

A Conceptual Model for Better Collaboration

Abstract

Transportation services, infrastructure, systems and technology are increasingly complex and interconnected, which naturally results in professional specialisation and greater diversity and size of the teams that create change. All the while there are higher expectations of efficiency and value for money from central and local government.

Meeting those expectations requires ways of collaborating more effectively between individuals, teams, disciplines and organisations, combined with the challenge of working in an increasingly complex industry.

To do this we need ways to identify when, how and why it is necessary to collaborate with each other. One way to achieve this is to employ a conceptual model that illustrates how industry processes are interconnected. Such a model can identify the people that need to be involved, the conversations that need to be had, and the questions that need to be asked.

This paper will present a simple yet powerful conceptual model that illustrates the interconnection between all the major processes that occur within the transportation engineering industry, from strategic and planning processes, to project development and delivery, asset management and operations.

A number of case studies will illustrate the use and applicability of the model.

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Introduction

Transportation practitioners need more effective ways to collaborate. Individuals, teams, disciplines and organisations must all collaborate, and yet the challenge is not simply to aim for it, but also to believe in it and practice it. The challenge is also finding the answers to:

- Which topics require collaboration?
- At what point should we consider collaborating?
- Who should we collaborate with?

One way to answer these questions is to employ a conceptual model that illustrates the interconnection of teams and industry processes. This paper presents a conceptual model that illustrates the relationship between industry work practices and the many variables which affect transportation networks, and is structured as follows:

- **Model scope and terminology** – a description of the scope and terminology used in the model, as well as the motivation for its creation;
- **Model development** – an outline of the properties of the transportation system and how they are expressed in the conceptual model;
- **Model validation** – a few examples of how the model explains the transportation system and processes within the industry; and
- **Model application** – discussion on how the model can be used to investigate and identify opportunities for collaboration.

Model Scope and Terminology

Dictionary.com defines conceptual model as “a type of diagram which shows a set of relationships between factors that is believed to impact or lead to a target condition”. The conceptual model (“the model”) presented in this paper was originally developed to explain the relationship of traffic operations activities (“Operations”) to:

- a) Variables affecting the transportation network (“network variables”); and
- b) Industry practices which occur during the course of managing transportation networks (“network activities”).

Operations are the activities delivered by the NZ Transport Agency (NZTA) Traffic Operations Centres (TOCs) in Auckland¹, Wellington and Christchurch. These activities include control of traffic signals and ramp signals, traveller information and management of network conditions. Operations seeks to control real time transport network conditions despite network variables affecting them. **Network variables** include:

- **Environmental** factors affecting transportation demand, which vary based on time of day week or year, and as a result of land use, economic and population growth, weather, energy costs, technology, public policy;
- **Priorities** of transport authorities which include road user charges, target and level of investment, provision and incentives for particular mode choices;
- **Capability** of the network such as the physical arrangement of the network, road space allocation, or the design and configuration of capital investments;

¹ The Joint Transport Operations Centre is a partnership between the NZTA and Auckland Transport.

- **Availability** of the network, which relates to whether or not part of a network is available for use due to maintenance, faults or incidents; and
- **Control** of operational capabilities which includes network monitoring, dispatch emergency services for incidents, ramp signals, variable message signs, traveller information, corridor optimisation, coordinated road works.

The objective of transport authorities is to manage these network variables. To achieve this, authorities and individuals undertake a range of industry practices, described here as **network activities**, which include:

- **Strategy**, which is concerned with development of strategic direction and investment programmes, typically undertaken by central government agencies and regional planning and investment teams;
- **Planning**, which is concerned with development and delivery of changes to network capability, and is typically undertaken by planners and designers;
- **Maintenance**, which is concerned with the maintenance and renewals of transportation assets, and is typically undertaken by asset managers and road maintenance contractors; and
- **Operations**, which is concerned with the real time management of the transportation network and is typically undertaken by traffic signal engineers, and TOC operators.

The network variables and the choices made in these network activities invariably affect Operations because they contribute to the condition of the network at any one time ("real time network conditions"). This is what the model seeks to illustrate.

Model Development

To develop the model it was necessary to understand the relationship between the network variables and the network activities. It is clear that Operations is influenced by each of the network variables noted above, but the relationship between each network variable and the other network activities is not immediately obvious.

Network activities are hierarchical in the level of detail and treatment of network variables. Strategy is the highest level network activity and is primarily concerned with addressing environmental conditions and allocating investment appropriately. Strategy therefore does not typically address specific network capabilities, such as the number of lanes, but it does give direction to their conception. This hierarchy is repeated for each successive level of network activity. In other words:

- Strategies inform but do not prescribe the development of plans;
- Plans inform but do not prescribe the development of projects;
- Projects inform but do not prescribe necessary maintenance activity; and
- Maintenance activities inform but do not prescribe the necessary operations.

To understand the relationship between network activities and network variables, network variables were expressed as inputs, actions and outputs to each network activity, where:

- An input is a network variable that directly influences the network activity;
- An action is what is performed within the network activity; and
- An output is a network variable which will flow from but will not necessarily be prescribed by a particular network activity.

Initially, inputs and outputs to network activities were described, as **Table 1** shows.

Table 1 – Input and output variables for selected network activities

Network Activity	Sub-Activity	Variable				
		Demand from the environment	Priorities of transport authorities	Capabilities of the network	Availability of the network	Operational control of the network
Strategy	Regional Land Transport Strategy	Input	Action	Output	Output	Output
	Regional Land Transport Programme (RLTP)	Input	Action	Output	Output	Output
Planning	Project design	Input	Input	Action	Output	Output
	Corridor management plans	Input	Input	Action	Output	Output
Maintenance	Corridor access	Input	Input	Input	Action	Output
	Road maintenance	Input	Input	Input	Action	Output
Operations	Corridor optimisation	Input	Input	Input	Input	Action
	Incident management	Input	Input	Input	Input	Action
Real time network conditions		Input	Input	Input	Input	Input

This indicates that network activities cascade in influence over each of the subsequent network activities. **Table 2** illustrates a few specific examples.

