

# IMPACT OF BIKES ON CHRISTCHURCH MULTIMODAL TRANSPORT SYSTEM

(This paper has been peer reviewed)

## Ashley Thomson, Presenter

*Main Author*

3<sup>rd</sup> pro Civil Engineering in completion of BE(Hons)

Complex Transport Systems Laboratory, Civil and Environmental Eng., University of Canterbury

Email: ath125@uclive.ac.nz

---

## Billy Goble, Presenter

*Main Author*

3<sup>rd</sup> pro Civil Engineering in completion of BE(Hons)

Complex Transport Systems Laboratory, Civil and Environmental Eng., University of Canterbury

Email: wgo23@uclive.ac.nz

---

## Associate Professor Mehdi Keyvan-Ekbatani

*Main Supervisor*

PhD, MSc, BSc

Complex Transport Systems Laboratory, Civil and Environmental Eng., University of Canterbury

Email: mehdi.ekbatani@canterbury.ac.nz

---

## Cameron Davis

*Co-Supervisor*

PhD Candidate

Complex Transport Systems Laboratory, Civil and Environmental Eng., University of Canterbury

Email: cameron.davis@pg.canterbury.ac.nz

---

## ABSTRACT

The performance of urban transportation networks is central to economic productivity, quality of life, and sustainable development. Sustainable transport is a key priority for New Zealand as it works towards reducing CO<sub>2</sub> emissions and creating resilient, liveable cities. Promoting active transport modes, such as cycling, is central to this transition, with national and local governments investing heavily in infrastructure to encourage a shift from private vehicles. Christchurch has committed over 60 km of separated cycleways, supported by \$177.3 million in funding from the New Zealand Transport Agency for 2024–2034, highlighting its strong focus on sustainable transport. Despite this progress, current traffic simulation models for New Zealand do not adequately capture the effects of cycling. This study develops the first detailed microscopic traffic model of cycle lanes in Christchurch, New Zealand, offering new insights into how active modes influence traffic dynamics, congestion, and overall network performance. Microscopic traffic modelling offers a highly detailed overview of the performance of a network and is especially useful for investigating traffic signal coordination and intersection operations. This study updates the Christchurch microscopic model in the Aimsun simulation environment to reflect the current network. The methodology involves incorporating updated intersection layouts, signal control plans, and cycle lanes sourced from OpenStreetMap and validated against aerial imagery. Demand data is taken from Christchurch City Council's macroscopic SATURN model to ensure consistency between models. Simulations were conducted under two scenarios: (1) a base bimodal network, and (2) a multimodal network including cycling. Key performance indicators such as total travel time, delay, and traffic density will be compared across scenarios. We expect the results to show how active modes affect current traffic conditions. The study will deliver valuable insight into how cycling infrastructure affects network performance, supporting Christchurch's long-term goal of transitioning to a sustainable and resilient multimodal transport system.

## INTRODUCTION

The optimal performance of a city's transportation network is essential to economic productivity, environmental sustainability, and the quality of life of its residents. Predicting how a transportation network performs under various changing conditions is a key focus of transportation engineering. While empirical traffic data can be used to understand the current performance, predictive modelling is essential for understanding future outcomes under various scenarios. These models can help influence both long-term infrastructure planning and operational strategies. Generally, transport models fall into two categories: macroscopic models, which treat traffic as a continuous flow, focusing on characteristics such as traffic density, traffic volume, or flow speed, and microscopic models, which simulate the interactions and movements of individual vehicles (Hajidavalloo et al., 2023).

Microscopic traffic modelling offers highly detailed insights into the performance of a network and is especially useful for investigating traffic signal coordination, intersection operations, and public transport networks. The Complex Transport Systems Laboratory (CTSLAB) currently holds a highly detailed microscopic model of the greater part of the Christchurch urban road network for use in the Aimsun simulation environment (Mousavizadeh, O., & Keyvan-Ekbatani, M. 2024) (Mousavizadeh, O., & Keyvan-Ekbatani, M. 2026). This research builds upon that work by utilising Aimsun to examine the impact of cycling activity and dedicated cycle infrastructure on the overall performance of Christchurch's multimodal transport system.

