Crawler lanes	No crawler lanes
2013	AM peak (EB)	840	40	880	25%	27%	A	A
	IP (avg EB and WB)	350	30	380	11%	12%	A	A
	PM peak (WB)	990	30	1,020	29%	31%	B	B
2021 (0%)	AM peak (EB)	1,140	50	1,190	34%	37%	B	B
	IP (avg EB and WB)	430	50	480	14%	17%	A	A
	PM peak (WB)	1,270	50	1,320	37%	40%	B	B
2031 (50%)	AM peak (EB)	1,690	70	1,770	50%	54%	C	C
	IP (avg EB and WB)	660	50	710	21%	24%	A	A
	PM peak (WB)	1,770	60	1,840	52%	56%	C	C
2041 (100%)	AM peak (EB)	1,950	80	2,020	57%	62%	C	C
	IP (avg EB and WB)	820	50	870	26%	28%	A	A
	PM peak (WB)	2,000	60	2,060	59%	63%	C	C

The analysis of the central case scenario, based on the medium growth land use scenario, shows the following:

- HCVs comprise a small percentage (around 2% to 3%) of vehicles forecast to used P2G
- HCV volumes on P2G range from 30 vehicles per hour in the AM peak (EB) in 2011 to a forecast 80 vehicles per hour in 2041 in the AM peak (EB)
- during peak periods, traffic volumes using P2G under the core scenario suggests that LoS C is the lowest that the road may experience in 2041, with the PM peak (WB) reaching a VC ratio of 59% with crawler lanes and 63% without
- in the Inter-peak, traffic volumes using P2G are low, with resulting levels of service not forecast to exceed LoS A under any future scenario
- inter-peak traffic volumes are so low that a 4 lane P2G layout (without dedicated crawler lanes) would deliver good levels of service, with the inside lane effectively being a lane for slow moving vehicles
- from a traffic volume perspective, there is no significant change in V/C ratios nor levels of service between 'with' and 'without' crawler lane scenarios

Conclusion:

- analysis of the V/C ratios and forecast HCV movements for the core scenarios suggest that, from a simplistic traffic volume perspective and using the existing modelling tools, crawler lanes would not be required to maintain a good level of service for all users of P2G, with minor delays for general traffic due to slow moving HCVs only likely to be a possible issue in the peak periods
- this analysis does not account for the fact that HCVs may travel slower than cars, resulting in some congestion and inferior levels of service than are reported above

Project recommendations

- that a more detailed traffic assessment of the requirement for crawler lanes be developed for the SAR assessment, possibly utilising and extending the existing Petone Interchange S-Paramics model and considering a range of HCV growth scenarios
- that this updated modelling work be combined in the SAR with relevant safety assessments to provide justification for any decision regarding crawler lanes

9.1.2 Difference in HCV volumes between WTSM 2011, WTSM 2013 & NWSM 2013

This section presents a review of HCV modelling undertaken to date in WTSM 2011, NWSM 2013 and WTSM 2013, looking at both P2G itself and the wider network.

P2G HCV volumes

Analysis presented previously in this report showed that daily HCV volumes are 18% lower across the region in WTSM 2013 compared with WTSM 2011, the result of revising and updating the WTSM HCV model.

Focussing on P2G, analysis was undertaken to better understand differences in HCV volumes between the following assignments:

- WTSM 2011 base year matrix assigned to P2G network
- WTSM 2013 base matrix assigned to P2G network
- NWSM 2013 base matrix assigned to P2G network

This analysis is presented in **Table 15** below.

Table 15 P2G Forecast HCV volumes in WTSM 2011, WTSM 2013 and NWSM 2013

Year	WTSM 2011		WTSM 2013		NWSM 2013	
	AM (EB)	PM (WB)	AM (EB)	PM (WB)	AM (EB)	PM (WB)
AM	75	60	50	40	35	25
IP	75	75	40	25	30	30
PM	45	70	20	20	25	30

The analysis shows that whilst the 2013 NWSM HCV demand is derived from WTSM 2011 HCV demand, the matrix adjustment and estimation process has reduced HCV volumes considerably to better reflect the more detailed count set used for NWSM.

As a consequence, the 2013 NWSM P2G HCV volumes are broadly similar to the WTSM 2013 P2G HCV volumes that have been estimated using the improved HCV model within WTSM. This suggests that if NWSM 2013 were to directly used HCV demand from WTSM 2013, only limited matrix adjustment techniques would be required.

Wider network HCV volumes

Figure 6, **Figure 7** and **Figure 8** below compare WTSM 2011, WTSM 2013 and NWSM HCV volumes across key links on the wider network.

Figure 6 HCV comparison – AM

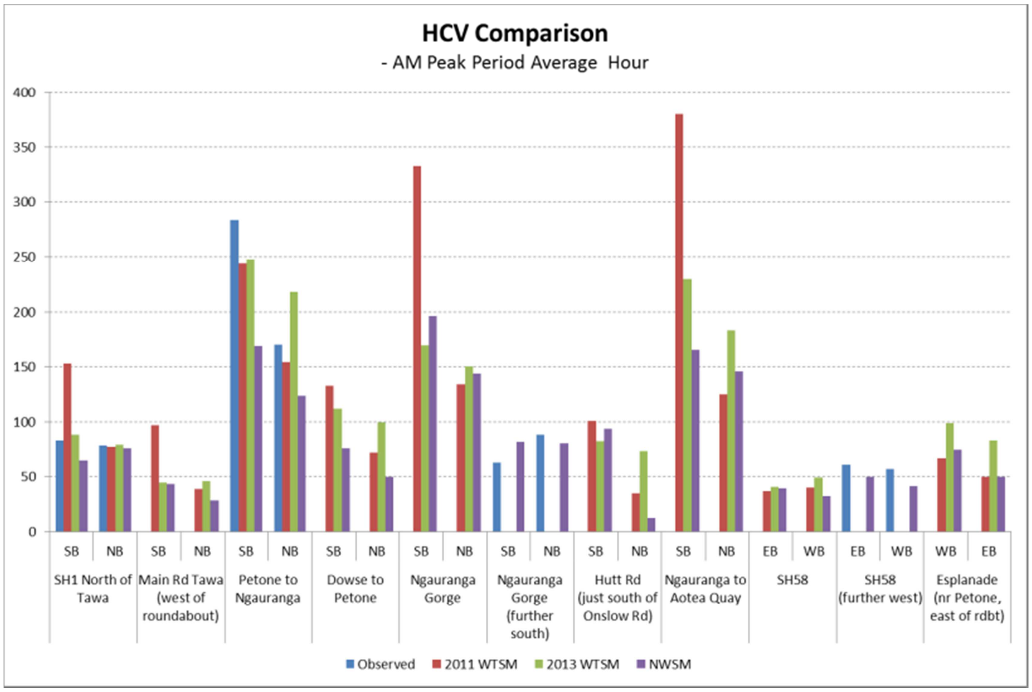


Figure 7 HCV comparison – IP

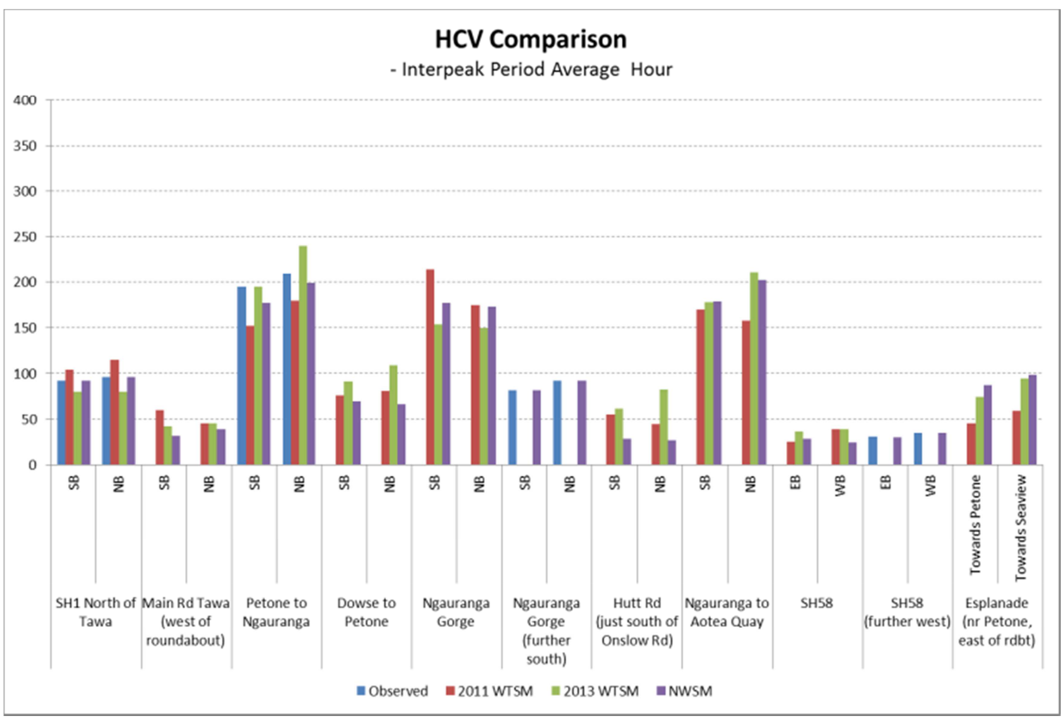
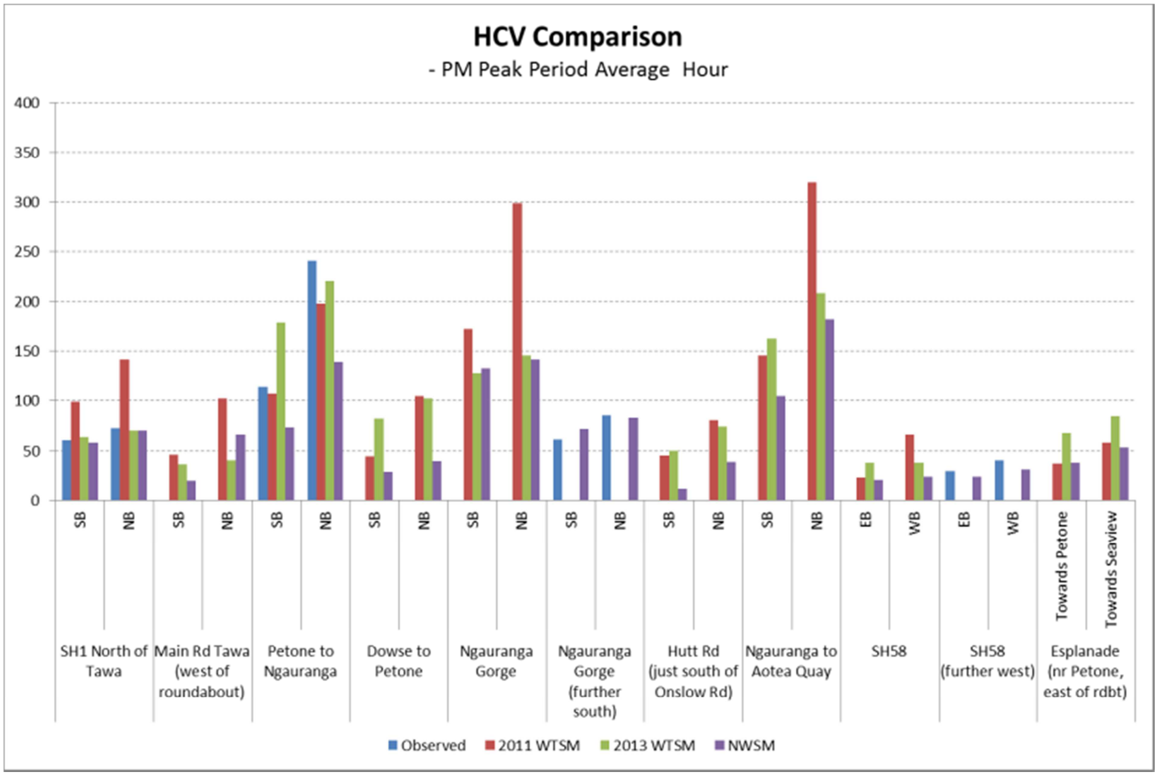


Figure 8 HCV comparison – PM



Focussing on the comparison between WTSM 2011, WTSM 2013 and NWSM 2013, the NWSM 2013 HCV volumes show a good correlation with WTSM 2013, confirming the conclusions drawn from the P2G specific analysis documented above, namely that better representation of HCV demand in WTSM 2013 (compared with WTSM 2011) is already accounted for in NWSM 2013, providing confidence that the over-estimation of HCV volumes in WTSM 2011 is not carried through to NWSM 2013 and resulting NWSM future year models.