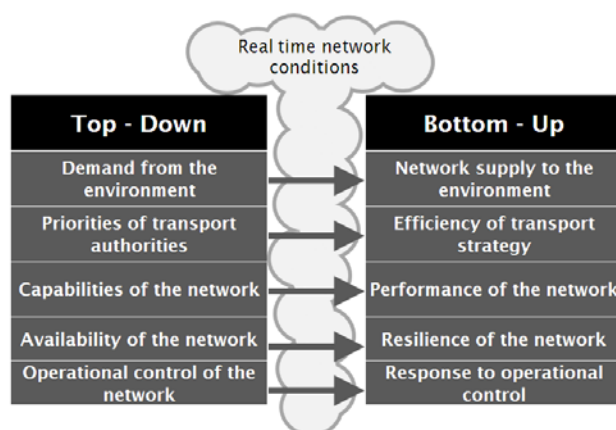
Table 2 – Specific examples of how network activities respond to network variables

Activity	Demand from the environment	Priorities of transport authorities	Capabilities of the network	Availability of the network	Operational control of the network	Legend
Development of the RLTP	Public policy (GPS)	Production of the RLTP	List of RLTP projects	RLTP investment in maintenance, contributing to desired levels of asset resilience	RLTP investments which enhance operational control	Output
Delivery of the Waterview Project	Need to support Auckland growth, GPS objectives, etc	Priority funding for Roads of National Significance	Design of the Waterview Connection Project including lanes, links, layout, systems, specification	Whole of life design for resilience of tunnel systems, improving asset availability during operation	New operational controls (ramp signals, lane controls) result in enhanced operational response	Action
Status of the Northern Busway	North Shore population, Waitemata Harbour	Investment in Northern Busway, public transport services	Two lanes built on Northern Busway, frequency of stations and services	One lane closed on the Northern Busway due to road works	Actuated temporary traffic signals in place to manage delays	Input

This approach describes the hierarchy of network variables and their relationship with network activities, but it does not explain the cumulative contribution of each network activity to overall network supply. For example:

- Operational control of ramp signals shape overall transportation supply by incentivising road users to defer trips or take alternative modes;
- Optimisation of a corridor enhances the performance of a network capability, contributing to overall network supply; or
- Maintenance activities contribute to overall network efficiency by minimising the impact of pavement rutting or mitigating the risk of road washouts.

One method of accounting for this two-way flow of variables is to express them by their effect on network supply (a “bottom-up” description) as opposed to their response to network demands (a “top-down” description). This conversion is illustrated in **Table 3** below.

Table 3 – Expression of network variables by their relationship to network supply

It is therefore possible to express the network variables by how they are shaped by each network activity from the top down, *and* by how they cumulatively affect the network activities from the bottom up.

The top-down expressions of the variables are the source of real time network conditions, while the bottom-up expressions of the variables are consequences of real time network conditions. This relationship indicates the network variables have a feedback loop effect on network activities, and that it is during real time network conditions where they coincide. The network variables could therefore be expressed as the following feedback loops:

- Demand / supply;
- Priority / efficiency;
- Capability / performance;
- Availability / resilience; and
- Control / response.

In summary, development showed that the model would need to exhibit the following properties if it were to adequately explain the relationship between network activities and variables:

- Traffic operations, and real time network conditions are affected by all the network variables;
- Network activities, from strategy to operations, are hierarchical and are affected by the cumulative influence of higher level network activities;
- Network variables cumulatively influence higher level network activities; and
- Network variables occur as feedback loops that coincide during real time network conditions.

A number of conceptual models were drafted to explain these relationships and groups of activities and variables. Through trial and error the model shown in **Figure 1** was conceived.

