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Framework and Conceptual Solution for Integrating Road Network Operations Planning into Real-time Traffic Management

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Contents

Executive Summary **7**

1 Introduction **11**
1.1 Objectives 11
1.2 Project Strategy / Scope of Work 12
1.3 Project Outcomes 13

2 Review of Literature **14**
2.1 Similar planning to operations frameworks 14
2.1.1 TMR network optimisation framework 14
2.1.2 Victoria's SmartRoads Framework 15
2.1.3 AUSTROADS Network Operations Planning Framework 19
2.1.4 FHWA - Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach 20
2.1.5 NZ - Network operating framework 22
2.2 Key components of the frameworks 24
2.2.1 High-level vision, function and objectives 25
2.2.2 Network hierarchy 26
2.2.3 Operating Targets 27
2.2.3.1 Road Use Hierarchy of VicRoads 29
2.2.3.2 Mode share priorities of One Network Framework 29
2.2.3.3 Modal Priority Assessment of Roads and Streets Framework 30
2.2.3.4 Target Minimum Performance LoS of Network Operations Planning Framework 31
2.2.4 Performance Gaps 31
2.2.5 Strategy Selection 33
2.3 Gaps and Findings from Literature Review 34

3 Conceptual framework **37**
3.1 Proposed structure of the framework 37
3.2 High-level vision, function and objectives 40
3.3 Movement and Place matrix for Queensland 41

3.4 Identification of M&P matrix categories . . . 41
3.5 Process of gap evaluation . . . 43
3.6 Assigning desired priority . . . 45
3.7 Observed priority . . . 47
3.7.1 Key Performance Indicators . . . 48
3.8 Relevant strategies . . . 49
3.9 Design of the database Ops DB . . . 53
3.10 Case study in Brisbane . . . 56
3.10.1 Identification of Movement and Place categories . . . 56
3.10.2 Priority assignment . . . 57
3.10.3 Observed priority estimation . . . 58
3.10.4 Visualizing performance gaps . . . 59
3.10.5 Strategy selection . . . 59
3.11 Summary . . . 61

4 Prototype Interface **63**
4.1 Area Selection . . . 63
4.2 Priority Assignment . . . 65
4.3 Observed Priority Estimation . . . 68
4.4 Visualizing Performance Gaps . . . 69
4.5 Strategy Selection . . . 71
4.6 Operation Database (Ops DB) . . . 74
4.7 Real-Time Monitoring . . . 76
4.8 Summary . . . 77

5 Conclusions **79**
5.1 Summary of Key Findings . . . 79
5.2 Limitations and Recommendations for Future Research . . . 80

6 Appendix **82**
6.1 Movement and Place frameworks from literature . . . 82
6.1.1 New South Wales' Movement and Place framework . . . 82
6.1.2 Victoria's Movement and Place framework . . . 84
6.1.3 AustRoads' Movement and Place framework . . . 86
6.1.4 New Zealand's One Network Framework . . . 88
6.1.5 Auckland's Roads and Streets Framework . . . 90
6.1.6 London's Street Family Framework . . . 94
6.2 Comprehensive list of Key Performance Indicators . . . 96

List of Figures

1 Proposed structure of the framework 8

2.1 SmartRoads framework 15
2.2 Road network at Camberwell junction 16
2.3 Operating gap example 17
2.4 An example of a change assessment for general traffic 18
2.5 An example of a change assessment for each transport mode 19
2.6 Example of an objective tree 22
2.7 The process diagram of Network Operating Framework of New Zealand . . 22
2.8 General structure of the framework 24
2.9 Road Use Hierarchy of VicRoads 29
2.10 Mode classification and mode share priority by New Zealand's ONF 30
2.11 Modal priority chart - Roads and Streets Framework of Auckland 30
2.12 Minimum target performance matrix by Austroads 31
2.13 Operating gap example 32

3.1 General structure of the framework 38
3.2 Modified structure of the proposed framework 38
3.3 Proposed structure of the framework 39
3.4 Simplified solution to the proposed framework 40
3.5 (a) M&P matrix for urban areas (b) M&P matrix for urban areas 42
3.6 (a) Identification of M&P categories for the selected area; (b) M&P matrix of the area selected; 43
3.7 The process of gap evaluation 44
3.8 A sample of priority matrix 45
3.9 DP matrix for (a) Through movement; (b) From or To movement; 46
3.10 Base Desired Priority matrix 47
3.11 Modified DP matrix 47
3.12 Priority matrix with gaps 52
3.13 Framework of Ops DB 53
3.14 Structure of Ops DB 54
3.15 Scenarios - Component of Ops DB 54

3.16 Links - Component of Ops DB 54
3.17 Strategies - Component of Ops DB 55
3.18 KPIs - Component of Ops DB 55
3.19 KPI observations - Component of Ops DB 56
3.20 Ipswich city corridor 57
3.21 Different link types 58
3.22 (a) Identification of M&P categories of the study area; (b) M&P matrix of the area selected; 58
3.23 Initial desired priority values 59
3.24 Priority matrix with desired priority values of the link of interest 59
3.25 Observed priority values of the link of interest for Through movement . . . 60
3.26 Observed priority values of the link of interest for From or To movement . . 60
3.27 Visualisation of gaps of the link of interest 60
3.28 Process of selection of a strategy through Ops DB 61

4.1 Map highlighting the selected area and key intersections along Wembley Road. 64
4.2 Illustration of various area types, including shopping centers and school zones 64
4.3 Segmentation of the selected area into smaller links 65
4.4 Interface for assigning M&P category to links 66
4.5 Visual representation of desired priorities by travel mode 67
4.6 Top desired priorities for each link shown in a simplified, zoomed-out view 67
4.7 Links along the eastern side of Wembley Road 68
4.8 Map displaying performance gaps with color-coded lines indicating the difference between desired and observed priorities 69
4.9 Visualization of gaps in public transportation performance for from/to movement 70
4.10 Bar charts comparing desired and observed priorities for three links, highlighting performance gaps 71
4.11 Window for selecting and evaluating improvement strategies for links . . . 72
4.12 Details about relevant KPIs and recommended strategies for addressing gaps for each link 72
4.13 Access to stored scenarios in the database associated with proposed strategies 73
4.14 Analysis showing the impact of strategies on observed KPIs 73
4.15 Comprehensive details on database components 74
4.16 Overview of chosen strategy, its applications, locations, and impact on different KPIs 75
4.17 Analysis of KPIs, including scenarios, performance changes, and recommendations 75
4.18 Illustration of the process linking strategy selection to the computation of observed priorities for real-time monitoring 76

4.19 List of active scenarios for ongoing monitoring 76
4.20 Window for tracking changes in scenarios over time, with analysis options based on observed priority data 77

6.1 A sample of movement and place project by NSW 84
6.2 Movement and place framework by Victoria 85
6.3 Road type and function 87
6.4 (a) M&P focus areas for improving travel time (b) M&P focus areas for improving pedestrian facilities 88
6.5 A case study of Movement and place framework by NZ 90
6.6 Typology matrix of Roads and Streets framework of Auckland 91
6.7 Roads and Streets Framework process of Auckland 92
6.8 Types of streets as defined by London's Street Family Framework 95

List of Tables

2.1 Overview of various Movement and Place frameworks in use 28
2.2 Limitations of the key components of the framework 35

3.1 Definition of through movement and from/to movement for different modes 44
3.2 KPIs of Public Transport (PT) for Through movement 49
3.3 KPIs of Public Transport (PT) for From or To movement 49
3.4 KPIs of Pedestrians for Through movement 50
3.5 KPIs of Pedestrians for From or To movement 50
3.6 KPIs of Cyclists for Through movement 51
3.7 KPIs of Cyclists for From or To movement 51
3.8 KPIs of Private Vehicles (PV) and Freight (F) for Through movement . . . 51
3.9 KPIs of Private Vehicles (PV) and Freight (F) for From or To movement . . 51

4.1 Example calculation of observed pedestrian priorities for links 1, 2, and 3 . 68

6.1 Comprehensive list of KPIs of Public Transport (PT) for Through movement 97
6.2 Comprehensive list of KPIs of Public Transport (PT) for Through movement (Contd.) 98
6.3 Comprehensive list of KPIs of Public Transport (PT) for From or To movement 99
6.4 Comprehensive list of KPIs of Pedestrians for Through movement 100
6.5 Comprehensive list of KPIs of Pedestrians for From or To movement 101
6.6 Comprehensive list of KPIs of Cyclists for Through movement 102
6.7 Comprehensive list of KPIs of Cyclists for From or To movement 103
6.8 Comprehensive list of KPIs of Private Vehicles (Freight) for Through movement 104
6.9 Comprehensive list of KPIs of Private Vehicles (or Freight) for From or To movement 105
6.10 Details of various performance dashboards 106
6.11 Details of various performance dashboards (Contd.) 107

Executive Summary

This project focuses on developing a performance-based, multi-modal network management framework to translate high-level directions and planning aspirations into network operating plans and facilitates their creation and management using a prototype interface.

To understand current practices and advancements in real-time traffic management, considering the inclusion of high-level directions, a review phase was conducted as part of the project. This phase examined similar frameworks and best practices from Australia and other countries, including TMR's network optimization framework, Victoria's SmartRoads, and New Zealand's network operating frameworks.

While these frameworks offer valuable insights, some do not fully consider the Movement and Place (M&P) concept, lack detailed implementation guidelines for different travel modes, and rely on assumptions that can challenge system performance evaluation. These limitations highlight the need for innovative approaches to address the shortcomings of existing frameworks and provide more robust solutions for managing road networks.

As a result, this project proposed a new framework that offers a straightforward and detailed approach for translating high-level objectives such as safety, accessibility, and efficiency into real-time traffic control operations. Figure 1 presents the overall structure of the proposed framework.

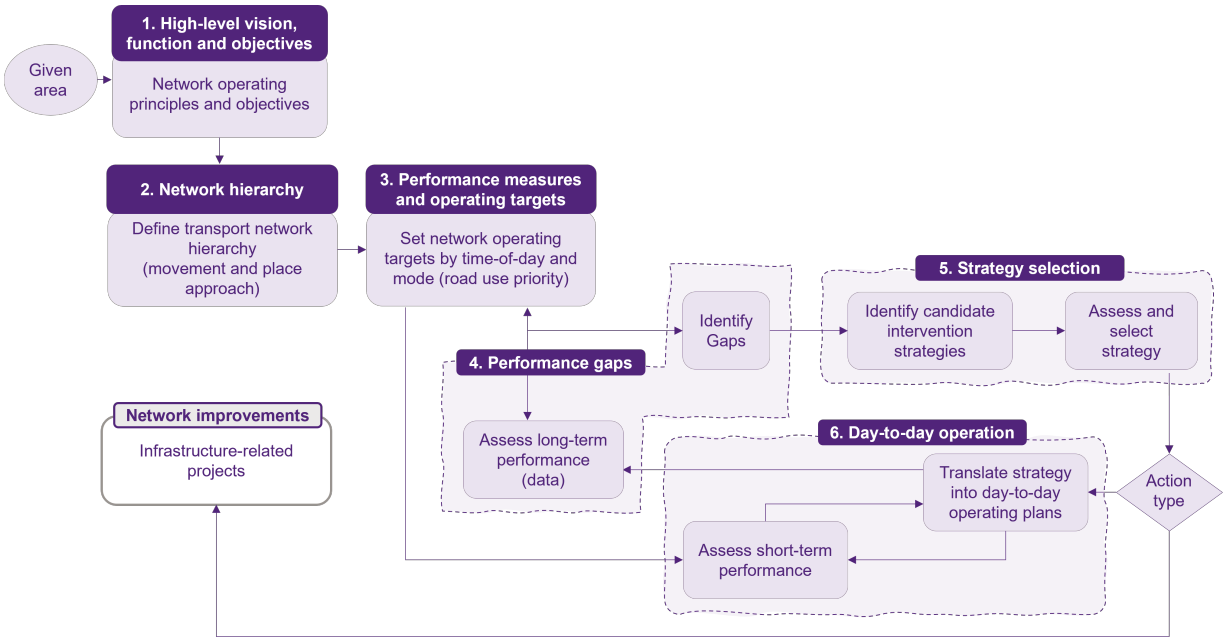


Figure 1: Proposed structure of the framework

The framework consists of six main components, each addressing a specific aspect of the overall system. Following is an explanation of these components:

1. High-level vision, function and objectives

This framework is designed to align with the strategic goals established by TMR. These objectives focus on creating an accessible and convenient transport system, ensuring safety for all travelers, providing seamless and personalized journeys, enhancing the efficiency and reliability of transport for people and goods, and promoting sustainable, resilient, and livable communities.

2. Network hierarchy

The proposed framework performs analysis at the link level, dividing areas into smaller segments based on consistent characteristics. It utilizes the Movement and Place (M&P) approach to classify links, balancing transportation needs with the development of livable spaces. This classification considers location-specific attributes, road-use characteristics, proximity to public transport, and the presence of activity centers. The M&P classification assigns a score from 1 to 5 for both movement and place functions. Since link classification depends on the type of activities and activity centers, links may be classified differently at various times of the day.

3. Operating targets

Operating targets, referred to as "desired priorities," represent the desired performance of the traffic network, integrating the network hierarchy with high-level objectives. They are defined numerically, ranging from one (poor performance) to six (best performance). These targets are set for each travel mode (pedestrians, cyclists, public transport, private vehicles, freight) under different movement types (from/to and through). For each travel mode and movement type, the desired priority is defined based on movement and place link classification and the desired priority matrix.

4. Performance gaps

Performance gaps for each mode and movement type are determined by calculating the difference between the desired priority and the observed priority, both measured on a scale from 1 to 6. Observed priorities are derived from specific KPIs related to mobility, safety, accessibility, reliability, and sustainability. Different methods, such as lowest value, regular average, or weighted average, are used to calculate the observed priority. The performance gap is defined as the difference between desired and observed priorities, highlighting areas that need improvement.

5. Strategy selection

The framework incorporates a range of improvement strategies that are practical and feasible for TMR. These strategies fall into four categories: road transport, intelligent transport solutions, public transport, and regulation and policy, addressing both the supply and demand aspects of the network. Additionally, a conceptual Operations Database (Ops DB) was developed as part of this project to facilitate the evaluation and selection of strategies, bridging the gaps between observed and desired performance. The Ops DB provides a systematic, data-driven knowledge base, including entities such as Scenarios, KPIs, Links, Strategies, and KPI Observations. This may assist to identify and recommend effective strategies based on past implementations and their impacts.

6. Day-to-day operation

The general structure of the framework includes two loops: the first for short-term performance monitoring and the second for long-term performance monitoring. Both loops aim to enhance the observed performance to meet the 'operating targets.' The short-term loop focuses on calibrating and adjusting day-to-day operating plans, while the long-term loop updates the strategies and translates them into new operating plans.

Prototype Interface

In addition to the overall framework design, this project introduces a user-friendly prototype interface suitable for both experienced and less-experienced operators. It operationalizes the framework by visualizing priorities and performance gaps, suggesting improvement strategies, and including real-time monitoring to track changes, analyze KPIs, and export data for further analysis, supporting continuous improvement.

Chapter 1

Introduction

Integrating road network operations planning into real-time traffic management is essential, especially in the context of multi-modal transportation networks and dynamic demand patterns. Instead of focusing on individual goals and ignoring the impact on the overall network performance, it is sensible to work towards a holistic approach that prioritizes the operational issues with larger performance gaps. Aligning network operating plans with high-level directions can promote sustainable transportation goals such as reducing greenhouse gas emissions, promoting active transportation modes, or supporting public transit. By incorporating such operational plans and strategies, transportation agencies can contribute to long-term environmental and societal goals.

However, this necessitates a seamless collaboration and communication among stakeholders involved in transportation planning and operations, transport planners, traffic operators and researchers. Such an inter-disciplinary coordination allows for more efficient allocation of resources such as staffing, equipment, and infrastructure investments. Therefore, developing a framework to translate high-level intent of transport planning into network operating plans and local traffic control plans is critical for optimizing transportation efficiency, responsiveness to dynamic conditions, coordination across modes and time-of-day, enhancing safety, supporting sustainable transportation goals, facilitating collaboration and communication, and efficient resource allocation.

1.1 Objectives

This project aims to develop a framework for performance-based, multi-modal network management that can translate directions from various strategies, policies, and plans into dynamic, real-time traffic control operations. The project objectives are:

1. Develop a framework to translate the high-level intent of transport planning into network operating plans that that will guide the Transport Main Roads (TMR) road operations staff to develop multi-modal operational strategies that are appropriate for the road classification based on movement and place principles.

2. Develop a conceptual solution to operationalise the framework, which includes enabling the creation and management of network operating plans and developing proof-of-concept interfaces and visualization that provide network operations practitioners with real-time information on network performance, gaps against key performance indicators, and recommended operational plans to support better alignment between day-to-day operations and higher level strategies.

1.2 Project Strategy / Scope of Work

The overall scope of this project includes developing a framework and conceptual solution for integrating road network operations planning into real-time traffic management, gathering requirements to implement the framework, and developing a concept of operations and prototypes to show how the solution conceptually works.

A comprehensive review of the following studies was conducted as an integral part of this project:

- Similar frameworks and best practices that exist in other states in Australia and other countries
- Relevant strategies, network operating principles and objectives, transport network hierarchies by government stakeholders
- Planning and operational guides and tools available in TMR
- Key performance indicators (KPI) for transport network planning and operations
- Existing data sources and evaluated strategies considered by TMR

Chapter 2 discusses all the aforementioned studies and more in detail along with their limitations and field implementation challenges.

Based on the insights gathered from the literature review, Chapter 3 of this project presents a framework for performance-based, multi-modal network management that can translate directions from various strategies, policies, and plans into dynamic traffic control operations. The proposed framework translates the high-level directions into network operating plans and into real-time operations through a network management system. In addition to proposing the structure of the framework, the project provides a conceptual solution to operationalise the framework by:

- Enabling the creation and management of network operating plans (considering the higher-order inputs and understanding how these are processed)
- Presenting network performance, gaps and the potential benefits for initiatives
- Showing how the control system takes direction from the network operational planning intent and performance information

Chapter 4 provides conceptual interfaces and visualisation that will demonstrate the recommended operational plans, providing a level of traceability back to higher-level strategies. The developed concepts along with real-time monitoring are explained by implementing on a study area in Logan city.

1.3 Project Outcomes

The project successfully achieved the expected outcomes, listed as follows.

1. A comprehensive literature and best practice review of relevant frameworks, strategies, network operating principles, practical guides and tools.

2. A conceptual solution to incorporate the M&P concept into the planning phase that effectively combines various location-specific factors such as road operational and geometric characteristics (signal, design speed, number of lanes), road space allocation (mixed traffic, bus-only lanes, bus-taxi lanes), place characteristics (type of stop or destination, activity type), and the demand and density of each mode over different times of the day (cars, buses, trucks, cyclists, pedestrians).

3. A visualisation concept in terms of 'priority matrix' is developed, for depicting road use priorities capturing multi-modal and time-of-day operational intent.

4. Provision of a comprehensive list of well-defined key performance indicators to analyse the network performance for multiple applications.

5. Operation Database (Ops DB) enabled a better linkage and communication between the planning and operation phases, by storing and linking all the information and knowledge in and out of each phase in a digital format that is easily searchable, shareable, and reusable. In addition, the database build a knowledge base for future strategy recommendations to improve certain KPIs from the historic experience.

6. A prototype visualisation interface to demonstrate performance at locations against objectives and the resulting operating gaps in an effective and efficient manner.

7. Performance monitoring is enabled for users to monitor the impact of changes over time in a selected scenario, analyze changes in relevant KPIs, and export data for further analysis and reporting.

Chapter 2

Review of Literature

2.1 Similar planning to operations frameworks

Management of road networks is an ever-evolving challenge, particularly as urbanization and mobility demand grow. This section presents real-world examples of planning to operations frameworks, providing insights on how such processes improve traffic flow, increase safety, and accommodate modern transportation needs. Through critical consideration of the key goals, objectives, strategies, and implementation of different frameworks, there can be a deeper understanding of new directions for framework development.

2.1.1 TMR network optimisation framework

The Department of Transport and Main Roads (TMR) has developed a network optimization framework. This framework places emphasis on prioritizing low-cost and non-infrastructure solutions, striking a balance between greater efficiency, improved reliability, and constrained funding. TMR utilizes a network optimization framework to envisage future transportation requirements. Through this approach, they are able to maximize investments, optimize infrastructure utilization, and effectively address transportation challenges.

TMR strives to incorporate the network optimization framework as a standard practice within its infrastructure planning process. This approach enables them to accomplish many benefits with limited resources. These include enhanced returns from government investment, decreased travel time for both passenger transport and private vehicles, improved travel time reliability, enhanced customer experience, reduced vehicle operating costs, as well as lowered vehicle emissions, accidents, and other associated impacts.

TMR's network optimization framework encompasses a variety of low-cost and non-infrastructure solutions specifically designed to address various transport problems. They focus on increasing the capacity of, or demand for, elements of the existing transportation system. This approach targets both the supply and demand sides of the network, providing opportunities to address more network-wide issues.

The network optimization solutions within TMR's framework cover areas such as road and public transport, intelligent transport solutions, and regulation and policy. These solutions include HOV lanes, incident management systems, signal optimization, bus priority lanes, and education campaigns. Leveraging these solutions can improve performance, increase capacity, and enhance the reliability of the existing network.

While the network optimization framework offers many benefits, it is specifically designed to ensure that network optimization solutions are assessed during the options analysis phase of major projects. It is not intended to serve as a real-time management tool, including defining operational intent, assessing a corridor or area for operating gaps, and selecting optimization strategies to reduce these gaps.

2.1.2 Victoria's SmartRoads Framework

SmartRoads, the framework developed by VicRoads for managing the current and future operations of Victoria's road network. It provides tools to manage competing road use priorities, congestion, evaluate network performance, and assess candidate improvement/operation plans. With a long-term approach, SmartRoads is designed to increase the safety and efficiency of the road network while supporting the growth of activity centers by prioritizing specific modes of transport on certain roads and at particular times of the day. Specifically, this approach seeks to balance competing interests for road space, effectively managing congestion and ensuring safety, all while supporting the establishment of a sustainable transport system for the future. SmartRoads provides decision-making tools for improving the road network's efficiency for all users, including general traffic, freight, transit, cycling, and walking. It consists of several elements. Fig. 2.1 outlines these elements as sequential steps typically applied to an area around a road corridor, precinct, or activity center.

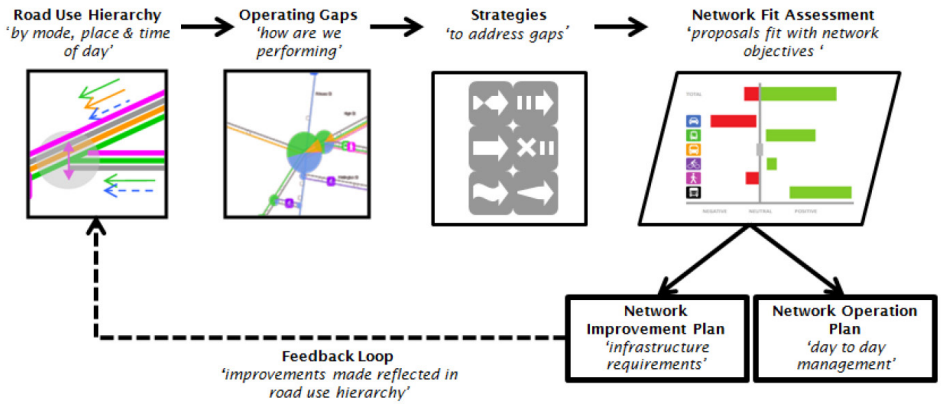


Figure 2.1: SmartRoads framework

The following subsections describe each element in the framework in more detail:

Road use hierarchy

The road use hierarchy outlines the vision for the road network's management. It involves the strategic road use and the relative priority assigned to each transport mode. The strategic road use determines priority based on transport mode and place (e.g., activity centers or shopping areas), acknowledging the relationship between the transportation network and the place it serves. Relative priority is assigned at one of five levels of encouragement, indicating the degree of priority for each mode during different times of the day and based on the surrounding activities, enabling a more efficient utilization of road space.

Fig. 2.2 shows an example of a simplified road network at Camberwell Junction in Melbourne. In this example, primary emphasis is placed on the bus (orange) and tram (green) priority routes that lead directly to the activity center. Bicycles are prioritized along separate routes (purple), while pedestrians (pink) are prioritized inside the activity center. For smooth traffic flow, general traffic (blue) is encouraged to pass around the center rather than through it.

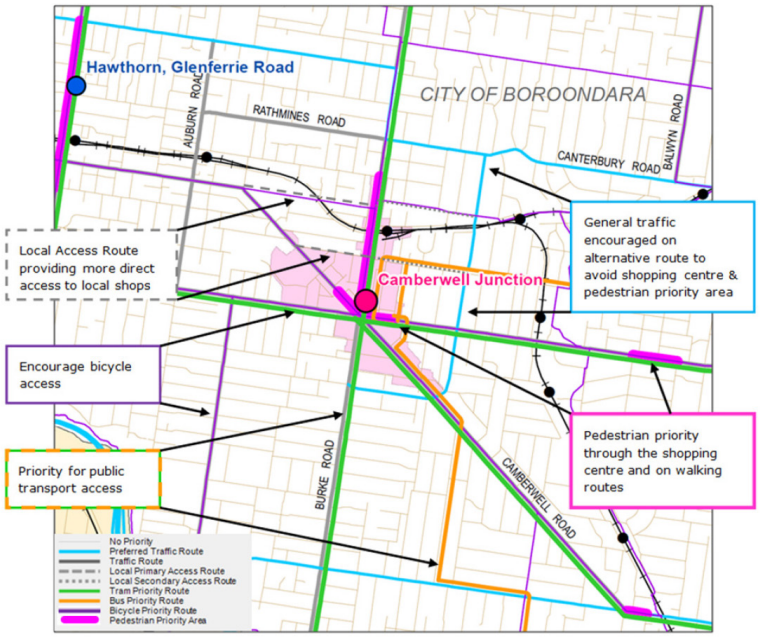


Figure 2.2: Road network at Camberwell junction

Operating gaps

The operating gap represents the difference between the desired performance and the actual performance of the network. It offers an analysis of the deficiencies in the road network and facilitates the improvement process. The operating gap is assessed based on multiple factors, which include:

- Level of service: This factor assesses the performance of each mode of transportation at a specific location
- Relative level of service: It serves as a measure of how effectively the network should operate
- Relative priority: priority granted to different modes according to government policies and other objectives
- Relative efficiency: The mode's capacity to transport people or goods
- Mode shift factor: This factor predicts the future growth of a particular mode

The operating gap provides insight into the complexity of the network's problems. Moreover, it facilitates quantitative analysis of the potential effects of proposed road improvements on all modes of transportation. To accomplish this, the network fit assessment tool, known as the NFA Tool, is employed to transform raw data into a more advanced network evaluation.

The NFA Tool provides a visual representation of operating gaps through pie charts displayed on a network map, as depicted in Fig. 2.13. Each pie size indicates the magnitude of the operating gap, where smaller pie sizes indicate better operational performance. Additionally, the proportions within the pie chart illustrate the extent to which deficiencies in specific modes contribute to the overall gap. In Fig. 2.13, the largest operating gap (highlighted in red) emphasizes that shortcomings in Public Transport (tram/bus) operations account more than half of the issues observed at this specific location (orange/green).

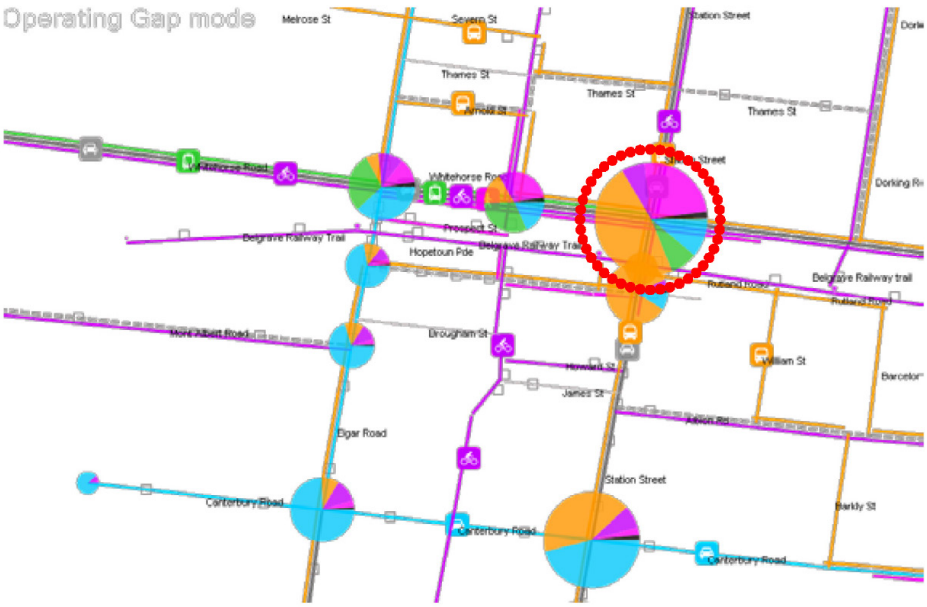


Figure 2.3: Operating gap example

Network strategies

Network strategies serve as guides for identifying solutions for network gaps. They offer supplementary direction concerning the specific interventions that can be employed to attain the desired level of priority. Typically, network strategies concentrate on subsets of the network rather than a single location. Each mode within the network is associated with a range of broad operational strategies. For instance, for public transport strategies may emphasize enhancing travel time reliability and increasing operating speeds. Strategies for bicycles often revolve around increasing on-road separation, minimizing conflicts with public transport, and providing more crossing opportunities. Similarly, pedestrian strategies prioritize reducing crossing delays, minimizing conflicts with other modes, and expanding available space.