When comparing modelled and observed HCV volumes, there is some apparent under-representation of HCV volumes in NWSM (and, to a lesser extent, WTSM) on SH2 between Ngauranga and Petone in the peak directions, which the steering group believe should be considered if NWSM is to be refined for the SAR stage of the project.

Conclusion

- over-estimation of HCV volumes in WTSM 2011 is addressed via the SATURN matrix adjustment / estimation process, resulting in HCV volumes in NWSM that correlate better with HCV volumes generated by WTSM 2013
- it is suggested that if NWSM were to be significantly updated for the P2G SAR, consideration should be given to using WTSM 2013 HCV demand as an input to any updated model

Project recommendation

- the limited observed data that is available suggests that further efforts should be made to improve the HCV validation in NWSM, particularly along SH2, and to verify the current number east-west HCV trips that are made via SH58 or SH1/Sh2 (and might re-route via P2G in the future)

9.1.3 WTSM HCV growth assumptions

HCV trips in WTSM 2011 are modelled as fixed demand – i.e. there is no redistribution of trips in response to changes in travel times from schemes such as P2G (although HCV trips can reassign between routes).

HCV growth rates are determined by a combination of employment growth in certain categories and assumed GDP growth per capita.

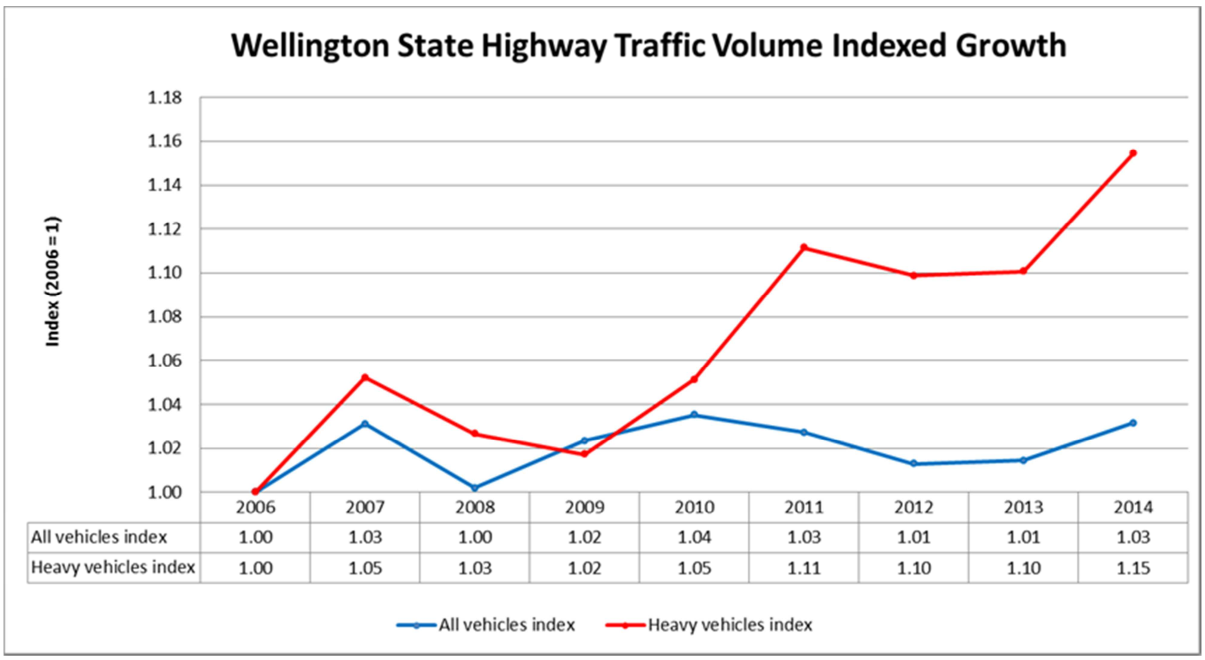
For WTSM 2011, employment was forecast to grow by 15% between 2011 and 2041, with GDP per capita forecast to grow by 1.8% per annum. The combined effect is annual growth in HCV trips of about 2.2% p.a from 2011 to 2041.

In terms of growth in region wide HCV trips this equates to:

- 26% between 2011 and 2021
- 47% between 2011 and 2031
- 67% over the entire 30 year period between 2011 and 2041

Figure 9 below shows indexed state highway VKT between 2006 and 2014, for all vehicles and HCVs.

Figure 9 Wellington state highway VKT, indexed, 2006 to 2014



	2006	2007	2008	2009	2010	2011	2012	2013	2014
All vehicles index	1.00	1.03	1.00	1.02	1.04	1.03	1.01	1.01	1.03
Heavy vehicles index	1.00	1.05	1.03	1.02	1.05	1.11	1.10	1.10	1.15

Source: https://www.nzta.govt.nz/assets/resources/state-highway-traffic-volumes/docs/SHTV-2010-2014.pdf

This shows that HCV growth has been around 15% over the 8 year period, compared with regional GDP per capita growth of around 25%[16] over the same period (regional GDP growth was 32%).

This recent relationship suggests that freight trips have grown by a rate equal to GDP growth and a multiplier of around 0.6 between 2006 and 2014. If such a trend were to continue for the next 30 years, freight trips might increase by around 50% to 55% between 2013 and 2043.

[16] Statistics NZ Regional GDP Growth

By comparison, another source of HCV growth data, the National Freight Demand study (NFDS), suggests that freight volumes (not trips, all modes combined) are forecast to increase by around 45% between 2012 and 2042.

Conclusion

- HCV growth rates are based upon regional employment and national GDP per capita growth assumptions, and reflect recent growth rates over the last 8 years (2006 to 2014)
- as with all forecasts, there is uncertainty relating to the input assumptions and the degree to which historic relationships / trends will be maintained into the future

Project recommendations

- given conflicting information regarding HCV assumptions that leads to uncertainty, analysis should be undertaken to better understand the sensitivity off the P2G project to different HCV growth assumptions
- best practice suggests that any sensitivity tests should be undertaken around a central forecast of 50% to 55% HCV growth between 2013 and 2043, slightly lower than the currently assumed 67% growth in WTSM between 2013 and 2043
- consideration should be given to modelling the impact of additional HCV trips being generated as a result of land use change associated with P2G, and the impact that this might have on levels of service
- traffic investigations should be combined with safety related investigations to develop and document the justification for HCV crawler lanes on P2G and the design of the Petone and Tawa interchanges

Wider recommendations

- for future projects where freight is an important component, it is suggested that HCV growth assumptions should be understood at an early stage during the project, with appropriate sensitivity tests developed if required

9.2 Interchanges

This section provides a brief summary of the modelling and development work that has been undertaken to date on the Tawa and Petone interchanges, together with recommendations for future work.

9.2.1 Tawa interchange

A micro-simulation model using S-Paramics was created for the proposed Tawa interchange in 2014, using cordoned flows from NWSM.

This initial model (Stage 1) was used to undertake high level investigations associated with the MCA assessment, but was subsequently updated to account for key generators within the area – Countdown and Takapu Road stations – and to account for traffic surveys undertaken around the interchange on March 31st 2015.

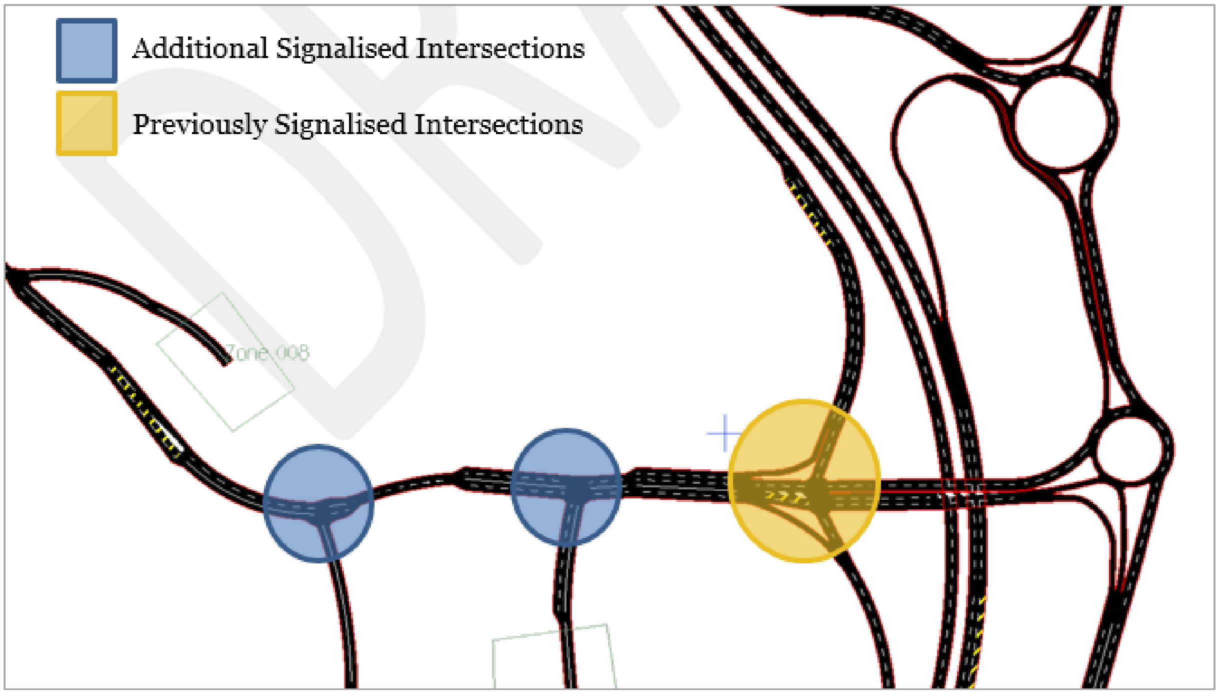
The revised model (Stage 2) was completed, with the following initial conclusions drawn from Stage 2 model runs which will feed into work during the next phase of the project:

- the current recommended interchange layout (the basis for MCA assessment) was no longer able to efficiently accommodate the level of predicted traffic

- the current recommended interchange layout (the basis for MCA assessment) requires improvements to both the Countdown roundabout and the Main Road / Willowbank Road intersections

- reducing the number of access points to / from Takapu Station from two to one (off Main Road) improves network performance within the area

Figure 10 Tawa Interchange (revised stage 2 model design)



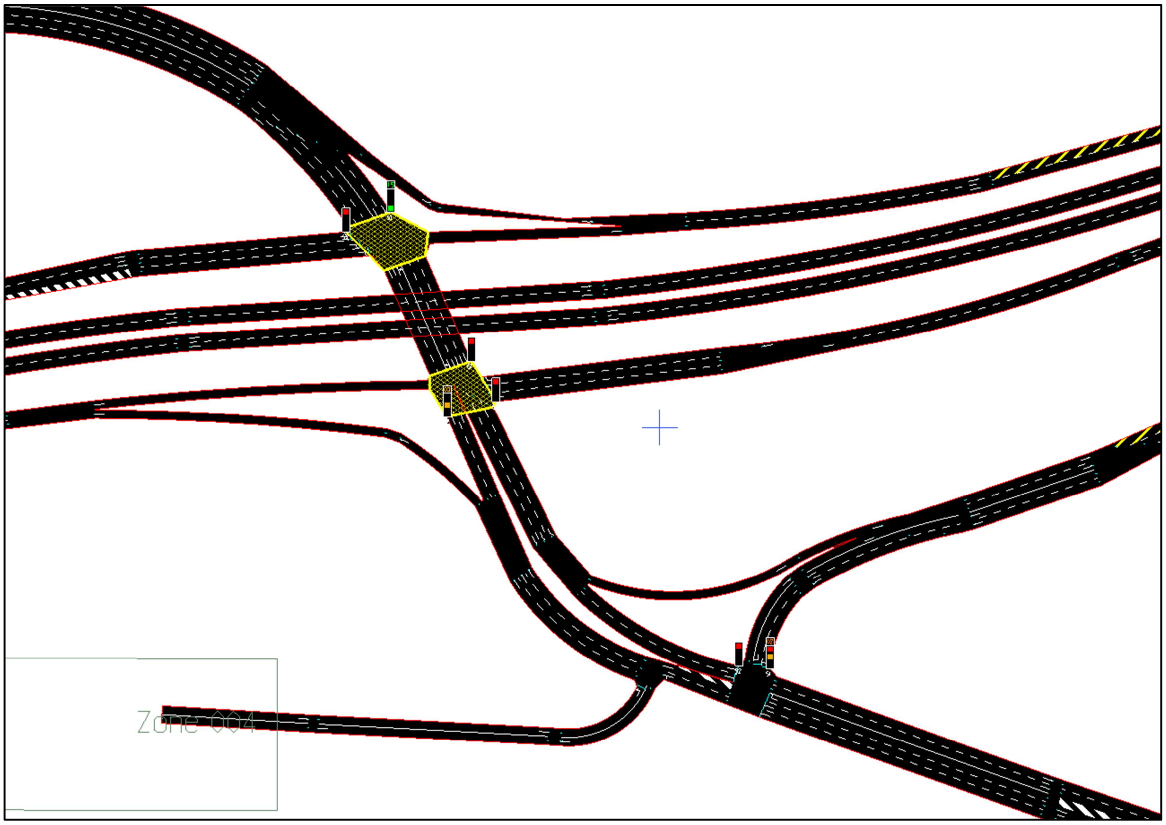
Whilst the initial conclusions from the Stage 2 model do not affect the validity of the MCA conclusions, given that a common interchange design was assumed for all options, they do provide important guidance for the next stage of the project.