Over the past decade, Christchurch has undergone significant changes to its transport infrastructure, with a primary emphasis on improving facilities for active transport users. New cycle lanes, shared paths, and intersection redesigns have been implemented citywide to promote cycling as a sustainable mode of transportation. However, the influence of these cycling-related upgrades on wider network performance, such as impacts on vehicle delay, intersection efficiency, and modal share, remains largely unquantified.

This project aims to simulate how different levels of bicycle traffic and dedicated cycle lanes affect the performance of Christchurch's transport network. To achieve this, demand data for cycling have been incorporated from the 2023 Census, using travel-to-work and education data aggregated by A3 statistical areas. This creates a realistic spatial distribution of cycling demand and accurately represents where cyclists enter, exit, and interact with the network. By creating and testing various scenarios in Aimsun, the study will evaluate the impact of increased cycling participation on congestion patterns, travel times, and multimodal interactions.

The results of this research will provide valuable insights for future transport planning and policy development, particularly in support of the Christchurch City Council's goal to promote active transport, reduce vehicle emissions, and improve network resilience. Additionally, this study will demonstrate the potential of microscopic simulation tools for capturing the generation of traffic between transport modes in real-world urban contexts.

With an estimated 2024 population of 412,000, accounting for 7.8% of New Zealand's total population, traffic congestion is becoming an increasingly significant issue for the city. The University of Canterbury and other polytechnics in the area have a higher percentage of the population driving to their education facilities, at 15.8%, compared to the national average of 10.4%. Additionally, passengers make up a smaller percentage, at 35.6%, compared to the national average of 40.8%. This creates a significant strain on the overall Christchurch network. The working population gap is not as pronounced, but Christchurch remains 3.9% above the average. While this is a substantial problem for Christchurch, the proportion of travel by bicycle is significantly higher than the national average for both commuting to work and education (5.4% compared to 1.9% and 8.9% compared to 3.5%). Considering biking is such a prominent mode of travel in Christchurch, it is vitally important to consider it when running simulations for the overall network (Statistics New Zealand 2025). This reinforces the importance of understanding how bike traffic interacts with other modes and how future cycling infrastructure investments could further improve network efficiency and sustainability.

The outcomes of this study are expected to support evidence-based decision-making for future active transport planning in Christchurch. By quantifying how varying levels of bicycle traffic influence

network performance, the findings will inform where additional cycling infrastructure can deliver the most benefits without compromising vehicle efficiency. Furthermore, this research contributes to a broader understanding of how multimodal modelling tools can be used to evaluate sustainability-focused transport interventions, aligning with New Zealand's national goals of reducing emissions and promoting low-carbon mobility.

## BACKGROUND

Traffic simulation models are a widely used tool in transportation engineering to help analyse and predict the performance of transport networks under various conditions. The choice of model that is evaluated is dependent on the level of detail required and the overall objectives of the analysis. Macroscopic models treat the traffic as one continuous flow, which focuses on variables that include density, flow, and average speed, which makes them more suitable for wide-scale planning (Hajidavalloo et al., 2023). This contrasts with a microscopic model, which simulates individual vehicle interactions and movements. Thus, allowing for a more detailed assessment of lane usage, signal control, and multimodal integration (Hajidavalloo et al., 2023).

Many microscopic simulation tools, such as Aimsun, have become increasingly prevalent in both professional practice and academic research. Aimsun has been recognised for its ability to model large-scale urban networks while incorporating signal control systems, public transport networks, and active modes of transport (Casas et al., 2010). Aimsun allows for the real-life simulation of signal timing, public transport schedules, and vehicle behaviour, making it an appropriate tool for analysing the impact of infrastructure changes and policy decisions. Zeng et al. (2019) demonstrate the importance of updating traffic simulation models to capture the shifts in urban transport networks during periods of redevelopment. Their findings highlight that infrastructure changes within a transport network substantially affect network performance. In the case of Christchurch, the current Aimsun model was last updated in 2018 (Lee et al. 2020) and does not account for any of the recent infrastructure changes, such as lane modification, intersection redesign, and the expansion of active transport infrastructure.