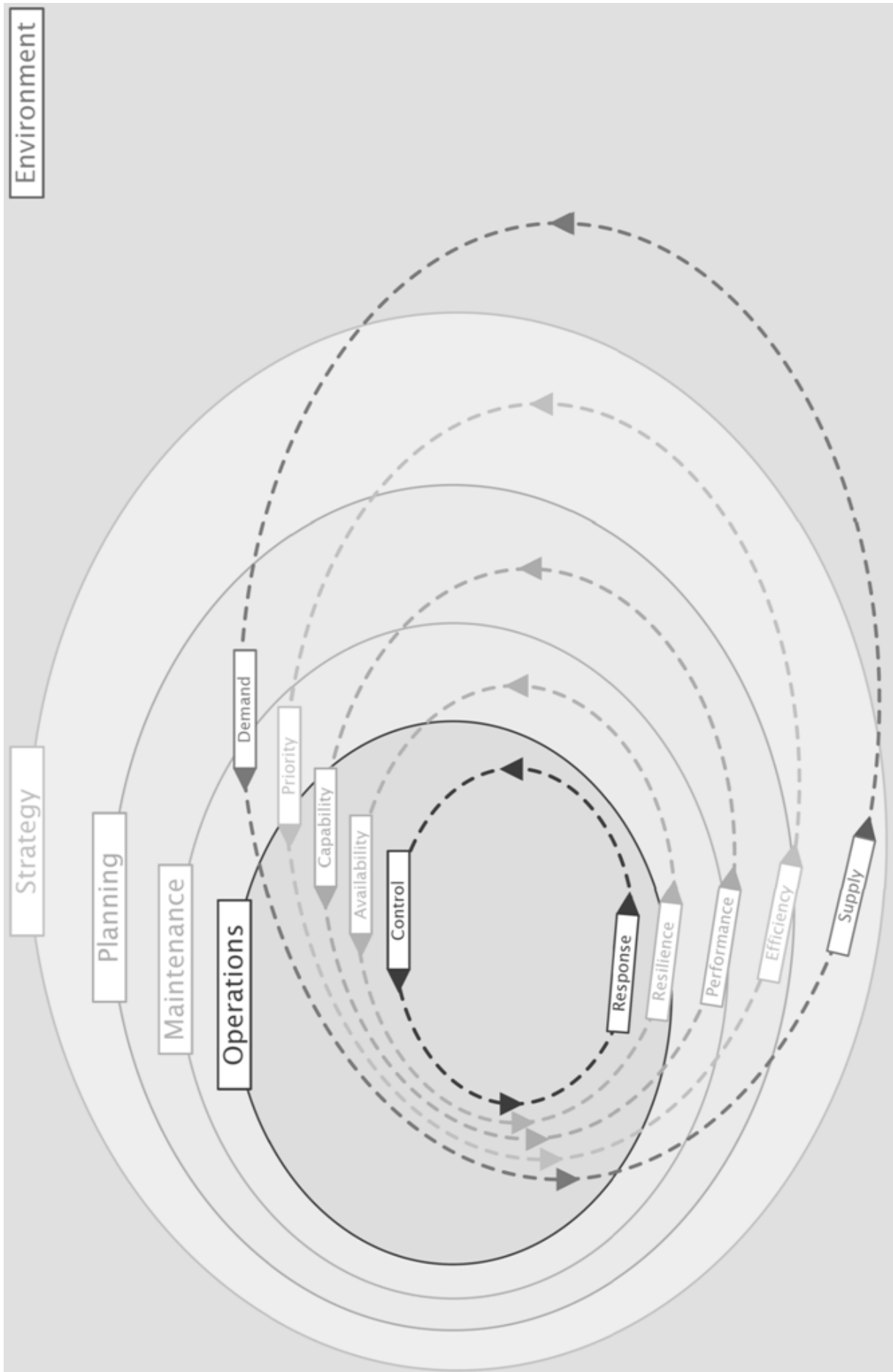


Figure 1 - The Conceptual Model

The properties of network activities and variables as illustrated by the model are shown in **Figure 2** below.

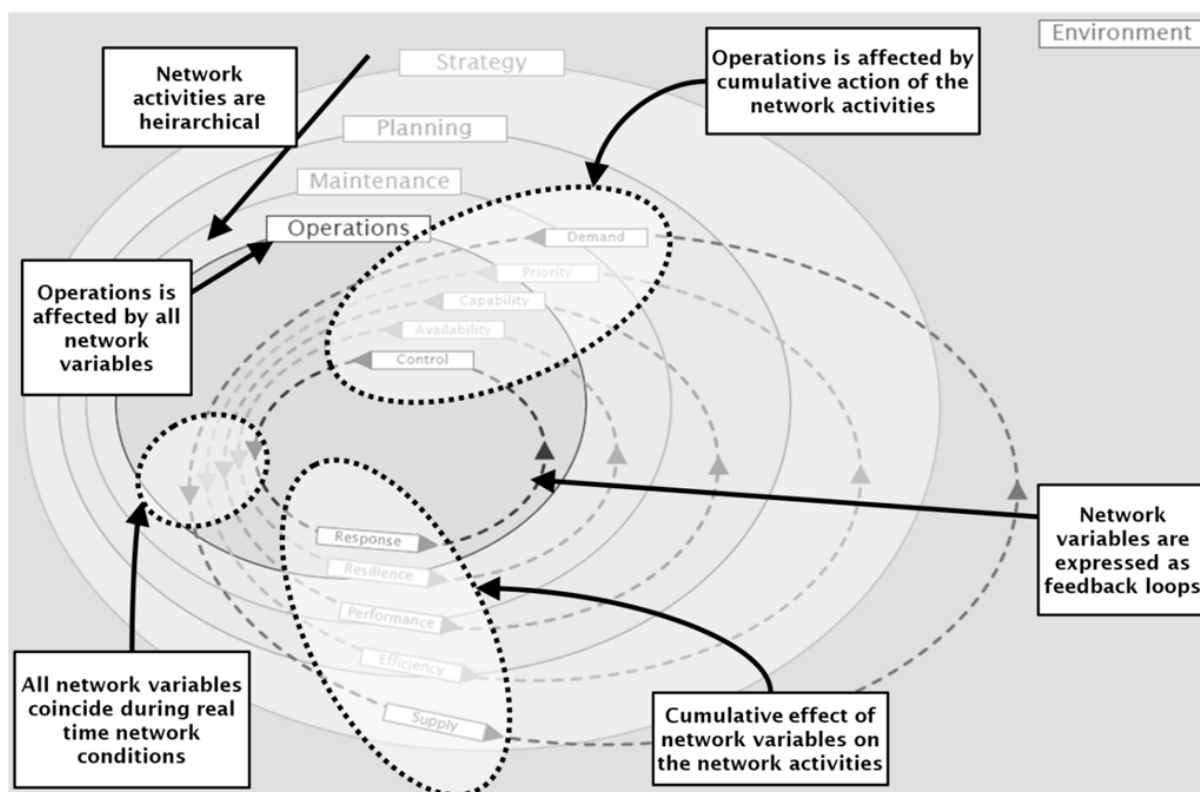


Figure 2 - Explanation of Properties of the Model

Model Validation

This section compares the predictions made by the model with situations and network activities that many transportation practitioners will be familiar with.