9.2.2 Petone interchange

An initial (Stage 1) version of the Petone Interchange S-Paramics model was developed prior to the multi-criteria assessment, from which an initial preferred layout interchange was identified, as shown in **Figure 11.**

The layout consists of signalised on / off ramps that are designed to run on a short cycle time to minimise delays and maximise vehicle throughput.

Figure 11 Petone Preferred Interchange Layout



This model will be updated for the next SAR phase of the project to optimise the interchange design and better understand the operation of P2G, SH1 and Petone Esplanade in the future.

Project recommendations

- based upon information detailed elsewhere in this report, the Tawa and Petone interchange S-Paramics models should be updated and extended
- the practitioner should take into account the respective strengthens and weaknesses of NWSM and WTSM, as highlighted in this report, when updating the models
- a comparison between S-Paramics and NWSM should be undertaken, focusing on key areas of the network and key attributes, to ensure consistency between models and in order that any differences between models can be understood
- the refined S-Paramics models will be used to better understand some of the detail operational issues on the network (i.e. traffic volumes during the peak of the peak, operation of crawler lanes, weaving and merging on SH1) and to optimise intersection design
- the investigations should account for forecasting uncertainty by modelling a range of scenarios
- the modelling work should be peer reviewed

9.3 SH1 North of Tawa

9.3.1 Introduction

The stretch of SH1 between Tawa Interchange and Linden, the location of the proposed interchange between SH1 and Transmission Gully, is currently a 4-lane motorway standard road with no upgrade planned associated with the opening of Transmission Gully.

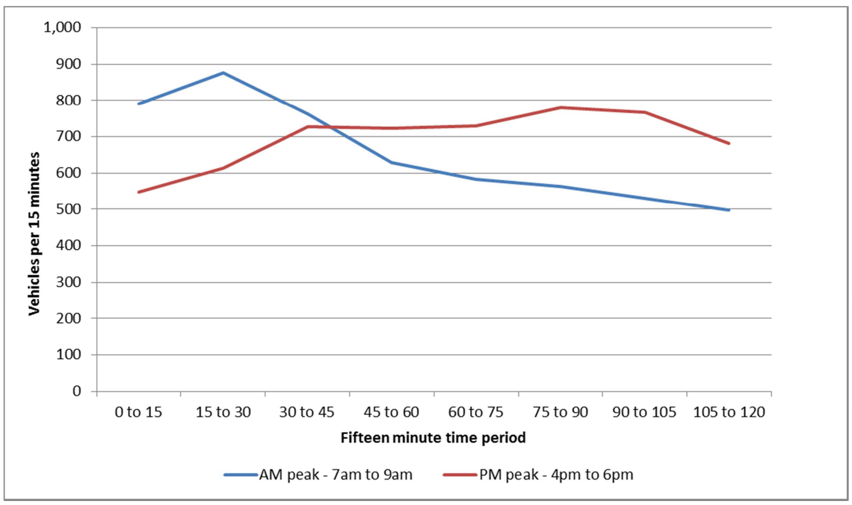
This section documents current observed traffic volumes and travel times on SH1 North of Tawa, summarises existing work undertaken looking at the need for 6 lanes north of Tawa and presents a revised assessment for the need for 6 lanes North of Tawa.

This analysis is undertaken from a traffic volume only perspective, accepting that there are wider issues surrounding the promotion of public transport and travel demand management as means of managing demand on the highway network.

9.3.2 Existing travel speed and traffic count data

Figure 12 below shows AM peak (southbound, 7am to 9am) and PM peak (northbound, 4pm to 6pm) traffic volumes by 15 minute time slice.

Figure 12 Observed Traffic volumes on SH1 North of Tawa



The data shows a pronounced 'peak' in traffic volumes in the AM peak between 7am and 7.30am, with volumes dropping by around 200 from this peak to 8am, before declining at a slower rate between 8am and 9am.

Whilst this pattern is possibly due to the timing of commuter trips to Wellington and limited peak spreading, additional work is required to confirm this view and to determine whether the peak in traffic volumes between 7am and 7.30am does result in noticeable changes in travel time and congestion.

In the PM peak, whilst there is a peak between 5.15pm and 5.45pm, possibly the result of commuters leaving Wellington at 4.30pm to 5pm passing through Tawa, the peak is less pronounced than in the AM peak.

Observed traffic volumes from a variety of locations across the region confirm that the PM peak is generally less pronounced then the AM peak, the result of people leaving work at different times and perhaps doing other activities (shopping, leisure) before leaving for home together with the lack of a school trips during the PM peak.

Whilst observed traffic volumes on SH1 north of Tawa during the AM peak and PM peak two hour periods are broadly similar, traffic volumes in the NWSM AM peak hour are lower than in the NWSM peak hour, a result of NWSM not representing the peak half hour between 7.00am and 7.30am.

Figure 13 below shows observed average travel speeds on SH1 between Porirua and Tawa (AM, 7am to 9am, SB) and Tawa and Porirua (PM, 4pm to 6pm, NB). The data was collected every March by moving car surveys, generating around 5 to 6 observations during each time period.

Figure 13 Travel speed on SH1 North of Tawa

	Average travel speed (kph)		
	2012	2013	2014
AM peak	63	84	69
PM peak	91	97	94

The travel speed data shows that, whilst there is some variability from one year to the next, AM peak southbound travel speeds are consistently slower (and more variable) than PM peak northbound travel speeds that suggest relatively free flowing conditions.

Conclusion

- there is considerable variation in traffic volumes throughout each modelled time period, suggesting that average hours (as modelled) may mask subtle variations in traffic volumes and levels of service within each time period
- travel speeds suggest that AM peak southbound levels of service are worse than PM peak northbound levels of service, as indicated by WTSM
- this is contrary to NWSM which suggests that current and future levels of service are worse in the PM peak northbound

Project recommendations

- observed data should be gathered from the existing NZTA TMS count and 'Bliptrack' Bluetooth system to verify and further understand variations and trends relating to traffic volumes and travel speeds along SH1 North of Tawa
- consideration should be given to the merits of updating the NWSM pre-peak model to better reflect the observed traffic volumes on SH1 North of Tawa in the AM peak between 7.00am and 7.30am
- the S-Paramics model of Tawa Interchange should be extended to cover SH1 North of Tawa to the Transmission Gully / SH1 interchange at Linden, providing the ability to model variations in traffic volumes throughout each time period and the impact that this might have on levels of service, together with weaving / merging
- differences between 'peak of the peak' and average peak hour / peak period traffic volumes should be better understood in the context of SH1 North of Tawa to improve our understanding of the impact that variability in traffic volumes might have on travel times and traffic congestions
- this information should be used during the SAR stage to understand levels of service on SH1 and to develop the phased managed motorway approach

Wider recommendations

- an understanding of travel times, travel time variability and flow variability across the wider network, particularly regarding the 'peak of the peak', should be developed when calibrating / validating models and using models for specific projects
- this data should be used to refine models, assist with the design of intersections / interchanges and develop economic analysis associated with the project

9.3.3 Existing analysis

Previous analysis, reported in the 'NZTA Options North of Tawa" report focussed on the following options:

- **Option 1 -** Wait and see – essentially do nothing and see whether congestion on SH1 North of Tawa in the years after the opening of P2G is severe enough to warrant attention
- **Option 2 -** Widen from 4 to 6 lanes North of Tawa
- **Option 3 -** Build an alternative link road route through the Takapu Valley, taking some traffic off SH1 and removing the need to widen

As part of these investigations, different conclusions were drawn from the 2031 analysis of both WTSM and NWSM, due to differences in the forecasts produced by both models and differing interpretations of forecast levels of service and associated requirements for additional capacity.

Whilst WTSM suggested that forecast traffic volumes could be accommodated by the existing 4 lane solution, NWSM suggested that there would be a need to widen in the future.

Subsequent analysis was undertaken to understand why different conclusions could be drawn from the two models. This analysis, documented in detail in **Appendix A10**, concluded that the differences were able to be explained with reference to the following, some of which have already been discussed earlier in the report:

- model coding and assumptions, including incorrect capacities that are currently assumed in the two models
- different time periods, with NWSM not capturing peak demand in the AM peak (SB) and WTSM not capturing peak demand in the PM peak (northbound)
- differences in traffic volumes driven by weaknesses in the validation of WTSM, in an area directly relevant to the P2G link road, particularly in the PM peak
- not capturing variability during peak periods i.e. an average 1hr or 2hr period can be misleading

9.3.4 Traffic volumes North of Tawa

Table 16 below shows peak period NWSM traffic volumes[17] on SH1 north of Tawa under a range of scenarios, together with volume / capacity ratios, assuming a capacity of 1,950 pcus per hour per lane.

The % value in brackets in the first column denotes the percentage of total traffic redistribution that has been assumed for each scenario.

[17] It should be noted that the traffic volumes upon which the V/C ratios and levels of service are based are average hourly volumes during the peak periods and a medium growth scenario.

Table 16 Traffic volumes, VC ratios and LoS on SH1 North of Tawa

Year	Direction	Traffic volumes			V/C ratio and LoS	
		Car	HCV	Total	V/C	LoS
2011	AM (SB)	2,240	70	2,310	61%	C
	PM (NB)	3,070	70	3,140	82%	D
2021 (0%) - 4 lane	AM (SB)	2,510	120	2,630	70%	D
	PM (NB)	3,410	120	3,530	94%	E
2021 (0%) - 6 lane	AM (SB)	2,510	120	2,630	47%	C
	PM (NB)	3,410	120	3,530	62%	C
2031 (50%) - 4 lane	AM (SB)	2,770	160	2,930	79%	D
	PM (NB)	3,590	150	3,750	100%	F
2031 (50%) - 6 lane	AM (SB)	2,790	160	2,950	53%	C
	PM (NB)	3,670	160	3,830	68%	D
2041 (100%) - 4 lane	AM (SB)	2,900	200	3,100	84%	D
	PM (NB)	3,650	190	3,840	103%	F
2041 (100%) - 6 lane	AM (SB)	2,930	200	3,130	57%	C
	PM (NB)	3,780	200	3,980	71%	D

The analysis shows the following:

- AM peak hour traffic volumes are forecast to be consistently 25% lower than PM peak traffic volumes
- in 2011, the AM peak V/C ratio is 61% (C) whilst the PM peak V/C ratio is 82% (D)
- in 2031, the V/C ratios and levels of service suggest that a 4 lane solution would see traffic experiencing 'moderate' delays' in the AM peak southbound (LoS D) but severe delays in the PM peak northbound, with a 100% V/C ratio equivalent to LoS F
- under a 6 lane solution, even the 2041 scenario suggests that the AM peak would still operate at LoS C (stable operating conditions) whilst the PM peak is on the margin of LoS C and D (moderate delays)

It is likely that during the 'peak of the peak', traffic volumes could be between 5% and 10% greater than the quoted average figures. Whilst uncertain, this would probably result in worse levels of service and higher V/C ratios than those quoted above (for a short length of time) and resulting congestion that might take a significant length of time to dissipate.