Recent research conducted by Jafari et al. (2022) emphasises the need to move from traditional car and public transport-centred simulation modelling approaches towards incorporating the requirements of cycling into city-wide simulation models. By doing this, it will provide us with a more realistic foundation for simulating a modern, multimodal transport network in a city that is aiming to reduce car dependency. Several case studies have demonstrated that explicitly modelling bicycle infrastructure within a microscopic simulation environment can change the network's performance outputs and planning conclusions. Microsimulation studies using Aimsun have compared different scenarios, including no bike lanes, conventional on-street bike lanes, and median bike lanes, and report measurable differences in delay time of vehicles and throughput across the network (Chalermwongphan and Upala 2019). A recent review of microscopic active mode simulation models further highlights that while many platforms, including Aimsun, while highly capable of representing dedicated cycling infrastructure, detailed cyclist behavioural models remain relatively limited and often require significant calibration methods, which reinforces the approach of incorporating active mode infrastructure first, with the option to incorporate advance cyclist behaviour models in future work (Pérez Castro, 2023). Thus, current efforts should focus on integrating realistic active mode infrastructure into transport simulations as a first step, while recognising the need for future development of cyclist behaviour models to capture the full complexity of multimodal interactions in future studies.

In recent years, research interest in cycling infrastructure has grown rapidly, as evidenced by the steady increase in publications on cycling and public transit, as shown in Figure 1 below.

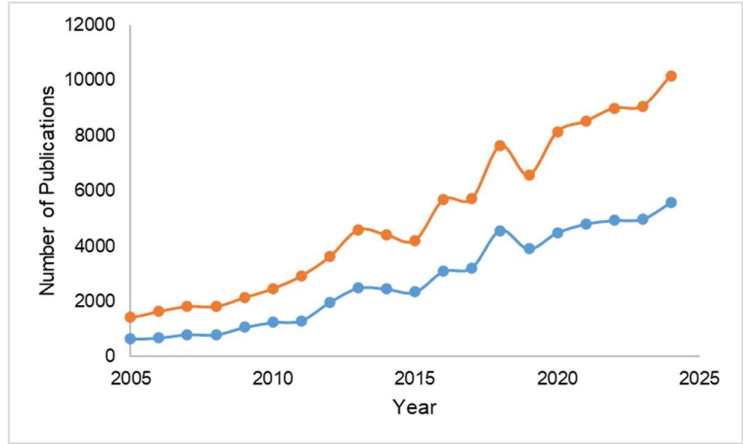


Figure 1: Publication trend over the years (blue: dedicated bus and bicycle lanes, orange: public transit promotion)

This global trend reflects a broader recognition of the cycling role in improving urban sustainability, reducing congestion, and lowering emissions. Christchurch’s transport strategy aligns closely with this international shift, with the city committing over 60km of separated cycleways and investing \$177.3 million in cycling infrastructure between 2024 and 2034, supported by the New Zealand Transport Agency (Christchurch City Council, 2024). This strong local focus on active transport highlights the importance of evaluating how increased cycling demand may impact network performance, rendering this study both timely and contextually significant.

## METHODOLOGY

### Data Collection

To create a realistic traffic simulation model of Christchurch, it is essential to use accurate input data. Figure 2 summarises the organisations that supplied relevant information for the network. The Christchurch City Council (CCC) provided several macroscopic Christchurch Assignment and Simulation Traffic (CAST) models in SATURN (Hall et al., 1980); the most up-to-date 2023 version was selected for this study. Three separate demand scenarios (A, B, C) were provided for this SATURN model, which were abstracted to obtain macroscopic traffic demand data. The existing 2018 Aimsun model (Lee et al., 2020), provided by the CTS Lab, will serve as the base for the microscopic simulation.