Assessing network changes

The Network Fit Assessment (NFA) process evaluates whether changes to road operations align with road hierarchy objectives. The SmartRoads NFA Tool generates visual representations, as depicted in Fig. 2.4 and Fig. 2.5, to illustrate the impact of a proposed change. In Fig. 2.4, the green and red dots signify the cumulative positive or negative effects of all modes at a specific location, respectively. The bar graph in Fig. 2.5 displays the range of impacts, from the worst-case to the best-case scenario, for each mode under consideration. These outputs effectively communicate the potential consequences of a proposal on the transportation network, enabling key decision-makers, even those without a transportation engineering background, to grasp the implications involved.

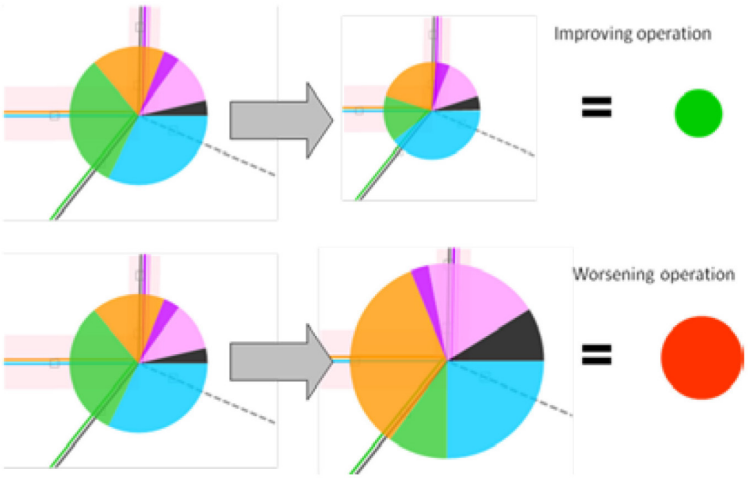


Figure 2.4: An example of a change assessment for general traffic

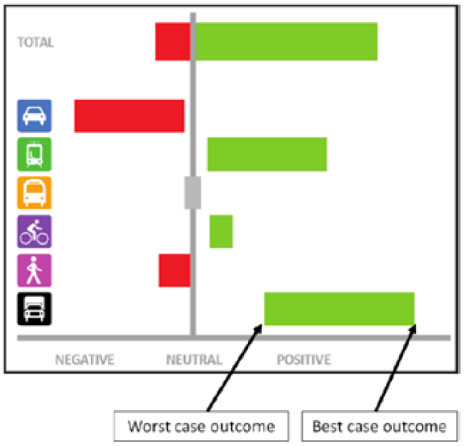


Figure 2.5: An example of a change assessment for each transport mode

The SmartRoads process culminates in two essential components: the Network Operating Plan (NOP) and the Network Improvement Plan (NIP). On the one hand, the NOP primarily focuses on enhancing the current operational efficiency of the existing network on a day-to-day basis, such as adjusting signal timing. On the other hand, the NIP outlines prospective infrastructure projects intended to improve network performance in the future, for example, constructing additional public transportation lanes. Both the NIP and NOP are derived from the strategic intent and operational objectives of the road use hierarchy, as well as the identification of existing and future operational gaps and the implementation of network strategies.

2.1.3 AUSTROADS Network Operations Planning Framework

The Austroads Network Operations Planning Framework is designed to assist network managers in monitoring road network performance and addressing gaps in service delivery. It recognizes the increasing complexity of road networks due to urbanization, population growth, and technological advancements. The framework aims to achieve objectives for both road agencies and road users while considering potential conflicts between their needs. It also plays a crucial role in infrastructure planning by enhancing the long-term efficiency of road infrastructure utilization. The framework consists of seven key steps:

- Setting clear objectives for network operations that align with overall performance improvement goals and prioritize service delivery to road users.
- Defining the geographic area, road hierarchy, and configuration of the road network, considering the integration of public transport and freight networks for effective transport systems.

- Establishing performance measures and standards to monitor network performance across various categories, including efficiency, reliability, productivity, amenity, safety, and environmental factors.
- Identifying management options to meet the needs of road users, such as traveler aid, road maintenance, traffic control, and demand management. The focus is on determining the most effective initiatives and their implementation strategies.
- Developing network operation plans by assessing the identified management options and incorporating a range of measures, including road improvements and intelligent transportation systems. These plans serve as inputs for road investment planning and resource allocation.
- Implementing network operation plans by considering interactions between initiatives, making operational adjustments, and collaborating with relevant government agencies. Prioritization and efficient roll-out strategies are emphasized.
- Continuously evaluating the plans and network performance by collecting data, reviewing cost-effectiveness, and assessing the extent to which objectives have been met. This iterative process helps refine strategies and ensure alignment with performance requirements.

2.1.4 FHWA - Advancing Metropolitan Planning for Operations: An Objectives-Driven, Performance-Based Approach

This guidebook outlines a comprehensive approach for enhancing metropolitan transportation planning through the integration of management and operations (M&O) strategies. The primary objective is to optimize the performance of both existing and planned transportation systems. M&O strategies encompass a wide array of activities, such as disseminating traveler information, coordinating traffic signals, managing incidents, and improving transit systems.

The proposed approach replaces the traditional project-based problem-solving approach to an objectives-driven, performance-based methodology. Instead of merely reacting to issues, the focus is on attaining desired system performance outcomes.

The approach revolves around specific operations objectives tailored to the regional transportation system, along with corresponding performance measures to achieve these objectives. These objectives and measures are integrated into the metropolitan transportation plan (MTP), enabling accurate tracking at the regional level and informing investment decisions.

The objectives-driven, performance-based approach to planning for operations includes the following key activities carried out collaboratively among planners, operators, and stakeholders:

1. Establishing one or more goals within the MTP, emphasizing efficient management and operation of the transportation system.

2. Developing regional operations objectives for the MTP, defining measurable statements of performance that align with the established goals.

3. Employing a systematic process to develop performance measures, analyze transportation performance issues, and recommend suitable M&O strategies.

4. Selecting M&O strategies within fiscal constraints to meet operations objectives for inclusion in the MTP and transportation improvement program (TIP).

5. Implementing M&O strategies through program investments, collaborative efforts, and specific projects.

6. Monitoring and evaluating the effectiveness of implemented strategies and tracking progress toward meeting regional operations objectives.

The approach is designed to be iterative, with regular monitoring and evaluation informing refinements and adjustments to operations objectives over time.

The integration of M&O in the MTP commences with the establishment of clear and concise goals that center on efficient transportation system management and operation. These goals serve as the foundation for defining measurable operations objectives, which, in turn, guide the selection and implementation of M&O strategies.

To support this guidebook, the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) have provided additional resources, including "Advancing Metropolitan Planning for Operations: The Building Blocks of a Model Transportation Plan Incorporating Operations"- A Desk Reference. This comprehensive reference includes tangible examples of operations objectives and associated performance measures that can be adapted to specific regions or directly incorporated into metropolitan transportation plans. It features cross-reference tables for easy access to operations objectives relevant to specific interests, followed by information sheets containing detailed operations objectives, performance measures, data requirements, M&O strategies, and anticipated safety benefits, organized by system performance outcomes and operations areas.

As a tool to assist in the development of a logical set of operational objectives, as well as to understand the relationship between goals, operational objectives, and M&O strategies, the desk reference presents the concept of an objectives tree, illustrated in Fig. 2.6. An objectives tree outlines the hierarchical relationship between outcome-based objectives and activity-based objectives, facilitating the linkage between regional goals, objectives, and M&O strategies. The process involves starting with a broad goal, creating higher-order outcome-based objectives, defining more specific and detailed operations objectives, and ultimately determining the necessary M&O strategies for accomplishing these objectives.

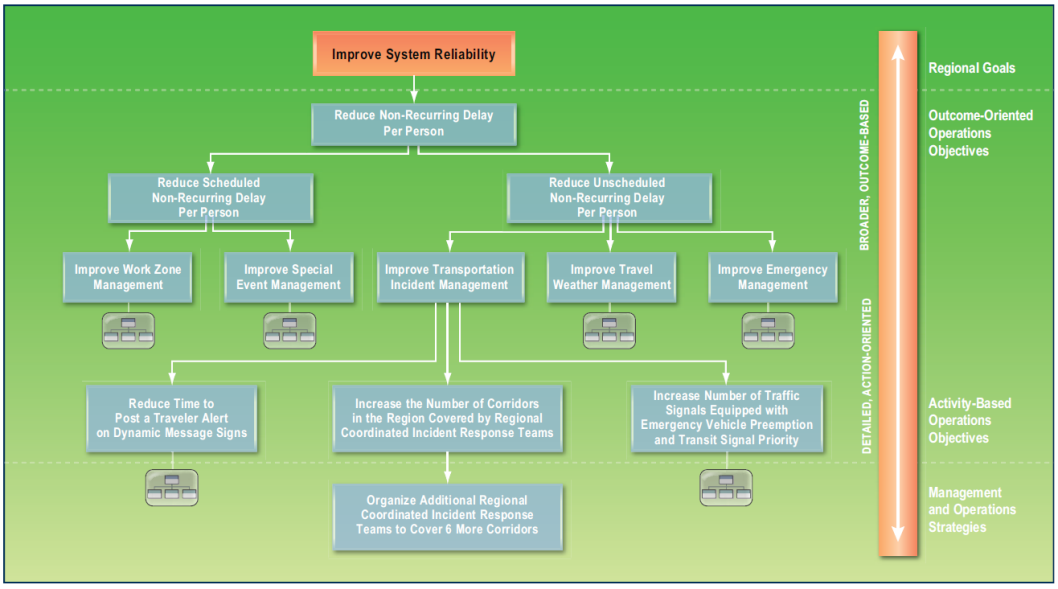


Figure 2.6: Example of an objective tree

2.1.5 NZ - Network operating framework

The network operating framework is designed fundamentally to link strategic intent with operational and planning policies through collaborative discussions across all stakeholders and at all levels. Similar to the previous frameworks, the framework focuses on the efficient movement of people and goods and not vehicles for a given time of day at network level. In addition, balancing the competing demands for limited space so as to achieve broader community goals is the holistic vision of this framework. The process followed in delivering network improvement plans and network operational plans is shown in Fig. 2.7.

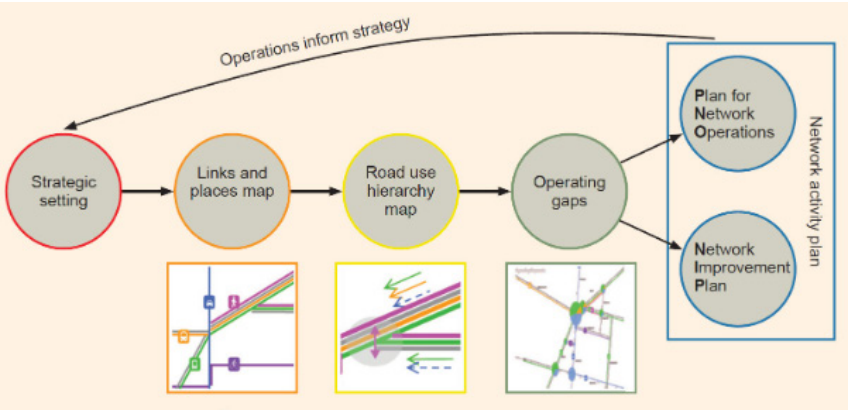


Figure 2.7: The process diagram of Network Operating Framework of New Zealand

As seen from the figure, the framework comprises four stages prior to the development of operational plans.

1. Strategic setting: This is the first stage of the framework where goals and objectives to ensure safe and efficient movement of people and goods are discussed. The outcome is an agreed set of short and clear strategic objectives and broad transport principles that help determine modal priority with respect to time of day.

2. Links and places map: At this stage, each mode on the network (pedestrian, public transport, cycling, general traffic and freight) and the adjacent land use are mapped, to describe the strategic modal network and land use types for the area. The map classifies the network into primary (main line) and secondary (feeder line) routes for each mode.

3. Road use hierarchy map: The road use hierarchy maps, as the name says, embeds time-based priority principles for each mode and by time of place that reflect the strategic intent decided in stage 1. Different kinds of road use hierarchies considered are:

   (a) Road use hierarchy - by mode: Unlike the traditional road hierarchies that classified based on the function of the road, this framework considers hierarchy based on the users of the road network. Such a classification would help alleviate congestion among the competing modes during peak periods.

   (b) Road use hierarchy - by place: The city centers and the activity centers that are common locations accommodating peak demand needs to be prioritized during morning and evening peak periods respectively. This would allow priority and space to be made available on other roads for other modes.

   (c) Road use hierarchy - by time: The desired road use priority may vary for different periods of the day depending on travel demand and the adjacent land use and activity. The four key time periods for road use are: AM peak (morning), inter peak (between AM and PM peak), PM peak (afternoon) and off peak (evening).

4. Operating gaps: At this stage, operating gap i.e. the difference of the current performance of the network from the desired performance of the network that is needed to deliver the strategic intent is evaluated.

This is followed by an assessment process that evaluates the impact of proposed plans to bridge the operating gap. The framework has a tool that visually demonstrates overarching effect and any detailed trade-offs being made in order to deliver strategic goals. It also enables users to make informed travel decisions in relation to how they see the network developing and being operated.

2.2 Key components of the frameworks

The general structure of the transport network planning to traffic operations framework, in view of the various frameworks from literature and the vision of TMR, is presented in Figure 2.8.

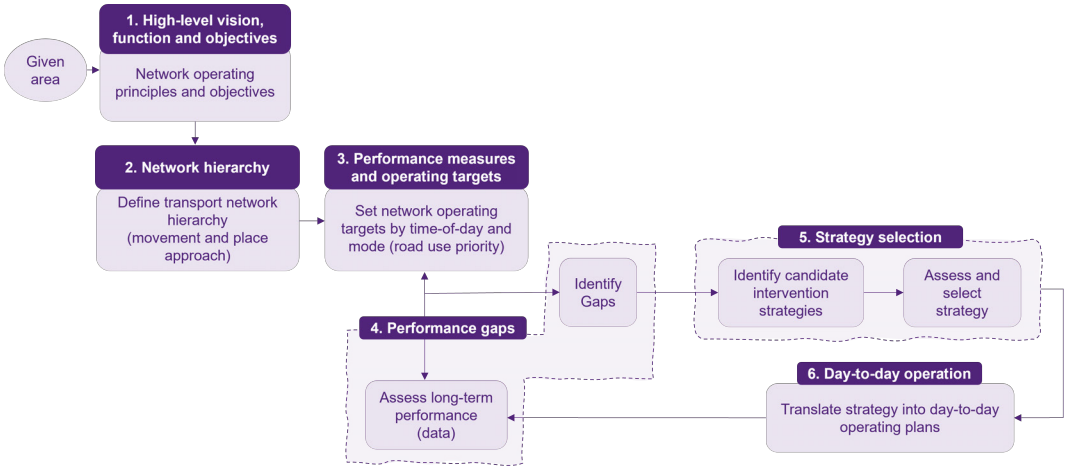


Figure 2.8: General structure of the framework

For a given area during a given time of day, the first stage towards building the framework is to consider the most relevant objectives with a high-level intent, among the network operating goals and principles in place. The consecutive stage is to classify the transport network hierarchy with respect to the significance of different types of roads in the network. Once the hierarchies are defined, network operating targets are set on each of the road categories with respect to the defined objectives or transport modes. In order to verify if the targets are met, the performance of the network is assessed through a predefined Key Performance Indicators (KPIs) and the available data sources. Subsequently, the operating gap which is nothing but the difference between the observed and target performance is quantified for various road categories under consideration.

The identified gaps are then listed in the order of priority with respect to each mode and Time of Day category. The consecutive step to this calls for the identification of relevant candidate intervention strategies. These strategies are high-level with broader outcomes (similar to 'Network Operating Plans' in the literature) and assessed over longer time periods. A quantitative assessment of the strategies aids in selecting the most critical and feasible strategy that bridges the operating gap the most. The selected strategy is then translated into day-to-day operating plans whose performance is monitored on a regular basis. Implementation of the day-to-day operating plans, that achieves the high-level intent in the best way possible, marks the last stage of the framework. Assigning targets and assessing the performance of the operating plans in comparison to those targets is an iterative process with respect to Time of Day and different objectives.

2.2.1 High-level vision, function and objectives

High-level objectives are a translation of the transport goals, planning policies and network operating principles of the concerned local and state level transport authorities, in view of a 'vision' for the study area. For example, the Transport Integration Act (TIA) set by Victoria Department of Transportation primarily enables equity and integration in decision making among different transport sectors. The following are the decision-making principles devised by TIA:

1. Integrated decision-making, wherein coordination between all levels of government and private sectors is ensured
2. Triple bottom line assessment, wherein economic, social and environmental impact on benefit-cost analysis is considered
3. Equity between people
4. The transport system user perspective
5. The precautionary principle, that ensures careful evaluation to avoid serious or irreversible damage to the environment
6. Stakeholder engagement and community participation
7. Transparency

In addition to these, safe-design principles, right-of-way principles for different modes and energy conservation principles are often considered in the frameworks. In line with these principles and transport planning policies, the objectives of a network operations framework are framed. Majority of the objectives are specific and are listed as:

1. Integration of land use and transport
2. Safety, security, health and well being
3. Network resilience
4. Accessibility and reliability
5. Efficient, reliable and productive transport for people and goods
6. Network resilience and adaptability to changing environments
7. Environmental sustainability
8. Social and economic inclusion

The above list constitutes the common objectives considered by Austroads, Victoria, New Zealand and New South Wales. A more detailed approach to this is developed by FHWA, where in the objectives are categorized into (i) Outcome-oriented operations objectives (broader) and (ii) Activity-based operations objectives (detailed). The outcome-oriented objectives are related to system efficiency, system reliability and system options (that refers to the user's mode and route choice options to make a trip). The activity-based objectives are related to the management of arterials, freeways, freight traffic, travel demand, transit operations, travel weather, work zone, emergency or incident management etc. that are associated with the broader level objectives. Such a detailed stratification of objectives instead of having them at the broader level, enables better understanding to the multiple categories of people associated with them. Once the objectives are framed, the performance of the network in achieving each of the objectives is evaluated to assess the operating gap prevailing in the current traffic situation.

2.2.2 Network hierarchy

This section discusses the need for a transport network hierarchy and the way in which road use hierarchies are defined for a given rural or urban transport network. The objective of this section is to understand the concept of the transport network hierarchies defined by various countries within Australia such as NSW, Victoria, NZ and AustRoads, and to explore the balance between them in order to achieve a better built environment.

The network hierarchy classification is achieved through "Movement and Place" (M&P) framework. It is a cross-disciplinary, place-based approach to the planning, design, delivery and operation of transport networks. It ensures integrated and efficient movement of people and goods with amenity and quality of places. The key objectives of the framework, in general, are

- Strong economy and quality of life - by supporting sustainable development, usage of space efficiently and enabling the movement of goods
- Successful places - by improving the amenity of places and supporting the need of all users
- Connecting the customers' whole lives - by balancing movement within, to and from, and through places along with making safer environments

Trade-offs may be required to achieve the best fit for these objectives. Different countries named their frameworks different with an overall goal to better integrate transport and land use. The different frameworks presented in this context are: (i) New South Wales' Movement and Place framework, (ii) Victoria's Movement and Place framework, (iii) AustRoads' Movement and Place framework, (iv) New Zealand's One Network Framework, (v) Auckland's Roads and Streets Framework and (vi) London's Street Family Framework. The detailed structure of the framework, different modules that it comprises of and different movement

and place matrices designed in the process are discussed in detail in the Appendix section of this report.

Overall, it can be stated that the Movement and Place framework offers a holistic approach to urban planning, ensuring that streets and transport systems contribute to both efficient mobility and vibrant, livable places. Developing policies and regulations that support the integration of movement and place considerations into all stages of urban and transport planning leads to more resilient and adaptable urban environments. Table 2.1 provides an overview of the M&P frameworks discussed.

To summarize, the Movement and Place framework, while beneficial, has several limitations that can impact its effectiveness and implementation. These limitations include:

1. Complexity in balancing conflicts of interest and prioritization challenges
2. Resource intensive and time consuming
3. Regulatory Constraints - Existing policies and regulations may not be flexible enough to accommodate the integrated approach required by the movement and place framework
4. Ensuring consistent application of the framework across different areas and projects can be difficult, particularly in large cities with diverse neighborhoods
5. Balancing movement and place needs with environmental sustainability can be challenging, especially in areas prone to pollution or ecological sensitivity
6. Changes to street design and usage can face resistance from local communities, especially if they perceive the changes as detrimental to their daily lives or if there is inadequate consultation
7. Impact Assessment - Measuring the success of the framework in achieving both movement and place outcomes can be complex, requiring sophisticated metrics and data collection

After deciding on the network or road use hierarchy, the key stages of the transport planning to network operations framework are: defining the operating targets and thereby assessing the current performance, analysing the gaps that are persistent with respect to achieving these objectives that are quantified through performance measures and incorporating different strategies to bridge the gaps. In other words, it can be said that all these stages are inter-dependent and therefore connected.

2.2.3 Operating Targets

Majority of the frameworks proposed the operating targets either in terms of modal priorities or road use priorities for different modes. However, the Time of the Day factor is considered by the SmartRoads framework of Victoria among the frameworks discussed in this report.

Table 2.1: Overview of various Movement and Place frameworks in use

Country	Framework	Description	Limitations
New South Wales	Movement and Place framework	Emphasis towards place-based strategic design and planning	Though this framework is first-of-its-kind, the implementation challenges, the regulatory constraints or the feasibility for field implementation is not explored
Victoria	Movement and Place framework	The highlights of the framework are as follows: • Future focused multi-modal approach to network planning with four distinct modules • Introduced movement and place matrix that encompasses the mix of function of various transport links and modes	Conflicting priorities, economic and commercial concerns, and space constraints are not explored
Austroads	Movement and Place framework	The highlights of the framework are as follows: • Balanced approach towards attaining equilibrium with respect to mobility and access while adhering to the priorities of users that changes with time of day and day of week • Classified transport network into multiple categories on the basis of their purpose to satisfy user needs and the modes used	Complexity in balancing conflicts of interest and prioritization challenges is very case-specific and is not discussed in detail
New Zealand	One Network Framework	The highlights of the framework are as follows: • Strategic tool that evolves out of the One Network Road Classification • Redefined place function by making it people-centric with due importance to their perception on different places as important destinations and movement function as a function of mobility of different modes • Introduced street families to integrate M&P function elements	The criteria considered while assigning M&P categories to different streets is not clear
Auckland	Roads And Streets Framework	The highlights of the framework are as follows: • Detailed framework on identification of different roads and streets with respect to their M&P functions • Serves as a reference guide for any strategic planning or management projects of Auckland	Modal priority definition and evaluation is not clearly discussed
London	Street Family Framework	The highlights of the framework are as follows: • Movement and Place axes are clearly defined for each category ranging from local significance to strategic significance • Real-world case studies were demonstrated through practical illustrations of how the principles can be transformed into practical solutions	The discussion on field challenges in implementation against the existing policies and regulations is lacking

2.2.3.1 Road Use Hierarchy of VicRoads

The road use hierarchy of VicRoads is the combination of strategic road use with the relative priorities of each mode by place and Time of Day, as shown in Figure 2.9.

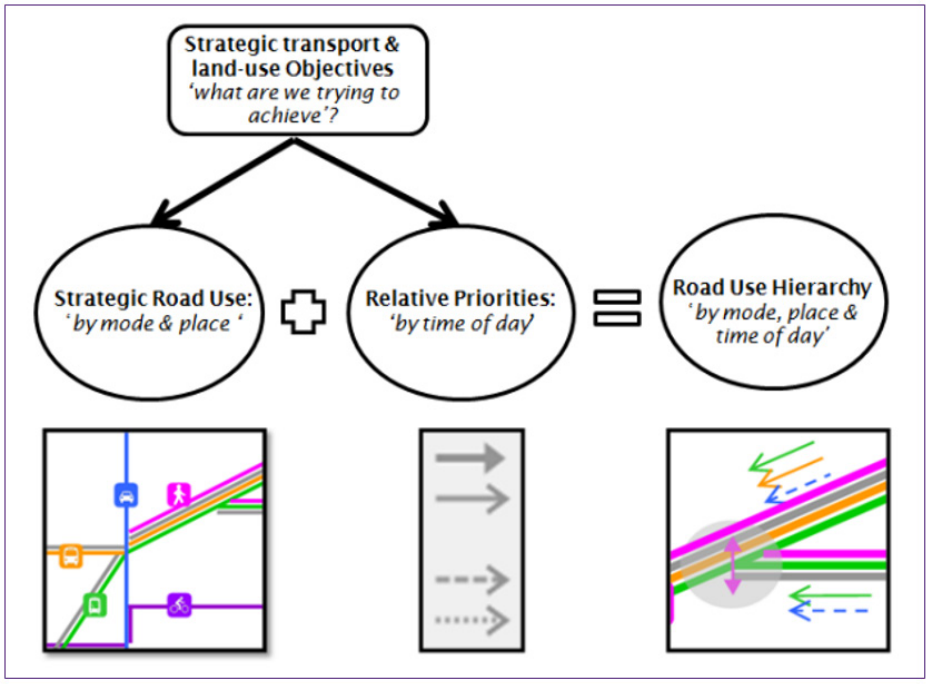


Figure 2.9: Road Use Hierarchy of VicRoads

Strategic road use is the map of a city or a suburb showing the modes that have the highest priority on each route across the whole day. This is super-imposed by the level of encouragement given to each mode depending on the features of the location. Five levels of encouragement, represented by arrows (as shown in Figure 2.9) for four key time periods - AM peak (morning), High off-peak (between AM and PM peak), PM peak (afternoon) and Off peak (evening). This is one way of representing the target road use priority by mode, place and time of day. However, the implementation of this concept is fraught with challenges that require careful planning, robust stakeholder engagement, and flexible, adaptive management. Balancing the dual objectives of enhancing transport efficiency and creating high-quality urban spaces necessitates a nuanced approach that takes into account the specific limitations and context of Victoria Road.

2.2.3.2 Mode share priorities of One Network Framework

As discussed in sub-section 2.2.2, New Zealand classified different modes of the transport network based on their strategic significance. Once the modes are classified, the ONF demonstrates mode shares, mode conflict and assists in determining mode share priorities at different locations, as shown in Figure 2.10.

Mode	Prefix	Factor
General Traffic	GT	People movement per day
Freight	F	Goods movement per day
Public Transport	PT	Indictive vehicle and people movement per day
Cycling	C	Strategic significance and network connection
Walking	W	Strategic significance and pedestrian network

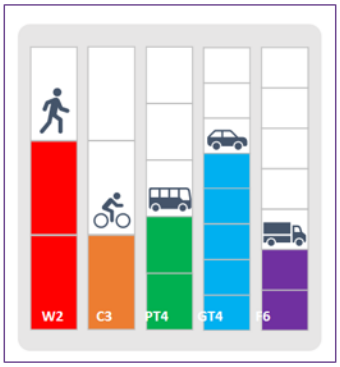


Figure 2.10: Mode classification and mode share priority by New Zealand's ONF

Through the mode share priority diagrams, one gets to understand the prevailing Level of Service or performance of different modes at a glance. Such a visualisation that may vary with time of day and day of week is highly useful and informative in network performance evaluation.

2.2.3.3 Modal Priority Assessment of Roads and Streets Framework

As discussed in sub-section 2.2.3, Auckland's RASF provides modal priority through a modal priority chart. For this purpose, modal priority is assessed in three ways - (a) Existing observed, (b) Existing optimal and (c) Future. A sample modal assessment template is shown in Figure 2.11.

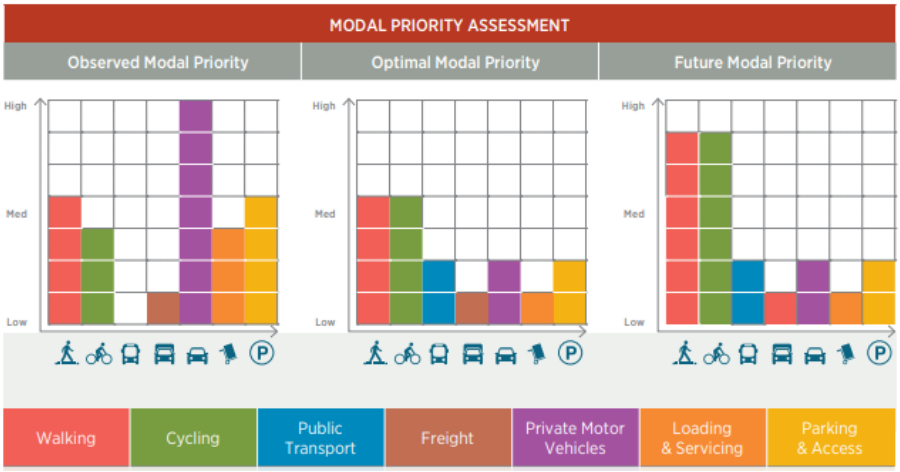


Figure 2.11: Modal priority chart - Roads and Streets Framework of Auckland

This provides a visualisation of the optimal modal priority in view of the observed and future modal networks, thereby serving as a reference guide for any planning and management decisions.

2.2.3.4 Target Minimum Performance LoS of Network Operations Planning Framework

The Network Operations Planning framework of Austroads presented the concept of 'Desired Level of Service (LoS)' to set the minimum performance targets for various modes. Similar to the Movement and Place matrix, Austroads introduced LoS criteria based on delays and operations speeds of each mode on a mode and place matrix. With sub-category of each mode on Y-axis and category of place on X-axis, the matrix shows minimum desired LoS for peak and off-peak periods, as shown in Figure 2.12.

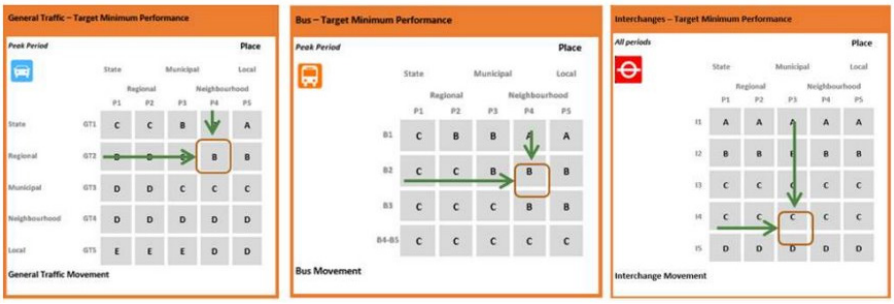


Figure 2.12: Minimum target performance matrix by Austroads

This concept is perceived to be more practical and relatable as it is defined with respect to the commonly used LoS measures in transport networks. By prioritizing various transportation modes, these frameworks attempted to create a more balanced, efficient, and sustainable transportation network, addressing the needs of diverse users while promoting environmental, economic, and social benefits.