Conclusions

- traffic volumes suggests that if a 6 lane solution were not provided North of Tawa, there is a risk that in 2031 the traffic volumes might result in significant congestion during the AM peak and PM peak time periods
- such congestion could affect travel times and travel time variability for vehicles travelling between Wellington (on SH1), Lower Hutt (via P2G), Porirua and Kapiti / the north (via TG)
- with traffic volumes in the 'peak of the peak' up to 10% greater than the average hourly traffic volumes, 'significant' or even 'moderate' delays over an average hour could results in continuing delays during the peak of the peak and consequent residual queues remaining for some of the remainder of the peak hours

- a 6-lane solution would still deliver largely stable operating conditions in 2041, even when accounting for increased traffic volumes during the peak of the peak

Project recommendations

- better understand observed traffic volumes, capacities and travel times / travel time variability along SH1 North of Tawa, particularly focussing on the peak of the peak
- extending the S-Paramics model based on new observed information and revised capacities to model the impact of traffic volumes during the 'peak of the peak' and to understand the impact that weaving and merging between Tawa interchange and Linden (TG) interchange might have upon levels of service
- undertake an assessment of when / if 6 lanes North of Tawa may be required, based upon a range of future scenarios and including incremental BCR analysis

9.4 Petone area

This section contains analysis of forecast traffic volumes on SH2 and Petone Esplanade under the core medium distribution scenario, including P2G, as outlined in **Section 8.9**.

9.4.1 SH2 Ngauranga to Petone

Table 17 below shows peak period traffic volumes and V/C ratios on SH2 south of Petone (assumed capacity of 1,900 pcus per hour per lane as calculated from HCM)

Table 17 Traffic volumes, VC ratios and LoS on SH2 South of Petone

Year	Direction	Traffic volumes			V/C ratio and LoS	
		Car	HCV	Total	V/C	LoS
2011	AM peak (SB)	3,570	170	3,770	103%	F
	PM peak (NB)	3,620	150	3,780	103%	F
2021 (0% redistribution)	AM peak (SB)	3,160	230	3,410	95%	E
	PM peak (NB)	3,500	200	3,720	103%	F
2031 (50% redistribution)	AM peak (SB)	3,260	280	3,550	100%	F
	PM peak (NB)	3,500	220	3,740	104%	F
2041 (100% redistribution)	AM peak (SB)	3,280	310	3,600	102%	F
	PM peak (NB)	3,460	240	3,720	104%	F

The analysis shows that V/C ratios are over 100% in 2011 and remain at similar levels in all future scenarios, showing that SH2 between Ngauranga and Petone will remain operating at capacity with LoS E or F.

9.4.2 Dowse to Petone

Table 18 below shows peak period traffic volumes and V/C ratios on SH2 between Dowse and Petone (assumed capacity of 1,900 pcus per hour per lane).

Table 18 Traffic volumes, VC ratios and LoS on SH2 Dowse to Petone

Year	Direction	Traffic volumes			V/C ratio and LoS	
		Car	HCV	Total	V/C	LoS
2011	AM peak (SB)	2,570	80	2,650	72%	D
	PM peak (NB)	2,810	40	2,850	76%	D
2021 (0%)	AM peak (SB)	2,710	140	2,850	79%	D
	PM peak (NB)	3,220	90	3,320	90%	E
2031 (50%)	AM peak (SB)	2,820	180	3,000	84%	D
	PM peak (NB)	3,350	110	3,470	94%	E

2041 (100%)	AM peak (SB)	3,040	210	3,260	91%	E
	PM peak (NB)	3,390	130	3,520	96%	E

The analysis shows the following:

- in 2011, the AM peak V/C ratio is 72% (LoS C) and the PM peak V/C ratio is 76% (LoS D)
- through time, the traffic volumes and V/C ratios increase, with 'moderate to significant' delays forecast in 2031 (LoS D/E) and 'significant delays' forecast on 2041 (LoS E/F)

9.4.3 Petone Esplanade

Table 19 below shows peak period traffic volumes and V/C ratios on Petone Esplanade (assumed capacity of 1,200 pcus per hour per lane). Note that these scenarios do not include the Cross Valley Link (CVL).

Table 19 Traffic volumes, VC ratios and LoS on The Esplanade

Year	Direction	Traffic volumes			V/C ratio and LoS	
		Car	HCV	Total	V/C	LoS
2011	AM peak (WB)	620	70	700	59%	C
	PM peak (EB)	700	60	760	63%	C
2021 (0%)	AM peak (WB)	640	80	730	62%	C
	PM peak (EB)	880	80	960	80%	D
2031 (50%)	AM peak (WB)	700	80	780	67%	D
	PM peak (EB)	930	80	1,010	85%	D
2041 (100%)	AM peak (WB)	690	90	780	67%	D
	PM peak (EB)	1,140	90	1,230	102%	F

The analysis shows the following:

- currently (2011) Petone Esplanade operates at LoS C
- through time, traffic volumes are forecast to increase, with levels of service decreasing to LoS D in 2031 and LoS F in the 2041 PM peak (EB)

9.4.4 Cross Valley Link

Whilst all the recent P2G modelling work undertaken has assumed that the Cross Valley Link (CVL) would not be in place, the effect of the CVL option has been subject to some preliminary testing using the 2013 NWSM.

Preliminary modelling of these options undertaken for the 2015 CVL PFR were, based on P2G Option C and assumed a level of de-powering on the Esplanade.

Figure 14 below shows the Cross Valley link options as modelled for the 2015 PFR.

Figure 14 Cross Valley Link Options modelled for 2015 PFR

Initial results suggest that for the options that assume an entirely new link road following the alignment of the current railway line – SV2, SV3 and SV8 - traffic volumes would decrease slightly on Petone Esplanade, increase slightly on SH2 between Petone and Dowse and also increase on connecting roads between CVL and Seaview, with corresponding changes in levels of service.

It is recommended, however, that further analysis be undertaken during the SAR stage to understand the combined impact that P2G, CVL and Esplanade de-powering associated with these options (traffic calming, speed restriction of 30 km/hr, new intersection layouts) might have upon the highway network and levels of service.

Conclusions

- levels of service on SH2 between Petone and Ngauranga are forecast to remain largely unchanged at LoS F during peak periods, regardless of the modelled year, growth assumptions or whether P2G is built or not
- based on current assumptions, the existing road layout and capacity between Petone and Dowse would start to result in 'significant delays' from 2031 onwards, with the likelihood that CVL would lead to additional delays

Project recommendations

- better understand the impact that traffic flow variability and flow breakdown associated with the 'peak of the peak' might have upon travel times and speeds in the vicinity of Petone Interchange
- better understand travel time and traffic volume validation on Petone Esplanade

- give consideration to adding a 'pre pre peak' to NWSM to capture the 'peak of the peak' (in terms of demand) at Petone Interchange and the impact that this might have upon capacities and traffic volumes throughout the remainder of the AM peak period
- ensure that the analysis of benefits on this section of SH2 includes the procedures in A3.18 and A3.19 of the EEM
- better understand how the CVL options might affect travel times and levels of service on SH2, at Petone Interchange and along the Esplanade, as part of the SH2 PBC
- update the Petone Interchange S-Paramics, potentially extending its geographic extent to cover SH2 between Ngauranga and Petone, SH2 between Dowse and Petone and parts of the Petone Esplanade, to undertake the analysis specified above as part of the next phase of the P2G project and as part of the SH2 PBC

9.5 Emissions

In its decision on the Transmission Gully project, the Board of Inquiry did not take account of the effects of the project upon greenhouse gas emissions on the basis that these (a) are not a relevant consideration under the RMA because they are subject to control by other mechanisms and (b) the net effect is likely to be positive anyway.

Notwithstanding this, the Transport Agency has requested that the P2G modelling work should provide some indication of likely impacts of the project upon pollutant levels.

At this stage of the P2G assessment, the only analytical tool available to the project team to assess emissions associated with P2G is the SATURN model.

This models emissions in a very simplistic manner, with them being a function of speed, distance and assumptions regarding the future fleet split (diesel / petrol) and likely future improvements in vehicle efficiency and does not account for gradients and acceleration / deceleration.

Therefore should a more detailed assessment of the emissions impact of P2G be required, a more appropriate specialist tool such as NZTA's Vehicle Emission Prediction Model (VEPM) is recommended.

In a qualitative sense, P2G is likely to affect emissions as follows:

- the link road itself will provide a shorter and faster journey for trips re-assigning from SH58 and SH1/2, resulting in a reduction in emissions
- whilst P2G is hilly, SH58 and SH1/2 are themselves hilly routes, so re-assignment to P2G is unlikely to result in any significant change in emissions per kilometre travelled
- the redistribution of trips and resulting increase in VKT (average trip length will increase for the redistributed trips) will result in an increase in emissions, although the overall increase would be small as redistributed trips comprise a very small percentage of total trips within the region
- de-congestion on SH1 and SH2 associated with P2G will improve average travel speeds and should reduce stop-start delays and associated acceleration / deceleration phases, resulting in a reduction in emissions

Conclusions

- the current tools are not adequate for providing a full, quantitative assessment of impact of P2G in terms of vehicle emissions

- qualitative analysis suggests that the P2G link road has the potential to reduce emissions on key parts of the network due to improved / shorter travel times and de-congestion of existing stretches of SH1 and SH2

Project recommendation

- should a quantitative assessment of the impact of P2G in terms of vehicle emissions be required, it is recommended that VEPM (or similar) be used

10 Sensitivity testing

Sensitivity testing is undertaken to address the inevitable uncertainty in modelling relating to input assumptions and forecasts that are produced.

The principle behind sensitivity testing is to look at a range of alternative scenarios around a central case scenario, to determine the extent to which project outcomes and conclusions might change if future scenarios are different to the central case.

10.1 WTSM and WPTM - public transport and tolling sensitivity tests

Two sensitivity tests were run in WTSM and WPTM to assess the impact that the following might have upon forecast traffic volumes:

- additional public transport measures
- additional public transport measures + tolling of P2G

The tests were run in WTSM and WPTM in 2031 for the AM peak[18].

The purpose of the additional PT test was to determine the extent to which potential rail improvements might increase PT demand and also affect highway demand on P2G and SH1.

Whilst not currently part of any formal upgrade programme, the improvements listed below that are part of the additional PT test have been discussed with the GWRC rail operations team and are part of longer-term aspirational network improvements:

- an approximate 25% increase in Park & Ride capacity across the network
- enhanced service frequencies across the whole network, with 12 minute peak time frequencies on the Kapiti line
- 5% faster travel times across the whole network
- new station at Glenside (servicing Churton Park area and North Wellington suburbs).

The purpose of the tolling test was to determine the level of toll ($1.10 following initial tests) that would be required to reduce demand on P2G by a target of 30%[19], and the impact that this might have upon the state highway / local road network and the public transport system.

Table 20 and **Table 21** below summarises the highway and PT results from these series of tests.

Table 20 Summary of WTSM 2031 sensitivity tests - highway

Year	Time period	Option		Option + APT		Option + APT + Toll	
		Volume	V/C	Volume	V/C	Volume	V/C
SH1 N of Tawa	AM (SB)	3,130	55%	3,060	54%	2,900	51%

18 WPTM does not model the PM peak

19 A toll diversion target specified by NZTA

P2G	AM (EB)	2,150	65%	2,160	65%	1,430	43%
SH2 Petone to Ngauranga	AM (SB)	3,700	100%	3,660	99%	3,680	100%
SH2 Dowse to Petone	AM (SB)	3,370	91%	3,340	91%	3,100	84%

Table 21 Summary of WPTM 2031 sensitivity tests – rail patronage, AM peak only

Year	Time period	Change in PT patronage	
		Option to Option + APT	Option + APT to + APT + Toll
Kapiti Line @ Takapu Road	AM (IB)	+250	+30
Kapiti Line @ Glenside	AM (IB)	+600	+60
Johnsonville Lines @ Crofton Downs	AM (IB)	-50	-0
Hutt Line @ Petone	AM (IB)	+200	-5
Bus on Ngauranga Gorge (JVL / Newlands to Wellington)	AM (IB)	-90	-30

Comparing the option and option + additional PT, the additional PT measures on their own result in:

- an extra 250 passengers using the train from stations north of (and including) Takapu Road, the result of frequency and travel time improvements
- approximately 350 people using the new Glenside station, a mix of modal shift from car to PT, re-assignment from existing Johnsonville line rail services and re-assignment from competing bus services between Churton Park and Wellington CBD
- an additional 200 passengers on the Hutt Valley line, due to frequency and travel time improvements
- a small decrease in traffic volumes and small associated improvements in V/C ratios north of Tawa, as the increase in rail trips from north of Tawa (around 250 passengers) equates to only a small reduction in the number of vehicle trips
- little modal shift from car to PT and no corresponding significant decrease in traffic volumes or changes to V/C ratios on SH2 between Ngauranga and Petone

Comparing the option + additional PT and option + additional PT + tolling scenarios, the analysis shows that the tolling of P2G results in the following:

- the desired 30% reduction in traffic volumes on P2G link road of ~750 vehicles (AM peak, EB) and ~550 vehicles (PM peak, WB), mostly the result reassignment back to SH1/SH2 rather than modal shift from car to PT
- a reduction in traffic volumes on SH1 North of Tawa of between 150 and 200 vehicles per hour in both the AM and PM peak

- an increase in the number of vehicles travelling in the counter-peak direction on SH2 of 350 vehicles (AM peak, NB) and 200 vehicles (PM peak, SB), the result of North Wellington / Tawa to Lower Hutt trips in the AM peak (and vice-versa in the PM peak) reassigning back to SH2/SH1 from P2G
- whilst tolling does not significantly change inbound traffic volumes on SH2 between Ngauranga and Petone, with SH2 operating at capacity under the option, option + PT and option + PT + tolling scenarios, it is likely to affect the actual demand that wants to use SH2 between Ngauranga and Petone, with this extra demand being held (queued) elsewhere on the network due to capacity constraints between Ngauranga and Petone
- results in minimal modal shift from car to PT on the Kapiti line.