Real Time Network Conditions on the Auckland Harbour Bridge

The model suggests that real time network conditions, which are managed by Operations, will be dependent on the influences of all network variables. An example of all the network variables impacting upon real time network conditions is to consider the Auckland Harbour Bridge (AHB) on any given day, which is subject to the following variables:

- **Demand** – the amount of people and goods attempting to cross Waitemata Harbour, which is dependent on environmental factors such as fuel price or economic growth as well as weather, time of the day or week;
- **Priorities** of transport authorities – the level of subsidies for public transport on the Northern Busway and incentives for use of transit lanes, which is shaped by Strategic decisions of Auckland Transport (AT) and the NZTA;
- **Capabilities** of the network – the number of lanes on the bridge to accommodate the number of vehicles attempting to cross the AHB as well as presence of alternative routes such as the Western Ring Route;
- **Availability** of the network – the placement of the AHB moveable lane barrier or road closures needed for maintenance, or the availability of alternative routes; and

- **Control** of the network – the ramp signals cycle times on the Esmonde Road On-Ramp, signal at interchanges to the north, use of traveller information to mitigate the effects of incidents, which is managed by the JTOC.

Figure 3 below illustrates how the model describes this situation.

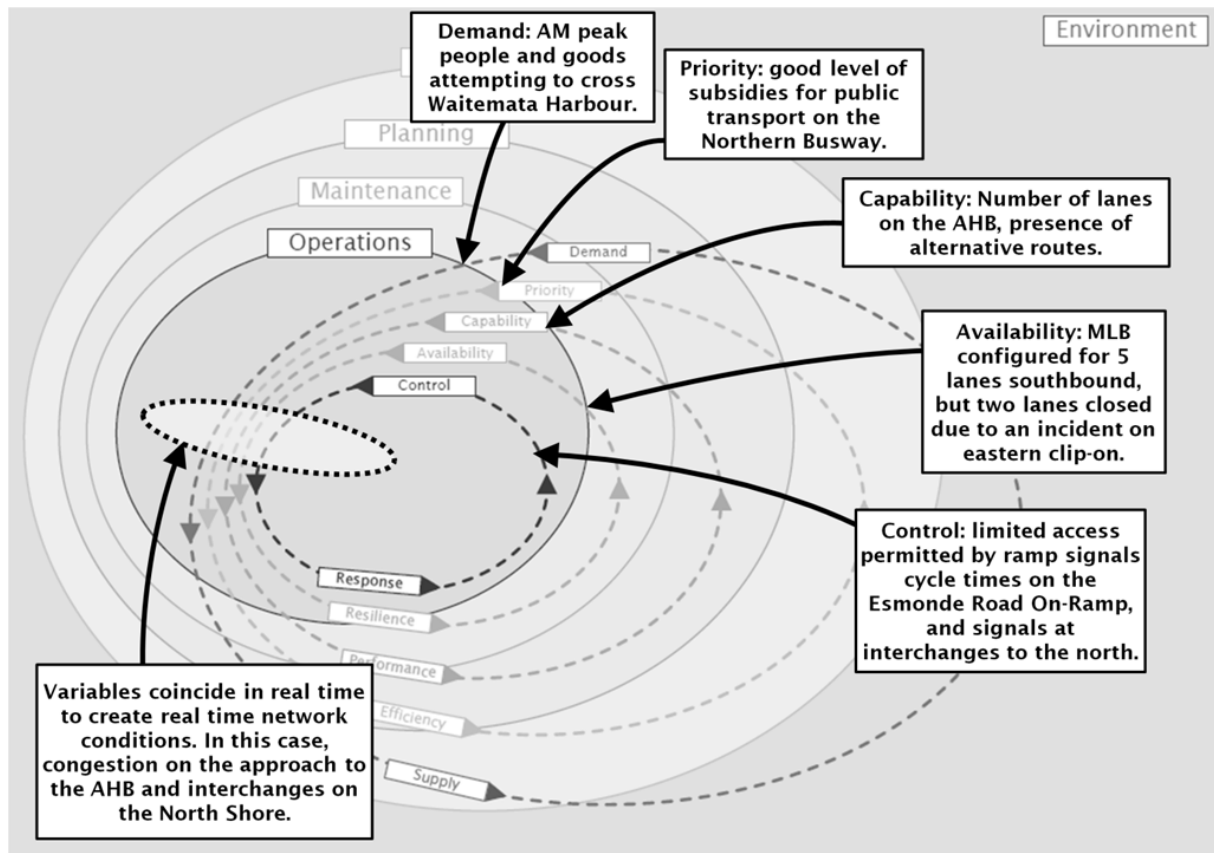


Figure 3 - Explanation of how real time network conditions are described by the model

Thus the AHB validates the model's prediction that real time network conditions will be dependent on all network variables.

NZTA Statement of Intent and State Highway Asset Management Plan, and the Regional Land Transport Strategies

Strategy activities are best summarised by the suite of high level industry documents such as the NZTA Statement of Intent (SOI) and State Highway Asset Management Plan (SHAMP), and the various regional land transport strategies (RLTS). The model suggests that these documents should consider two network variables; supply / demand and priority / efficiency. The model predicts that Strategy will:

1. Consider any network demand as an input;
2. Give a description of overall network supply to the environment;
3. Recognise that network efficiency is the cumulative effect of network performance, resilience and response;
4. Seek to prioritise network capabilities, availability and control.

How the model expresses these relationships is shown in **Figure 4**.