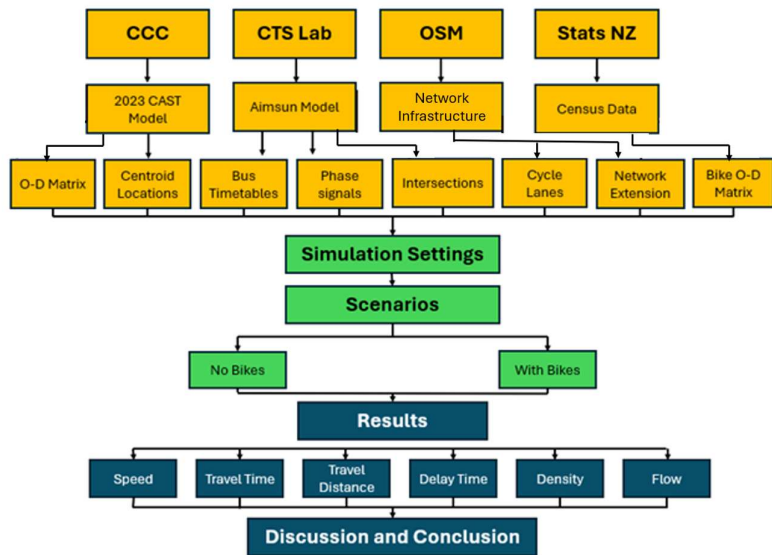


Figure 2: Flow diagram of collected data

### Network Preparation

To focus the scope of the project on the central Christchurch network, the SATURN model was boxed as close as possible to the existing Aimsun network, and the Origin-Destination matrix demand data was then extracted. Once extracted, it was clear that discrepancies existed between the models. To resolve these discrepancies, the Aimsun network was updated to match the SATURN model, which contained the most current demand data. To use this data, corresponding centroid numbers (called zones in SATURN) and locations had to be added to the network. This process involved adding 149 centroids, 49 new internal centroids and 100 external centroids to align with the updated network boundaries. While adding these additional centroids, the edge of the network was corrected to match the SATURN network. This process involved fixing sections placed in the wrong areas, adding new sections, cutting existing sections, and reconnecting existing internal centroids to match these changes in Aimsun. While updating the network, several discrepancies and errors became evident when cross-checking centroid IDs between the new boxed network and the previous CCC model. To stay consistent with the current CCC SATURN model, the Aimsun model was changed to match it. Centroid 2912 was deleted in Aimsun, as this element had been removed in the SATURN model. Next, it was discovered that five of the centroids had updated IDs: centroid 1829 was changed to 683, 1815 to 684, 1803 to 692, 1783 to 723, and 1776 to 732. These changes had not been reported in the model update documentation from the CCC. Lastly, centroid 1605 was removed as it corresponded to a modelling error. This centroid was displaying car demand out of the cycle path, so it has been deleted from the demand matrix and was reported to the CCC, which will be updated in the next iteration of the SATURN model.

### Cycleway Modelling

The next step for this model was to integrate the cycle lanes into the network. The cycleway data sourced from OSM required substantial refinement before it could be used in the Aimsun model. The final processed network is shown in Figure 3. Extensive corrections were needed, as much of the original data was inaccurate or outdated. To get the most accurate representation of the current Christchurch cycleways, Google Maps imagery and street view were used to validate the network. The OSM data only included the shared pathways that are physically separated from the road. This approach saved time while still providing a realistic representation of the network, as the separated pathways enable cyclists to travel off the road and avoid interacting with traffic. While this provides an accurate simulation, it fails to consider the impact that parked cars have on cyclists and how cycle lanes remove this issue. Because of this, a real-life cyclist would be slightly more impaired than the model would suggest and would travel more slowly through the city. To reduce the computational demand for the model, cycleways that have long distances between intersections are replaced by centroids, which correspond to cycle demand.