Conclusions

The additional PT measures, which are mostly targeted at the Wellington journey to work market segment, result in:

- a small increase in rail patronage on the Hutt Valley line and an increase in Kapiti line rail boardings north of Takapu Road
- modal shift back from bus to rail and a shift from the Johnsonville line to Kapiti line services, primarily the result of opening Glenside Station
- small reductions in traffic volumes resulting from modal shift from car to PT
- no significant change in highway levels of service at key locations
- demonstrates that P2G traffic volumes and levels of service are not sensitive to additional PT measures

The tolling sensitivity test results show:

- negligible modal shift from car to PT
- limited re-assignment back from P2G to SH1 / SH2 in the peak P2G direction of travel (AM – eastbound, PM – westbound) which corresponds to the counter-peak direction of travel on SH2
- no significant change in highway levels of service
- increased demand along SH2 at peak times, with some of this extra demand likely to be held (queued) upstream due to capacity constraints on SH2 between Ngauranga and Petone

Project recommendations

- enhancements to the PT network could be advanced as soon as practically possible, there are not linked to the completion of the P2G project
- current multi-modal issues and constraints along the SH2 corridor should be investigated in more detail as part of the SH2 PBC, with PT transport measures such as those outlined above being actively considered as part of any multi-modal solution along the SH2 corridor

Wider recommendations

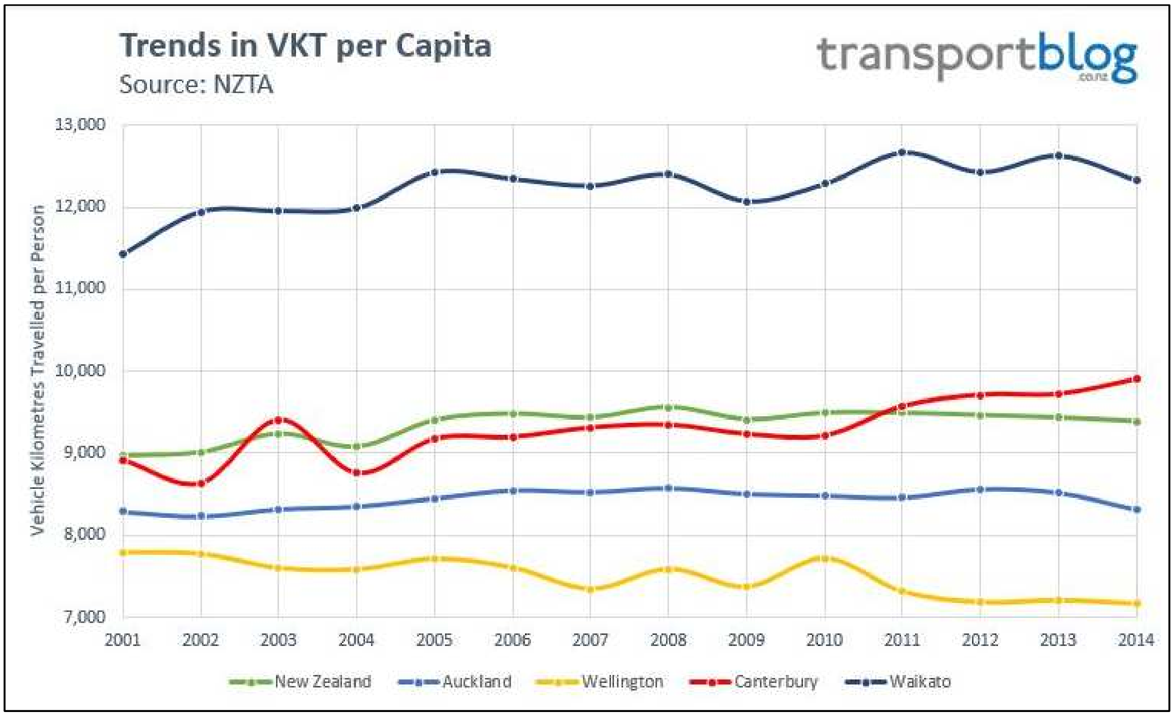
- discussions regarding the extent to which an integrated, multi-modal solution could meet project objectives should occur at the outset of any future significant projects and should be consistent with the NZTA PBC approach

10.2 WTSM – VKT per capita

Whilst not strictly a sensitivity test, analysis was undertaken to understand changes in vehicle kilometres through time, expressed in per capita terms, between the WTSM 2011 and future year (2021, 2031 and 2041) modelled years.

The issue of VKT per capita is very topical and relevant at present. Whilst historically (prior to 2000), VKT per capita increased at a relatively steady rate, as **Figure 15** below shows, since 2000 VKT per capita has remained relatively flat across New Zealand as a whole and has actually declined in the Wellington region.

Figure 15 Trends in VKT per capita



Whilst there is considerable uncertainty relating to what VKT per capita is likely to do in the future – decline, stabilise or grow – a general consensus is that any increase in VKT per capita is likely to be small, with a possibility that increased urbanisation and city living may contribute to a decrease in VKT per capita in urban areas such as Wellington City.

Figure 16 below shows forecast changes in matrix based VKT per capita (i.e. based upon persons who reside within the TA area) for the various TAs within the Wellington region, derived from the WTSM models that are used to assess the P2G scheme.

The underlying relationships that drive these patterns are based upon the original 2001 WTSM equations together with updated 2013 car ownership data to account for the fact that car ownership rates did not grow as significantly between 2006 and 2011 as they did in previous inter-censual periods.

Figure 16 VKT per capita

Annual VKT per capita (x1000)							
	2011	2021	2031	2041	2011 - 21	2011 - 31	2011 - 41
WCC	4.79	4.63	4.72	4.59	-3.3%	-1.5%	-4.2%
PCC	5.41	5.29	5.54	5.46	-2.4%	2.4%	0.8%
KCDC	4.74	4.76	4.95	5.06	0.4%	4.5%	6.7%
HCC	5.43	5.66	6.11	6.15	4.3%	12.7%	13.3%
UHCC	6.69	7.15	8.00	8.07	7.0%	19.6%	20.7%
Wairarapa	7.81	8.66	10.38	10.51	10.8%	32.9%	34.5%
Region	**5.40**	**5.45**	**5.79**	**5.69**	**1.0%**	**7.2%**	**5.4%**

At a regional level, VKT per capita is forecast to increase by only 5% between 2011 and 2041.

Looking at the individual TAs, VKT per capita is forecast to decrease by 4% in Wellington City between 2011 and 2041, the result of population growth being concentrated in areas such as Wellington CBD where public transport infrastructure is strong.

Whilst there appear to be large increases in VKT for Upper Hutt and the Wairarapa, these are based on relatively low population totals and reflect modelled changes in trip patterns and distribution within these TAs that may not be fully realised.

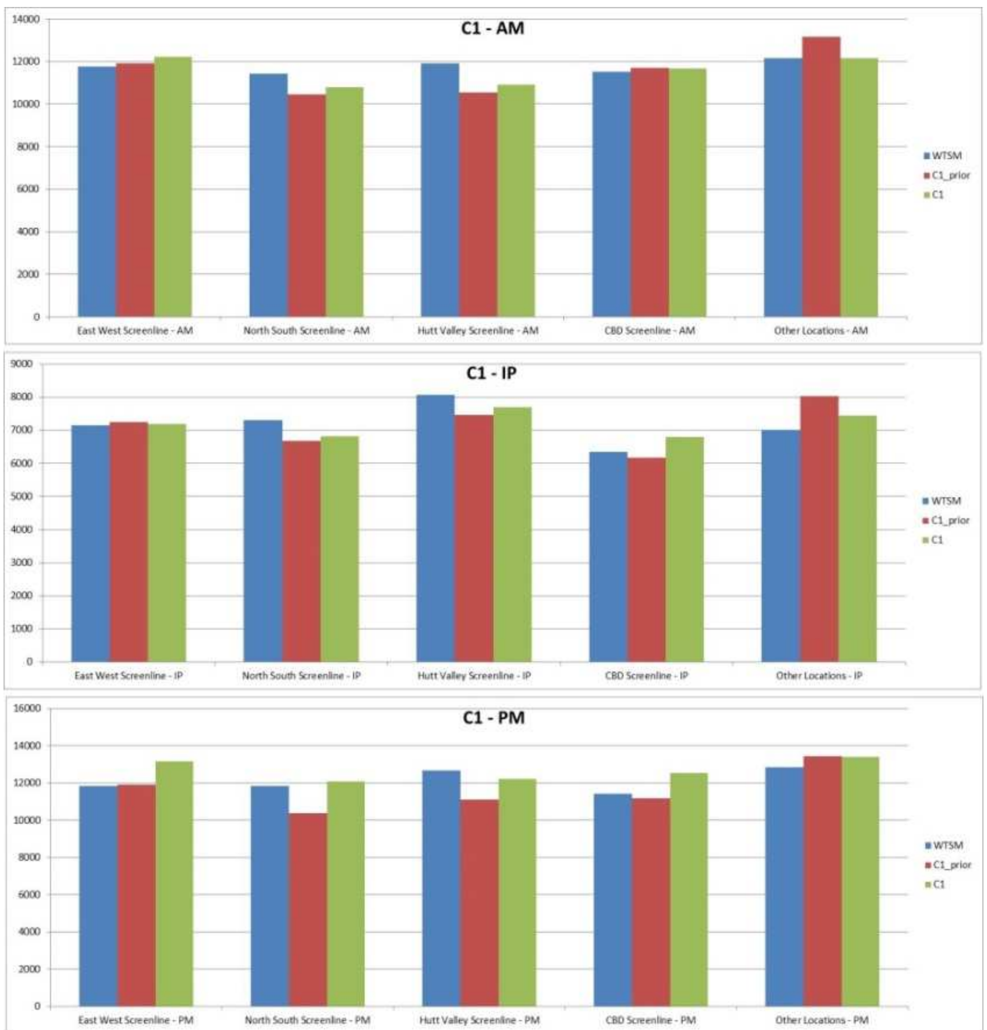
10.3 NWSM - impact of matrix estimation

As mentioned previously in this report, some of the differences in traffic volumes and travel times between WTSM and NWSM are driven by different capacity assumptions on key parts of the network together with matrix adjustment and matrix estimation procedures implemented in NWSM to improve the level of validation.

Questions were raised in the modelling workshop in June 2015 regarding the extent to which the matrix adjustment and matrix estimation changes affect demand and resultant travel times in NWSM

A sensitivity test was undertaken in NWSM by assigning the NWSM 'prior'[20] and NWSM 'post[21]' to the networks to compare the differences in high level screenline crossing volumes between the NWSM prior, NWSM post and WTSM assignments, as shown in **Table 22**

Table 22 Screenline flow comparison – C1



[20] Matrices taken directly from WTSM and factored to NWSM time period – no further adjustments nor matrix estimation

[21] Matrices taken directly from WTSM and factored to NWSM time period, adjusted at sector level to better match counts and run through matrix estimation to improve the validation

The analysis shows the following:

- at a high level, screenline crossing volumes are generally between 10% of each other for all time periods / screenline
- differences between the WTSM and the NWSM prior matrix are small and related to differences in the time period definitions, combined with the fact that the NWSM time period scaling process uses different factors depending on the sector to sector movements in question, rather than one global factor for the matrix as a whole to translate from the WTSM peak period to NWSM peak hour
- the changes in screenline crossing volumes between the AM peak and Inter-peak prior / post ME assignments are relatively small, suggesting that the input prior matrices are relatively accurate robust in their own right
- the differences between the NWSM prior and post ME matrices are more significant in the PM peak, the result of NWSM having to estimate / scale up trips to account for the under-representation of traffic volumes in WTSM that was highlighted earlier in the comparison between WTSM and NWSM presented in Chapter 6

Table 23, Table 24 and **Table 25** below show the absolute and percentage difference in sector to sector demand between the prior and post ME matrices, providing another measure to assess the extent to which matrix adjustments / estimation changes the input demand.