2.2.4 Performance Gaps

The operating gap represents the difference between the desired performance and the actual performance of the network. It offers an analysis of the deficiencies in the road network and facilitates the improvement process. The performance gaps are represented quantitatively in view of the available data sources and future scope of the framework. In general, the operations performance reports in terms of annual trends of speed, throughput, Changeable Message Signs (CMSs), incident response duration, frequency of emergency calls etc. generated by Traffic Management Centers (TMCs) serve as a reference to identify gaps. The quantification process of performance gaps that is notable among the discussed frameworks is by Smartroads framework of Victoria and is discussed below.
VicRoads assessed the operating gap based on multiple factors, which include:

- Level of service: This factor assesses the performance of each mode of transportation at a specific location

- Relative level of service: It serves as a measure of how effectively the network should operate
- Relative priority: priority granted to different modes according to government policies and other objectives
- Relative efficiency: The mode's capacity to transport people or goods
- Mode shift factor: This factor predicts the future growth of a particular mode

The operating gap provides insight into the complexity of the network's problems. Moreover, it facilitates quantitative analysis of the potential effects of proposed road improvements on all modes of transportation. To accomplish this, the network fit assessment tool, known as the NFA Tool facilitates more advanced network evaluation of potential strategies.

A visual representation of operating gaps is displayed through pie charts on a network map, as depicted in Fig. 2.13. Each pie size indicates the magnitude of the operating gap, where smaller pie sizes indicate better operational performance. Additionally, the proportions within the pie chart illustrate the extent to which deficiencies in specific modes contribute to the overall gap. In Fig. 2.13, the largest operating gap (highlighted in red) emphasizes that shortcomings in Public Transport (tram/bus) operations account more than half of the issues observed at this specific location (orange/green).



Figure 2.13: Operating gap example

While this process is crucial for improving road safety, efficiency, and overall network performance, there are several potential drawbacks:

- The empirical process of gap assessment by VicRoads will be outdated, with the traffic patterns and road usage changing rapidly
- Solutions derived from gap assessments may sometimes not align well with broader strategic goals or long-term planning objectives, therefore the gaps, objectives and strategies needs to be connected

2.2.5 Strategy Selection

According to M&P framework of AustRoads, the traffic management strategies can be categorised as either demand management or supply management directions. The travel demand management is largely concerned with the factors that influence the decision to travel and mode choice. A few of the demand side strategies include:

- Reducing dependence on the private vehicles to a possible extent
- Encouraging people to better plan their travel
- Using more sustainable forms of transport
- Use of traffic signal systems to provide transit priority
- Better traveller information systems
- Infrastructure strategies such as reduction in network capacity or allocation of road space to other modes
- Limitations on parking spaces of private vehicles, especially in city centers, where public transport plays a significant role

However, the traditional travel demand management measures are generally considered on the supply side, that are directed at marginal increases in capacity or level of service, without substantial road infrastructure investment. Supply side strategies typically include:

- Hierarchy of the use of roads in the network
- Effective access controls
- Kerbside parking management
- Lane use management (e.g. reversible lanes, shoulder lane use)
- Optimisation of peak flows on major arterials
- Optimisation of traffic signal timings
- Improved incident management

- Improved freeway management (e.g. ramp metering, speed management through variable speed limits)
- Improved driver information
- Increased vehicle occupancy
- Implementing special lanes and facilities for non-motorised traffic

Selecting traffic operational strategies based on assessed gaps involves a systematic approach that ensures the identified gaps are effectively addressed while aligning with broader transportation goals.

2.3 Gaps and Findings from Literature Review

Integrating network planning with traffic operations is crucial for efficient transportation systems, yet there are often gaps in the literature. In the process of identifying them, this chapter conducted a comprehensive literature review of the existing frameworks and methodologies. The general limitations identified from the existing transportation planning to traffic operations' frameworks are as follows:

1. Limited or few case studies in the context of network operations from different regions or jurisdictions where successful integration is achieved
2. The challenges in data availability, quality, or compatibility to investigate the integration of network planning and traffic operations in real-time are not sufficiently explored
3. Translation of theoretical insights into actionable strategies for traffic operations within the context of network planning is crucial but not considered in the literature
4. The inter-dependency of each of the key components of the framework is ignored
5. The impact of emerging technologies such as Artifical Intelligence, Internet of Things, and connected vehicles that may impede seamless coordination between network planning and traffic operations is not investigated
6. The 'gap' calculation seems to be relying heavily on data, and if the data is inaccurate, incomplete, or outdated, the assessment may yield incorrect conclusions
7. Prioritizing which gaps to address first can be subjective, potentially leading to perceived or actual biases in the decision-making process

In addition to these, there are individual gaps identified in the key components of the framework and are listed in Table 2.2.

Table 2.2: Limitations of the key components of the framework

High-level objectives	**Network hierarchies**	**Operating targets**	**Performance gaps**	**Strategy selection**	**Day-to-day operations**
Majority of the objectives considered are general and are not translated from the high-level planning intent	The concept of network hierarchies is only implemented in the context of urban planning	The assigned desired LoS in the literature is not associated with high-level intent	A proper definition and choice of key performance indicators that compute performance gaps is not observed	Lack of a decision supporting system in the selection of appropriate and optimal operational strategies	There are no case studies found in the literature with feasible Network Operation Plans (NOPs) being implemented
The definition and the choice of objectives must consider the spatio-temporal demographic to make them relevant and feasible	The pre-determined hierarchy needs to be flexible and dynamic to cater to the real-time events and traffic demand scenarios	The operating targets will not truly reflect the desired LoS if they are static	The computation of gaps is static based on empirical equations	There are no standards defined for impact assessment of relevant strategies	The execution of this component needs a fusion of historic and real-time experience
The objectives need not be fixed but can be updated based on the prevailing conditions and the implementation challenges experienced	The hierarchy must essentially be synchronous with the high-level intent of planning and objectives considered	There is no standard procedure to assign road use priorities for various modes in the network	Use of existing case studies from the database is beneficial in identifying and prioritizing feasible gaps	There is a need for a learning-based evaluation for timely decisions on the strategies to be implemented	The experience on day-to-day operations as a result of the operational strategies implemented has to be evaluated with respect to a time-frame

To summarize, it can be inferred that successful implementation depends on effective coordination, adequate resources, and meaningful community engagement, along with flexible policies and adaptive management strategies.

Chapter 3

Conceptual framework

This chapters presents the methodology behind the concept of an integrated framework that translates the high level intent of planning policies to day-to-day traffic operations. The concept leading to the individual components of the framework and their inter-dependency is discussed in detail with examples in the subsequent sections. Towards the end, the chapter introduces a comprehensive database named 'Ops DB' that connects the key performance indicators to relevant strategies. It could be an efficient tool with multiple applications such as performance analysis of multi-modal networks, assessment of strategies and more specifically integration of planning to operations, in the field of traffic control and management.

3.1 Proposed structure of the framework

From the literature review, the general structure of the framework is observed to be comprising of six. essential components, namely - (i) High level vision, function and objectives, (ii) Network hierarchy, (iii) Operating targets, (iv) Performance gaps, (v) Strategy selection and (vi) Day-to-day operations. Figure 3.1 depicts the process flow among these components, encompassed with a single loop that assesses the long-term performance of the selected strategies and updates the observed performance and gaps accordingly. While this process takes longer to evaluate the performance of an implemented strategy, inclusion of a short-term performance evaluation of the day-to-day operations would be more efficient.

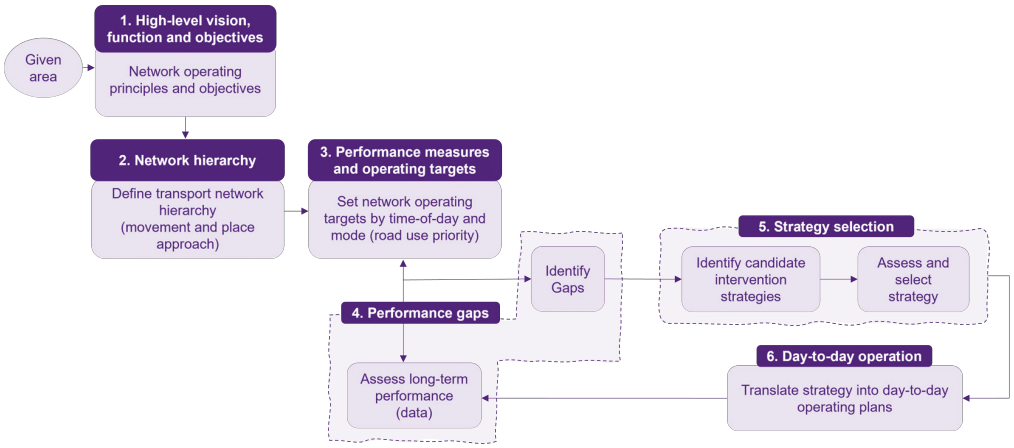


Figure 3.1: General structure of the framework

The general structure of the framework can be modified in a way that it would include dual loops, one each for short-term and long-term performance respectively. Figure 3.2 shows the structure of the proposed framework, with the loops highlighted. Both the loops update the observed performance to the 'operating targets', that directly influences the selection of strategies.

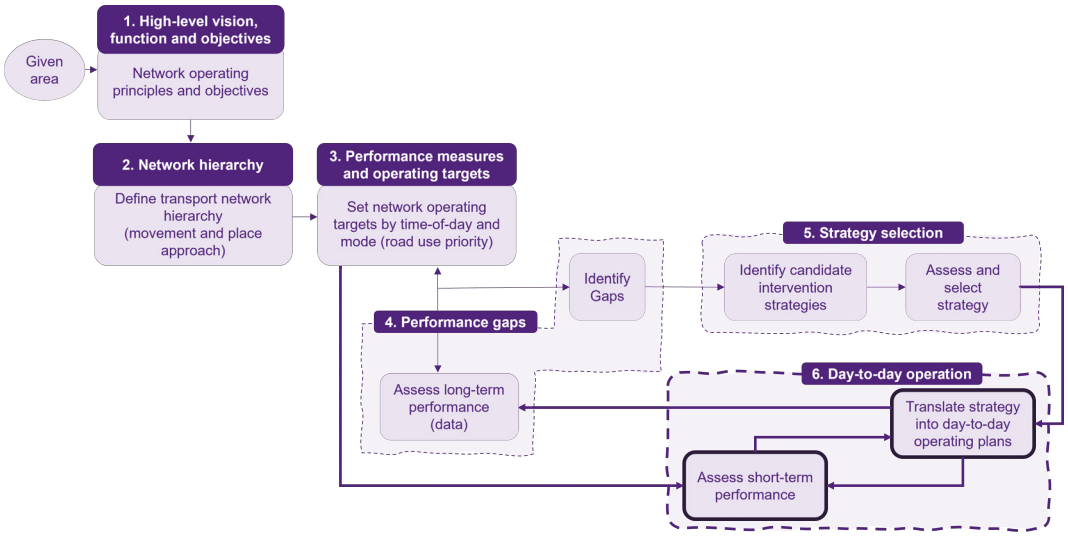


Figure 3.2: Modified structure of the proposed framework

The relevant strategies may range from infrastructure related to traffic operations related ones. Therefore, a decision point regarding the 'type of action' is introduced after the strategy selection component. Figure 3.3 depicts the complete structure of the proposed framework. Since infrastructure related improvements are out of the scope of this project, such strategies are re-directed to the concerned department accordingly. The process in which operational strategies are connected to the high level planning intent and the observed network performance is discussed further.

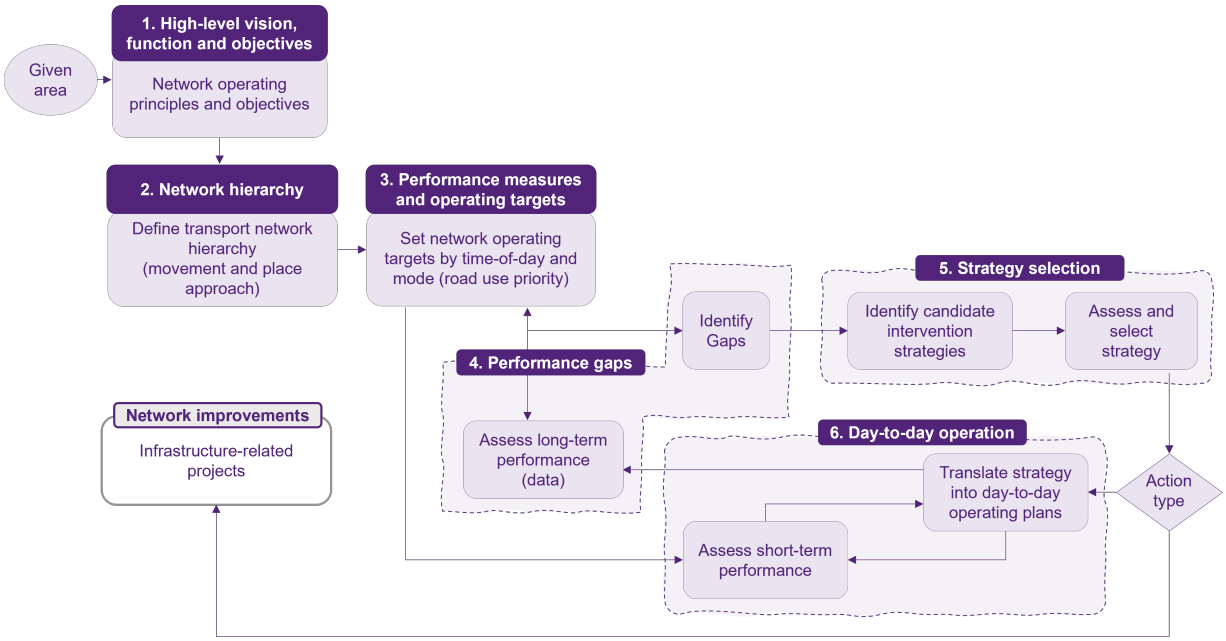


Figure 3.3: Proposed structure of the framework

The high level intent of the planning policies in terms of network operating principles and objectives defined for each type of link in the hierarchy is considered to be the first component in this integration process. A given area that is essentially a combination of different types of links, is assigned a transport network hierarchy (2nd component) based on the movement and place function of each of the links. In conjunction with the high-level objectives, network operating targets are assigned for each of the modes in the traffic stream, on a time-of-day basis (3rd component). This is analogous to 'road use priority' in literature, but defined for each type of movement and place category. In this project, it is termed as 'desired priority'. Further, the performance of the links for each and movement type is determined with the help of relevant key performance indicators (KPIs). The so computed performance is termed as 'observed priority'. For this purpose, KPIs that are well defined, measurable and relevant for each mode and movement type need to be identified. Once the observed priority is obtained, the consequent performance gap is computed as the difference between desired and observed priorities (4th component). Once the gap and the KPIs resulting in the gap are known, the relevant strategies are considered and evaluated to improve associated KPIs. The necessary strategies (5th component) and the resulting day-to-day performance of each of them in relation to the performance gap is studied, so as to choose optimal strategy that fits the purpose (6th component). The selected strategy is then translated into day-to-day operating plans whose performance is monitored on a regular basis. Implementation of the day-to-day operating plans, that achieves the high-level intent in the best way possible, marks the last stage of the framework. Assigning targets and assessing the performance of the operating plans in comparison to those targets is an iterative process with respect to Time of Day

and different objectives. This whole process of a series of actions is shown as a simplified solution to the proposed framework in Figure 3.4.

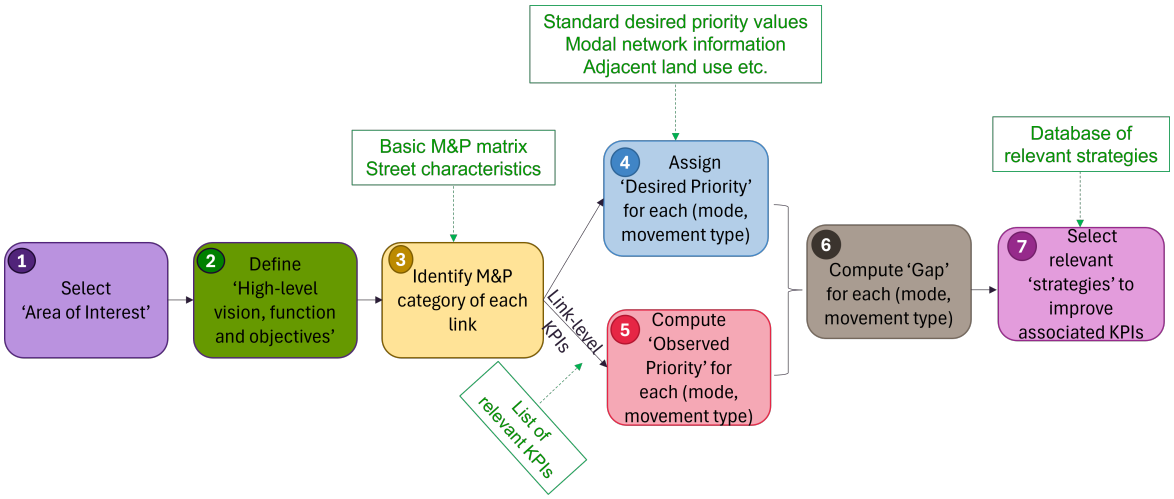


Figure 3.4: Simplified solution to the proposed framework

The necessary inputs required at different stages in this framework are: (i) High-level vision and objectives, (ii) Basic Movement and Place Matrix for Queensland, (iii) Base desired priority matrix, (iv) List of relevant KPIs, and (v) A database of relevant strategies. The process in which these inputs are obtained is discussed further.

3.2 High-level vision, function and objectives

Upon the selection of an area of interest, the framework calls for a collaborative identification of a vision and the associated strategic objectives for the study area. This involves a shared understanding of the desired future state between the project team, key stakeholders and/or community representatives, to bring the best benefit to the community. Specific understanding of the issues and opportunities of the study area may assist in establishing the vision. This shared vision combined with the overarching goals set by transport authorities are further translated into strategic objectives. Different authorities may establish and prioritize various objectives and intents based on the regional transport plans, modal plans and other operational plans. However, this work focuses on the five strategic goals set by TMR:

1. Accessible, convenient transport
2. Safe journeys for all
3. Seamless, personalized journeys
4. Efficient, reliable, and productive transport for people and goods
5. Sustainable, resilient, and liveable communities

3.3 Movement and Place matrix for Queensland

Since a given area or a network is a combination of a number of links with different characteristics, a link-level analysis is recommended in this framework. Therefore, the consecutive action post definition of a shared vision and objectives, is to identify the category of each of the links in the Movement and Place matrix, based on their location-specific attributes.

Queensland's Movement and Place matrix is considered to be a great enabler of embedding planning intent into day-to-day practice. It is envisioned to support the integrated delivery of the five strategic outcomes of Transport Main Roads (TMR): (i) Accessible, convenient transport, (ii) Safe journeys for all, (iii) Seamless, personalised journeys, (iv) Efficient, reliable and productive transport for people and goods, and (v) Sustainable, resilient, and liveable communities. Queensland's Movement and Place policy introduced M&P based network classification hierarchy as a 5x5 matrix for urban areas and a 5x3 matrix for rural areas. Eleven broad categories of road and street environments that broadly encapsulate the range of typologies across Queensland are considered. Figure 3.5 shows the M&P matrix for urban and rural areas respectively. As shown in the figure, each of the eleven categories is characterised by a different balance of movement and place functions.

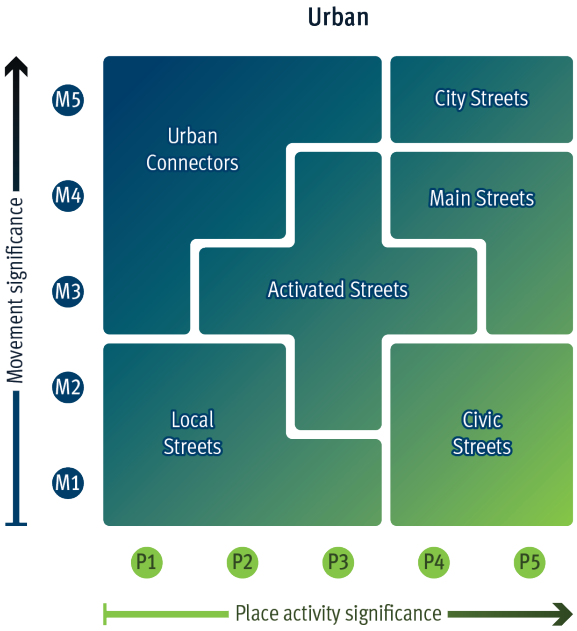
The next step is to identify the M&P category of each of the links of a given network or area, in line with the associated M&P matrix. However, no standard rules or guidance has been provided on the ways to identify the type of a particular link and categorize it into M&P matrix elements. For demonstration purposes, the following section discusses certain attributes that are in general used to classify the links on the basis of M&P matrix categories.

3.4 Identification of M&P matrix categories

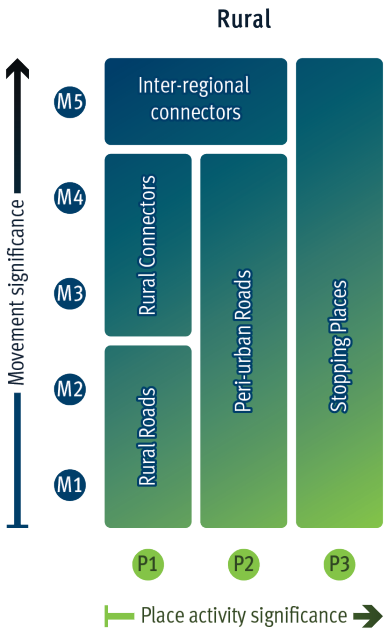
Assuming that a network of links, as shown in Figure 3.6, is chosen to analyse its network performance. Based on the features listed as follows, the M&P categories of each of the links in this area are identified.

- Location-specific attributes such as the type of street, type of land use (for example: residential, industrial, commercial)
- Road-use characteristics such as number of lanes, presence of footpath
- Proximity of public transport facilities
- Type of activities and the presence of activity centers in the neighborhood

These features can be identified without the use of any real-time data. A sample example is shown in Figure 3.6 for reference.

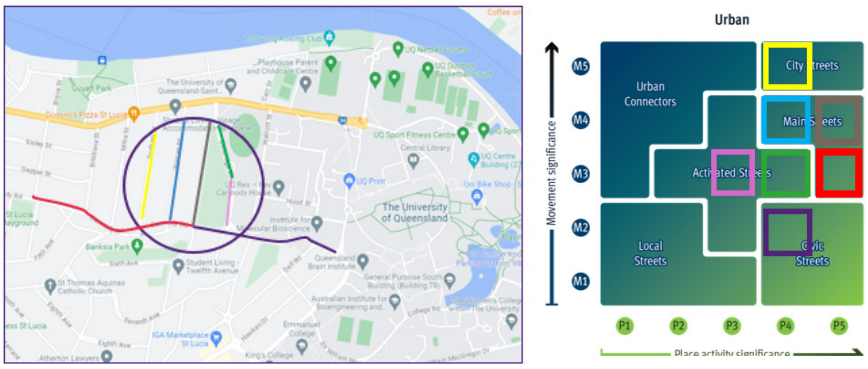


(a) a



(b) b

Figure 3.5: (a) M&P matrix for urban areas (b) M&P matrix for urban areas



(a) a (b) b

Figure 3.6: (a) Identification of M&P categories for the selected area; (b) M&P matrix of the area selected;

3.5 Process of gap evaluation

Once the M&P categories are identified, the subsequent steps in Figure 3.4 i.e. steps 3, 4 and 5 are necessarily aimed at evaluating the performance gap on the link. Figure 3.7 explains the process of gap evaluation with the help of a flowchart. Once the M&P categories are identified, the target LoS or the desired priority of various modes on the link are assigned from the 'Desired Priority' matrix. In order to evaluate the performance gap, one needs to assess the observed performance for each of the modes and the movement types of the link. This is directly related to the key performance indicators considered for each (mode type, movement type). From the evaluated KPI measures, the link-level observed LoS or the observed priority is determined. The performance gap, is then computed to be the difference of the observed LoS from the target LoS, or in other words, the difference between the desired and observed priorities.

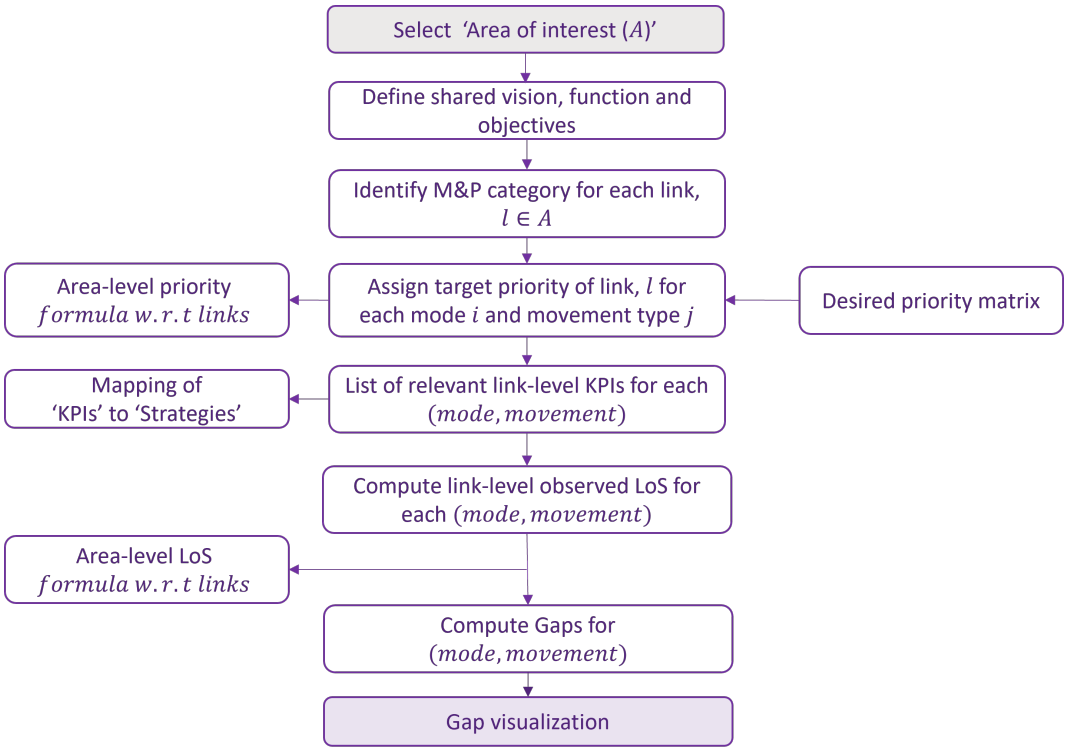


Figure 3.7: The process of gap evaluation

In order to assign target LoS from desired priority matrix, one needs a base desired priority matrix with priority numbers assigned for each M&P category, mode and type of movement. The priority matrix is designed to be a 6*5 matrix with priority level on Y-axis and mode types on X-axis for different types of movements. The two types of movements considered in this context are - From/To movement and Through movement, in contrary to the three defining elements of movement across an area (To/from, Through and Within) of TMR. The reason being the link-level analysis considered in this framework, wherein the trips involving pedestrians and cyclists that may originate and end within the same link are included in To/from movement. Table 3.1 discusses the definitions of these movements for each of the five modes (pedestrians, cyclists, public transport, private vehicles and freight) considered in this project. A sample priority matrix is shown in Figure 3.8.