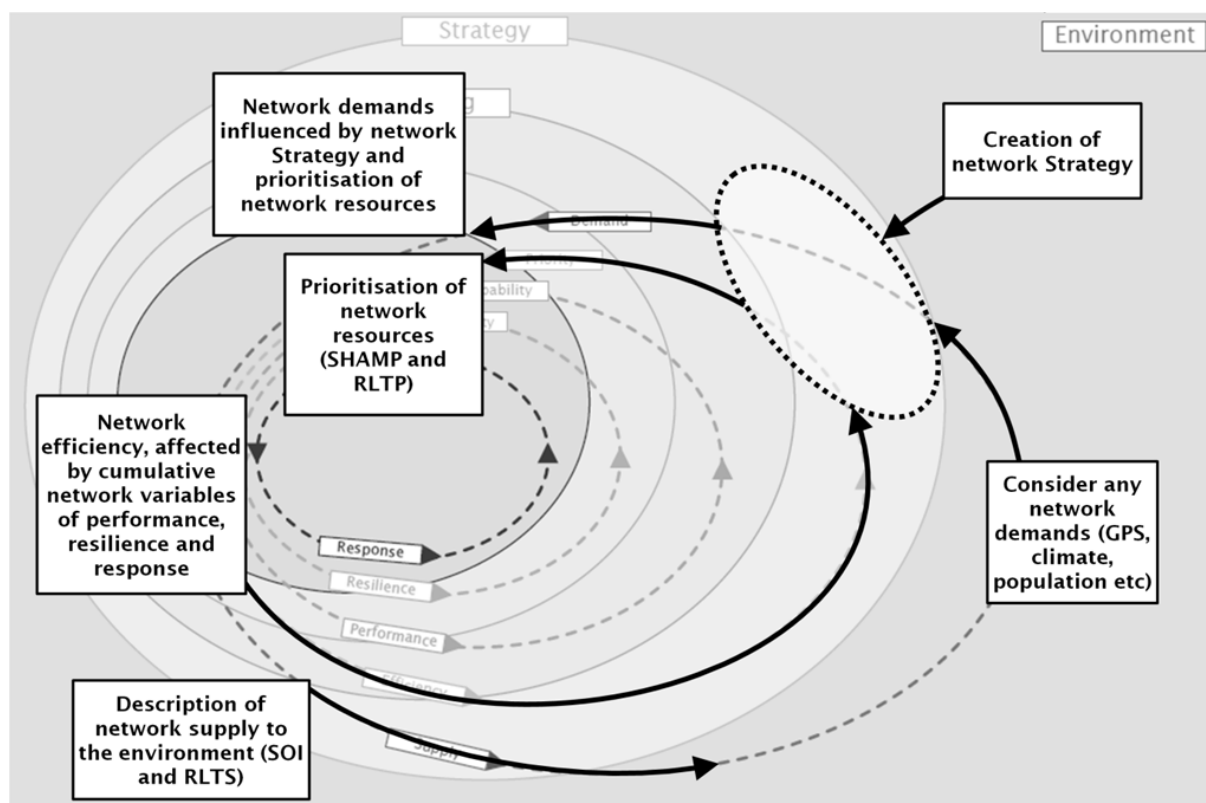


Figure 4 - Explanation of how Strategy activities are described by the model

The first two predictions are illustrated by the SOI and the Auckland RLTS (ARLTS).

Public policies are classified as a network demand, for example the Government Policy Statement on Land Transport Funding (GPS). The GPS states government priorities for the transport network, including economic growth and productivity (including the Roads of National Significance), value for money and road safety.

As expected, these priorities are addressed in the SOI. However, the model predicts that the SOI must address all potential network demands. The SOI validates this prediction in Section 2 by outlining the other factors that will be considered during the course of the NZTA's activities. These include other government policies, population growth, demographic change, economic growth, volatility in fuel prices, technological change, state of the construction industry etc. The model also predicts that the SOI should state the overall supply of the network to the environment, which is outlined in Section 8 - Statement of Forecast Service Performance.

The relationship of the GPS and the SOI is similar to that of the Auckland Plan (AP) and the ARLTS which broadly address similar topics, but in a local government setting. The model is again validated by the ARLTS where Section 2 outlines external objectives and outcomes that need to be considered during the course of transportation planning for the Auckland region, but which, critically, are not exclusively informed by the AP. The ARLTS states the expected supply the environment, which is outlined in Section 5 - Policies, which includes a suite of policies that shape overall network supply including "improving transport choices", "network management" and "additional road capacity".

Thus the SOI and RLTS validate predictions 1 and 2 above. The model's predictions can be illustrated by the SHAMP and the Canterbury RLTS.

For the state highway network, the prioritisation of transportation resources occurs through the SHAMP. The resources prioritised are network capabilities, levels of availability and operations. The SHAMP outlines the pertinent network demands in Sections 2 to 7 before seeking to prioritise capabilities, levels of service for network availability and operational controls in Sections 8 to 12. On page 50 it recognises that overall network efficiency is made up of performance of network capabilities, on page 48 it notes the effect of maintenance on network security (which is a synonym for availability) and on page 49 it outlines the role of active traffic operations.

Meanwhile, the RLTSs fill the role of the SHAMP for each regional network. The Canterbury RLTS outlines the pertinent network challenges and considerations (which are synonyms for demands) on pages 1 and 23 to 26. It states the overall supply of the network to the environment on pages 3 to 9. In terms of the contributions network efficiency, it outlines new investment in local roads and state highways (synonym for capabilities) and prioritisation of maintenance and renewals (synonym for availability) on pages 29 – 34, and it recognises that overall network efficiency is contributed to by "active management of the road network" (synonym for control) on page 28.

Thus the RLTP and SHAMP validate predictions 3 and 4 while giving consideration to predictions 1 and 2.

Traffic Signal Design

Traffic signal design is considered to be part of the Planning network activity as it is concerned with creation of new capabilities for the network. The model predicts that traffic signal design will:

1. Consider network demand and priorities as an input to development of the signal design capability; and
2. Consider the desired performance outcome of the signals, including the cumulative effects of maintenance work on availability and anticipated operational controls.

This is illustrated by **Figure 5** overleaf.

The Roads and Traffic Authority (RTA) traffic signal design guideline and the Auckland Traffic Management Unit (TMU) traffic signals design guidelines validate the model's predictions. Both documents are industry design guidelines, which are produced under the Strategy activity, but they collectively address how the designer should consider traffic demands and the detailed requirements of maintenance and operations.