Table 23 AM ME effect – Option C1

			KCDC	PCC	WCC	Petone	HCC	UHCC	
ME effect	KCDC	1	- 23	157	- 208	- 24	135	- 26	
	PCC	2	- 69	561	874	- 36	129	- 44	
	WCC	3	- 25	269	19	159	216	- 36	
	Petone	4	19	86	223	437	42	139	
	HCC	5	32	- 52	- 433	29	147	70	
	UHCC	6	- 57	79	- 35	- 26	576	- 898	
									2,405
ME effect	KCDC	1	0%	16%	-25%	-12%	40%	-11%	
	PCC	2	-8%	5%	20%	-4%	10%	-9%	
	WCC	3	-9%	16%	0%	20%	17%	-9%	
	Petone	4	19%	16%	20%	21%	2%	55%	
	HCC	5	17%	-7%	-20%	1%	2%	8%	
	UHCC	6	-31%	24%	-5%	-9%	74%	-6%	
									2.3%

Table 24 IP ME effect – Option C1

			KCDC	PCC	WCC	Petone	HCC	UHCC	
ME effect	KCDC	1	- 26	207	- 17	0	14	- 28	
	PCC	2	5	451	97	1	- 96	- 71	
	WCC	3	1	178	231	262	- 35	- 59	
	Petone	4	- 4	- 5	130	97	327	- 1	
	HCC	5	- 3	- 51	- 71	214	- 1	84	
	UHCC	6	- 51	- 96	- 56	- 60	47	- 1,059	
									557
ME effect	KCDC	1	0%	30%	-6%	0%	10%	-24%	
	PCC	2	1%	4%	5%	0%	-14%	-23%	
	WCC	3	0%	11%	1%	43%	-4%	-19%	
	Petone	4	-4%	-1%	24%	4%	18%	0%	
	HCC	5	-2%	-8%	-7%	12%	0%	13%	
	UHCC	6	-36%	-31%	-16%	-28%	7%	-7%	
									0.6%

Table 25 PM ME effect – Option C1

			KCDC	PCC	WCC	Petone	HCC	UHCC	
ME effect	KCDC	1	-9	105	-4	6	18	2	
	PCC	2	403	958	491	2	-16	129	
	WCC	3	161	517	125	-22	-67	396	
	Petone	4	-26	74	152	545	213	299	
	HCC	5	55	98	80	578	797	322	
	UHCC	6	-31	-60	-81	12	192	-1,132	
									5,281
ME effect	KCDC	1	0%	12%	-1%	6%	10%	1%	
	PCC	2	38%	7%	22%	0%	-2%	32%	
	WCC	3	23%	13%	0%	-2%	-3%	56%	
	Petone	4	-13%	8%	19%	22%	10%	100%	
	HCC	5	16%	8%	6%	27%	7%	37%	
	UHCC	6	-12%	-11%	-18%	4%	20%	-7%	
									4.4%

The analysis shows the following:

- whilst there are some significant absolute increases in short-distance intra-TA (i.e. within Porirua, within Hutt City) trips, in percentage terms these changes are relatively small
- there are some larger percentage changes in trips between areas of interest to P2G, for example Petone to Porirua and Petone to Hutt City, although in absolute terms the numbers are relatively low
- most significant changes in trips at a sector to sector level are within the range +/- 10% to 20%

The purpose of the matrix adjustment and estimation process is to improve the validation of the project model (NWSM), particularly at a turning level in order that intersection capacity and delays can be more accurately modelled, whilst also preserving the trip distribution patterns determined by WTSM.

Changes between the NWSM prior and post ME matrices can be explained in terms of the following:

- WTSM demand is generated from demographic data and household survey observations that date from 2001
- some movements – such as those to / from Wellington CBD – will have a good sample rate, whilst other movements – such as those between smaller TAs and east-west movements between Porirua and Petone – will be based on a much smaller sample
- this results in a lower level confidence being placed in the movements that have a relatively small sample, providing more scope for this movements to be adjusted / estimated to better represent traffic counts
- as the household survey data relates to 2001, it is possible that travel patterns and trends have changed slightly between 2001 and 2011 (validated model years), meaning that the matrices need to be adjusted to better reflect current travel patterns (in NWSM 2013)
- the NWSM zone system and network is more detailed than the WTSM zone system and network, resulting in some short distance trips (i.e. intra Upper Hutt, intra Porirua) only being represented as non-assigned internal trips within a specific WTSM zone

- it is therefore reasonable that NWSM , with its more detailed representation of the network and zone system and more comprehensive set of calibration counts, should use matrix adjustment and estimation tools to improve the representation of shorter distance trips that may exist as intra-zonal trips in WTSM

Conclusions

- differences between the WTSM and NWSM (prior) matrices can be explained in terms of different model time periods
- differences between the NWSM prior and post ME matrices mean that large absolute changes generally translate to small percentage changes whilst large percentage changes generally relate to low absolute numbers
- the differences between the NWSM prior and post ME matrices are reasonable and can be explained and justified by reference to the parent WTSM model and differences in the network representation, zone system and count set between NWSM and WTSM

Project recommendations

- during any potential refinements of NWSM, the need to successfully validate the model is balanced against the need to preserve underlying travel patterns generated by WTSM
- this process should look at changes between prior / post ME matrices and also changes in trip length distribution

Wider recommendations

- for future projects, comparisons between WTSM and any proposed project models (such as NWSM) should take place at an early stage in the process, so that changes can be considered for WTSM in order to minimise the need for matrix estimation techniques in the lower tier models and to improve consistency between strategic and project models

10.4 NWSM - representation of merges

Initial analysis of modelled and observed travel times on SH2 in NWSM showed that modelled travel times on SH2 between Petone and Ngauranga were considerably faster than observed travel times in the AM peak.

More detailed analysis suggested that one reason for these differences could be that mid-block modelled capacities (~2,050 vph per lane) are slightly higher than observed mid-block capacities (1,900 vph per lane), whilst another reason appeared to be that NWSM was not accurately representing delays caused by the Petone on-ramp merge that start to occur around 6.45am and lead to a reduction in effective capacity and increase in delays that can take up to 2 hours to dissipate.

The steering group decided to investigate the extent that different techniques in SATURN for modelling bottleneck queues, such as those that occur at the Petone on-ramp merge, might result in different interpretations of delays and queues caused by the bottleneck. This analysis largely draws upon work done to date by Jacobs, in consultation with the peer reviewer, when developing the existing model and justifying the methodology.

By means of background, SATURN provides a number of priority markers with three main methods available for representing interaction of vehicles at motorway merge points – these are outlined below, together with examples of their effect in NWSM:

- M coding: Merge coding where all priority is given to the mainline and therefore all delays are imposed on the on ramp traffic
  - observations on SH1 and SH2 in Wellington indicate that traffic on the main line tends to move to the right to allow on ramp traffic to join meaning that M coding would overestimate delays to the on ramp traffic and underestimate the impact on the main line
- Q coding: Downstream merge coding where the capacity constraint is applied to both the mainline and on ramp traffic. This is the methodology currently used to reflect traffic joining SH1 and SH2 in Wellington, resulting in a similar delays for both mainline and ramp traffic
  - Q coding, together with decreased saturation flows, is used between Melling and Petone on SH2 where the intersections are more closely spaced, to reflect delays associated with merging traffic from the on-ramp, and is also used at the Petone on-ramp. This coding is used as standard practice throughout the model
- W coding: Weave coding where there is an additional capacity reduction due to higher levels of lane changing. W coding is typically applied to a motorway section between an on and off ramp consisting of the motorway and a slip road
  - this coding is not applied in NWSM as, in the opinion of the modellers, there are no instances on the network where a significant amount of lane changing takes place over a short distance in-between intersections

Whilst 'W' coding is not used in the validated base NWSM model (nor future year models), a number of sensitivity tests were undertaken at a high level to understand how "W" coding at key locations along SH1 and SH2 might affect travel times.

In general the following observations can be made from these tests:

- the difference in delays in the AM peak (SB) between the proposed TG/SH1 interchanges and the Tawa interchange is 15s (along a 3km stretch of SH1) between the current Q coding layout and a W coding layout
- flows increase and delays decrease on SH2 between Ngauranga and Dowse as a result of using W coding instead of Q coding, as the capacity constraint at the Petone on-ramp (due to Q coding) is removed yet delays due to weaving between Ngauranga and Petone are minimal due to the long distance between the two interchanges

The weaving coding in the SATURN models does not appear to reflect the observed congestion between Petone and Ngauranga well and so it is not recommended to replace the Q coding with W coding in the SATURN testing.

Conclusions

- different methods for coding merges / weaving in SATURN result in small changes in traffic volumes and the representation of delays / queues
- whilst the Q coding methodology that is currently used in NWSM better reflects observed traffic speeds and delays compared with W coding, NWSM still does not accurately reflect observed delays that are driven by conflicts at the Petone on-ramp and Ngauranga Gorge merge in the AM peak

Project recommendations

- accepting that considerable effort was put into replicating observed travel times on SH2 in NWSM 2013 (using 2012 and 2014 Bluetooth data), this work should be reviewed together with the updated 2015 Bluetooth data to determine a range of travel times by route section / time period (in consultation with the peer reviewer) that can be used as a basis to investigate whether further improvements to the travel time validation can be achieved_
- depending on the extent to which NWSM can replicate observed traffic delays, consideration should be given to extending / updating the S-Paramics model to develop a suite of modelling tools that replicate observed travel times, delays and travel patterns in the area of interest for P2G

10.5 NWSM - zero growth sensitivity test

A sensitivity test was undertaken to determine the benefits that the P2G link road might generate under a current year (2013) scenario that implicitly assumes no traffic growth or land use development, effectively representing a zero growth scenario.

This assessment is contained in full in **Appendix A12** of this report and summarised below.

Three options were assessed against the Do Minimum:

- Option C – 6 lanes North of Tawa
- Option C – 4 lanes North of Tawa
- Option D – Takapu Link

All options were assessed using the 2013 base year version of NWSM, with numbers / LoS representative of average travel conditions over the peak hour.

Table 26 shows traffic volumes for key links within the area of interest, focussing on Do Minimum and Option C.

Table 26 Traffic volumes for 2013 zero growth sensitivity tests

Year	Direction	Do Minimum		Option C	
		Vehicles	V/C	Vehicles	V/C
SH1 North of Tawa (6 lane)	AM (SB)	2,310	60%	2,480	43%
	PM (NB)	3,140	82%	3,400	59%
P2G	AM (EB)			880	26%
	PM (WB)			1,030	30%
SH2 Ngauranga to Petone	AM (SB)	3,770	102%	3,400	92%
	PM (NB)	3,780	103%	3,650	99%

The analysis shows that:

- P2G attracts around 1,000 vehicles per hour during peak periods under a base year 2013 scenario, with the resulting V/C ratios between 26% and 30%
- of these 1,000 vehicles, between 30 and 40 are forecast to be HCVs

- SH2 between Ngauranga and Petone is effectively at capacity in the base year; P2G results in a small decrease in traffic volumes and an associated slight improvement in the V/C ratio
- traffic volumes on SH1 North of Tawa increase slightly, resulting in V/C ratios that imply significant delays may be experienced in the PM peak (NB) under a 4 lane future scenario

The forecast traffic volumes on P2G under the zero growth scenario could be accommodated on a 2 lane alignment whilst still delivering an acceptable level of service (C), although 4 lanes would provide a slightly better level of service by allowing faster vehicles to overtake slower vehicles on uphill sections of P2G.

Table 27 shows travel times for key links within the area of interest for the Do Minimum and Option C 2013 assessments.