Table 3.1: Definition of through movement and from/to movement for different modes

Type of movement	Pedestrians	Cyclists	PT	PV	Freight
From/To	Movement that originates or ends on or within the link		Access to a bus or train station on a given link	Access to a parking space or a loading dock on a given link	
Through	Movement through the link		Movement of transit through the link	Movement through the link	

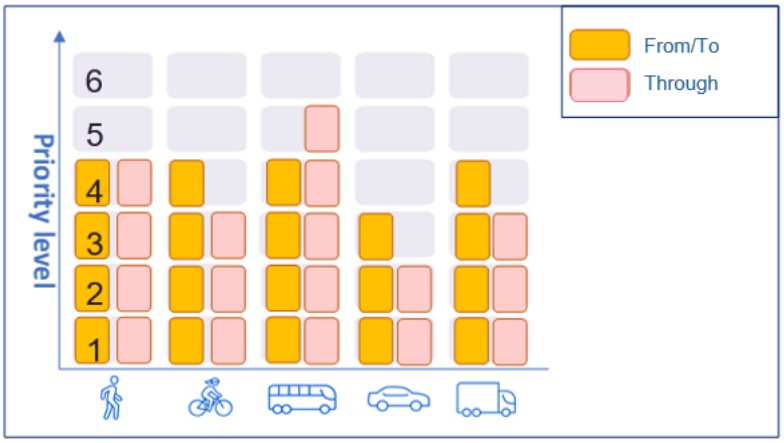


Figure 3.8: A sample of priority matrix

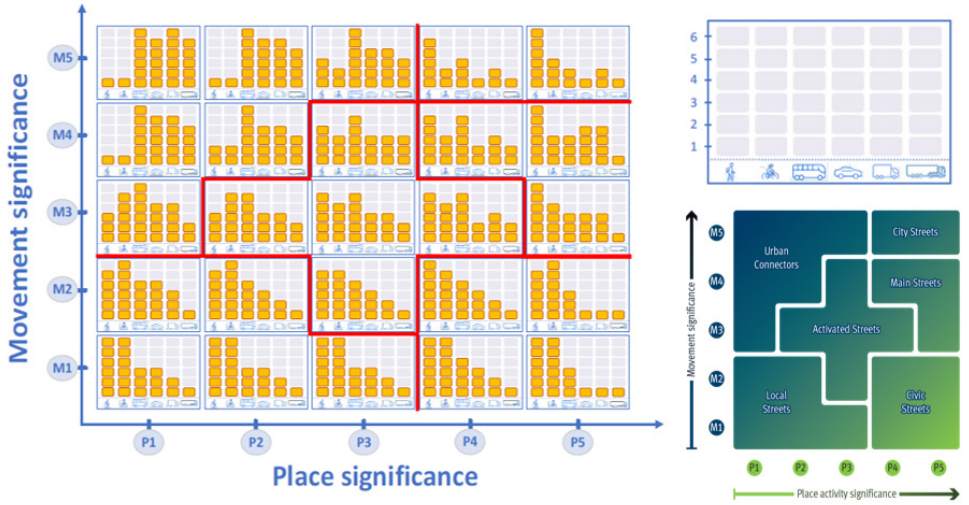
3.6 Assigning desired priority

The values on the priority level axis of Figure 3.8 is analogous to 'Target LoS' assigned based on the street characteristics, type of land use, M&P category and access to PT. These values are assigned on a scale of 1 to 6 with one being the lowest (similar to LoS F) and six representing the highest priorities (similar to LoS A) respectively. The initial desired priority values are assigned on the basis of visual observations of the street and its surroundings such as

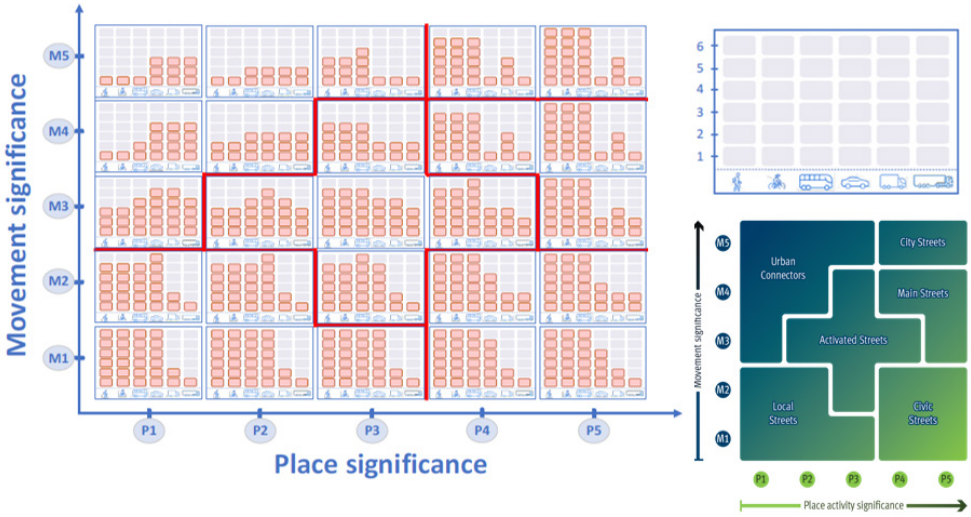
1. Presence of on-street parking
2. Active street frontage
3. Crossing opportunities
4. Presence of bus stops or train stations
5. Presence of loading docks
6. Predominant modes
7. Type of land use
8. Presence of sidewalks
9. Speed limit

In accordance with these features, the desired priority matrix is developed for each of the M&P categories. The desired priority matrices of all the 25 categories, separated by broader categories of M&P matrix i.e. for city streets, main streets, civil streets, activated streets, local streets and urban connectors are shown in Figures 3.9(a) and (b) for through and from or to movements respectively. Figure 3.10 shows the overall desired priority matrix for each

mode and movement type.



(a) a



(b) b

Figure 3.9: DP matrix for (a) Through movement; (b) From or To movement;

The desired priority matrix values are finalised after a detailed discussion with the stakeholders along with the planning and operations teams of TMR. These act as default priority values that can be modified by user based on the existing traffic or location-specific situation. In other words, the desired priority values are user-configurable but the extent to which they can be modified must be constrained by certain thresholds.

The base desired matrix provided in Figure 3.10 is applicable for traffic scenarios with the predominant travel modes being pedestrians, bicycles, public transport, private vehicles and freight. In scenarios or networks where primary service vehicles are predominant and need to

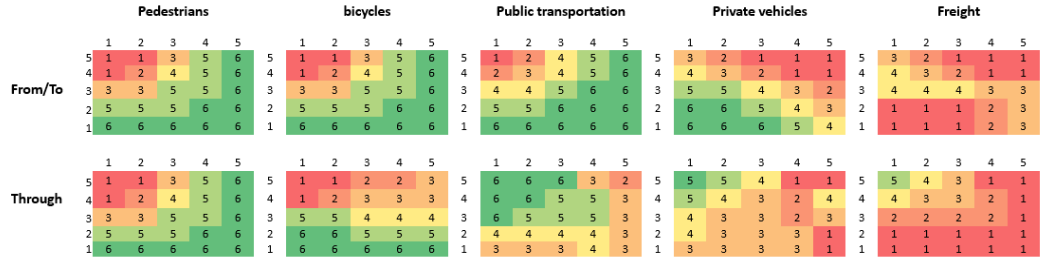


Figure 3.10: Base Desired Priority matrix

be prioritized, considered it as a part of freight travel mode is not sensible. Therefore, freight travel mode can be split into two distinct categories as light freight (small rigid vehicle and smaller - Austroads class 1 to 3) and heavy freight modes (heavy freight vehicle and larger - Austroads class 4 and above). The resulting desired priority matrix with modified modes is shown in Figure. The desired priority values in this figure are modified as well, in accordance with the discussion with TMR's operators and planners. These modifications considered certain field practices, for example 'zero' priority to pedestrians and cyclists on motorways (M5-P1). From this, it can be inferred the proposed framework is easily extensible to cater to any number of travel modes in the network.

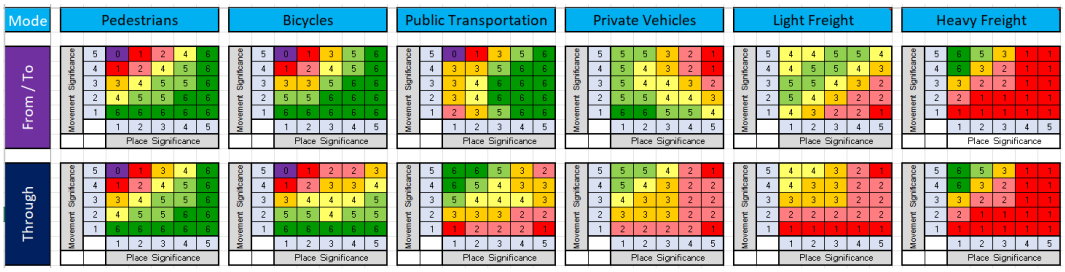


Figure 3.11: Modified DP matrix

Once the desired priority is assigned, the consecutive step is to evaluate the performance of the link and quantify it in terms of observed priority with the help of key performance indicators.

3.7 Observed priority

The observed priority of each mode on a given link is essentially a function of multiple KPIs that may hold different weights in defining its network performance. However, observed priority is an integer value on a scale of 1 to 6. Therefore, one may consider a simple average or a weighted average or a worse KPI of the set of observed KPIs to obtain the value of observed priority. The choice of calculation can be decided by the user while choosing the relevant KPIs. Therefore, the observed priority (OP) for each mode i and movement type j is

either of the following equations.

$$OP = \frac{\sum_{l=1}^{L} KPI_l}{L} \tag{3.1}$$

With w_l being the assigned weight of each KPI_l,

$$OP = \frac{\sum_{l=1}^{L} KPI_l * w_l}{\sum_{l=1}^{L} w_l} \tag{3.2}$$

$$OP = Min.of KPI_l \forall l \in 1 to L \tag{3.3}$$

3.7.1 Key Performance Indicators

Since the focus of the project is to connect planning policies to network operations, the Key Performance Indicators (KPIs) to be used in obtaining observed priorities are chosen in terms of the following objectives.

- Mobility
- Safety
- Accessibility
- Reliability
- Sustainability

Tables 3.2 and 3.3 shows the relevant KPIs identified for Public Transport with respect to the objectives that seemed appropriate for through movement and from/to movement respectively. The tables present the definition of KPI in the context of this project, the reference organization or article that had previously referred to the subject KPI, the mode of measurement with respect to the data available at TMR and the time frame of measurement. Similarly, Tables 3.4 and 3.5 presents KPIs for pedestrians, Tables 3.6 and 3.7 for cyclists, Tables 3.8 and 3.9 for private vehicles and freight, in the order of through movement and from or to movement respectively. The comprehensive list of KPIs for each of these modes is presented in Tables 6.1 to 6.9 of Appendix.

With the suitable KPIs identified and measured from Tables 3.2 to 3.9, the associated observed priority is computed using any of the Equations 3.1 to 3.3. For a given link, observed priority obtained for all the modes and movement types is represented in the form of 'arrows' on the priority matrix. The so computed observed priority is further used for calculating the 'performance gap'. As mentioned earlier, gap of mode i and movement type j is expressed as

$$Gap(i,j) = Desired priority(i,j) - Observed priority(i,j) \tag{3.4}$$

Table 3.2: KPIs of Public Transport (PT) for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average travel time of PT through the link	Austroads, FHWA	Diff. in travel time stamps using GPS data or loop detector data	Short-term
	Average delay time (control delay or stopped delay) of PT at intersections		Diff. in actual and desired travel time using GPS data or loop detector data	
	Avg. person throughput during peak period	Austroads	Smart card data - Translink	Short/long
Safety	Number of crashes involving PT per traffic volume	TMR, New Zealand	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
Sustainability	Average value of fuel savings	Kaparias et al. 2011	Survey of Motor Vehicle Use, Australian Bureau of Statistics	Long-term
Reliability	Variability of travel time	FHWA	Standard deviation of travel time using GPS data	Short/Long
	On-time performance of transit		Arrival times from selected stations from transit operators	Short term
	Speed difference of PT with respect to average traffic speed	Kaparias et al. 2011	Data from speed gun and GPS	Long-term

Table 3.3: KPIs of Public Transport (PT) for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Frequency of public transport	Kaparias et al. 2011	PT operators or GIS database	Short-term
	Access and reliability of transit information		Passenger surveys	Long-term

The gap is considered to exist for positive values of Equation 3.4 i.e. only for the cases where desired priority is more than the observed priority. Figure 3.12 shows the priority matrix with desired and observed priorities along with the associated gaps for all the modes and movement types.

As expressed in Figure 3.12, the arrows that are ‘red’ in colour represent the modes experiencing performance gaps in achieving the desired LoS. By default, the next task is to identify suitable strategies from the point of view of traffic operators to bridge these identified gaps. For this purpose, a comprehensive list of suitable strategies needs to be developed.

3.8 Relevant strategies

The strategies that are considered viable and operable by TMR in the context of the project are as follows

1. Bus priority lanes
2. Public transport jump lanes
3. Transit signal priority
4. HOV lanes

Table 3.4: KPIs of Pedestrians for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average delay of pedestrians	FHWA	Data on wait time for pedestrians at intersections or path blockages from State and local transportation department	Short-term
	Pedestrian Level of Service (Ability to move in desired path)	Amoroso et al. 2012	Data on capacity and space requirements (m^2 per pedestrian)	Long-term
Safety	Separation from motorists No. of crashes involving pedestrians No. of interactions with cyclists	Austroads Research Report, 2015	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
Accessibility	Percent of intersections with pedestrian features	FHWA	Inventory of pedestrian facilities	Long-term

Table 3.5: KPIs of Pedestrians for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	No. of crosswalks per kilometer	Austroads	Inventory of pedestrian facilities	Long-term
	Discomfort due to crowdedness on footpath	Eboli et al. 2023	Pedestrian survey	Short-term
	Accessibility to public transport		GIS database and pedestrian survey	Long-term

5. Truck restrictions
6. Turning lanes
7. Parking management
8. Incident management systems
9. En-route information systems
10. Variable speed limits
11. Signal optimization
12. Lane use management system
13. Ramp metering
14. Education campaigns

In addition to this, a few of the feasible strategies for pedestrians and cyclists are suggested as a part of this project, after an internal discussion with the team of TMR.
For cyclists:

1. Increase on-road separation
2. Variable Speed Limits (VSL) or Variable Message Sign (VMS) boards in sensitive areas like schools
3. Priority at intersections – separate push buttons for cyclists (infrastructure) and signal timing optimization (operations)

Table 3.6: KPIs of Cyclists for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average delay time (control delay or stopped delay) of cyclists at intersections	FHWA	Data on wait time for cyclists at intersections or path blockages from State and local transportation department	Short-term
	Average travel time of cyclists through the link			Short-term
	Length of exclusive bicycle lanes/km (separation from motorists and pedestrians)	Amoroso et al. 2012	State and local transportation department	Long-term
	Comfort due to inter-modal interactions	Austroads Research Report, 2015	Cyclists' survey	Long-term
Safety	Separation from motorists	Austroads Research Report, 2015	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
	No. of crashes involving cyclists			Long-term
Accessibility	Percent of intersections with significant features for cyclists (push buttons and separated crossings)	FHWA	Inventory of bicycle facilities	Long-term

Table 3.7: KPIs of Cyclists for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Ability to access a bike parking space Ability to park or ride in the vicinity of train stations and shopping centres Condition and continuity of separate bicycle facilities	Austroads Research Report, 2015	Maps and GIS database from State and local transportation department	Long-term
	Realized Detour Ratio (Ratio of the cyclist's actual trip distance to the Euclidean distance for a given OD)	Chou et al. 2023	Cyclists' trajectories from crowd-sourced GPS data	Short-term

Table 3.8: KPIs of Private Vehicles (PV) and Freight (F) for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average travel time of PV (or F) through the link	Austroads, FHWA	Diff. in travel time stamps using BT data or loop detector data	Short-term
	Average delay time (control delay or stopped delay) of PV (or F)	FHWA	Avg. time for which detectors are occupied with PV	
	Average no. of stops (other than signals) in a given time period	Kaparias et al. 2011	Avg. values of number of stops using CV data	Long-term
	Average door-to-door trip time	FHWA	O-D and passenger surveys	Long-term
Safety	Number of crashes involving PV (or F) per traffic volume	TMR, New Zealand	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
Reliability	Variability of travel time	FHWA	Standard deviation of travel time using STREAMS data	Short/Long
Sustainability	GHG emissions by PV (or F)	New Zealand	Annual report on Greenhouse Gas Emissions from Australian Transport	Long-term
	Ambient air quality concentration of NO_2 and PM_{10} through PV (or F)		Emission modelling	

Table 3.9: KPIs of Private Vehicles (PV) and Freight (F) for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Realized Detour Ratio (Ratio of the vehicle's actual trip distance to the Euclidean distance for a given OD)	Chou et al. 2023	Vehicles' trajectories from crowdsourced GPS data	Short-term

4. Increase visibility through line markings
5. Increase in crossing opportunities
6. Smooth transition from footpaths/bicycle lanes to crosswalks
7. Reduce interactions with pedestrians (especially at PT stops) through fully separated bicycle lanes

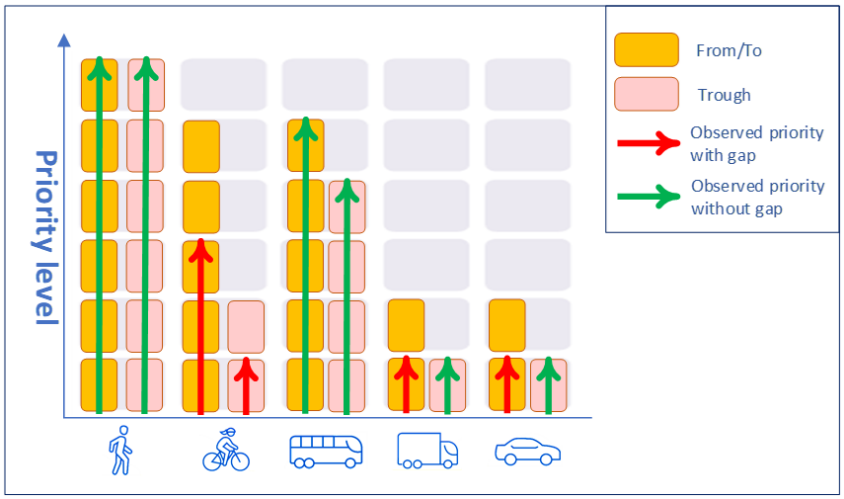


Figure 3.12: Priority matrix with gaps

For pedestrians:

1. Priority at intersections
    - Push buttons for pedestrians (infrastructure) and enable exclusive right-of-way at unsignalized intersections
    - Signal timing optimization at signalised intersections (operations)
2. Increase in crossing opportunities (especially on longer arterials)
3. Reduce conflict with other modes
    - Separate footpaths
    - Separate crossing opportunities for cyclists and pedestrians
    - Wider footpaths (especially intersections and PT stops)

With the list of considerable strategies in place, the immediate critical task would be to evaluate and identify optimal strategies that helps in mitigating the performance gaps. For this purpose, the impact of a given strategy or a combination of strategies at both local level i.e. link level and area level i.e. network levels needs to be quantified. This may necessitate the application of any or a combination of the below alternatives.

- Existing evaluation models or software
- Existing analytical models
- Microscopic simulation
- Macroscopic simulation

- Knowledge based models or empirical models

Use of any of these evaluation alternatives is strategy specific and also bears respective limitations in their application for area level purposes. Therefore, an universally applicable solution similar to accessing an operations database is perceived to be an efficient alternative. For that purpose, one needs to design an operation database, termed as a part of this project as 'Ops DB'.

3.9 Design of the database Ops DB

Operation Database (Ops DB) is fundamentally designed to build a knowledge base in a systematic way that is more data-driven. Ops DB is anticipated to serve multiple purposes such as:

- Facilitates conversion of the existing data sources into tangible and quantifiable form
- Analyzes the possible variety of metrics with maximum transparency
- Acts as a robust tool in connecting KPIs to gaps to strategies

Keeping the end application in view, the structure of the database is necessarily designed to be comprising of inputs in terms of link characteristics, traffic attributes and performance metrics and output in terms of the list of optimal strategies in hierarchy. Figure 3.13 presents the framework of Ops DB with detailed process flow. In the context of the current project, the characteristics of the link for which the gap evaluation is carried out, is taken as the input and an active search of similar scenarios in the database is enabled. The identification of similar scenarios is considered in terms of area characteristics such as type of area, demand flows, types of link, link features etc. in addition to similar performance issues. Once such scenarios with maximum possible similarity are identified, the strategies implemented and the associated KPI improvements of the identified scenarios is studied to determine the optimal strategies to be implemented for the considered study area.

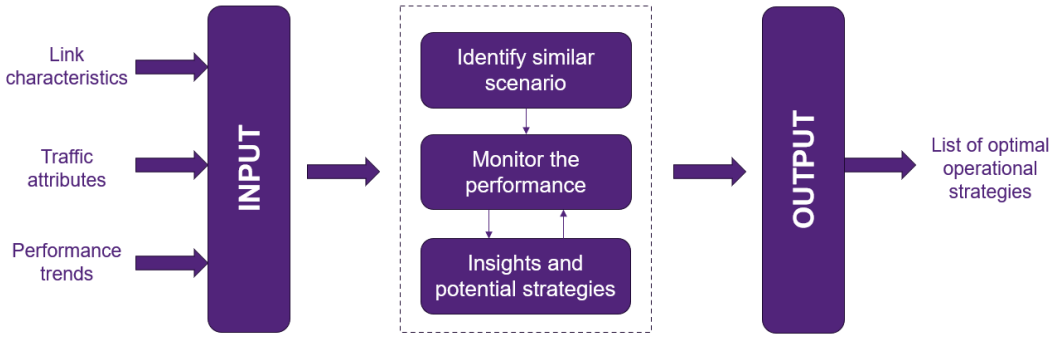


Figure 3.13: Framework of Ops DB

The essential building blocks or entities of the database are listed to be: Scenarios, KPIs, Links, Strategies and KPI observations, as shown in Figure 3.14. Each of these entities are represented as separate tables and are further discussed in detail.

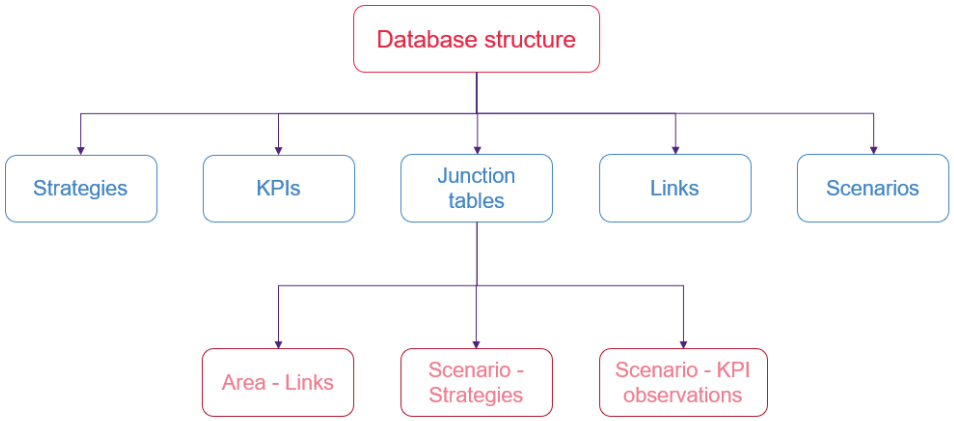


Figure 3.14: Structure of Ops DB

'Scenarios' presents a tangible list of case studies that constitute the following attributes: location (country, city, area), time frame of observation or analysis (start and end times), implemented strategies and traffic flow information. Figure 3.15 depicts the structure of 'Scenarios' with some sample data included for demonstration. The attribute 'Area-Links' in Figure 3.15 describes set of links that are numbered prior. Figure 3.16 shows the features considered for each link and this is a subset of Scenarios (Figure 3.15). As seen from Figure 3.16, 'Area-Links' include the detailed name and address of the street, the movement ranking, place ranking, speed limits, type of area it is a part of, number of lanes and its length. In addition to 'Area-Links', 'Scenario-Strategies' is also a subset of Scenarios (Figure 3.15).

scenarioID	country	city	area	startTime	endTime	strategySet	vehFlow	PtFlow	pedFlow	bicyclesFlow	freightFlow
1	Australia	Brisbane	1,2	2012-02-14	2013-05-04	18, 23	1090	134	213	137	321
2	Australia	Brisbane	1,2	2016-01-03	2017-01-03	9	1140	184	263	187	371
3	Australia	Logan	4,5,6	2014-08-07	2015-08-07	1,3	850	53	255	327	121
4	Australia	Logan	4,5,6	2019-05-03	2021-05-03	39, 42, 31	915	118	320	392	186
5	Australia	Gold Coast	7	2016-01-03	2018-01-03	6, 20, 22	965	168	370	442	236
6	Australia	Gold Coast	7	2014-08-07	2015-08-12	30, 34	850	53	255	327	121
7	Australia	Gold Coast	7	2019-05-03	2020-05-03	38	915	118	320	392	186

Figure 3.15: Scenarios - Component of Ops DB

LinkID	address	movementRanking	placeRanking	speedLlimits [km/h]	direction	areaType	lanesNumber	length
1	Frederick St, Toowong QLD 4066	3	5	50	two-way	Main Streets	4	700
2	State Route, Toowong QLD 4066	4	1	70	two-way	Urban Connectors	5	600
3	Wembley Rd, Slacks Creek QLD 4127	4	2	70	two-way	Urban Connectors	6	800
4	State Route 50, Berrinba QLD 4117	4	3	60	two-way	Activated Streets	4	1200
5	State Route 95, Slacks Creek QLD 4114	4	4	60	two-way	Main Streets	4	1100
6	Kingston Rd, Slacks Creek QLD 4114	4	5	50	two-way	Main Streets	5	780
7	Hooker Blvd, Broadbeach Waters	5	1	70	two-way	Urban Connectors	5	1500

Figure 3.16: Links - Component of Ops DB

Figure 3.17 contains different strategies listed in Section 3.7, along with their type and a detailed description of each of them. For example, parking management can be enforced

in different ways such as parking guidance systems, time-limited parking, resident permit parking, parking enforcement, demand based pricing etc. All possible types for each strategies are identified and included in Figure 3.17.

strategyID	name	type	description
1	Bus priority lanes	-	lanes on roadways exclusively reserved for buses
2	Public transport jump lanes	-	dedicated lanes at intersections that allow transit vehi
3	Transit signal priority	active priority	granting priority to transit vehicles based on real time
4	Transit signal priority	passive priority	granting priority to transit vehicles based on historica
5	HOV lanes	-	Multi-occupancy highways or roadways
6	Truck restrictions	specific speed limits	Specific speed limits for trucks are determined by the t
7	Truck restrictions	parking regulations	include restrictions on where and for how long trucks ca
8	Truck restrictions	route restrictions	limitations on certain roads or routes that trucks can u
9	Turning lanes	protected right-turn lanes	Safe right turns with a green arrow
10	Turning lanes	unprotected right-turn lanes	Yield for right turns
11	Turning lanes	protected left-turn lanes	Safe left turns with a green arrow
12	Turning lanes	unprotected left-turn lanes	Yield for left turns
13	Parking management	Parking Guidance Systems	uses sensors, cameras, and digital signage to guide driv
14	Parking management	Time-Limited Parking	allows parking for a specified duration
15	Parking management	Resident Permit Parking	Residents are issued permits that allow them to park on
16	Parking management	Parking Enforcement	parking enforcement officers, electronic ticketing syste
17	Parking management	Demand-Based Pricing	Pricing for parking spaces can vary based on demand and
18	Incident management systems	-	collaboration between first responders, tow services, ar
19	En-route information systems	dynamic route guidance	recommendations for the best and quickest routes
20	En-route information systems	real-time traffic updates	provide live information about the current state of traf
21	En-route information systems	Variable Message Signs	display real-time information to drivers, such as travel
22	Variable speed limits	-	changing the speed limits on roadways in real-time based
23	Signal optimization	-	adjusting the timing of traffic signals to improve the
24	Lane use management system	-	strategies and technologies used to optimize the allocat
25	Ramp metering	-	controlling the rate at which vehicles enter a freeway c
26	Education campaigns	road Safety	focus on general road safety practices
27	Education campaigns	impaired Driving Prevention	against driving under the influence of alcohol or drugs
28	Education campaigns	public Transit Promotion	Encouraging the use of public transportation
29	Education campaigns	environmental Awareness	Campaigns promoting eco-friendly transportation choices
30	Increase on-road separation	road markings	-
31	Increase on-road separation	vertical separation	-

Figure 3.17: Strategies - Component of Ops DB

Another important entity of the database is ‘KPI’. The KPIs listed in Tables 3.2 to 3.9 are included in the database as shown in Figure 3.18. It constitutes the KPI ID, definition of each KPI, the objective it is related to, the relevant mode and movement type, the time frame and mode of measurement.

KpiID	name	description	objective
1	Average travel time	Average travel time of PT through the link	Mobility
2	Average delay	Average delay time (control delay or stopped delay) of PT at intersections	Mobility
3	Person throughput	Avg. person throughput during peak period	Mobility
4	Number of crashes	Number of crashes involving PT per traffic volume	Safety
5	Fuel savings	Average value of fuel savings	Sustainability
6	Variability of travel time	-	Reliability
7	On-time performance	On-time performance of transit	Reliability
8	Speed difference	Speed difference of PT with respect to average traffic speed	Reliability
9	Frequency	Frequency of public transport	Accessibility
10	Transit information	Access and reliability of transit information	Accessibility
11	Average delay	Average delay for pedestrians	Mobility
12	Level of Service	Pedestrian Level of Service (Ability to move in desired path)	Mobility
13	Separation level	Separation from motorists	Safety
14	Number of crashes	Number of crashes involving pedestrians	Safety

mode	movement type	time frame	Reference	Measurement
Public Transport	Through	Short-term	Austroads, FHWA	Diff. in travel time stamps using GPS data or loop detector data
Public Transport	Through	Short-term	Austroads, FHWA	Diff in actual and desired travel time using GPS data or loop de
Public Transport	Through	Short/long	Austroads	Smart card data - Translink
Public Transport	Through	Long-term	TMR, New Zealand	Annual summary reports by Road Trauma Australia and Office of Ro
Public Transport	Through	Long-term	Kaparias et al. 2011	Survey of Motor Vehicle Use, Australian Bureau of Statistics
Public Transport	Through	Short/Long	FHWA	Standard deviation of travel time using GPS data
Public Transport	Through	Short term	FHWA	Arrival times from selected stations from transit operators
Public Transport	Through	Long-term	Kaparias et al. 2011	Data from speed gun and GPS
Public Transport	From/To	Short-term	Kaparias et al. 2011	PT operators / GIS database
Public Transport	From/To	Long-term	Kaparias et al. 2011	Passenger surveys
Pedestrians	Through	Short-term	FHWA	Data on wait time for pedestrians at intersections or path block
Pedestrians	Through	Long-term	Amoroso et al. 2012	Data on capacity and space requirements (m^2 per pedestrian)

Figure 3.18: KPIs - Component of Ops DB

In order to connect ‘Scenarios’ and ‘KPIs’, a new entity called ‘Scenario-KPI observations’ is introduced. ‘Scenario-KPI observations’ comprise of KPI ID, Scenario ID, period of observation or measurement of the KPI, value of the KPI before and after implementation of a particular strategy and the associated percent change observed. Figure 3.19 shows the ‘Scenario-KPI observations’ component of Ops DB.

Since this section is limited to the discussion of the ‘design’ aspect of Ops DB, it ends here. The demonstration of the way in which Ops DB is used as a part of the implementation of the entire framework is discussed with the help of a case study in the following section.