The RTA guideline highlights the need for appropriate investigation into problem definition, and stresses that "planning problems can result from LATM schemes, new road openings, development access and anticipated traffic growth", which relates to the efficiency of the wider road network.

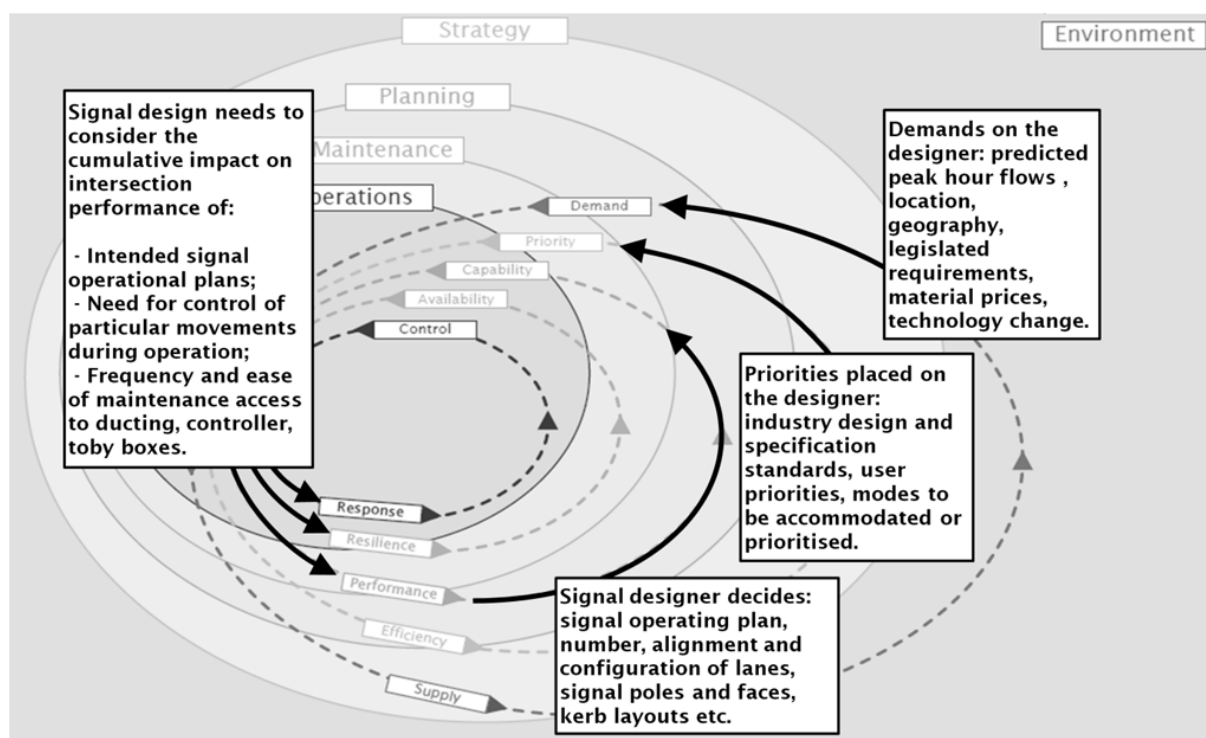


Figure 5 – How traffic signal design activities are described by the model

The TMU guideline focuses on requirements that will ensure operational control of the intersection; from necessary design details on pages 6 to 9 to signal phasing on pages 9 to 19. The requirements for maintenance are implicit in the TMU guideline, but are explicitly stated in the RTA guidelines with respect to locating the signal controller on page 12-1 and 12-2. Thus the TMU and RTA guidelines collectively validate the predictions of the model.

Project Investigation and Scheme Assessments

Project investigation and scheme assessment is also part of the planning activity. The model therefore predicts it should:

1. Consider network demand and priorities as an input to scheme development;
2. Consider the desired performance outcome of the scheme, including the cumulative effects of maintenance work on availability and anticipated operational controls.

The variables that are considered as part of network planning and project development are illustrated by the NZTA minimum standard Z/6 Scheme Assessment Reports (SAR), which succinctly summarises the requirements for an adequately prepared SAR as follows:

- “A statement defining the project objectives”, i.e. it is a requirement to state the objectives for change to the network capability / performance variable;
- “An overview of the engineering, economic, planning, and social and environmental aspects of the project”, i.e. it is a requirement to state the how the scheme will accommodate the network demand / supply variable; and
- “A brief overview of the analysis undertaken of the options against the four assessment categories of Social and Environmental, LTMA Compliance, Economic and Other Client Requirements and against the specific objectives

of the project”, i.e. it is a requirement to state how the scheme aligns with network priority / efficiency expectations.

This shows how the NZTA minimum requirements for SARs validate the treatment of network variables that the model suggests will be necessary as part of the network planning activity. This is further illustrated in **Figure 6**.