Table 27 Travel time comparisons for zero growth sensitivity tests, minutes

Year	Direction	Do Minimum	Option C	
		Time (mins)	Time (mins)	Diff
Porirua to Wellington	AM peak (EB)	15.7	13.0	-2.7
	PM peak (WB)	18.7	13.0	-5.7
Porirua to Petone	AM peak (EB)	15.2	8.3	-6.8
	PM peak (WB)	22.2	9.0	-13.2
Dowse to Wellington	AM peak (EB)	11.7	8.7	-3.0
	PM peak (WB)	14.8	10.5	-4.3

The analysis shows that:

- travel times for all routes would improve significantly as a result of the P2G link road
- Porirua to Petone travel times would improve by 7 minutes (AM, eastbound) and 13 minutes (PM, westbound).
- travel times on SH1 and SH2 would improve by between 2 to 4 minutes as a result of de-congestion associated with P2G

Table 28 below shows the indicative BCR assessment of the three options for a 2013 zero growth scenario:

Table 28 Zero growth BCR, 2013

Cost	Option C with SH1 Imp.	Option C	Option D
PV Costs ($m)	181	150	177
PV Benefits ($m)	196	175	201
BCR	**1.1**	**1.2**	**1.1**

Costs were assessed, based on the ‘most likely’ construction costs for each variant (including the P4 variant Petone to The Crest), with no allowance for maintenance costs at this preliminary assessment stage.

The BCR figures show that the P2G link road is likely to provide significant benefits to the region irrespective of the level of traffic growth that might occur in the future.

Similar analysis was undertaken in WTSM and is documented in Appendix A5. It also demonstrates that even when modelled using a 2013 scenario with no traffic growth, P2G still generates significant travel time savings and de-congestion benefits.

Conclusions

- the zero growth sensitivity test suggests that P2G would attract around 1,000 vehicles per hour in the peak directions (AM eastbound, PM westbound) and provide de-congestion and travel time benefits along SH1 and SH2
- the BCR analysis suggests that P2G would provide a level of benefits that would outweigh costs regardless of the level of growth that might occur in the future

Project Recommendation

- a full BCR assessment of P2G under a range of scenarios – zero growth, lower growth, central case and higher growth and different levels of trip redistribution – is recommended to be undertaken as part of the SAR process

Wider recommendation

- a zero growth test, including travel time and BCR analysis, should be undertaken towards the start of any modelling work associated with significant infrastructure projects, to understand the extent to which the project might provide benefits under a pessimistic scenario and to provide a benchmark against which other tests can be compared

11 Levels of service under recommended growth scenarios

Section 8.10 outlined a range of recommended scenarios, to be used during the next modelling phase of the project, that provide a range within which the traffic volumes resulting from the P2G link road are likely to sit.

These scenarios, based on the WTSM 'medium' land use scenario, are reproduced below in **Table 29.**

Table 29 Proposed scenarios for SAR modelling

Year	Zero growth redistribution scenario	Medium redistribution scenario	Higher redistribution scenario
2011	2011 Demand, Option network		
2021	2021 Do Min demand, Option network		
2031	2031 Do Min Demand, Option network	2031 Option demand (50% of redistributed trips), Option network	2031 Option demand (100% of redistributed trips), Option network
2041	2041 Do Min Demand, Option network	2041 Option demand (100% of redistributed trips, Option network	2041 Option demand (150% of redistributed trips, Option network[22]

Whilst initial results from these scenarios may change slightly during the next stage of the project, as the scheme is optimised and modelling tools updated, analysis is presented below to give an indication of expected mid-block levels of service using the existing modelling tools as used for the multi-criteria assessment.

[22] Note that the 2041 higher redistribution scenario has not yet been run

11.1 Initial results from recommended scenarios

Tables 30, 31 and 32 below show the traffic volumes and levels of service on P2G, SH1 North of Tawa and SH2 Ngauranga to Petone that correspond to the to the scenarios outlined above, together with an estimate of the percentage of traffic that can be categorised as 'redistributed' traffic.

Table 30 P2G traffic volumes under different redistribution assumptions

AM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	880	0%	27%	880	0%	27%	880	0%	27%
2021	1,190	0%	37%	1,190	0%	37%	1,190	0%	37%
2031	1,490	0%	46%	1,770	16%	54%	2,030	27%	62%
2041	1,620	0%	50%	2,130	24%	65%	TBC		
Inter-peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	380	0%	12%	380	0%	12%	380	0%	12%
2021	480	0%	15%	480	0%	15%	480	0%	15%
2031	570	0%	18%	710	20%	22%	850	33%	26%
2041	580	0%	19%	870	33%	27%	TBC		
PM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	Volume	% redist
2013	1,020	0%	31%	1,020	0%	31%	1,020	0%	31%
2021	1,320	0%	40%	1,320	0%	40%	1,320	0%	40%
2031	1,570	0%	48%	1,840	15%	56%	2,070	24%	63%
2041	1,620	0%	50%	2,110	23%	64%	TBC		

Analysis of the P2G link road shows the following:

- all 2021 scenarios assume no trip-redistribution and result in V/C ratios less than 40% during the peak periods and less than 20% in the Inter-peak
- in 2031, the central case shows that about 15% of peak and 20% of inter-peak traffic using P2G is redistributed traffic, with the resulting V/C ratios around 60% in the peak periods and nearer 20% during the inter-peak
- if no redistribution of trips were assumed in 2031, the peak period V/C ratios would be nearer 40%
- in 2041, the full redistributional impact (assumed for the central case) results in around 25% of peak period trips and 33% of inter-peak trips on P2G being redistributed trips, resulting in peak period V/C ratios of just over 60% and inter-peak V/C ratios of around 25%

The analysis shows that the inter-peak demand response is more significant than the peak period demand response, due to a larger proportion of inter-peak trips being the kind of discretionary trips ('shopping' and 'other' trip purposes) that are generally more elastic than commuter trips

The Inter-peak demand response, in terms of redistributed trips, appears to be around 40% higher than the peak period demand response (33% for 2041 central case in Inter-peak compared with 24% for the central case in the AM peak).

Whilst guideline elasticities and literature suggests that the Inter-peak demand response can be 100% greater than the AM peak demand response, even if this were the case, the V/C ratios on P2G would still be very low and levels of service would still be acceptable.

Table 31 SH1 North of Tawa traffic volumes under different redistribution assumptions

AM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	2,480	0%	65%	2,480	0%	65%	2,480	0%	65%
2021	2,630	0%	47%	2,630	0%	47%	2,630	0%	47%
2031	2,850	0%	51%	2,950	3%	53%	3,030	6%	55%
2041	2,930	0%	54%	3,130	6%	57%	TBC		
Inter-peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	1,210	0%	33%	1,210	0%	33%	1,210	0%	33%
2021	1,290	0%	24%	1,290	0%	24%	1,290	0%	24%
2031	1,430	0%	27%	1,490	4%	28%	1,540	7%	29%
2041	1,480	0%	28%	1,590	7%	30%	TBC		
PM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	3,400	0%	88%	3,400	0%	88%	3,400	0%	88%
2021	3,530	0%	62%	3,530	0%	62%	3,530	0%	62%
2031	3,750	0%	67%	3,830	2%	68%	3,900	4%	69%
2041	3,830	0%	69%	3,980	4%	71%	TBC		

Note: assumes 4 lanes in 2021, 6 lanes in 2031

Table 31, focussing on SH1 North of Tawa, shows the following:

- the V/C ratios and forecast levels of service do not significantly change between 2021, 2031 and 2041, regardless of the redistribution approach used
- inter-peak VC ratios are very low – around 25%
- the percentage of traffic that can be categorised as 'redistributed' is greater in the Inter-peak (maximum of 7%) compared with the AM peak (maximum 6%) and PM peak (maximum 4%)

Table 32 SH2 Ngauranga to Petone traffic volumes under different redistribution assumptions

AM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	3,400	0%	93%	3,400	0%	93%	3,400	0%	93%
2021	3,410	0%	95%	3,410	0%	95%	3,410	0%	95%
2031	3,430	0%	97%	3,550	3%	100%	3,660	6%	103%
2041	3,520	0%	101%	3,600	2%	102%	TBC		
Inter-peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	1,740	0%	49%	1,740	0%	49%	1,740	0%	49%
2021	1,860	0%	54%	1,860	0%	54%	1,860	0%	54%
2031	2,050	0%	59%	2,060	0%	60%	2,070	1%	60%
2041	2,080	0%	61%	2,090	0%	61%	TBC		
PM Peak									
Year	Zero redistribution			Central case (Medium redistribution)			Higher redistribution		
	Volume	% redist	VC LoS	Volume	% redist	VC LoS	Volume	% redist	VC LoS
2013	3,650	0%	99%	3,650	0%	99%	3,650	0%	99%
2021	3,720	0%	103%	3,720	0%	103%	3,720	0%	103%
2031	3,730	0%	104%	3,740	0%	104%	3,750	1%	104%
2041	3,700	0%	104%	3,720	1%	104%	TBC		

Table 32, focussing on SH2 between Ngauranga and Petone, shows the following:

- current V/C ratios and levels of service show 'significant delays' during both peak periods / directions
- the V/C ratios and forecast levels of service do not significantly change between 2013 and 2041, with significant delays forecast during peak periods / directions
- inter-peak V/C ratios are consistently between 45% and 55%, regardless of the future scenario that is assumed

Conclusion

- initial analysis shows that levels of service do not change significantly at key locations on the network between zero, medium and high redistribution scenarios

Project recommendations

- the 2041 high redistribution scenario need to be developed and run
- this analysis should be refined during the SAR stage, based upon possible refinements to NWSM and the latest intersection designs

- consideration should be given to undertaking similar analysis in the S-Paramics model, to account for variability in traffic volumes throughout peak periods and determine a range of traffic volumes and levels of service that might be expected at key points on the network

Wider recommendations

- for future projects, outcomes such as traffic volumes and levels of service should be represented as a range of possible outcomes, with commentary regarding the likelihood of these scenarios eventuating rather than focusing on one scenario, to reflect uncertainty

12 Conclusions and recommendations

The NZ Transport Agency requested a Steering Group be established to provide guidance for transport modelling associated with major projects in the Wellington Region, with the P2G project the first to benefit from this approach.

This report has outlined the substantive technical work that was undertaken during these investigations, together with the conclusions that can be drawn and the recommendations for how the transport modelling can be improved and refined at the next, more detailed SAR stage of the project.

The recommendations can be split into two categories – project specific conclusions and associated recommendations, plus wider recommendations relating to best practice and a blueprint for how future modelling projects should be run and resourced.

This section focusses on the detailed project conclusions and recommendations, with wider conclusions and recommendations from the process contained in the executive summary:

Table 33 below summarises project specific actions, conclusions and recommendations.

Table 33 Summary of project specific actions, conclusions and recommendations

Area	Conclusion	Recommendations
Modelling system	The tiered modelling system used to assess P2G is current best practice, with a similar approach employed when TG and M2PP were assessed. WTSM and NWSM have been peer reviewed and provide a suitable basis for the work undertaken to date to evaluate options for P2G	The tiered approach should continue to be used for the P2G SAR stage, with adjustments made to NWSM (if justified) and the S-Paramics model developed further to optimise the scheme and understand operational effects in more detail
Capacity assumptions	The capacities in WTSM and NWSM at several key locations are slightly different between NWSM and WTSM. Capacities estimated from the HCM procedures were used for presenting consistent analysis across both models in this report.	Existing work undertaken when developing capacities, speed-flow curves and the modelling of merges for NWSM 2013 should be reviewed. This work should be used to investigate the extent to which travel time validation in NWSM can be improved, particularly along SH2 and Petone Esplanade, without compromising the predictive capabilities of the model. SH1 should also be considered as part of this analysis, drawing upon additional Bluetooth data the it is recommended by collected, to ensure that no bias is introduced to the model as a result of concentrating efforts on improving the validation of SH2 only
WTSM 2011 and WTSM 2013	The 2011 version of WTSM has been used for all P2G work that fed into the multi-criteria analysis.	More detailed analysis should be undertaken to understand differences between WTSM 2011 and WTSM 2013 in relation to P2G and