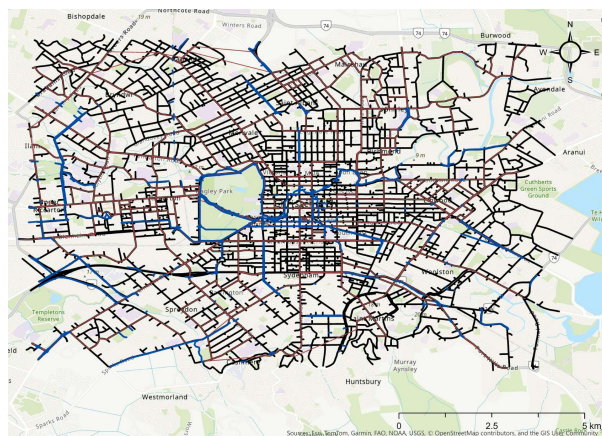


Figure 3: Final transport network (roads: black lines, cycleway: blue lines, bus lanes: red lines)

### Signal Plan

Since council signal plans were unavailable, an initial approach implemented a 10-second end-of-cycle window that activated when a detector was triggered. Another option considered was a 4-second interphase followed by a 10-second exclusive phase for bicycles. This approach would have

added 14 seconds of delays for cars compared to the baseline model without bicycles. Which was why the approach was discarded. Ideally, bicycles would be allowed to move concurrently with cars, as occurs in real life. However, in an actuated signal system, this was not feasible because the entire phase would fail to activate if no bicycles were detected, including the car phase. To address this, the intersections were modelled with fixed phases, using Aimsun's built-in give-way logic to allow for bicycles to cross while vehicles yielded, better representing real-world interactions. Phase plans from the previous model (in which the council signal plan was acquired) were used and modified. A 10-second bicycle phase was incorporated such that horizontal bicycle movements occurred simultaneously with horizontal vehicle movements, and vertical bicycle movements occurred with vertical vehicle movements. When multiple movements were either horizontal or vertical, the corresponding bicycle phase was assigned to the movement that caused the least overlap with other turning movements. Figure 4 illustrates an example intersection: phase 1 corresponds to vertical vehicle movements, so the 10-second bicycle phase was added to the shorter horizontal phase; phase 2 combines the original phase 2 with the new bicycle movements, and phase 3 corresponds to the original phase 2.

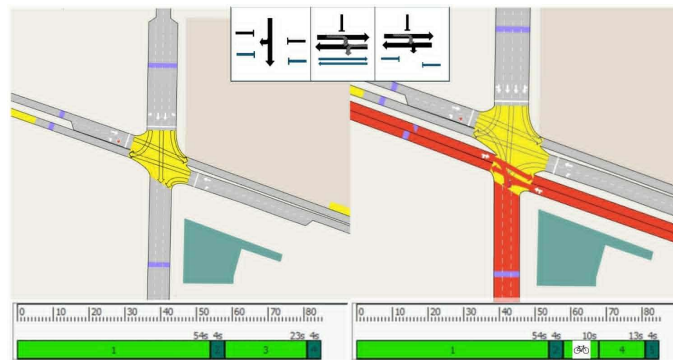


Figure 4: Signal plan before and after for separated double lane cycleways (cycleway turns in red), phase plan top middle  
 For the pedestrian crossings (Figure 5) included in the model, turns directing bicycles into the intersection were excluded, as these movements would have disrupted the flow of vehicle traffic.

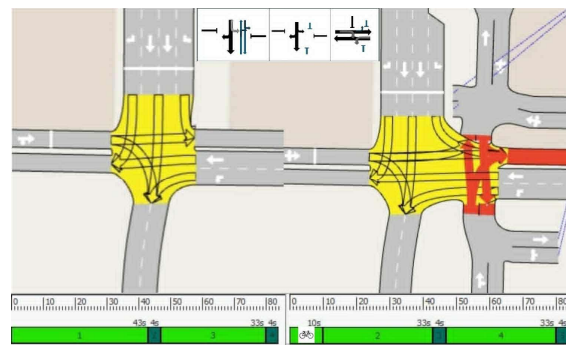


Figure 5: Signal plan before and after for a pedestrian crossing (cycleway turns in red), phase plan top middle)