ObservationID	KpiID	ScenarioID	start	end	ValueBefor	ValueAfter	change [%]
1	32	10	2010-01-01 00:00:00	2012-05-02 00:00:00	98	63	-36
2	20	6	2010-01-02 00:00:00	2012-05-03 00:00:00	63	95	51
3	2	6	2010-01-03 00:00:00	2012-05-04 00:00:00	20	91	355
4	7	4	2010-01-04 00:00:00	2012-05-05 00:00:00	69	68	-1
5	34	10	2010-01-05 00:00:00	2012-05-06 00:00:00	48	91	90
6	22	9	2010-01-06 00:00:00	2012-05-07 00:00:00	33	48	45
7	30	8	2010-01-07 00:00:00	2012-05-08 00:00:00	20	20	0
8	12	3	2010-01-08 00:00:00	2012-05-09 00:00:00	20	90	350
9	35	10	2010-01-09 00:00:00	2012-05-10 00:00:00	75	100	33
10	25	8	2010-01-10 00:00:00	2012-05-11 00:00:00	33	96	191
11	28	1	2010-01-11 00:00:00	2012-05-12 00:00:00	50	24	-52
12	5	4	2010-01-12 00:00:00	2012-05-13 00:00:00	70	40	-43
13	39	6	2010-01-13 00:00:00	2012-05-14 00:00:00	95	49	-48
14	2	3	2010-01-14 00:00:00	2012-05-15 00:00:00	82	29	-65
15	25	6	2010-01-15 00:00:00	2012-05-16 00:00:00	55	61	11
16	18	5	2010-01-16 00:00:00	2012-05-17 00:00:00	62	18	-71
17	37	5	2010-01-17 00:00:00	2012-05-18 00:00:00	90	58	-36
18	21	2	2010-01-18 00:00:00	2012-05-19 00:00:00	93	36	-61
19	33	7	2010-01-19 00:00:00	2012-05-20 00:00:00	39	50	28
20	21	2	2010-01-20 00:00:00	2012-05-21 00:00:00	56	15	-73
21	26	5	2010-01-21 00:00:00	2012-05-22 00:00:00	83	33	-60
22	35	1	2010-01-22 00:00:00	2012-05-23 00:00:00	47	51	9
23	32	10	2010-01-23 00:00:00	2012-05-24 00:00:00	33	56	70
24	37	9	2010-01-24 00:00:00	2012-05-25 00:00:00	45	75	67
25	25	3	2010-01-25 00:00:00	2012-05-26 00:00:00	61	79	30
26	14	1	2010-01-26 00:00:00	2012-05-27 00:00:00	72	47	-35
27	4	7	2010-01-27 00:00:00	2012-05-28 00:00:00	86	68	-21
28	8	7	2010-01-28 00:00:00	2012-05-29 00:00:00	16	57	256
29	9	3	2010-01-29 00:00:00	2012-05-30 00:00:00	30	86	187
30	11	6	2010-01-30 00:00:00	2012-05-31 00:00:00	55	17	-69
31	15	6	2010-01-31 00:00:00	2012-06-01 00:00:00	43	68	58
32	10	4	2010-02-01 00:00:00	2012-06-02 00:00:00	45	23	-49
33	9	1	2010-02-02 00:00:00	2012-06-03 00:00:00	52	16	-69

Figure 3.19: KPI observations - Component of Ops DB

3.10 Case study in Brisbane

In order to demonstrate the implementation procedure of the proposed framework, the city of Ipswich that is located within the southwest of the Brisbane metropolitan area is chosen. As shown in Figure 3.20, a 1-km road stretch that extends from Ipswich City Mall to Queen Victoria Parade. The stretch is surrounded with several three-legged and four-legged intersections including Ipswich central library, Ipswich art gallery, Ipswich civic center, Ipswich railway station, House rental accommodations, Riverheart parkland, Restaurants, Enterprise and training company etc. In other words, it can be said that the selected area showcases a perfect mix of mixed land use with different area types such as residential, recreational, educational and activity centers. The subsections further explains implementation of different stages of the framework. The subsections below further explains implementation of different stages of the framework.

3.10.1 Identification of Movement and Place categories

The links along the chosen stretch are identified, as shown in Figure 3.21. Based on the report titled ‘iGO City of Ipswich Transport Plan’ by Ipswich city council, the type of each of links are recognised. In this process, a total of 36 links are observed ranging from arterials to main street sub-arterials.

In addition to these, the street visuals in all possible directions are extracted from Google maps to identify the movement and place categories of different links in the area. The so assigned M&P categories of the study area are shown in Figure 3.22. Though the analysis is

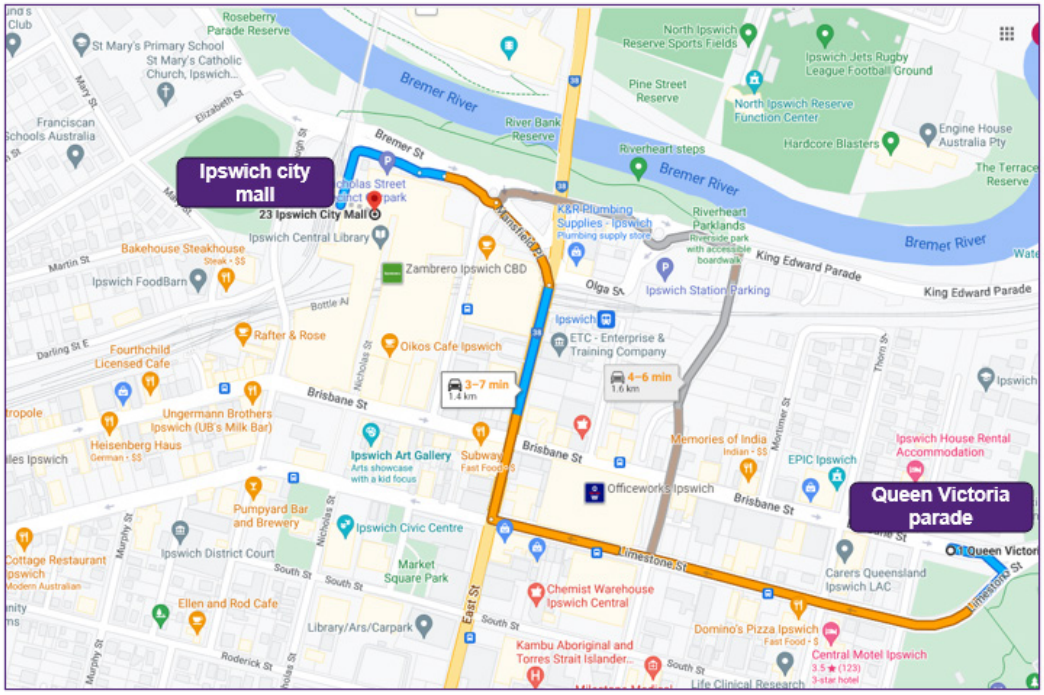


Figure 3.20: Ipswich city corridor

carried out for each of the 36 links, the analysis of a few of the links are discussed here, in order to ease the understanding process. Therefore, Brisbane street, which is a combination of links 18, 19 and 20 in Figure 3.21 is chosen.

It is a long arterial from Queen Victoria Street surrounded by mix of activity centres, commercial and residential zones. In addition, it is to be noted that the street belongs to M4-P4 category from Figure 3.21. Using this information, the following sub-section discusses computation of desired and observed priorities.

3.10.2 Priority assignment

Since the M&P category of the Brisbane street is already identified, the desired priority values can be extracted from the base desired priority matrix, as shown in Figure 3.23(a). However, as mentioned in section 3.5, these values can be modified if it is demanded by a particular scenario. It can be observed that the current study stretch has following features:

- Medium on-street activity
- Medium levels of interaction with adjacent land use
- Presence of on-road parking facilities
- No bicycle lanes
- No crossing opportunities

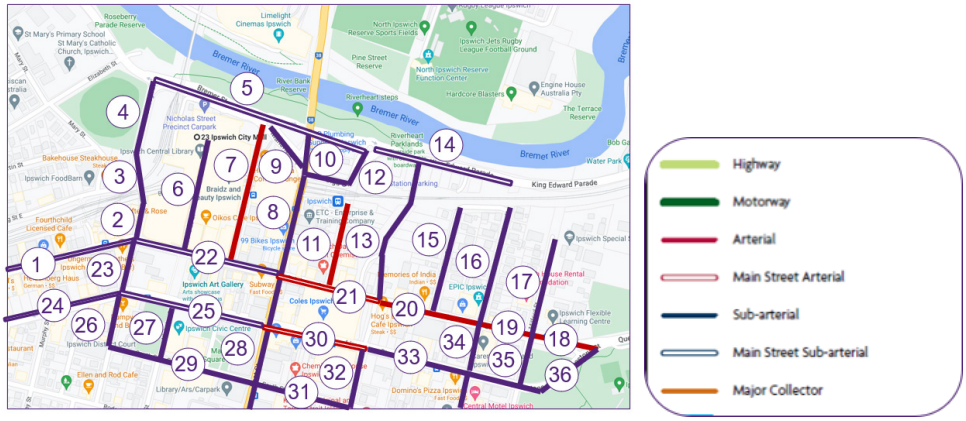
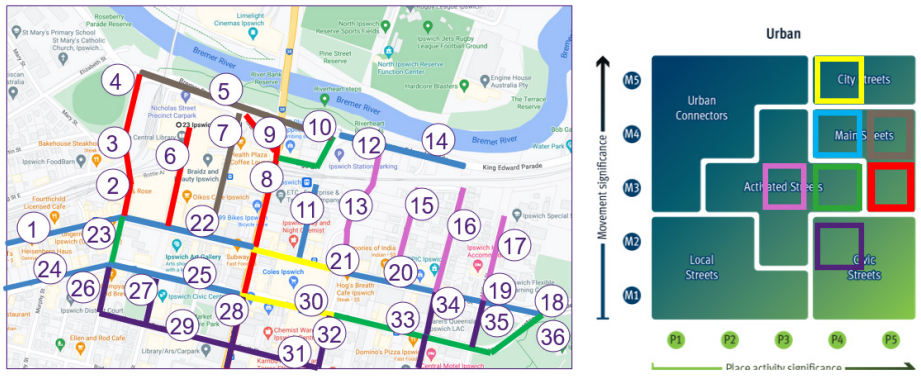


Figure 3.21: Different link types



(a) a (b) b

Figure 3.22: (a) Identification of M&P categories of the study area; (b) M&P matrix of the area selected;

- Presence of bus stops

With activity centers and eateries around and without the presence of bicycle lanes, the only way to access facilities surrounding this street would be through Public Transport and Private Vehicles. Therefore, the desired priority value of Private Vehicles for through and from/to movement are modified to ‘four’. Since the street connects different area types with mixed land use, the desired priority for Bicycles is also increased to ‘four’. In cases with abundant data, these decisions can be taken with more confidence. Figure 3.24 shows the desired priority values on the priority matrix of Brisbane street.

3.10.3 Observed priority estimation

In order to compute observed priority, relatively easily measurable KPIs with limited data are chosen. As shown in Figure 3.25 and Figure 3.26, a single individual KPI for each mode and movement type category are considered and the corresponding values are determined for through and from or to movements respectively.

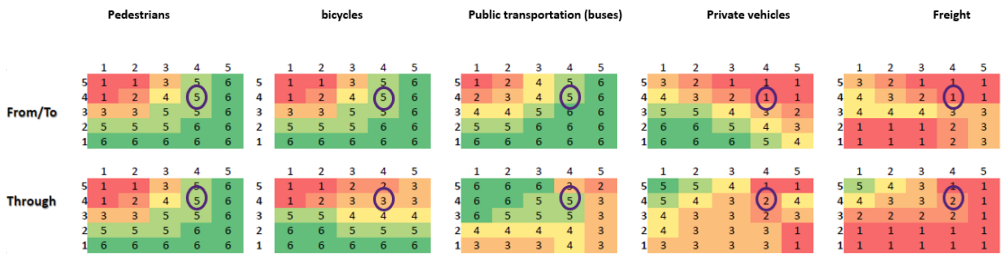


Figure 3.23: Initial desired priority values

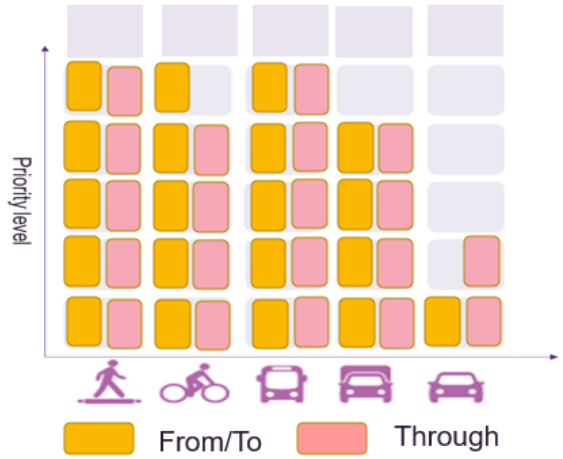


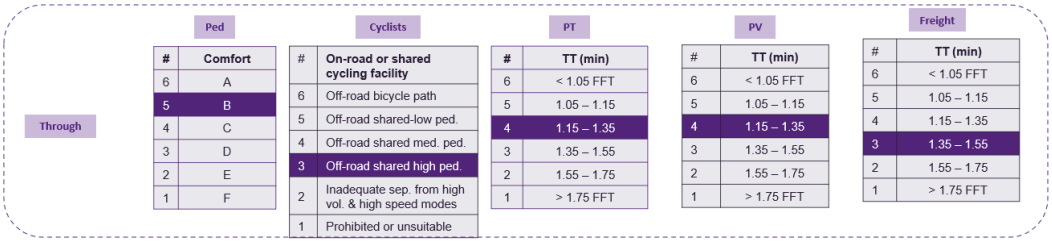
Figure 3.24: Priority matrix with desired priority values of the link of interest

3.10.4 Visualizing performance gaps

The so obtained desired priority and observed priority values are presented on the priority matrix of Brisbane street, as shown in Figure 3.27. From the figure, it can be observed that Public Transport and Cyclists experience lack of desired performance for both through and from/to movements. In addition, pedestrians are observed to experience poor LoS in the case of from/to movement. The feasible strategies may range from increasing crossing opportunities to enhancing facilities for PT passengers. However, the choice of appropriate strategy is explored through the use of the database, Ops DB.

3.10.5 Strategy selection

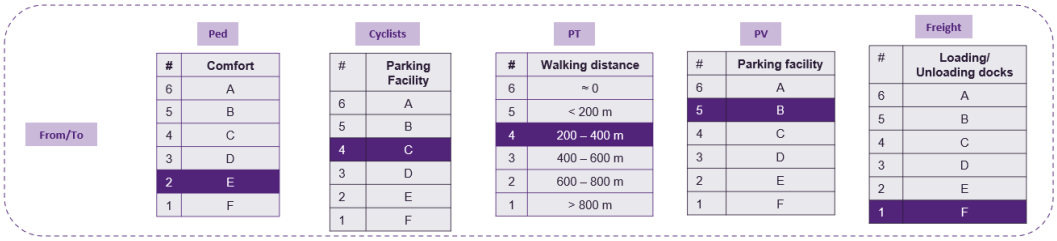
One can start the use of database from any component of interest, in this case, it's ideal to start the search and matching process from gaps. This is indirectly related to the KPIs that exhibited performance gaps in the previous step. For example, in the case of through movement of PT, the KPI - travel time (or delay) is observed to be more than the desired value (From Figure 3.25).



Through

Ped		Cyclists		PT		PV		Freight	
#	Comfort	#	On-road or shared cycling facility	#	TT (min)	#	TT (min)	#	TT (min)
6	A	6	Off-road bicycle path	6	< 1.05 FFT	6	< 1.05 FFT	6	< 1.05 FFT
5	B	5	Off-road shared-low ped.	5	1.05 – 1.15	5	1.05 – 1.15	5	1.05 – 1.15
4	C	4	Off-road shared med. ped.	4	1.15 – 1.35	4	1.15 – 1.35	4	1.15 – 1.35
3	D	3	Off-road shared high ped.	3	1.35 – 1.55	3	1.35 – 1.55	3	1.35 – 1.55
2	E	2	Inadequate sep. from high vol. & high speed modes	2	1.55 – 1.75	2	1.55 – 1.75	2	1.55 – 1.75
1	F	1	Prohibited or unsuitable	1	> 1.75 FFT	1	> 1.75 FFT	1	> 1.75 FFT

Figure 3.25: Observed priority values of the link of interest for Through movement



From/To

Ped		Cyclists		PT		PV		Freight	
#	Comfort	#	Parking Facility	#	Walking distance	#	Parking facility	#	Loading/ Unloading docks
6	A	6	A	6	≈ 0	6	A	6	A
5	B	5	B	5	< 200 m	5	B	5	B
4	C	4	C	4	200 – 400 m	4	C	4	C
3	D	3	D	3	400 – 600 m	3	D	3	D
2	E	2	E	2	600 – 800 m	2	E	2	E
1	F	1	F	1	> 800 m	1	F	1	F

Figure 3.26: Observed priority values of the link of interest for From or To movement

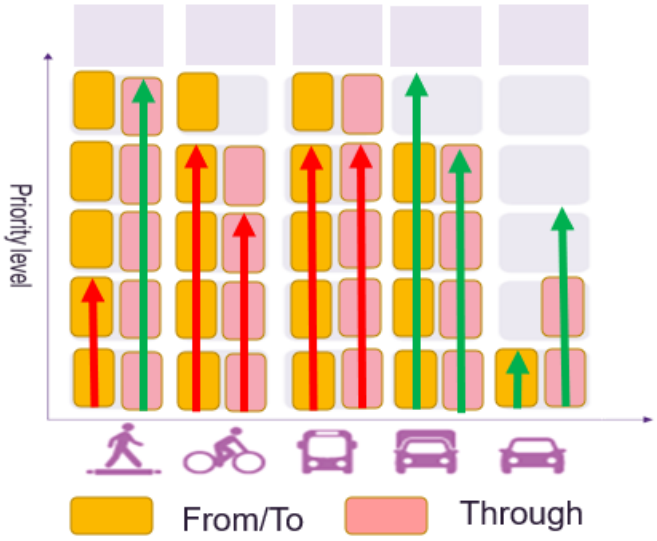


Figure 3.27: Visualisation of gaps of the link of interest

The first step is to search for the KPI ID of travel time or delay among the set of KPIs in the database i.e. from Figure 3.18. The corresponding Scenario ID and the percent change in KPI values can be found from KPI observation table i.e. Figure 3.19. This directs to the scenarios and the associated strategies that dealt with similar KPIs in Scenarios table (Figure 3.15 and Figure 3.17). From this, the strategies that have shown improvement in travel time and are feasible for this scenario are chosen to be provision of bus priority lanes and transit signal priority. The entire selection process of optimal strategy is illustrated clearly

in Figure 3.28. As mentioned previously, this is a simple demonstration of the proposed framework with limited data.

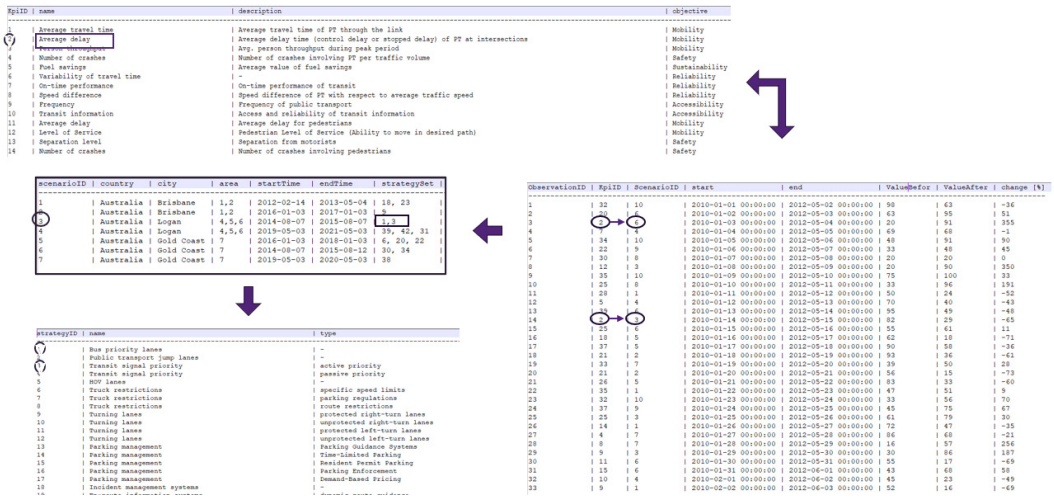


Figure 3.28: Process of selection of a strategy through Ops DB

3.11 Summary

The chapter presented the integrated framework that translates the high level intent of planning policies to day-to-day traffic operations proposed, as a part of the project. The framework encapsulates the lessons learned from the literature and overcomes majority of the limitations listed in the previous chapter. By detailing the concept and interdependence of various components within this framework, the chapter provides clarity on how these ideas translate into actions. The case study in the city of Ipswich helps illustrate these concepts further.

The introduction of the Ops DB, a comprehensive database linking key performance indicators to relevant strategies, is considered to be a valuable addition. Such a tool could greatly enhance efficiency in traffic control and management by providing a centralized resource for decision-making and monitoring progress. It is anticipated to have huge potential for various applications with one of them relevant to the project, is discussed in this chapter. Overall, the end applications of the proposed framework are multi-fold ranging from:

- Real-time performance review: The real-time monitoring of the associated KPIs at local and area level enables planners and operators to take relevant and timely decisions
- Multi-modal networks: The attributes, KPIs and strategies defined mode-wise reflect the short-term and long-term impact of various policies and objectives on other modes

- Strategy assessment: Quantitative evaluation of strategies over time at similar locations or of similar scenarios helps in analyzing the impact propagation of strategies and their choice
- Integrating planning to operations: Relating the high-level intent of the planners to the strategies implemented at the operators' level indicates the extent to which the intent is achieved

Chapter 4

Prototype Interface

This chapter discusses the conceptual design of the prototype interface developed as part of this work. The interface implements the framework described in the previous chapter. It is designed to be user-friendly and suitable for both experienced and less-experienced operators. The design is illustrated through an example of a real-world corridor, noting that this design fits different area types, including traffic networks.

The chapter begins with corridor/area selection and division into links with similar characteristics. It then discusses how desired priorities are assigned to each link based on the M&P classification and represented on the map. Afterward, it evaluates the observed priorities using some KPIs and compares them to the desired priorities to identify performance gaps and visualize them on the area map. Next, it explores strategy selection to address these gaps and describes the database design, explaining how users can manage its various components, including scenarios, strategies, and KPIs. Finally, the chapter introduces the real-time monitoring functionality that facilitates performance evaluation, enabling users to track scenarios' changes and generate analyses over time.

4.1 Area Selection

This example focuses on Wembley Road, located in Logan City at the southern end of the Brisbane metropolitan area. As shown in Figure 4.1, it extends from Kingston Road to Logan Motorway. Along the corridor, several links intersect it, such as Railway Parade, Mayes Ave, and Bardon Road. Therefore, the selected area incorporates segments of these roads, as their impact on the corridor's performance cannot be ignored. For instance, improvements made to the adjacent minor approaches may have unexpected consequences on the corridor's performance.

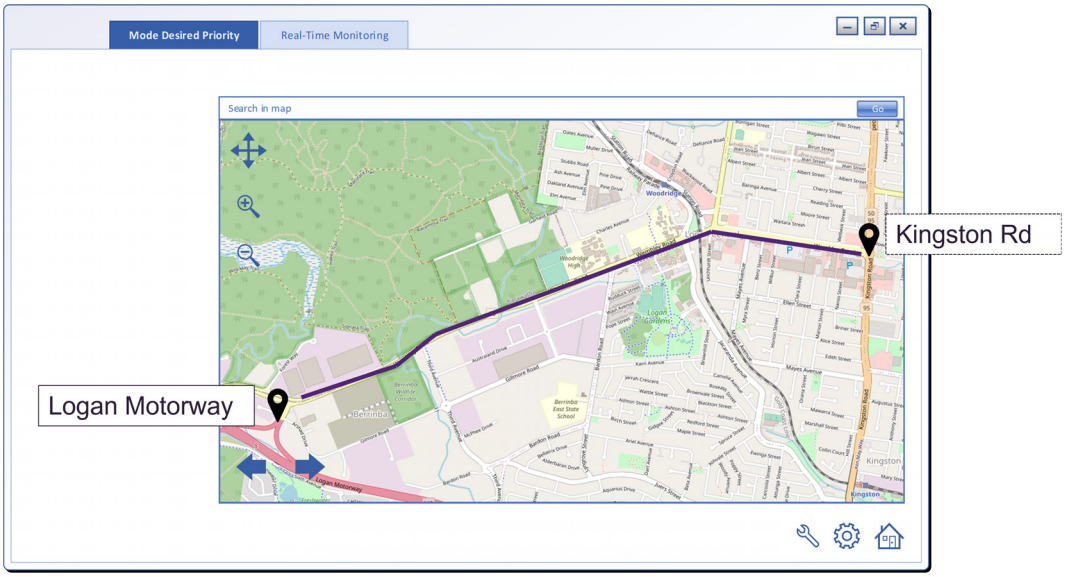


Figure 4.1: Map highlighting the selected area and key intersections along Wembley Road.

As shown in Figure 4.2, this corridor crosses different area types. Some of these areas include shopping centers, industrial sites, service facilities such as the Logan City Council, Central Library, and school zones. Additionally, the western part of Wembley Road, in its current design, is primarily devoted to facilitating thorough movement. Therefore, to ensure fair treatment of these diverse areas, it is essential to handle the road segments that traverse them differently. This approach requires subdividing the area into smaller links that share similar attributes, as shown in Figure 4.3.

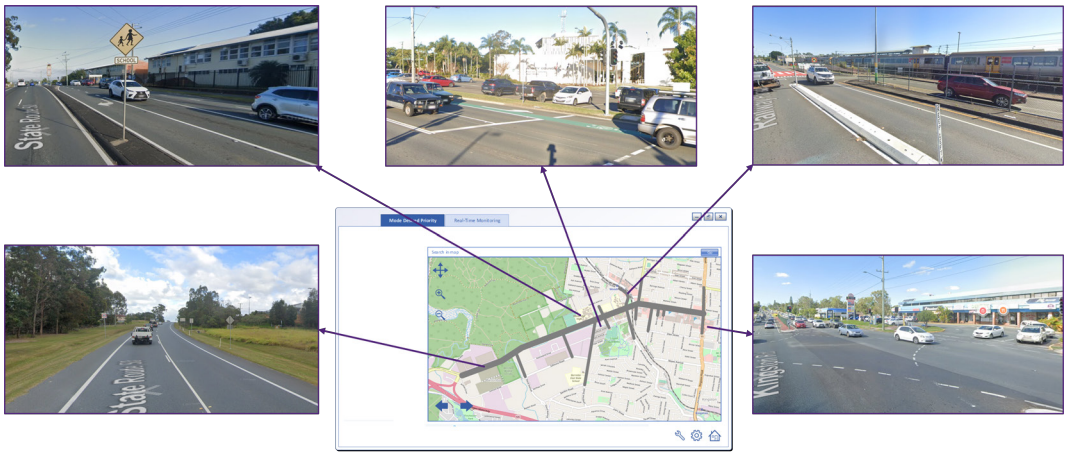


Figure 4.2: Illustration of various area types, including shopping centers and school zones

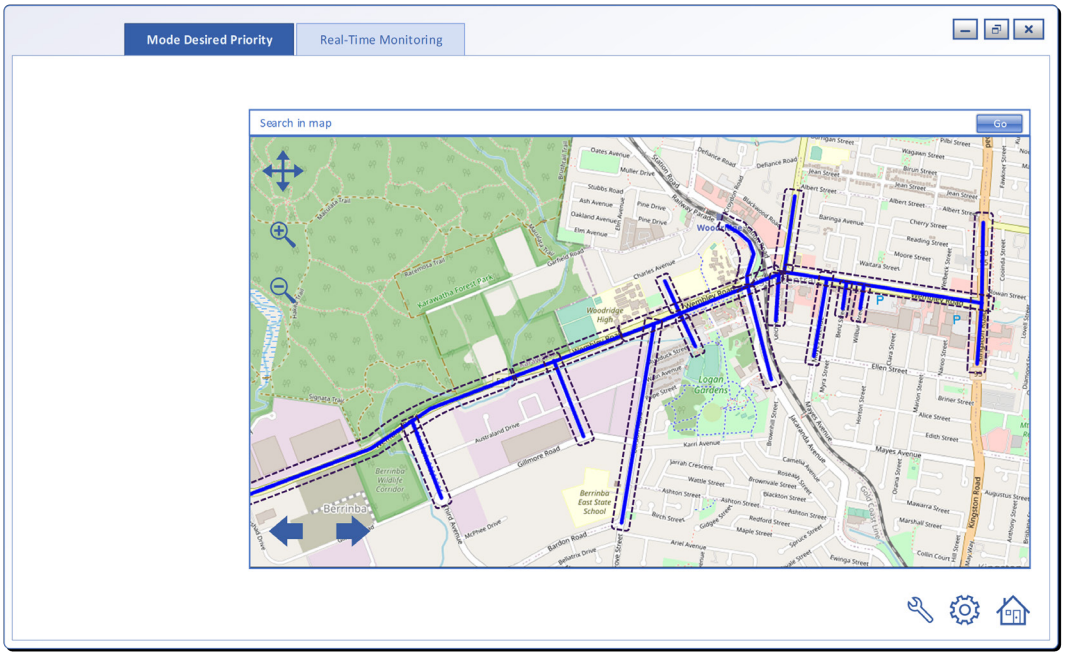


Figure 4.3: Segmentation of the selected area into smaller links

4.2 Priority Assignment

The next step involves assigning the desired priorities across all links for each mode, covering both from/to and through movements. All that is needed is the M&P category for a specific time of the day that aligns with the high-level vision. The desired priorities may vary at different times of the day because links may be classified differently at various times. For instance, shopping areas are less crowded in the morning, but demand increases throughout the day. However, demand in school zones is high during morning and evening peak hours, but low at night.