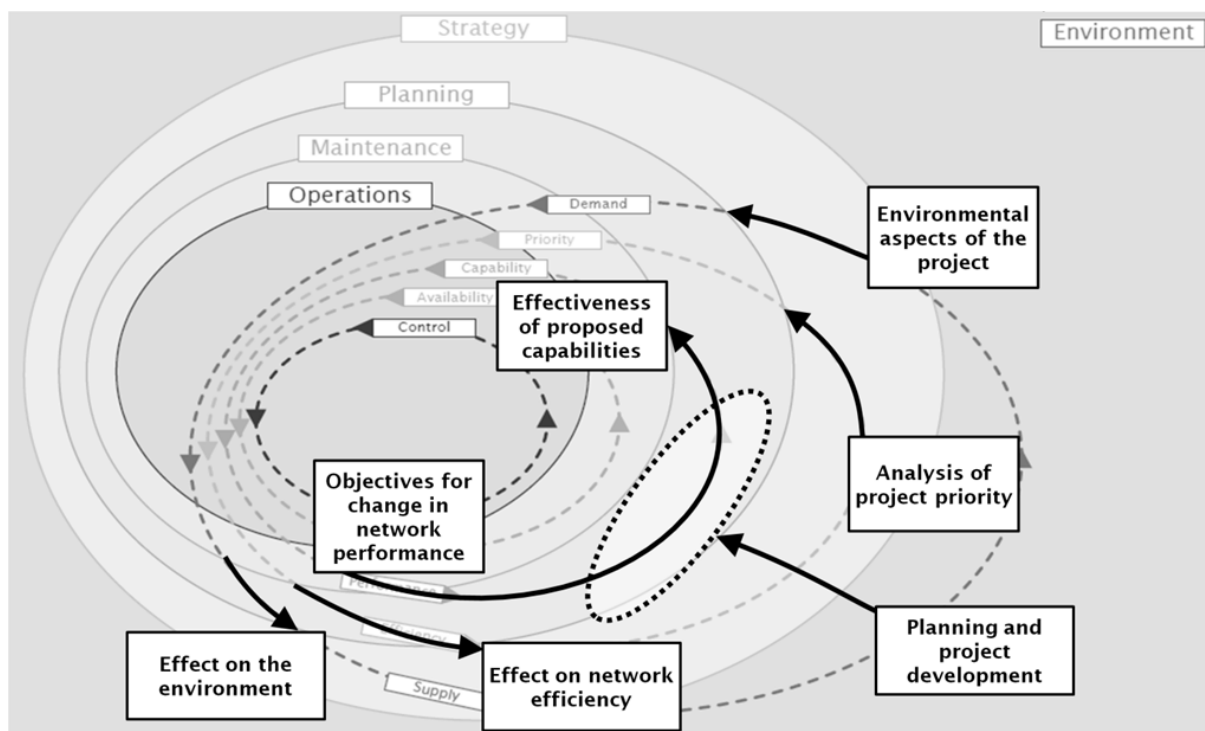


Figure 6 - Explanation of how network planning and project development activities are described by the model

Model Application

As mentioned previously, it is the objective of authorities managing the network to manage the network variables, and so typically it is also the role of industry practitioners. Practitioners typically undertake tasks within one network activity, yet network variables frequently cross boundaries between activities.

Managing network variables is similar to passing a ball within a team, except the ball is a network variable and the team members are strategists, planners, designers, maintainers and operators. The way to catch the ball is to use the same language.

To find the answers to the questions posed at the beginning:

- Which topics require collaboration?
- At what point should we consider collaborating?
- Who should we collaborate with?

Take the following steps:

1. Identify the network variable that is to be changed;
2. Identify the network activity in which you practice; and

- Use the model to see where the variable is going to be passed onto in the future, and what it is dependent on.

Once these are identified, the model can be used to identify the relationships that need to be formed for collaboration. Two examples follow.

A **strategist** wishes to allocate priority to resources that will enhance network efficiency. The network variable that needs to be changed is priority / efficiency. Efficiency is ultimately a consequence of real time network conditions and is influenced by the following:

- Response of the network to Operational control, i.e. how effective are we at manipulating demand in real time?
- Resilience of the network, i.e. how often does the network fail?
- Performance of network capabilities, i.e. are we getting the most out of what we've already got?

Therefore, the strategist should collaborate with operators about methods for increasing network response to feasible controls, maintainers about methods for enhancing network resilience, and with planners on what new capabilities could contribute to the desired change in performance.

Only when consideration is given to each of will it be possible to identify a package which will enhance overall network efficiency. In creation of the priorities, the strategist will also need to consider the effect of network demands. These relationships are illustrated in **Figure 7** below.