Separated cycleways function differently depending on the layout. In Christchurch, there are single lanes, double lanes on one side and single lanes on each side. The logic was the same throughout all of these intersections. The bikes may not turn across traffic, regardless of whether this is a right or left turn. They would have to reroute if they wanted to go down that road, or they should have been on the road to make this turn with the cars. As illustrated in Figure 6, right-turn movements for bicycles are prohibited because they would intersect with traffic operating during the newly added cycleway phase (indicated in yellow). In real life, some cyclists would get off their bikes and cross at the crossing, but this could not be modelled, as this would have required all traffic light intersections to have all the pedestrian crossings modelled, which would have been too time consuming. One turn that was allowed for the bike was to go from the bike lane straight onto the road, but only when there were no cars. This would enable the bikes to get onto the road if they needed to make a right turn at a later intersection that was banned from the cycleway.



Figure 6: Signal groups for a single lane on each side, separated cycleway (cycleway turns in yellow)

## Bike Demand

To ensure accurate demand estimates, 2023 census data on travel to work and education were used for all Statistical Area 3 (SA3) zones across New Zealand. This dataset provided the most reliable estimate available, as no information was available for total or recreation trips, which are typically inconsistent. The data was already structured in an origin-destination format and contained over 14,000 entries, representing all SA3 zones across New Zealand. To extract information relevant to this study, a list of Christchurch SA3 zones was compiled, and the dataset was filtered to include only records where both the origin and destination were within these zones. Python was then used to convert the resulting 569-row table into a 37x37 O-D matrix suitable for the model.

It was found that not all 37 areas were represented in both the model and the demand dataset; therefore, some zones were ultimately excluded. The resulting matrix represented the total number of trips between each pair of areas. To integrate this data into the Aimsun model, the demand values needed to be assigned to the corresponding centroids. For this model, bicycle centroids were strategically placed across Christchurch at locations where OSM cycle paths terminated. This process resulted in a large number of centroids without predefined IDs, allowing specific IDs to be given for easier integration into the O-D matrix.

The number of centroids in each area was then reviewed to ensure sufficient coverage and to prevent artificial congestion that could occur if too many bicycles were generated from a single centroid. For this study, a minimum of one centroid was required for 75 bicycle trips per day. To satisfy this condition across all areas, additional bicycle centroids were placed at road ends where car centroids already existed. Car centroids themselves were not used, as their IDs were predefined in the SATURN model and could not be modified.

Each centroid was assigned a unique five-digit ID, with the first two digits indicating the zone, the third digit showing the number of connected links, and the last two digits identifying the specific centroid (e.g., the third centroid in Riccarton with four links was 20403). Initially, link numbers were included to split demand across links, but this was later removed to avoid unrealistically concentrating bicycle traffic. A total of 220 centroids were added to the model to represent bicycle demand.

To assign the correct demand values to the bicycle centroids, a Python script was developed to automate the population of the Aimsun demand matrix. The Aimsun matrix contained over one million cells (approximately 1,000 x 1,000), making manual editing impractical. The script also imported the 37 x 37 area-demand matrix and iterated through all the centroid IDs in an empty Aimsun matrix. For each cell where both the row and column IDs were five-digit bicycle centroid IDs, the script extracted the first two digits of each ID to identify the corresponding origin and destination areas. These area codes were then used as keys to retrieve the relevant demand values from the 37 x 37 matrix. Each value was scaled according to the total number of centroids in its respective origin and destination areas to ensure proportional distribution. Finally, the updated matrix was exported as an Excel file and imported into Aimsun as the new bicycle demand matrix.

The demand data represent trips for work and education, which account for the majority of bicycle travel during the 7:00-9:00 AM simulation period. Of these trips, approximately 58% are for work purposes and 42% for educational purposes. Many education trips, however, are to tertiary institutions such as the University of Canterbury and Ara Polytechnic, where travel is more evenly distributed throughout the day. To account for this, 35% of the total daily bicycle demand was applied to the morning peak simulation. Figure 7 (left) illustrates the magnitude of origin trips across the

network, while Figure 7 (right) shows the corresponding destination trips. Destination volumes are substantially higher than origins in both the City Centre (496 to 6,198) and Ilam (924 to 2,517), reflecting concentrations of work locations and the University. Areas without hotspots show a sharp decrease in destination trips, aligning with the overall origin totals.