The process of dividing areas into links and classifying these links based on M&P categories is assumed to be done during system initialization. Therefore, by default, the interface will feature a network organized into links, with each link classified into M&P categories based on the time of day. However, if assigning new categories to a specific link is required, or if users want to modify the current M&P categories, this can be done by clicking on the required link on the map. This action will directly open another window that displays the link priorities and the link analysis, as illustrated in Figure 4.4. Inside the link priorities, users can assign the M&P category for a specified time range. By selecting a category, the default desired priorities based on the desired priority matrix will appear on the right side as column bars ranging from zero to six. Additionally, these priorities can be updated or modified for specific scenarios by selecting the mode and movement type from the dropdown menus on the right side of the desired priorities and then adjusting the priority level using

the "+" and "-" buttons, respectively. Finally, all these changes can be saved by clicking on the save icon.

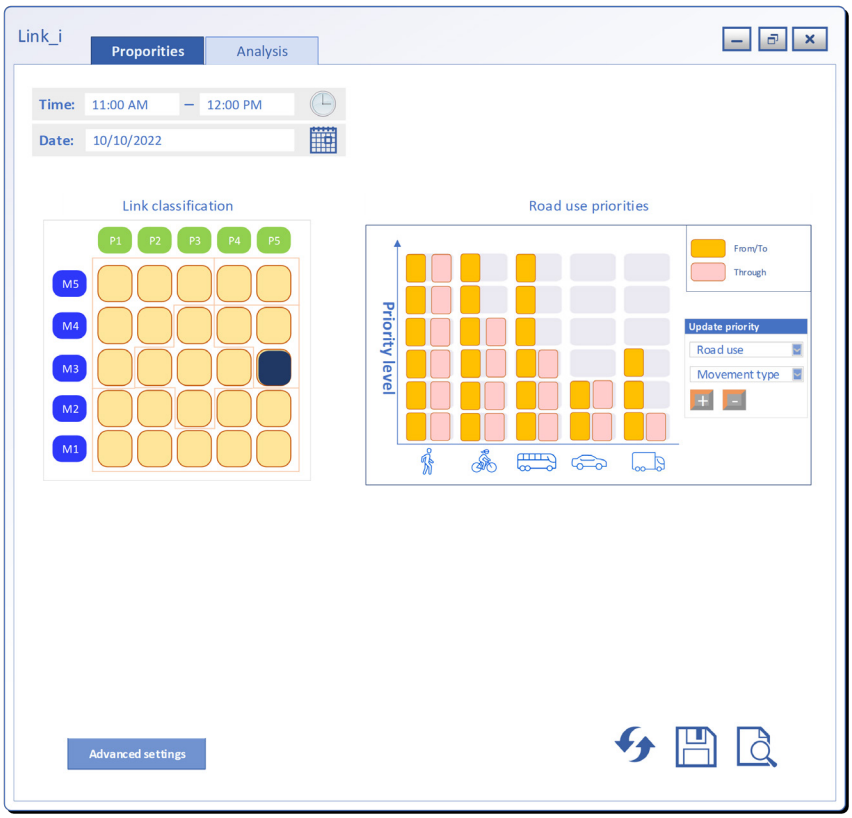


Figure 4.4: Interface for assigning M&P category to links

The desired priorities are presented in the "mode desired priority" window, as shown in Figure 4.5. In this window, priorities are represented as lines where the color of each line indicates different travel modes, and the width of the line reflects the priority level. On the right side of the window, users can present the priorities for a specific time period, for all modes, or some of them, and for from/to or through movement. When zooming out, the number of lines decreases, indicating that the displayed priorities are for the modes with the highest levels of priority. For example, zooming out to the maximum displays only the top priority of each link, as shown in Figure 4.6. In this case, if more than one line appears, this suggests multiple modes share the highest priority on that link. Conversely, when zooming in, the number of lines increases, providing a more detailed view of the priorities for different modes.

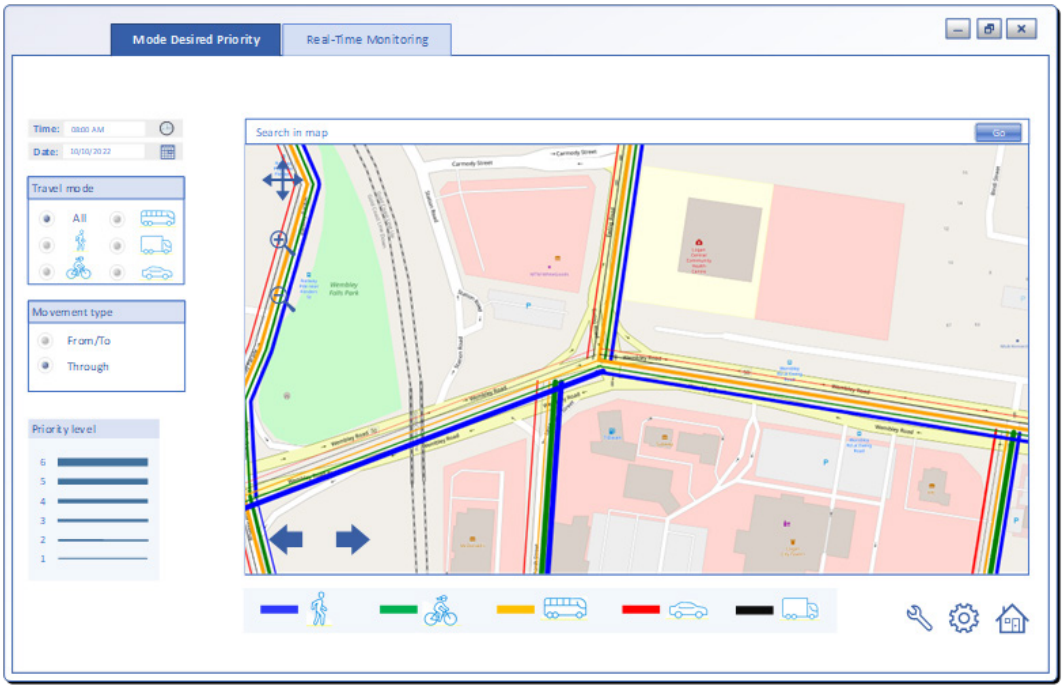


Figure 4.5: Visual representation of desired priorities by travel mode

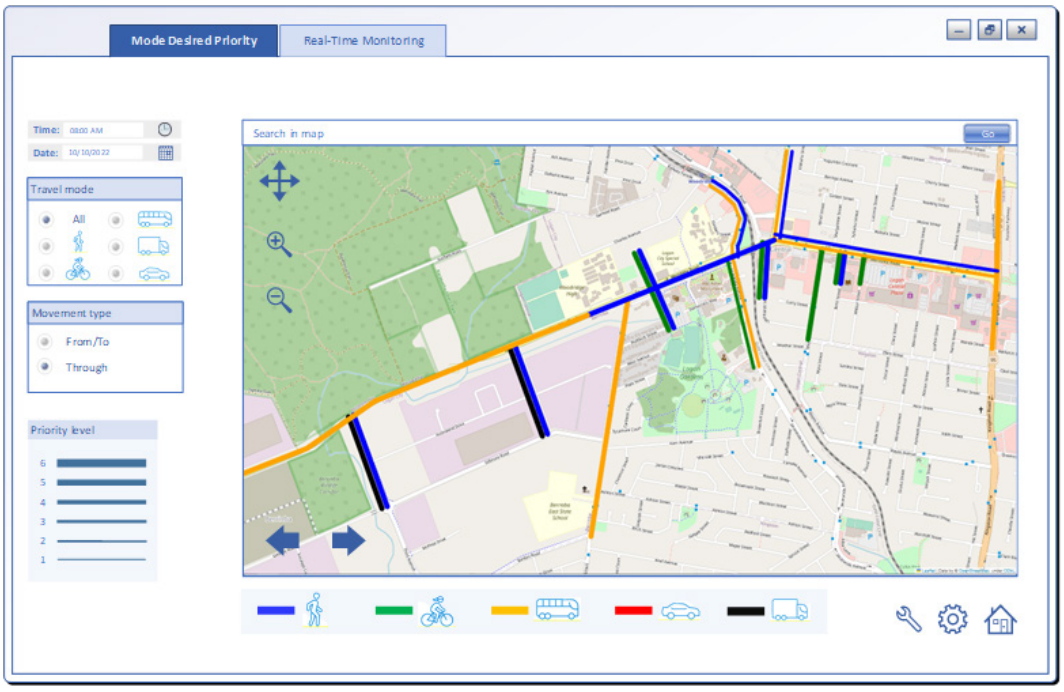


Figure 4.6: Top desired priorities for each link shown in a simplified, zoomed-out view

4.3 Observed Priority Estimation

After assigning the desired priority to the various modes, the next step involves calculating the observed priorities. These priorities represent the actual performance of each travel mode. They are calculated based on the observed KPIs. For different movement types and travel modes, different KPIs might be applied. One or more KPIs can be utilized to estimate the desired priority based on user selection and available data. It is important to note that data processing occurs externally, outside of the interface, and each KPI value is fed as a value from 1 to 6.

Table 1 provides an example of the observed priority calculation for pedestrians through movement on links 1, 2, and 3, as illustrated in Figure 4.7. In this example, five KPIs have been evaluated. The estimated KPIs are listed under each link in the table as numerical values, ranging from one (the worst performance) to six (the best performance). The weight column indicates the weight assigned to each KPI. For example, the observed priority calculation for pedestrians at link 3, using the weights shown in Table 4.1, would be:

$$P_3 = \frac{2 \cdot 25\% + 5 \cdot 25\% + 4 \cdot 20\% + 2 \cdot 15\% + 3 \cdot 15\%}{100\%} = 3 \tag{4.1}$$

Table 4.1: Example calculation of observed pedestrian priorities for links 1, 2, and 3

		Lonk No.		
KPI	Weight	1	2	3
Crossing delay	25%	2	3	3
Footpath congestion	25%	5	4	1
Exposure to vehicles	20%	4	6	4
No. bicycles passing or meeting	15%	2	3	4
Crossing opportunities	15%	3	3	4
Avg.		3	4	3



Figure 4.7: Links along the eastern side of Wembley Road

Generally, the observed priority at link j is calculated as the sum of KPI values multiplied by their relevant weights, divided by the total weights. Based on this simple calculation, the observed priority for pedestrians at link 3 equals 3. In addition to a weighted average, the observed priority can be calculated using other methods, including a regular average and the worst-performing KPI. It is important to note that priorities are expressed as whole numbers, so results may sometimes need to be rounded. This process can be applied to all travel modes at all relevant links for both movement types. Eventually, by comparing the observed priority with the desired priority, the performance gap can be easily determined.

4.4 Visualizing Performance Gaps

In the proposed interface, gap estimation is automatically performed based on desired and observed priorities. To visualize the estimated gaps on the network map, users can switch from the "mode desired priority" window to "gap monitoring" in the interface. The gaps are represented as lines, as shown in Figure 4.8. The color of each line indicates the gap level, ranging from green to red. Green lines indicate no gaps on these links, while red lines indicate poor performance with the most significant gaps. In this window, users can display the performance gaps of different travel modes and movement types. Additionally, it is possible to modify the KPIs and the calculation method applied to estimate the observed

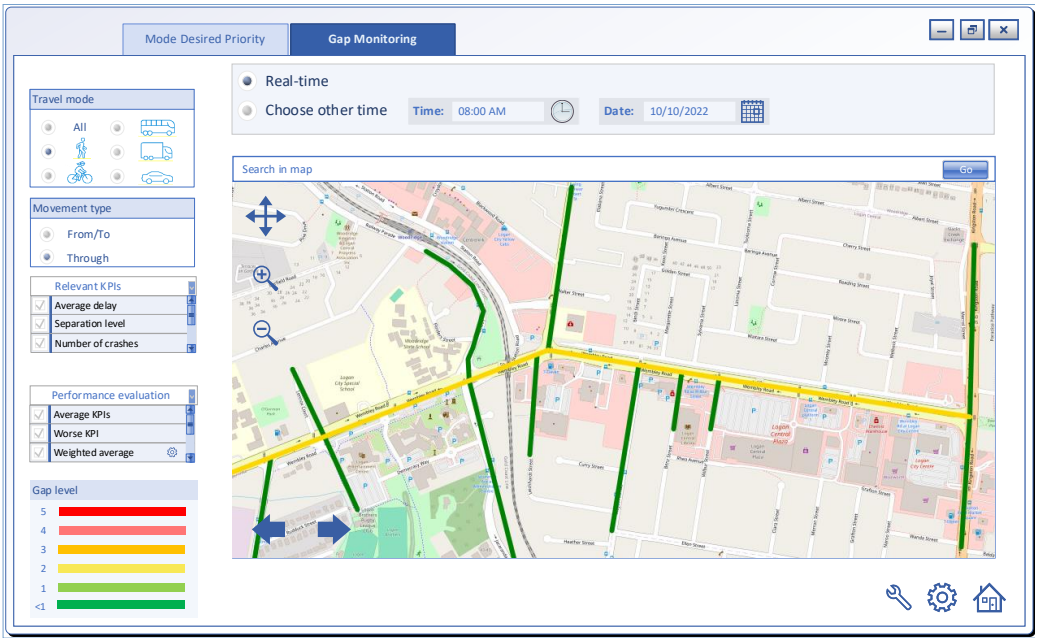


Figure 4.8: Map displaying performance gaps with color-coded lines indicating the difference between desired and observed priorities

The prototype user interface has been developed to allow any date and time range period to be selected for a gap monitoring. The interface also incorporates an additional option to analyse performance gaps using real-time data to assess the live network operating performance. This feature will be a valuable tool if it can be demonstrated that a reliable and verifiable live data feed can be provided for all transport modes.

Based on the gaps' information provided in Figure 4.8, the highest pedestrian gap in the presented area appears at the links marked with a yellow line, which indicates a gap level of two. Changing the selected travel mode and movement type updates the displayed gaps accordingly. For instance, Figure 4.9 illustrates public transportation gaps related to from/to

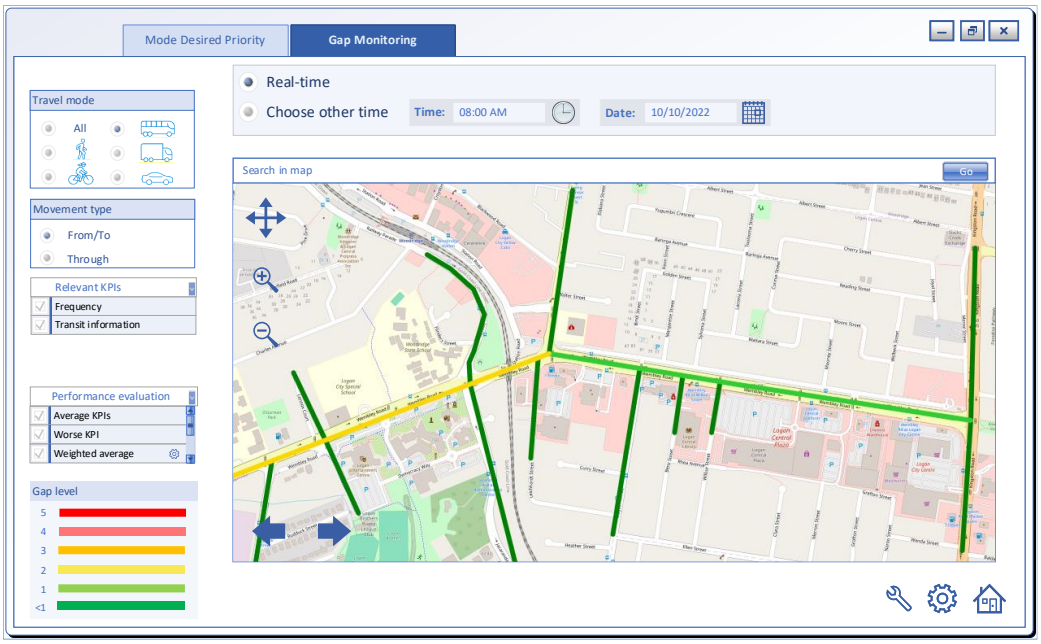


Figure 4.9: Visualization of gaps in public transportation performance for from/to movement

In addition, in the gap monitoring window, desired and observed priorities for each link can be presented as bar charts, providing more information about each travel mode, as shown in Figure 4.10. This figure shows the bar charts for three links on Wembley Road. On these charts, the desired priority appears as bars, and the observed priority as arrows. The difference between them represents the performance gaps. Green arrows indicate no gaps, while red arrows indicate gaps between observed and desired priorities.

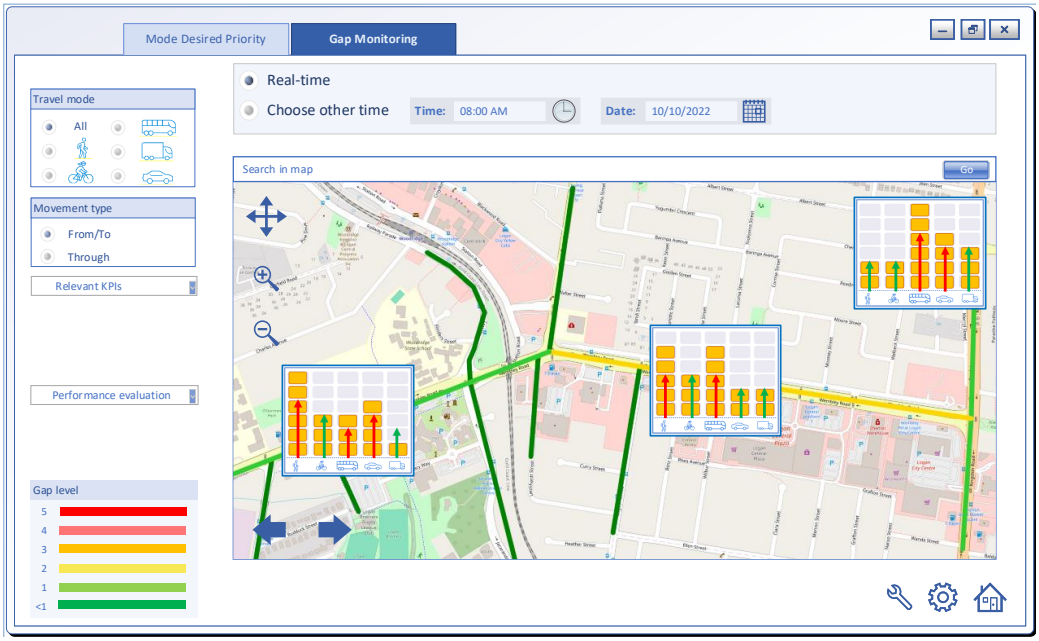


Figure 4.10: Bar charts comparing desired and observed priorities for three links, highlighting performance gaps

4.5 Strategy Selection

Gaps can be addressed by implementing one or more improvement strategies. In the proposed interface, this process begins by clicking on a specific link to open a new window, as illustrated in Figure 4.11. In this window, the Properties section focuses on link classification, and the Analysis section evaluates link performance. By selecting the Analysis option, users can choose to view either real-time performance or performance at a specific time. Once a selection is made, the performance of the link across all travel modes and movement types is displayed. In this context, the bars represent the desired priority, while the arrows indicate the observed priority.

Selecting one of these bars displays the relevant KPIs, as shown in Figure 4.12. The color represents the performance level: green indicates good performance, while red indicates poor performance. Additionally, suggested strategies derived from the database appear on the right side. For instance, if there is an issue with pedestrian separation levels, recommended strategies may include separating footpaths and bicycle lanes. The horizontal green bars beside each suggested strategy show the recommendation level, ranging from zero to one hundred percent.

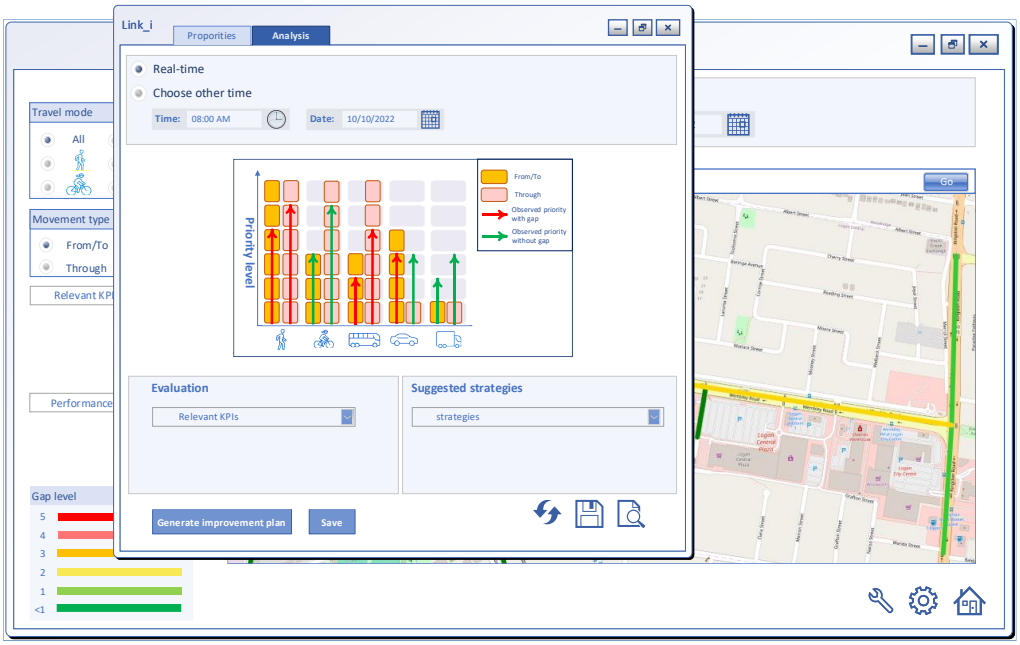


Figure 4.11: Window for selecting and evaluating improvement strategies for links

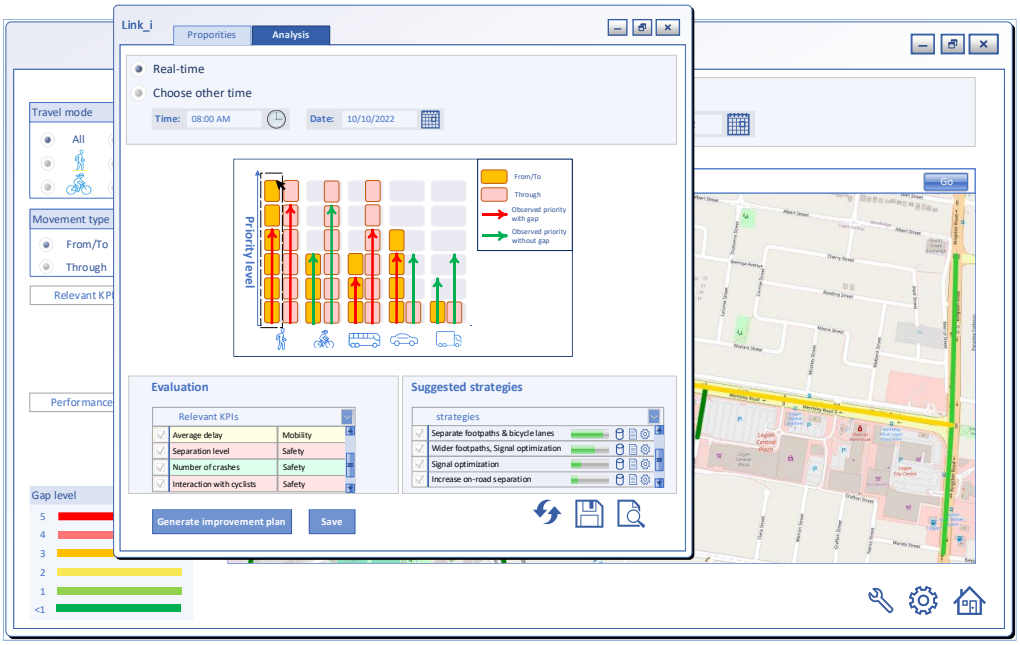


Figure 4.12: Details about relevant KPIs and recommended strategies for addressing gaps for each link

By clicking on the database icon, as demonstrated in Figure 4.13, the scenarios stored in the database that were used to reach these strategies can be viewed. Clicking on the information icon (middle icon) allows for viewing the analysis related to the implementation

of this strategy, as shown in Figure 4.14. This information provides indications about the affected KPIs. For example, some of the KPIs for pedestrians and bicycles will improve, but one KPI related to pedestrian crowding levels will worsen. According to the information

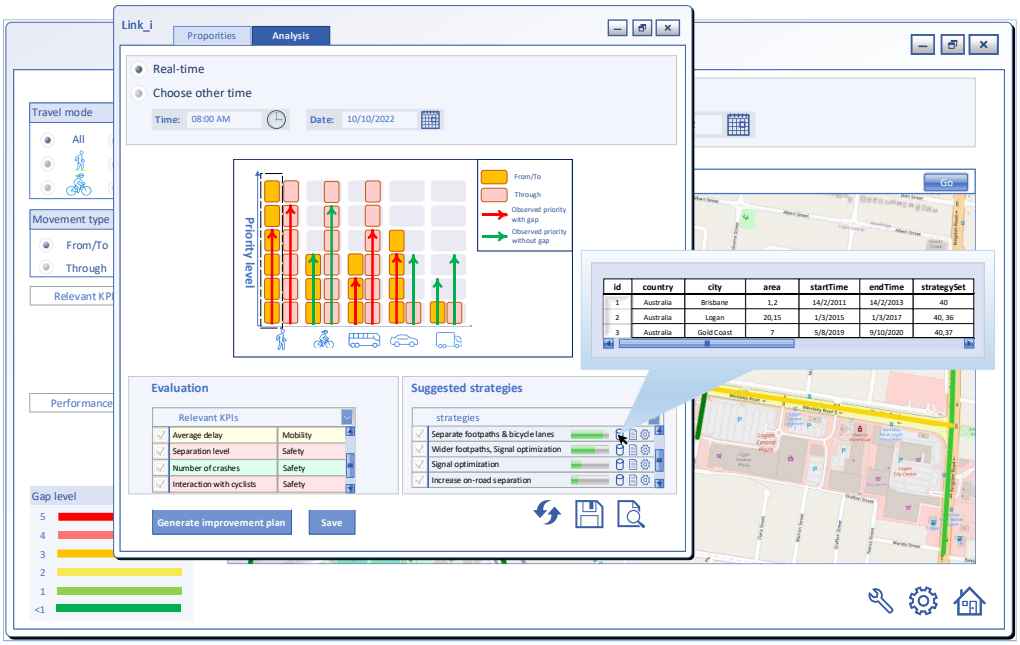


Figure 4.13: Access to stored scenarios in the database associated with proposed strategies



Figure 4.14: Analysis showing the impact of strategies on observed KPIs

4.6 Operation Database (Ops DB)

Detailed information about the stored data can be accessed in the database window, as illustrated in Figure 4.15. This window provides comprehensive details on all database components, including scenarios, available improvement strategies, KPIs, links, and KPI observations related to the stored scenarios. Users can filter scenarios by time range and specify locations by selecting countries and cities. New scenarios can be added automatically by uploading a file in the required format using the "Upload full scenario" button or manually by adding a new entry to the list. Users also have the option to delete a scenario by removing

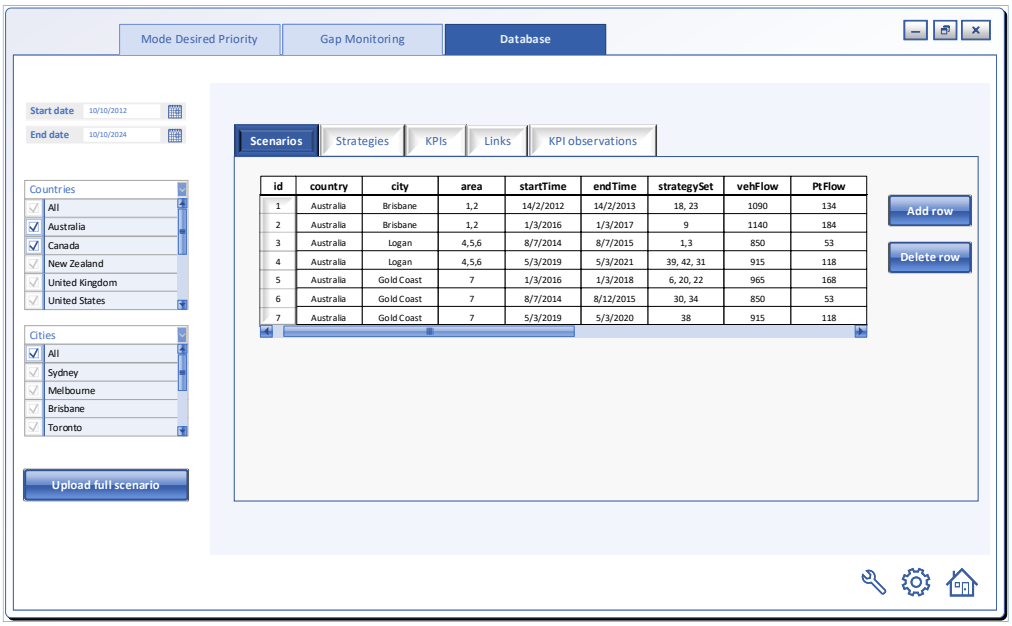


Figure 4.15: Comprehensive details on database components

Switching to the Strategies tab and clicking on a specific strategy opens a new window, as demonstrated in Figure 4.16. This window displays the strategy name, the number of times the strategy has been implemented, the scenarios that applied this strategy, the locations of these scenarios, and the selected time range. Additionally, this window provides statistics about the strategy, including aggregated information about the changes in the affected KPIs and the direction of these changes.