	An updated 2013 version of WTSM is available. Whilst high-level analysis suggests that it should not result in significantly different traffic volumes and levels of services on P2G and the surrounding network, this needs to be verified.	the surround highway network. A decision should then be take regarding whether to update NWSM to use demand from WTSM 2013. A decision should be taken regarding the requirement to develop a WTSM 2013 project model for the analysis of the P2G link road
Comparison of travel times and traffic volumes between WTSM and NWSM	Differences between both models are largely able to be explained in terms of different networks, time periods and capacities, representation of intersections and matrix adjustments Overall, NWSM more accurately reflects observed conditions than WTSM, which is the primary reason for using a project model	Consideration should be given to adjusting NWSM to better account for observed capacities on the state highway network and to better reflect a new (2015) dataset of travel times and delays, taking account of different datasets and the robustness of the model and its predictive capability under altered future year traffic demands Limitations with NWSM should also be understood and accounted for when extending the S-Paramics models
Comparison of NWSM and Bluetooth travel times	Considerable travel speed variability exists at peak times on Petone Esplanade and SH2 between Ngauranga and Petone. Current NWSM modelled travel times along certain routes do not lie within the range of observed travel times	NWSM should be updated to better reflect a new (2015) observed dataset of travel times within the area of Petone Esplanade and SH2 Similar analysis should be undertaken on SH1 and elsewhere to understand travel times and travel time variability to the same level of detail as SH2
Land use assumptions	Levels of service on P2G and selected other key links in the study area remain largely unchanged regardless of the land use / growth scenario that is assumed	The medium growth WTSM scenario should still be considered as the central case for P2G, with targeted sensitivity tests undertaken around this central assumption during the SAR stage of the project Develop and model targeted land use response scenarios, to determine how changes in land use resulting from P2G might affect levels of service
WTSM demand response	The redistribution of existing trips is the main demand response associated with P2G, with 10 to 20 years likely before a full response might be realised. Compared against similar schemes and guidelines, the demand response associated with P2G is relatively high.	The steering group agreed that assuming 0%, 50% and 100% of the full traffic redistribution effects estimated by WTSM for 2021, 2031 and 2041 respectively is an appropriate central case assumption moving forwards to the SAR stage Appropriate sensitivity tests should be undertaken around this core scenario. Additional work should be undertaken to

		confirm likelihood and scale of any true induced traffic effects that might accompany P2G scheme
HCV analysis	Whilst the validated WTSM 2013 base model shows an 18% reduction in HCV volumes compared to WTSM 2011, the existing NWSM 2013 modelled HCV volumes actually correlate well with the WTSM 2013 HCV volumes	Additional work should be undertaken to better understand HCV volumes that might use P2G under a range of future scenarios. The S-Paramics model should be extended to assess the impact on other road users of HCVs using the P2G link road. Together with relevant safety information, this analysis should be used to develop the justification for crawler lanes on P2G and to develop the Tawa and Petone interchanges
Interchanges	The S-Paramics modelling undertaken to date has only focussed on one medium scenario and has looked at the interchanges in isolation rather than looking at operational issues on other parts of the network	The S-Paramics models to be updated and extended to cover SH1 North of Tawa, P2G from Petone to the crest, SH2 from Dowse to Petone and sections of Petone Esplanade The updated models should be used to understand operational issues associated with crawler lanes and slow moving vehicles, weaving and merging and travel time variability caused by changes in traffic volumes throughout the peak periods
Data collection gaps	There is a need to collect additional count and O-D data, particularly relating to east-west movements and the variability of traffic volumes / travel times within peak periods, in order to verify modelled travel patterns, improve our understanding of the operation of the current network and to feed into refinements that may be made to the modelled tools	Based upon this new data, refinements (if justified) should be made to NWSM and updates made to S-Paramics. The data should also be used to verify current estimates regarding the number of trips that might use P2G in the future.
Zero growth sensitivity test	This assessment of P2G that assumes no traffic growth (2013 demand) still shows that the P2G scheme delivers significant travel time savings for east-west trips and significant de-congestion benefits for trips on SH1 and SH2	A similar approach should be undertaken for other significant transport schemes to understand the benefits even under the lowest (zero) growth scenario
SH1 North of Tawa	Observed travel times, traffic volumes and travel time variability are not as well understood on SH1 North of Tawa compared with SH2 Limited observed data suggests that peak	Additional observed data should be collected to improve the understanding of travel times and traffic volumes on SH1 North of Tawa Based on this information, NWSM capacities should be refined to better represent

	traffic volumes in the AM peak occur between 7.00am and 7.30am, outside of the modelled time periods Current analysis suggests that from 2031 onwards, a 6 lane solution North of Tawa may be required to maintain adequate levels of service	observed travel times The Tawa interchange S-Paramics model should be extended to model the impact that weaving and merging might have on levels of service The information should be used to determine a date range during which a 6 lane solution North of Tawa is likely to be required
SH2 Dowse to Ngauranga	Levels of service between Ngauranga and Petone a likely to remain unchanged (LoS F) in the future, regardless of the growth assumptions nor whether P2G is constructed Based on current assumptions, SH2 between Dowse and Petone will start to reach capacity, resulting in significant delays, from 2031 onwards If CVL were included in the P2G modelling, together with a depowered Esplanade, Dowse to Petone would likely reach capacity sooner than 2031	The S-Paramics model should be extended to model Ngauranga to Dowse, Petone to the crest and the western part of Petone Esplanade Using Bluetooth and traffic volume data, NWSM should be refined and S-Paramics updated to better represent observed travel times, travel time variability (S-Paramics only) and queuing at the Petone on-ramp during the AM peak between 6.30am and 9am The impact that CVL might have upon the operation of Petone Interchange and levels of service on SH2 between Petone and Dowse should be investigated further.
WTSM sensitivity testing	Additional PT measures to promote modal shift from car to PT do not significantly change levels of service on P2G	Whilst outside of the scope of this project, public transport solutions should be considered during future investigations looking at how to reduce congestion and improve levels of service on the corridor between the Hutt Valley and Wellington
NWSM sensitivity testing	The changes to the NWSM matrices as a result of matrix adjustments / estimation are considered proportionate to the increased level of detail and more detailed validation criteria in NWSM compared with WTSM. The changes do not significantly change the underlying trip distribution derived from WTSM Furthermore, investigations looking at different techniques for coding merges in SATURN concluded that the current 'Q' coding technique employed in WTSM is more appropriate and reflective of observed delays than the alternative "W'	The impact of matrix estimation should be monitored should any refinements be made to NWSM.

	coding technique	
LoS under different growth scenarios	Initial analysis shows the levels of service do not change significantly at key locations on the network between the zero, medium and high redistribution scenarios.	The LoS analysis should be refined at the SAR stage, based upon updated models and optimised scheme designs

A1. Steering group members

NZ Transport Agency

Tony Brennand is the Steering Group Chair, and has involvement through his national role at the NZ Transport Agency in establishing best-practice for transport modelling of major projects.

Kesh Keshaboina is a member of the Steering Group, and has responsibility to consider the modelling assessment from a regional perspective on behalf of the NZ Transport Agency.

Greater Wellington Regional Council

Andrew Ford is the WTSM model practitioner for GWRC, and is a member of the Steering Group.

Nick Sargent is a member of the Steering Group, and holds overall responsibility for the data and analysis undertaken using the WTSM on behalf of GWRC. He was unavailable for the Workshop, but has been involved in the ongoing development of the model assessments.

P2G Project Team

Eliza Sutton is a member of the Steering Group, and is involved in the assessment as the P2G Transportation Assessment owner.

Tim Kelly is a member of the Steering Group, and is involved in the assessment as the P2G Transportation peer reviewer.

Other Technical Stakeholders

Peter McCombs has been involved in the Steering Group on occasion as an observer, and is involved in the assessment as the P2G Strategic Transportation assessment owner. He has been supported in this role at times by **Catherine Mills**.

Darren Fidler and **Kerstin Rupp** have been responsible for the development of the NWSM model, including the most recent 2014 update. Their involvement has been via Opus direction, and also at workshops with the Steering Group.

A2: Workshop Actions

Table 34 Workshop Actions

Threat/Opportunity	Action	Outcome
There is a threat that the land-use assumptions underlying the baseline forecasts is unrealistic / unlikely.	Undertake tests in WTSM to determine the sensitivity of transportation forecasts to alternative land use-scenarios (Andrew Ford). GWRC to suggest alternative land use-test scenarios (Andrew Ford). Based on the outcome of these land-use sensitivity tests run selected scenarios through NWSM (Darren Fidler, if required).	**Section 5**, Steering Group (SG) report
There is a threat that the performance of the link road with alternative land use scenarios has not been tested and / or widely communicated. It is acknowledged that the transport assessment framework does not deal well with questions regarding induced land-use.	Update and circulate information regarding the alternative land-use scenarios already developed for use within WTSM (Andrew Ford). Agree suitability of alternative WTSM land-use scenarios and / or need for alternative (project specific) sensitivity tests (Steering Group). Circulate WTSM forecasts for alternative land use scenarios (Andrew Ford). For both the WTSM and NWSM base year models, compare fixed matrix forecasts with variable matrix forecasts to understand the nature of changes in travel behaviour and trip patterns *(*Andrew Ford and Darren Fidler*)*.	**Section 5**, Steering Group (SG) report
WTSM Trip Rates and Trip Characteristics are based on 2001 data which may now be out of date.	(Andrew Ford) to compare vehicle-km per person for WTSM base year and future years (do-min and option) and (Steering Group) to assess whether the results are reasonable.	**Section 10**, Steering Group (SG) report
There is an opportunity to better understand / document the alignment between WTSM and NWSM with regard to the base (existing) situation in order to create more confidence in forecasts developed using the models (i.e. how well does each model represent the existing problems). There is a risk that the lack of representation of Network Performance within WTSM could lead to over design of the link road and / or affect credibility of forecast demands.	Compare WTSM and NWSM baseline scenarios, identify significant differences (i.e. traffic volumes and travel times in area of interest) and explain these differences (Darren Fidler). Undertake sensitivity tests to determine the extent that differences in the way WTSM and NWSM distribute traffic / travel demands influence model outputs (e.g. forecast flows, delays) (Darren Fidler).	**Section 6**, Steering Group (SG) report
There is a risk that the distribution response cost are not appropriate.	Use an elastic version of the SATURN model to see how trip distribution and travel demand might change in response to changes in costs resulting from the P2G link road. Compare this demand response with the demand response in WTSM to determine whether or not both models are responding in a similar manner (Darren	**Section 8**, Steering Group (SG) report

	Fidler). Clearly identify and document WTSM demand response to new link road (Andrew Ford) Identify and document differences between do-min and option matrix and report on how reasonable the difference appear (Andrew Ford) make an appropriate range of manual adjustment to the NWSM matrices to determine the sensitivity of project outcomes to changes in the level of traffic redistribution (Darren Fidler with Steering Group to scope) Undertake sensitivity test with artificial penalty applied to link road (Andrew Ford)	
There is threat that the cross corridor travel demand (i.e. between the Western and Hutt Corridors) has not been validated.	Develop methodology for additional data capture from which to validate the demand (Eliza Sutton with Steering Group to scope)	Recommendatio n from SG report for next phase
Given that the Cross Valley Link is not a committed project, it has not been represented in the base models.	Define a sensitivity test that includes the Cross Valley Link (Steering Group).	**Section 9**, Steering Group (SG) report
The freight demand matrix within the current version of WTSM is fixed. There is a risk that the demands and hence forecast HCV flows are not responding to changing travel costs brought about by the P2G for some trips.	Recommend how accurate / realistic the forecasting of HCV volumes needs to be (i.e. are there any decisions that are heavily influenced by forecast freight demands and / or flows – business case? crawler lanes? etc.) (Eliza Sutton) compare HCV trip distribution and travel demand response in an elastic version of SATURN and WTSM to determine whether or not both models are responding in a similar way and allow an estimate of the demand response for the HCV matrix to be derived (Darren Fidler) consider using operational assessment of comparable "real-life" situation (e.g. Bombay Hills) to inform design elements for accommodating HCVs (Eliza Sutton)	**Section 9**, Steering Group (SG) report
WTSM does not fully replicate capacity constraints, particularly at interchanges. There is risk that this leads to unrealistic traffic distribution, leading to differences between WTSM and NWSM that undermine the credibility of the transportation modelling.	Compare and document the location and magnitude of over-capacity links in NWSM vs WTSM and assess the appropriateness of the likely influence on the transportation forecasts (Darren Fidler).	**Section 4**, Steering Group (SG) report; Section 6, Steering Group (SG) report
Some of the forecast travel times in the NWSM base model are not aligned with road users perceived experience. There is a risk that this undermines the credibility of the model.	Identify travel times relevant to the big decisions (e.g. State Highways, Petone Esplanade etc., see Section 2) and / or that are being challenged (Steering Group) Compare base year travel times against available travel time statistics derived from blue tooth or GPS data such as mean, max, min, variability etc. (Darren Fidler and Andrew Ford).	**Section 7**, Steering Group (SG) report