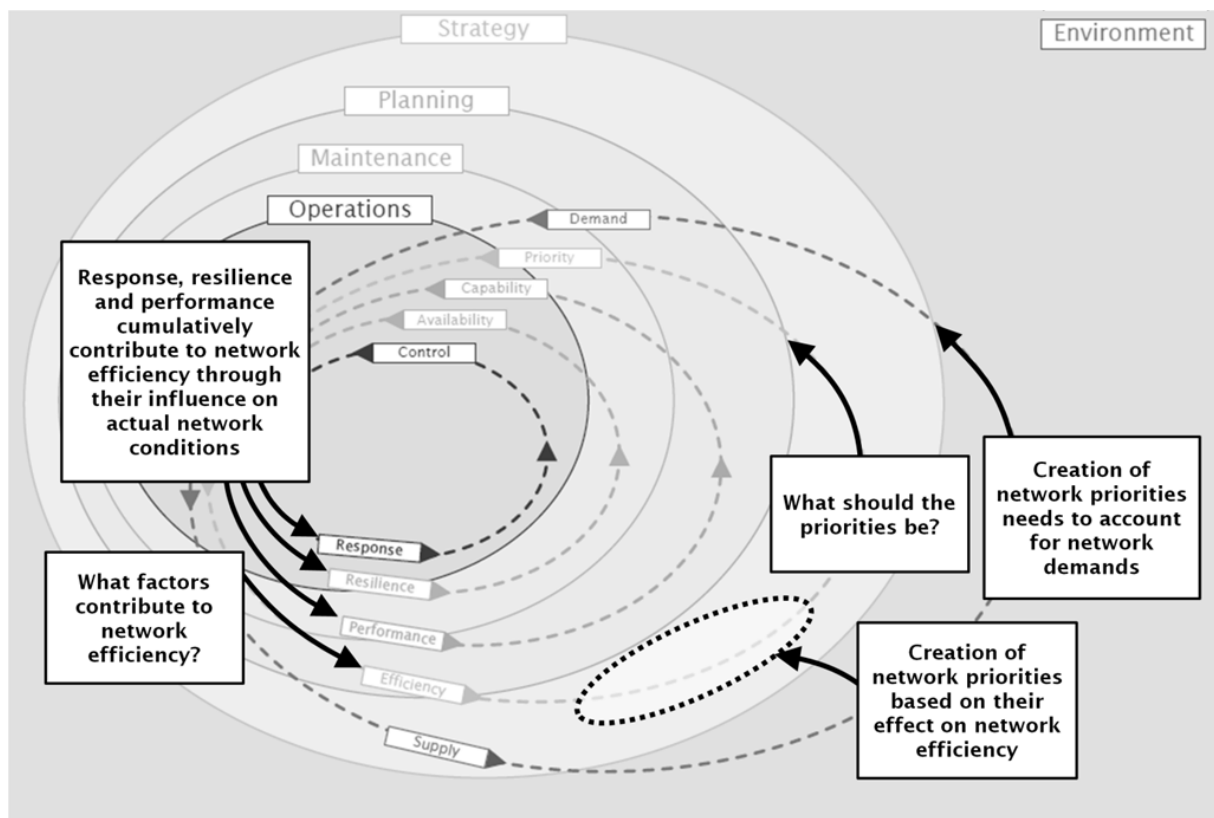


Figure 7 - How the Strategy network activity should create network priorities as described by the model

A **planner** proposes to develop a new arterial road upgrade project with improved bus network performance. The network variable that the planner seeks to change is

capability / performance. Development of the new capability should consider:

- Response of the network to Operational control, i.e. how effective are we at controlling traffic flow where buses need priority?
- Resilience of the network, i.e. how often will traffic signals fail preventing buses from getting priority at intersections?

Therefore, the planner should collaborate with operators about ways to enhance the performance of their proposed capability through desirable operational controls, such as advanced bus green time at signals. They should also collaborate with maintainers about ways to enhance the resilience of their proposed capability by minimising the frequency of faults at signalised intersections along the arterial corridor, as this will affect bus performance.

In creation of the capability priorities, the planner will also need to consider the *demand* for bus travel and *priorities* for levels of service in bus reliability which are both also managed by strategists. These relationships are illustrated in **Figure 8** below.

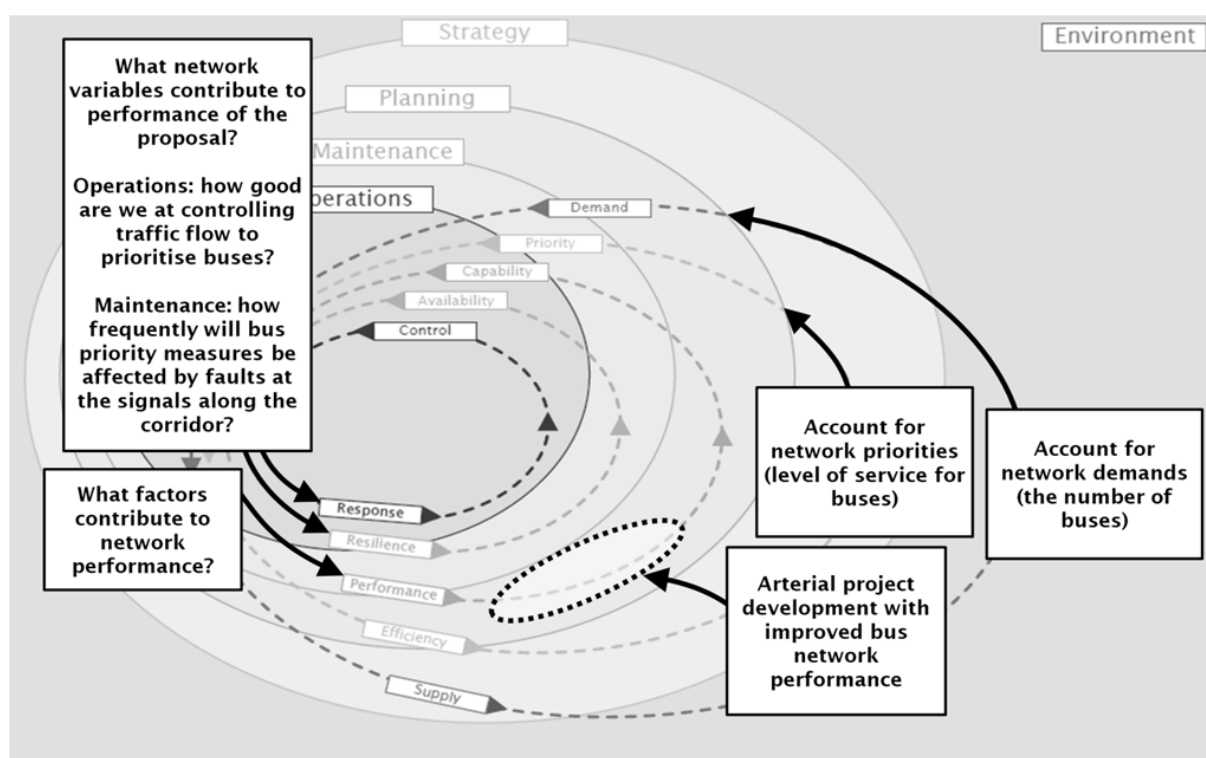


Figure 8 – How the Planning network activity should create new capabilities as described by the model

Conclusion

The objective of this paper was to describe a conceptual model that can be used to explain increasingly complex and interconnected transportation networks.

The model was originally developed to explain the relationship of Operations to the other network activities and variables, but can also be applied as a model for explaining the nature of the wider transportation network.

The model can be used as a collaborative tool to identify the relationship between network activities and network variables. By understanding and applying the properties of the network variables and activities, individuals can collaborate more effectively with other disciplines in the industry.

This is an important step in overcoming the competing demands that naturally occur when disciplines work together.

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