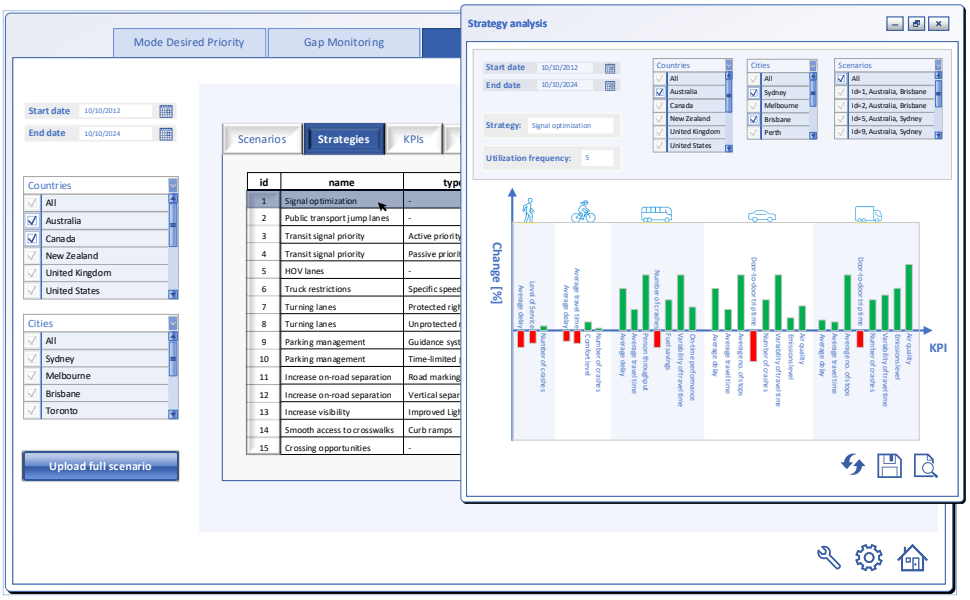


Figure 4.16: Overview of chosen strategy, its applications, locations, and impact on different KPIs

Similarly, switching to the KPI list and clicking on one of these KPIs opens a new window that displays the KPI analysis, including the scenarios that used this KPI and the time range of these scenarios, as shown in Figure 4.17. This figure depicts the proportion of cases where this KPI was improved, worsened, or where no information was provided about this KPI. Additionally, the window presents recommended strategies to address issues

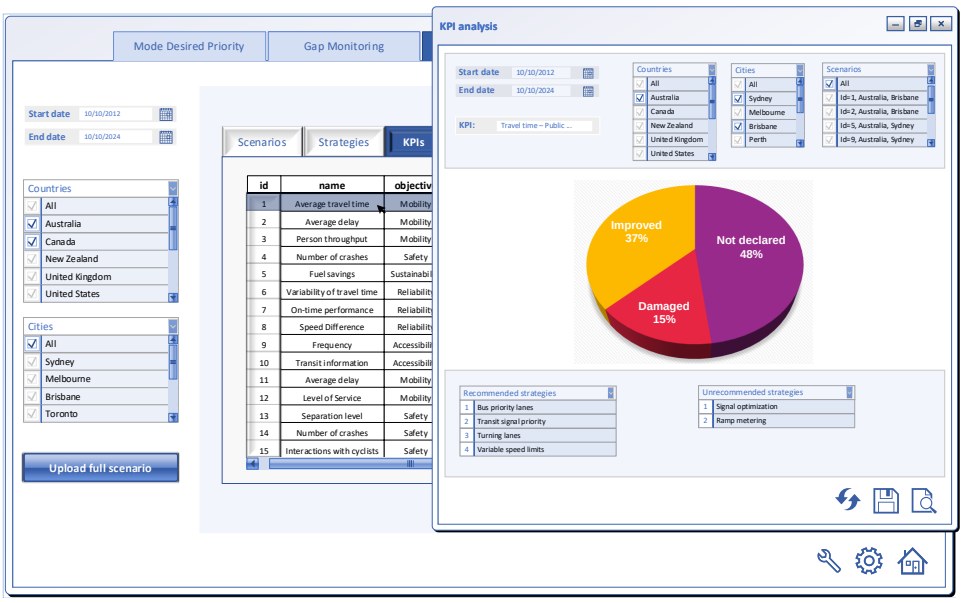


Figure 4.17: Analysis of KPIs, including scenarios, performance changes, and recommendations

4.7 Real-Time Monitoring

Up to this point, all the steps in the proposed framework have been covered, starting from area selection to addressing identified gaps by implementing recommended strategies, as demonstrated in Figure 3.4. However, one crucial step remains: real-time monitoring. This step represents the loop created by connecting Step 7 and Step 5, as illustrated in Figure 4.18. In other words, it links the strategy selection phase with the computation of the observed prior[illegible]

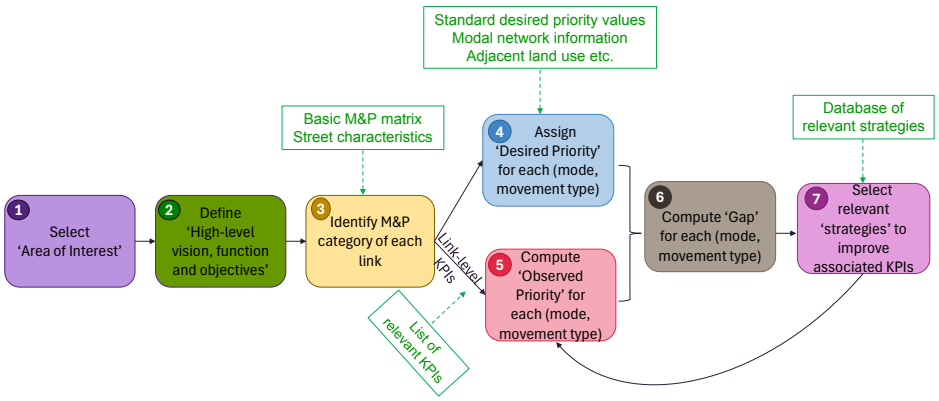


Figure 4.18: Illustration of the process linking strategy selection to the computation of observed priorities for real-time monitoring

For example, consider a scenario where an area has been selected, all framework steps have been implemented, and various strategies have been employed to address the identified gaps.

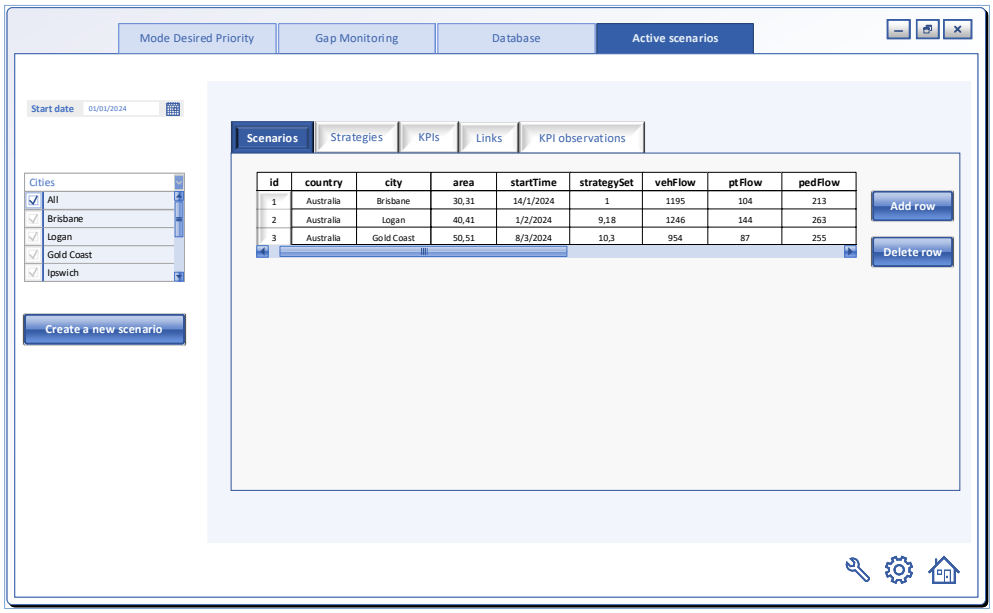


Figure 4.19: List of active scenarios for ongoing monitoring

To monitor changes over time in this scenario, clicking on it will open a separate window, as illustrated in Figure 4.20. This window shows the strategies that have been implemented and can generate an analysis for specific time periods, such as from the beginning to a given date. The analysis includes information about changes in the relevant KPIs over time based on historical data. Additionally, the data can be exported to an Excel sheet for further analysis and reporting.

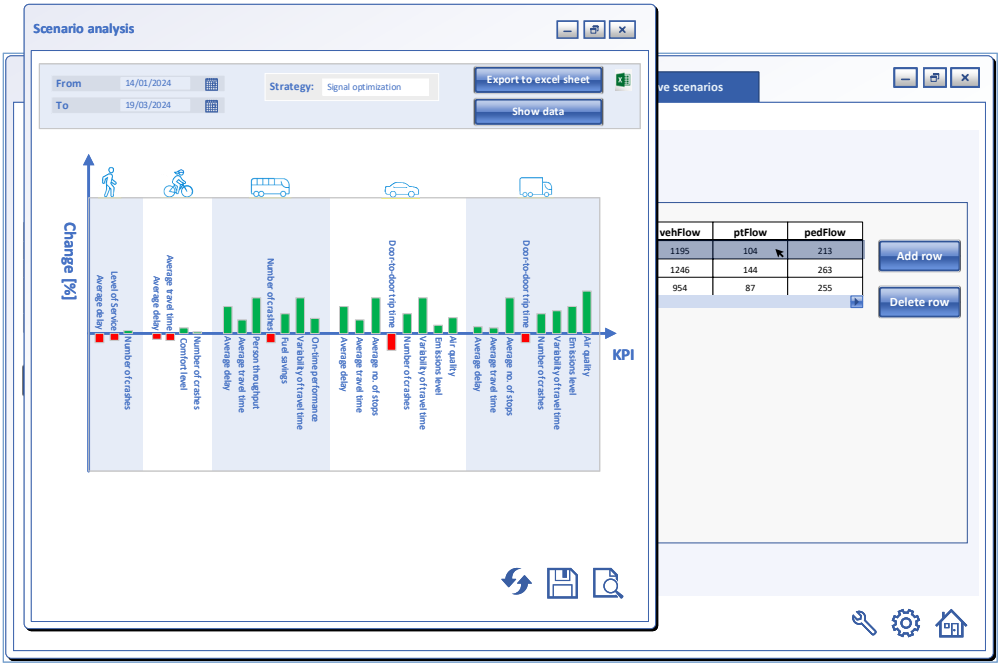


Figure 4.20: Window for tracking changes in scenarios over time, with analysis options based on observed priority data

4.8 Summary

This chapter outlines the prototype interface designed to operationalize the proposed framework. In the interface, the analysis process begins by selecting an area of interest and dividing it into smaller links with similar characteristics.

The next step involves assigning desired priorities across all links for each mode, covering both from/to and through movements. These priorities vary at different times of the day and can be presented in a separate window as lines.

After assigning desired priorities, the next step is calculating the observed priorities. Different KPIs might be applied for different movement types and travel modes.

The interface visualizes performance gaps based on desired and observed priorities. Gaps can be addressed by implementing improvement strategies. This process is performed in a separate window, which facilitates analyzing links' performance and suggesting recommended strategies derived from the stored data in the database. This data can be explored

in the database window, which provides comprehensive details on all database components, including scenarios, improvement strategies, KPIs, links, and KPI observations related to the stored scenarios.

Finally, in the real-time monitoring procedure available in the interface, users can monitor changes over time in a selected scenario, analyze changes in relevant KPIs, and export data for further analysis and reporting.

Overall, this chapter provides a comprehensive overview of the prototype interface, demonstrating how it supports the implementation of the proposed framework and facilitates continuous improvement through practical functionalities.

Chapter 5

Conclusions

5.1 Summary of Key Findings

This project focused on developing a performance-based, multi-modal network management framework for integrating high-level planning aspirations into real-time traffic control operations. The proposed framework aims to translate high-level directions into network operating plans. It facilitates the creation and management of these plans using a prototype interface.

To gain insights into the state of practice and the state of the art in real-time traffic management, especially those addressing the evolving challenge of managing road networks, the first phase of this project involved a comprehensive review of similar frameworks and best practices. This review included examples from Australia and other countries, such as TMR's network optimization framework, Victoria's SmartRoads, and New Zealand's network operating framework.

Although these frameworks provide valuable insights into traffic management, operations, and innovative approaches for infrastructure decision-making, some aspects still need more investigation and improvement. For instance, some of these frameworks may not fully consider the M&P concept, an essential component of creating a balanced transportation network. In addition, others may lack the level of detail required for practical implementation, such as addressing different travel modes, translating high-level directions into network operating plans, establishing appropriate performance measures to evaluate network efficiency relative to desired objectives, and establishing a clear link between network improvement plans and the actual performance of the transportation system. Moreover, reliance on assumptions within some - maybe most - reviewed frameworks can pose challenges when evaluating and analyzing system performance.

These limitations demonstrate the need for innovative approaches to address the drawbacks of existing frameworks and meet evolving network needs by providing more robust solutions for managing road networks.

The proposed framework offers a straightforward and detailed approach for translating high-level objectives such as safety, accessibility, and efficiency into real-time traffic control

operations. The first step in this process involves integrating the network operating principles and targets with the network hierarchy represented by the M&P classifications to determine the operating targets for all travel modes at different times of the day. Then, it identifies the performance gap for each mode by comparing the observed performance with the operating targets and finally suggests improvement strategies to address these gaps.

Suggested strategies can range from infrastructure-related actions, such as adding bus-dedicated lanes or turning lanes, to day-to-day operations, such as signal optimization and ramp metering. Strategy evaluation is conducted based on information provided by the operational database, which serves as a knowledge-based evaluation approach. This approach suggests using strategies that have been implemented in previous scenarios that match the current scenario in terms of area characteristics and observed KPIs.

Additionally, the proposed prototype interface facilitates the implementation of the proposed framework. It provides network operators with visual real-time information on network performance, including gap analysis between desired and observed performance, and recommended improvement strategies for bridging these gaps. It is designed to be user-friendly and suitable regardless of operator experience.

To conclude, the proposed framework developed within the scope of this project aims to bridge the gap between existing frameworks and best practices in the traffic management field and modern transportation needs to meet the increasing urbanization and mobility demands.

5.2 Limitations and Recommendations for Future Research

This section presents a list of limitations to the proposed framework and potential future research directions for improving its implementation:

- One of the key steps in the framework involves identifying the M&P classification of each link in the selected area. This classification directly affects the desired performance of each mode at different times of the day. In the current design, the M&P category is determined based on several factors, including location-specific attributes, road-use characteristics, and the type of dominant activities in the area. However, these factors do not always provide enough detail to select a distinct link category, mainly because some M&P categories have slight differences. As a result, different people focusing on different factors may classify the same link differently. Therefore, one of the most urgent tasks in future works is to propose some rules or procedures that facilitate the link classification process, reduce confusion, and provide distinct classifications for each link.

- The desired priority represents the intended performance for each travel mode at different times of the day. This priority can be assigned using the desired priority matrix and the M&P category of the relevant link. Initially, the priority values that appear in this matrix were set based on the M&P category and considering several

factors that feature each category, such as predominant modes in the link, type of adjacent land use, speed limit, and active street frontage. Then, these values were calibrated after a detailed discussion with the stakeholders along with the planning and operations teams of TMR. However, despite this strict and meticulous process of determining these values, they were not tested and calibrated against real-world scenarios. Therefore, the follow-up phase of the project should focus on the evaluation, calibration, and validation of the desired priority values to ensure robust and reliable implementation of the framework.

- Among the significant aspects of the proposed framework is the process of selecting strategies to address the identified gaps. In this process, available strategies are evaluated based on the data stored in the operation database. Despite the simplicity and reliability of this approach, its implementation in real-world operations remains challenging due to difficulties associated with data acquisition and availability, as well as the effort required to continuously update it with new data to accommodate changes in traffic networks. Therefore, one of the initial steps that should be considered before the implementation of the framework is to check the data availability and ensure that it covers all possible scenarios, providing enough information about the available strategies. It is also worth testing and comparing this approach against other evaluation methods, e.g., analytical models and simulation-based approaches.

- In the scope of this project, this framework was demonstrated using hypothetical case studies aimed at illustrating the different components of the framework and its implementation process. However, one crucial step before fully implementing this framework is to evaluate its feasibility and applicability using several approaches. e.g., using a microscopic simulation environment that provides a detailed representation of the traffic road networks to ensure reliability or testing in real-world scenarios to demonstrate its effectiveness and gain insights into potential improvements.

Chapter 6

Appendix

6.1 Movement and Place frameworks from literature

This section of the appendix discussed the detailed modules of different movement and place frameworks in literature.

6.1.1 New South Wales' Movement and Place framework

The NSW Movement and Place Framework is part of a broader trend towards more place-based strategic design and planning. The framework builds on a body of statewide, interstate and international work. It is being updated and expanded by Transport for NSW and the Department of Planning, Environment and Industry on a regular basis. The understanding of place and movement functions in the perspective of the objectives of the framework, is discussed below.

Understanding 'place'

While place is a physical space, it is perceived different by different people and at different scales. It comprises numerous elements such as the topography of the surrounding area, the underlying natural environment, the built environment, the physical enclosure and edges these create, but also the less tangible features such as activities generated within the place, their significance, and whether those activities occur in public or private spaces. Therefore, 'place' is predominantly dynamic that changes with change in activities of people using it. One way proposed to study is by analysing the key factors such as meaning, physical form and activity of a given place.

Understanding 'movement'

Movement enables people to connect with one another and pursue their activities, in addition to efficiently delivering goods and services to drive economic growth. The interaction between movement and place is dynamic i.e. places create demand for the movement of people and goods, just as movement serves and shapes places. They are inter-linked and inter-dependent, and therefore, movement can be classified into three groups with respect to place, as

1. Movement through a place, that does not engage with the place but can impact on it
2. Movement to and from a place, that interacts with the place and connects it to other places
3. Movement within a place that includes interaction within the local catchment of the place

Aligning movement and place

Aligning or balancing movement with respect to place is complex and includes the following considerations and recommendations.

- Identifying existing or proposed policies and plans for the road or street
- Understanding the purpose and relation of a specific link to the larger network
- Assessing the walkability and cyclability of short trips
- Assessing the role of public transport for longer journeys
- Strategies for enabling mode shift such as modal hierarchy, re-routing, on-the-ground campaigns and infrastructure
- Precautionary approaches to short-term demand
- Early identification of outcomes
- Promoting inter-disciplinary thinking by considering both movement and place assessments separate and then integrate them

The process of balancing movement and place largely requires compromise, either in terms of the limited space availability or in balancing value for money versus accommodating all possible functions. Figure 6.1 below explains different stages involved in delivering place benefits of a sample movement and place project.

DESIGN PROCESS	PROJECT STAGE	PREFERRED APPROACH
Discover	Operation	Use planned and unplanned incidents, special events and trials to identify improvements
	Definition	Invest in places, supported by movement
	Initiation	Include delivery of place benefits in terms of reference Agree project principles for both movement and place
Create	Planning	Develop multiple scenarios for delivering movement functions and improving place and identify a preferred scenario
Deliver	Execution	Use construction management to test solutions Ensure construction management addresses place
	Monitoring and control	Change control to refer back to place benefits
	Close	Undertake post-implementation surveys of changes to both movement and place
	Maintenance	Create multiple scenarios around the end-of-life of assets or asset renewal programs

Figure 6.1: A sample of movement and place project by NSW

6.1.2 Victoria's Movement and Place framework

The Movement and Place Framework of Victoria takes a future-focused, multi-modal approach to network planning. It takes into consideration the diverse role 'places' play in planning the types of transport modes appropriate to a local road or street. At its heart, the framework organises transport links by their 'place' and 'movement' roles into road and street types. The framework consists of four modules, as shown in Figure 6.2, that follows one another in a sequential manner.

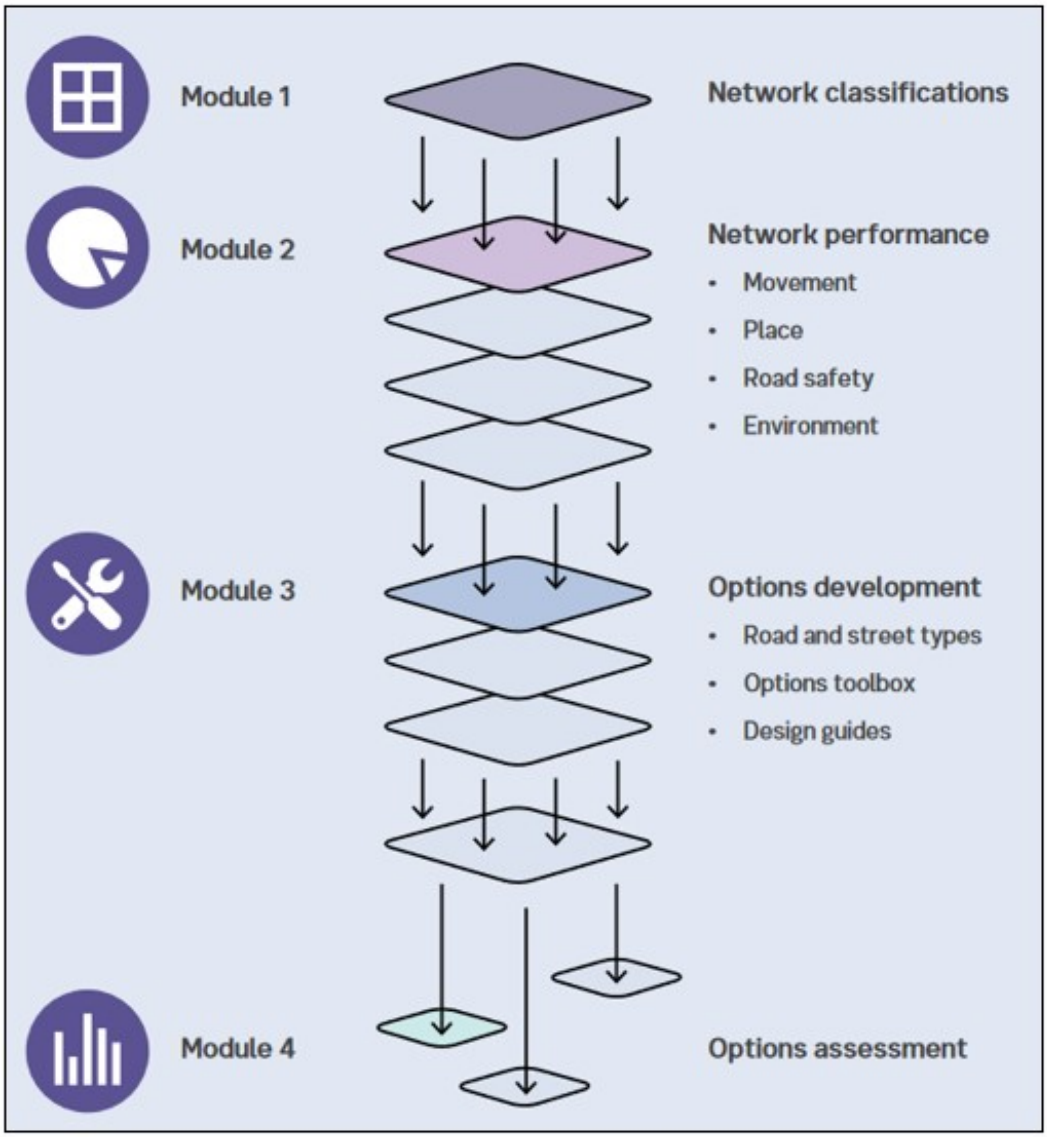


Figure 6.2: Movement and place framework by Victoria

Module 1: Network classifications matrix

Network classification matrix is classification of transport links in a given network by mapping them against a movement and place axis in accordance with their future movement and place functions. This involves further classification of movement and place, with the former representing the mix of transport links that are required to support the overall demand for movement across a network, and the later defined by state-level planning strategies. The classification of movement from M1 to M5 is determined by examining the overall mix and is a function of different transport modes on the link. While M1 represents the mass movement of people or goods on routes with state or national level movement function, M5 represents local movement. The movement classification is associated with mode classifica-

tion types such as general traffic (classified from GT1 to GT5), rail, tram, bus, freight, tourist, interchange, cycling and walking.

Place classifications represent the future vision for a place, defined from P1 to P5, ranging from places of state or national significance (P1) to local significance(P5). These place categories are defined to identify three different types of places i.e. places of activity, places of off-street activity and places of landscape and culture and how they are experienced by users.

Module 2: Network performance

Module 2 looks at how well links perform toward their aspirational functions and meet user requirements. To assess the performance of a link or corridor, its current performance is compared with its aspirational state. The resulting varying levels of performance are then described in a level of service (LoS) scale (from A to E), assessed under four themes - movement, place, road safety and environment.

Module 3: Options development

Module 3 provides tools and guidance to develop different options in order to close the gap between actual and aspirational performance. The process of developing potential options takes place in a sequential three step process, as listed below.

1. Defining the road and street type of the transport link: The road and street types considered are city hubs, connectors, city streets, activity streets, city places and local streets

2. Using the options toolbox that focus on potential interventions such as more efficient or flexible use of space, intelligent systems and management, substitute capacity, managing demand etc.

3. Considering interventions with reference to available design guides that cover both strategic-level and detailed design guidance

The road and street type, network operating parameters and the gap between current and future levels of service will together determine how each intervention will be employed in a given location.

Module 4: Options assessment

The overall aim is to assess how well a potential option improves the performance of the network in-line with the aspirations established through Modules 1 and 2.

6.1.3 AustRoads' Movement and Place framework

The primary goal of the movement and place framework of AustRoads is to provide for all users of the road network in an equitable and balanced manner. In other words, the framework manages various users and uses of the road network. It considers different functions of each road type within the road network and how it performs its functions to meet the community's, as well as users' needs. With respect to the movement, users using

different modes collectively focus on achieving better mobility, where as, it is achieving better access with respect to place, as shown in Figure 6.3.

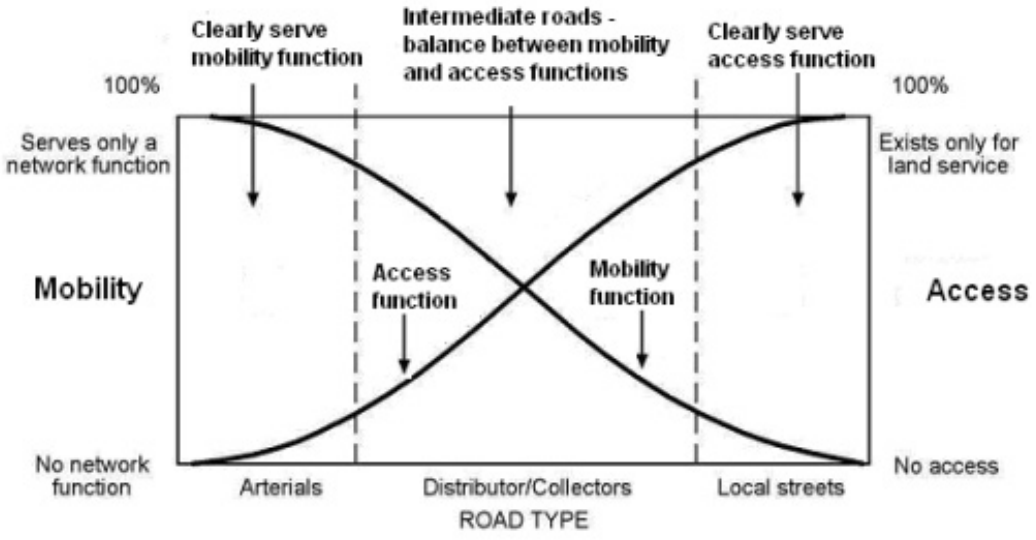
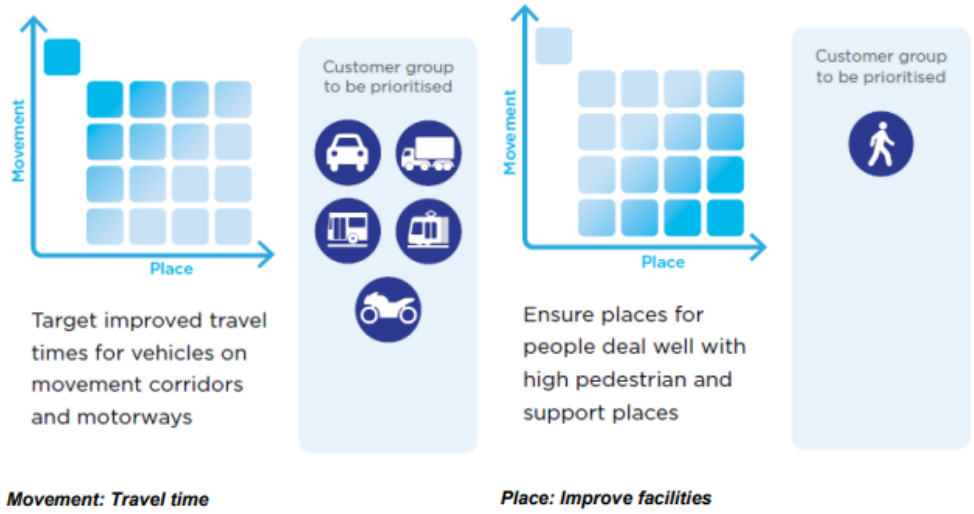


Figure 6.3: Road type and function

Finding a balance between access and mobility while adhering to the priorities of users that changes with time of day and day of week is challenging. For example, if the M&P strategy is to improve the travel time of motor vehicles, the focus needs to be on prioritising their use for movement of vehicles as shown in Figure 6.4a and if the strategy is to provide facilities for pedestrians, cyclists and other vulnerable road users, focus needs to be on prioritising their use as primarily places, as shown in Figure 6.4b.



(a) a (b) b

Figure 6.4: (a) M&P focus areas for improving travel time (b) M&P focus areas for improving pedestrian facilities

The M&P framework considers various transport networks of the road network that need to be managed in order to meet the needs of the users. For each type of network, the role and key management principles required to meet the primary needs of users were defined and classified.

6.1.4 New Zealand's One Network Framework

The One Network Framework (ONF) is a tool for a two-dimensional movement and place framework that evolved out of the One Network Road Classification (ONRC). The ONF was not designed to provide transport solutions, but it helps to establish the function of a road or a street, similar to the goal of any other movement and place framework. For this purpose, the framework intends to perform the following key shifts.

- A shift from vehicles to the network's functional importance for moving people and goods, by any mode
- Considers adjacent land use, and the role the transport network plays as part of the wider public realm
- When fully implemented, it will consider both the current and future movement and place functions of the network that will help identify the gaps and guide network changes and investment decisions seeking to close the identified gaps
- Introduces modal layers of walking, cycling, public transport, and freight, recognising that our roads and streets have different functions for different modes

Defining 'place'

For the ONF, place function is defined as the extent to which the land use along the side of a road or street is a destination that people want to visit or spend time in. The level of on-street activity shows the importance of a destination for people and gives a direct pointer to the classification of place. As the level of activity increases, accessibility requirements also increase, so does the classification of place function. The ONF classifies place function from P1 to P5 based on the amount of on-street activity, adjacent land use and pedestrian volume.

Defining 'movement' of people and goods

For the ONF, movement relates to how people and goods move along and across roads and streets by any mode. It uses a five-point scale for the classification of movement ranging from M1 to M5 based on the volume of people movement by all modes. In addition, as mentioned earlier, the ONF introduces classification of modes as

- General Traffic from GT1 to GT8
- Freight from F1 to F8
- Public Transport from PT1 to PT5
- Cycling from C1 to C3 and in addition, class CS (Cycling Special) is introduced which is a class for corridors supporting cycling within rural areas
- Walking from W1 to W3 and in addition, class WS (Walking Special) is introduced which is a class for walking that is undertaken mainly for recreational and tourism purposes and predominantly in the rural context

Defining ONF 'street families'

The ONF street families bring together the movement and place function elements to determine an overall classification for the road or street. The street categories considered for an urban network are transit corridors, urban connectors, city hubs, main streets, civic spaces, activity streets and local streets. The ones for rural network are inter-regional connectors, rural connectors, rural roads, peri-urban roads and shopping places. Each street category is assigned based on function or purpose of the road or street category such as density of on-street activity, intensity of use – dwell time, adjacent land-use, place and movement functions. Applying the ONF means to bring together the movement and place function elements to determine an overall classification for the road or street, as shown in Figure 6.5.



Figure 6.5: A case study of Movement and place framework by NZ

6.1.5 Auckland's Roads and Streets Framework

The Roads and Streets Framework (RASF) provides a framework for thinking about the Place and Movement function and identifies their level of significance. It is the first step in a process to identify the issues that must be addressed by a project, like the intent of any other M&P framework. For the purposes of RASF, the place function represents the catchment of a road or street and its adjacent land use as a destination in its own right. The framework considers three categories of place, i.e. P1 (predominantly local function with a small catchment of users), P2 (attracts activity from across a sub-region or neighbouring local board area) and P3 (attracts activity from across the region and even from across New Zealand and internationally). The Movement function of a road or street is defined as its level of strategic importance within the transport network, measured in terms of moving people, goods and services safely and efficiently between locations and accessing key destinations. The framework considers three categories of movement, i.e. M1 (Low strategic network significance that provides predominantly local access for people, goods and services), M2 (medium strategic network significance with increasing volume of users.) and M3 (high strategic significance with higher volume of users). All possible combinations of these movement and place categories results in total of nine typologies for roads and streets in

Auckland. The resulting typology matrix of Auckland with description of each element, is depicted in Figure 6.6.

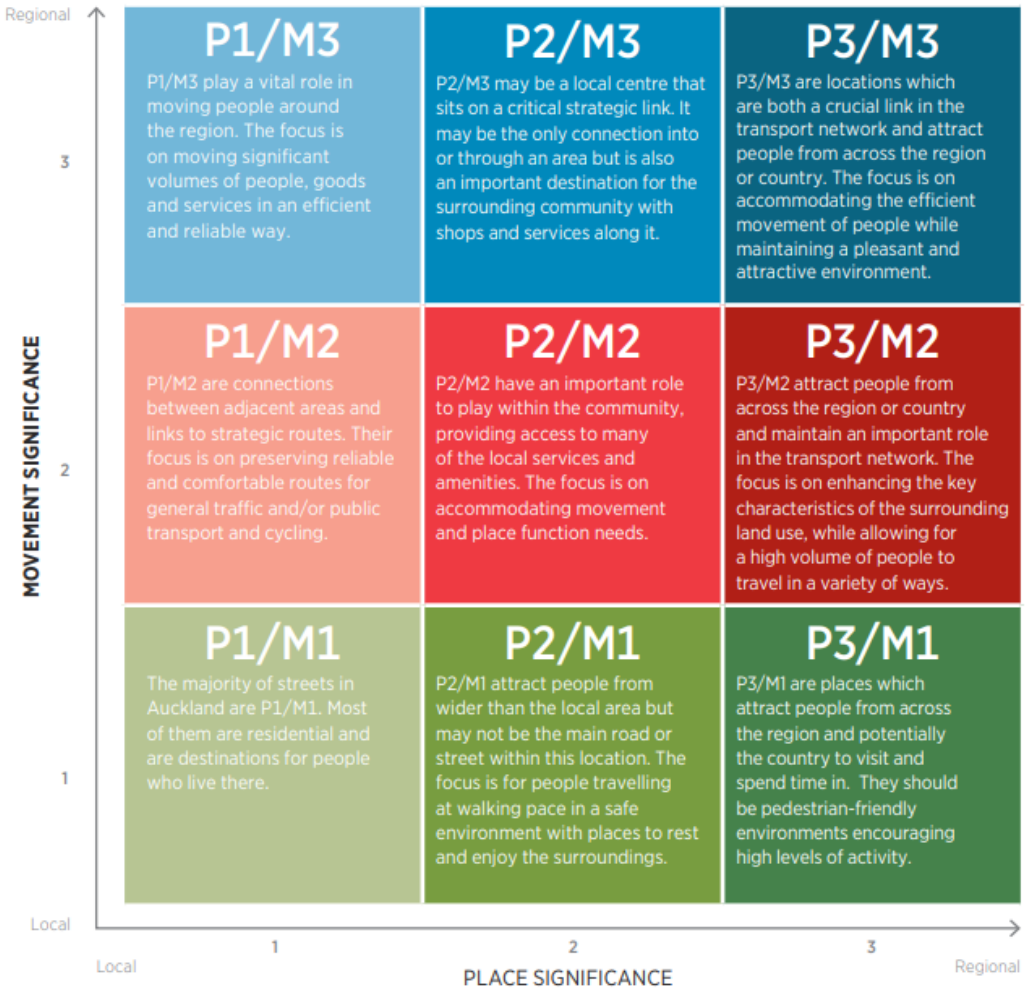


Figure 6.6: Typology matrix of Roads and Streets framework of Auckland

The next step is to identify different roads and streets under these categories. For that purpose, the RASF uses a five-stage process that constitutes - (i) Information gathering, (ii) Typology assessment for existing and future, (iii) Modal priority assessment, (iv) Prepare RASF mandate and (v) Application of RASF and TDM, as shown in Figure 6.7.

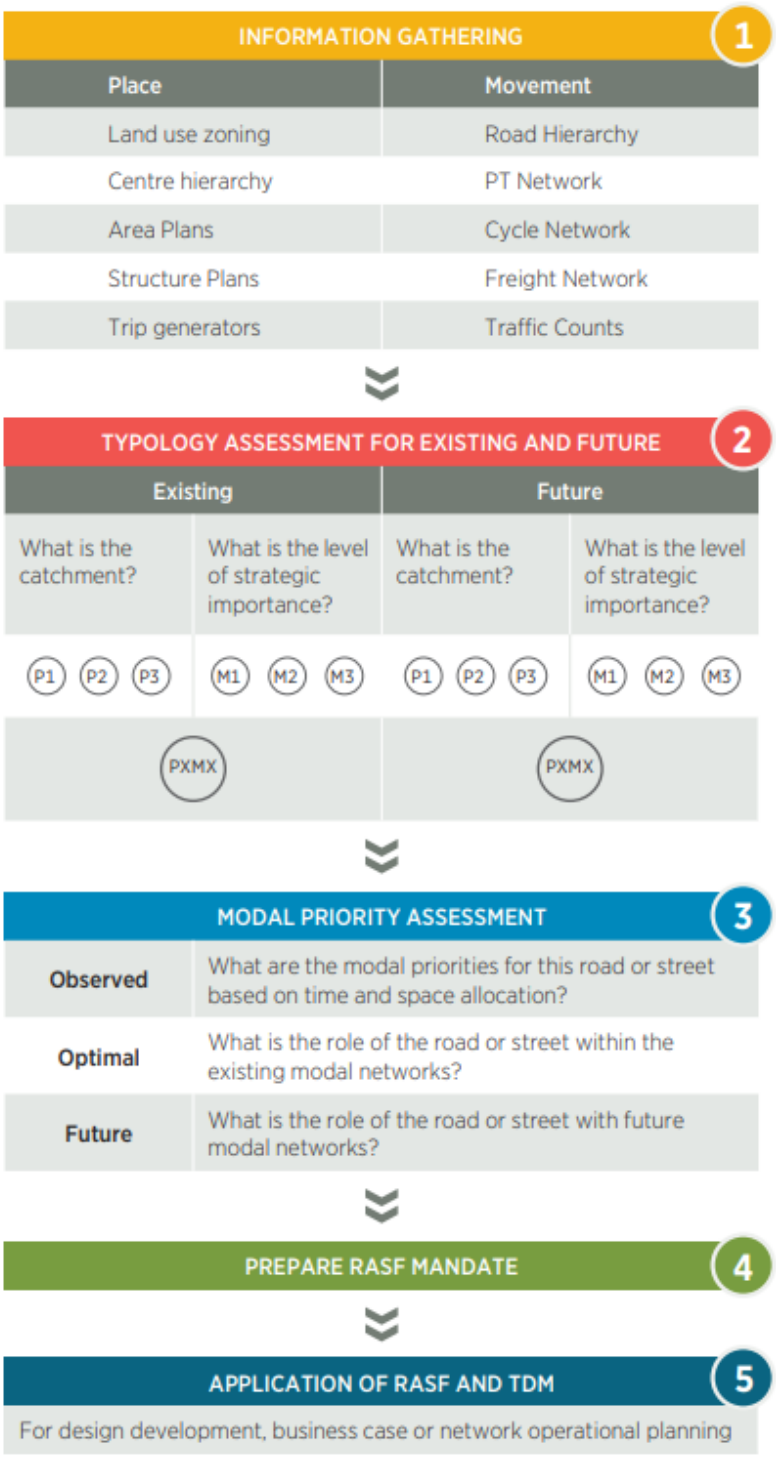


Figure 6.7: Roads and Streets Framework process of Auckland

(i) Information gathering

This is the first stage of RASF process that gathers as much information as possible about the road or street and its operation on the present day and the future. For movement function,

information on existing and future networks for Public Transport, Freight, Cycling, Walking and General Traffic, is collected. For Place function, land use drives catchment. Therefore, some of the relevant information would be the road network configuration, the presence of a high frequency bus route or land use zoning or other inputs regarding the number and the travel distance of people that reach the particular place.

(ii) Typology assessment for existing and future

This stage uses the information gathered in (i) to assign a typology for the existing scenario and identify typology for future. For this purpose, the listed actions are followed in sequence:

1. Identify existing typology - A road or street may be split into sections of similar characteristics and the typology of each section can be assessed independently.

2. Place Significance - Place assessment is a qualitative assessment, based on professional judgment, drawing on the evidence, rather than absolute thresholds.

3. Movement Significance - Movement assessment must consider all modes and their respective strategic modal networks. Some of the assessment may be qualitative, such as the criticality of the route within the network, which is important in understanding the full scope of the movement function.

4. Assigning a typology - The combination of the P value and M value provides the typology (e.g. P3/M2). The objective here is to ensure that the separate importance of a road or street's Place and Movement function is captured and considered to inform future project development rather than analytical perfection.

5. Identify future typology - This assessment follows the same process as defining the existing typology but is based on the information gathered about future changes to the street such as changes in land use and modal networks.

(iii) Assess modal priority for existing and future state

Once the relevant typology for each road or street section has been identified, the relative importance of different modes can be determined. Modal priority is represented on a modal priority chart. A mode scoring the highest possible level of priority would be one that is considered the most important within the road or street.

(iv) Produce the RASF Mandate

The Mandate is the starting point for any potential project on a road or street. It provides clear direction on Place, Movement, Modal Priority and safety, regardless of the project drivers. It allows gaps in network service, priority and safety to be recorded.

(v) Design development, business case or network operational planning

The RASF Mandate informs the design process via the Transport Design Manual (TDM). It also informs business case development and network operational planning. Designers and project managers should continually refer to the RASF Mandate throughout design

development to ensure that the values and priorities of the road or street are still being achieved.

Thus, RASF Mandate is the reference guide for any strategic planning or management projects and policies of Auckland.

6.1.6 London's Street Family Framework

London's Street Family Framework is a structured approach designed to categorize the city's streets based on two key dimensions: "movement" and "place". The framework's primary goals include identifying user needs, adapting to evolving functions, and balancing local and network demands. This systematic approach aims to mediate diverse street priorities and functions while providing a clear understanding for local communities and stakeholders.

The foundation of the framework is rooted in key objectives:

1. **Enhancing Movement**: The framework focuses on efficient movement for vehicles and people.
2. **Transforming Environments**: Enhancing cycling, walking, and public transportation environments
3. **Improving Public Realms**: Creating safer spaces for activities and enhancing overall urban experiences are central aspects of the framework.

To achieve these objectives, the framework utilizes two fundamental axes: "movement" and "place." The "movement axis" positions streets based on strategic importance, while the "place axis" recognizes streets' unique localized functions. This intersection forms the basis for categorizing distinct street types, as exemplified in Figure 6.8.

Each street type is linked to specific service standards and intervention options, facilitating informed decision-making that aligns with city goals. This systematic process ensures that roles, priorities, and interventions are well-defined for each street type, contributing to balanced and effective street management that meets the city's overall objectives.

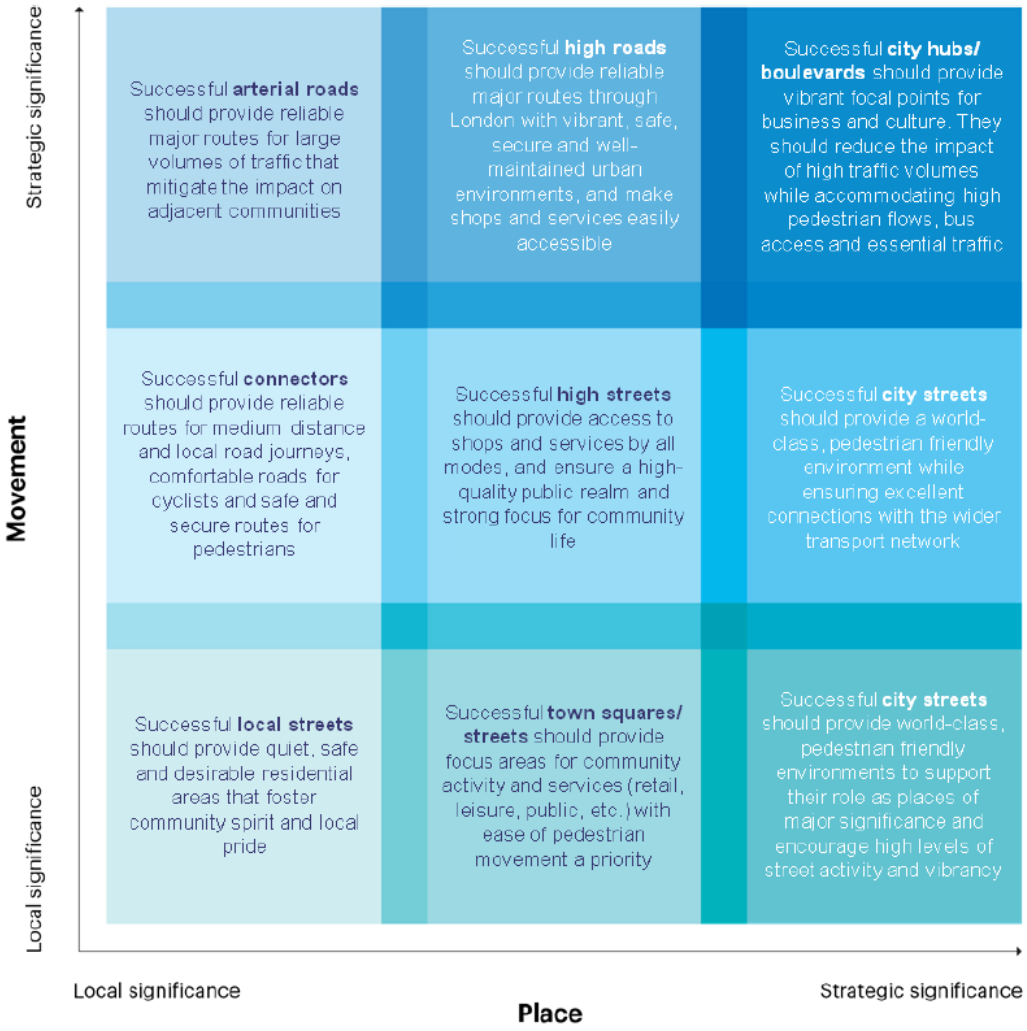


Figure 6.8: Types of streets as defined by London's Street Family Framework

However, the framework's scope extends beyond classification alone. It encompasses case studies and priorities for street types, delving deeper into the details of each type. For each street type, it examines the common challenges encountered within these segments, outlines the requirements for a successful operation of that type, and provides a compelling vision of how the ideal street might function. These concepts are demonstrated through real-world case studies, offering practical illustrations of how these principles can be transformed into practical solutions.

6.2 Comprehensive list of Key Performance Indicators

Tables 6.1 to 6.9 presents comprehensive list of Key Performance Indicators (KPIs) for different modes and movement types. In addition, a few of the dashboard views presented by TMCs across the world are listed in Table 6.10.

Table 6.1: Comprehensive list of KPIs of Public Transport (PT) for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average travel time index of PT (Ratio of travel time during peak period and free flow traffic conditions)	Austroads, FHWA	Diff. in travel time stamps using GPS data or loop detector data Avg. time for which detectors are occupied	Short-term
			Percent of avg. travel time during peak period to total travel time in a day	Long-term
	Average delay time (control delay or stopped delay) per vehicle	Austroads, FHWA	Diff in actual and desired travel time using GPS data or loop detector data	Short-term
	Average speed during peak periods per unit length		Avg. values of speed using GPS data	Short-term
	Speed differential between PT and other modes		Diff. of speed of PT from PV using speed gun and GPS data	Long-term
	Average no. of PT stops (other than the designated stops and signals) in a given time period	Kaparias et al. 2011	Avg. values of number of stops using GPS data	Long-term
	Ratio of average commuting times by public and private transport		Ratio of travel times using GPS data and loop detector data	Short-term
	Avg. person throughput during peak period	Austroads	Smart card data	Short/Long
	Public transport rides per capita	Kaparias et al. 2011	Passenger surveys	Long-term
	Percent of all trips made by transit	FHWA	Passenger surveys or local transit providers	
Safety	Number of casualties involving PT per traffic volume	TMR, New Zealand	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
	Number of red light violations and warnings, brake pedal activations involving PT	Kaparias et al. 2011	Red light cameras, vehicle data, pool of test drivers	
	Number of speed limit violations involving PT		Analysis of interlock-system-data and trip recorder information	Short-term
	Travel speed gap of PT	New Zealand	Difference between actual speed of PT and safe speed	
	Mean incident response time	FHWA	Fatalities data by TMR, incident responders and Office of Road Safety	Long-term

Table 6.2: Comprehensive list of KPIs of Public Transport (PT) for Through movement (Contd.)

Objective	KPI	Reference	Measurement	Time frame
Sustainability	Average value of fuel savings	Kaparias et al. 2011	Survey of Motor Vehicle Use, Australian Bureau of Statistics	Long-term
	GHG emissions by PT	New Zealand	Annual report on Greenhouse Gas Emissions from Australian Transport	
	Ambient air quality concentration of NO_2 and PM_{10} through PT		Real-time air quality monitoring by Clarity, IQAir etc.	
	Contribution of PT to air pollution with respect to total traffic demand	Djordjevic, B. and Krmac, E., 2016	Environment impact of transport in Australia by Bureau of Infrastructure and Transport Research Economic	
Reliability	Travel time buffer index (extra time most travellers add to their average travel time when planning trips)	FHWA	Passenger surveys / continuous point-based detectors	Long-term
	Average door-to-door trip time		O-D and Passenger surveys	
	Variability of travel time		Standard deviation of travel time using GPS data	Short/Long
	On-time performance of transit		Arrival times from selected stations from transit operators	short-term

Table 6.3: Comprehensive list of KPIs of Public Transport (PT) for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Access times to public transport facilities	Kaparias et al. 2011	Field data/ Passenger surveys/ GIS database	Long-term
	Walking distances from stations or parking spaces			
	Average distance and duration of transfers between modes			
	Average parking search time at public transport facilities		Passenger surveys	Short-term
	Public transport rides per capita			Long-term
	Frequency of public transport	TMR	PT operators / GIS database	Short-term
	Access and reliability of transit information		Passenger surveys	Long-term
	Percent of population within “N” minutes from nearest PT facility		GIS database / Household travel surveys	Long-term
	Percentage of users that are able to access on demand or high frequency transport (esp. during peak hours)		Field data/ Passenger surveys/ GIS database	Short-term

Table 6.4: Comprehensive list of KPIs of Pedestrians for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average delay for pedestrians during peak periods	FHWA	Data on wait time for pedestrians at intersections or path blockages from State and local transportation department	Short-term
	Pedestrian Level of Service (HCM, 2010)		Data on capacity and space requirements from State transportation department	
	Length of exclusive footpath/walkway	Amoroso et al. 2012	State and local transportation department	Long-term
	Footpath congestion	Austroads Research Report, 2015	Ability to move in desired path (m^2 per pedestrian)	
Safety	Separation from motorists	Austroads Research Report, 2015		
	Number of accidents involving pedestrians	Austroads Research Report, 2015	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
	Number of interactions with cyclists	HCM,2010		
Accessibility	Percent of roadways with pedestrian facilities	FHWA	Inventory of pedestrian facilities	Long-term
	Percent of intersections with pedestrian features			
	Average pedestrian comfort level		Pedestrian survey	

Table 6.5: Comprehensive list of KPIs of Pedestrians for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Ability to cross from an origin anywhere on the road (m)	Austroads Research Report, 2015	Maps from State and local transportation department	Long-term
	Distance to priority routes (m)	Austroads Research Report, 2015		
	Walking distance to parking (m)	Amoroso et al. 2012		
	Number of crosswalks per kilometre	Austroads		
	Comfort due to the presence of shops		Pedestrian survey	Short-term
	Evaluation of pavement condition	Eboli et al. 2023	Pavement quality survey and Pedestrian survey	Long-term
	Accessibility to public transport		GIS database and Pedestrian survey	

Table 6.6: Comprehensive list of KPIs of Cyclists for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average delay for cyclists during peak periods	FHWA	Data on wait time for pedestrians at intersections or path blockages from State and local transportation department	Short-term
	Length of exclusive bicycle lanes/km	Amoroso et al. 2012		
	Ease of travel (gradient)	Austroads Research Report, 2015	State and local transportation department	Long-term
	Average travel speed of bicycles		Cyclists' survey	
Safety	Separation from motorists			
	Number of accidents involving cyclists	Austroads Research Report, 2015	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
	Risk due to inter-modal interactions and surface unevenness			
Accessibility	Percent of roadways with bicycle facilities	FHWA	Inventory of bicycle facilities	Long-term
	Percent of intersections with significant features for cyclists			
	Average bicyclists' comfort level		Cyclists' survey	Short-term

Table 6.7: Comprehensive list of KPIs of Cyclists for From or To movement

Objective	KPI	Reference	Measurement	Time frame
	Percentage of bike lanes on the total length of the path	Eboli et al. 2023		
	Availability of parking facility and parking space	Austroads Research Report, 2015	Maps and GIS database from State and local transportation department	Long-term
	Condition and continuity of bicycle lanes	Austroads Research Report, 2015		
	Realized Detour Ratio (Ratio of the cyclist's actual trip distance to the Euclidean distance for a given OD)	Chou et al. 2023	Cyclists' trajectories from crowdsourced GPS data	Short-term
Accessibility	Cycling destination accessibility (distance to the closest facilities by cycling)	Wu et al. 2019	Cycling distance to the destination of interest from bicycle trip data	Long-term
	Comfort due to the on-road activity	Eboli et al. 2023	Cyclists' survey	Short-term
	Evaluation of bicycle path condition		Pavement quality survey and Cyclists' survey	Long-term

Table 6.8: Comprehensive list of KPIs of Private Vehicles (Freight) for Through movement

Objective	KPI	Reference	Measurement	Time frame
Mobility	Average travel time index of PV (or F)– Ratio of travel time during peak period to that during free flow traffic conditions	Austroads, FHWA	Diff. in travel time stamps using BT data or loop detector data Avg. time for which detectors are occupied with PV	Short-term
			Percent of avg. travel time of PV during peak period to total travel time in a day	Long-term
	Average delay time (control delay or stopped delay) per vehicle	Austroads, FHWA	Diff. in actual and desired travel time using BT data or loop detector data	Short-term
	Average speed of PV (or F) during peak periods per unit length	Kaparias et al. 2011	Avg. values of speed using loop detector data	Short-term
	Average no. of stops (other than signals) in a given time period		Avg. values of number of stops using CV data	Long-term
	Avg. vehicle km travelled during peak period	Austroads	CV data	Short/Long
	Percent of all trips made by transit	FHWA	Passenger surveys or local transit providers	Long-term
Safety	Number of casualties involving PV (or F) per traffic volume	TMR, New Zealand	Annual summary reports by Road Trauma Australia and Office of Road Safety	Long-term
	Number of red light violations and warnings, brake pedal activations involving PV (or F)	Kaparias et al. 2011	Red light cameras, vehicle data, pool of test drivers	Short-term
	Number of speed limit violations involving PV (or F)		Analysis of interlock-system-data and trip recorder information	
	Travel speed gap of PV (or F)	New Zealand	Difference between actual speed of PV and safe speed	Short-term
	Mean incident response time	FHWA	Fatalities data by TMR, incident responders and Office of Road Safety	Long-term
Reliability	Average door-to-door trip time	FHWA	O-D and passenger surveys	Long-term
	Variability of travel time		Standard deviation of travel time using CV data	Short/long
Sustainability	Average value of fuel savings	Kaparias et al. 2011	Survey of Motor Vehicle Use, Australian Bureau of Statistics	Long-term
	GHG emissions of PV (or F)	New Zealand	Annual report of GHG emissions from Australian Transport	
	Ambient air quality concentration of NO_2 and PM_{10} through PV (or F)		Real-time air quality monitoring by Clarity, IQAir etc.	
	Contribution of PV (or F) to air pollution with respect to total traffic demand	Djordjevic, B. and Krmac, E., 2016	Environment impact of transport in Australia by Bureau of Infrastructure and Transport Research Economic	

Table 6.9: Comprehensive list of KPIs of Private Vehicles (or Freight) for From or To movement

Objective	KPI	Reference	Measurement	Time frame
Accessibility	Availability of parking facility and parking space	Eboli et al. 2023	GIS database from State and local transportation department	Long-term
	Walking distance to/from parking facility	Austroads Research Report, 2015	GIS database from State and local transportation department	Long-term
	Realized Detour Ratio (Ratio of the cyclist's actual trip distance to the Euclidean distance for a given OD)	Chou et al. 2023	Cyclists' trajectories from crowdsourced GPS data	Short-term
	Availability of entry and exit points	Austroads Research Report, 2015	Intersections and ramps from GIS database	Long-term

Table 6.10: Details of various performance dashboards

S.No.	Title	Details and Source
1	**TMC Performance Dashboards_FHWA**	https://ops.fhwa.dot.gov/publications/fhwahop20032/fhwa20032.pdf
a	Regional Integrated Transportation Information System – Planning, Operation, Advanced Traveler Information System Dashboard	Provides pie charts on the number of disabled motorists, abandoned vehicles, crashes, debris etc, for various divisions of the state
b	Florida Department of Transportation - Operations dashboard	Surveillance of CCTV cameras, dynamic message signs and sensors Performance measures of the roadway system (both interstate and arterial network) Real-time visual alert to operators Provides a quantifiable review of potential alternative routes
c	Florida - Transportation performance measurement	https://www.fhwa.dot.gov/tpm/reporting/state/state.cfm?state=Florida Provides information on highway safety (No. of fatalities), highway infrastructure condition (No. of bridges in good condition) and highway reliability (Truck travel time reliability index)
d	Florida - DoT - Traffic Incident Management Dashboard	https://timdashboardtest.fdot.gov/Public/Dashboard Information on lane blocking events on freeways and crashes on all roads
e	Virginia - Planning, Reporting, Maintenance Dashboard	Travellers to access performance reporting across the system User-friendly interface Provides real-time information on safety, on-time delivery, projects, finance, structure condition, pavement condition and operations https://dashboard.virginiadot.org/

Table 6.11: Details of various performance dashboards (Contd.)

S.No.	Title	Details and Source
f	Oregon Department of Transportation - Planning & Maintenance Dashboard	Real-time maps with layers representing incidents, live traffic conditions, local events, and special information https://www.fhwa.dot.gov/tpm/reporting/state/state.cfm?state=Oregon Provides a quick look at performance measures across the system
g	Spokane Regional Transportation Management Center - Operations & Advanced Traveler Information System Dashboard	https://wsdot.wa.gov/about/data/multimodal-mobility-dashboard/dashboard/spokane/default.htm Displays real-time traffic information across multiple jurisdictions both locally and regionally Combining real-time volume and speed detectors, more than 100 live streaming camera feeds, variable message signs, and many other technologies
h	Florida - Operations & Advanced Traveler Information System Dashboard	Monitor the status and uptime of their ITS components and presents the uptime performance Flash alerts for items that are unavailable or need maintenance Displays a straight-line diagram whose x-axis indicates distance along a facility and the y-axis indicates current travel time Operators and managers to have a common vision of monitoring and responding to the status of their system
2	**Infrastructure performance board_Australia**	https://infrastructuredashboard.d61.io/nat_all Different sectors - Transport, Water supply, Communication and Energy sectors Measures - Speed and Reliability, Price, Safety, Activity and Investment