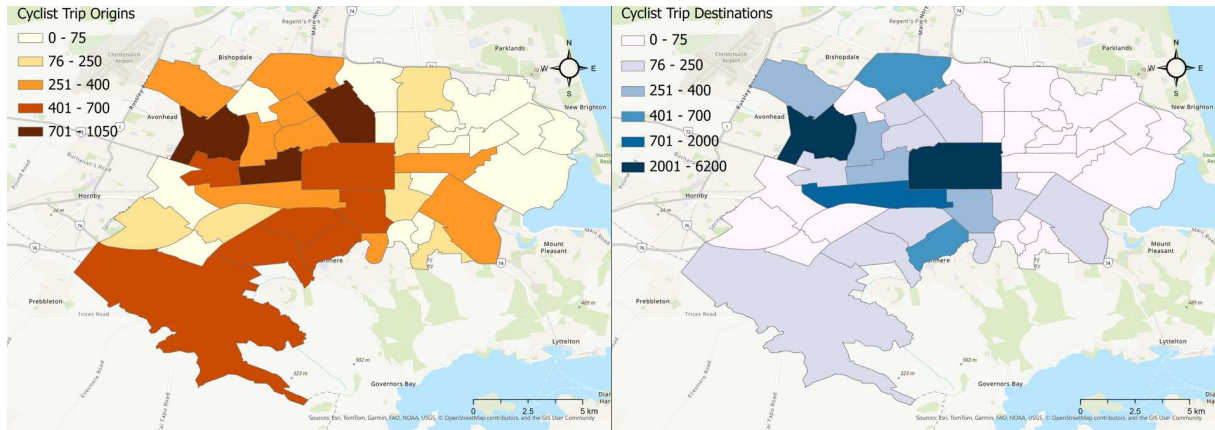


Figure 7: Cyclist trip origin count (left), and cyclist trip destination count (right)

### Cycleway Preference Implementation

While running the simulation, it was clear that the bikes were using the road just as much as they were using the cycleways. This created more congestion on the roads, which defeats the purpose of the cycleways being in the model. People are also much more likely to use separated cycleways as they are a lot safer and avoid interacting with the cars. To implement this in Aimsun, a script was run to increase the cost in the cost function of the bikes for using the road. To achieve this, the script increased the cost of using the road for all vehicle types, but not for the cycleways. The script ran through all the section types, and for any section that had fewer than three non-allowed vehicle types (all section types other than cycleways), it would increase the user cost to 5. This does not affect the cars in any way, as the cost for all the roads uniformly increases. Then, to enable the cost to increase, the user weight had to be increased from 0 to 1 in the simulation setting.

### Simulation Settings

This simulation was set to run during the weekday morning period from 7:00 to 9:00 AM. The demand profile for cars gradually increases until it reaches a peak of 26,654 vehicles, and bike demand remains at a constant 2,603 for each half-hour period (Figure 8). Two simulation scenarios will be run: the first scenario is cars and buses with no bike demand, and the second scenario is with car, bike, and bus demand. Dynamic traffic assignment was enabled in both simulations with a C-logit-based route choice model updated every 90 seconds. Eight replications were conducted for both scenarios, using the same eight random seeds for consistency.

To ensure realistic cycling behaviour, cyclists' performance parameters were informed by empirical data from KUTSCH, Kessler and Bogenberger (2025), who analysed urban bicycle dynamics using drone footage from Munich, Germany. Their findings indicated an average cycling speed of approximately 20.5 km/h with a standard deviation of 5.5 km/h, and an average acceleration of around 0.75 m/s<sup>2</sup> (ranging from 0.48 to 1.23 m/s<sup>2</sup>). These parameters replaced Aimsun's default values to improve behavioural accuracy. Minimum acceleration values were not reported in their study and were therefore assumed to follow a uniform distribution based on the observed maximum.

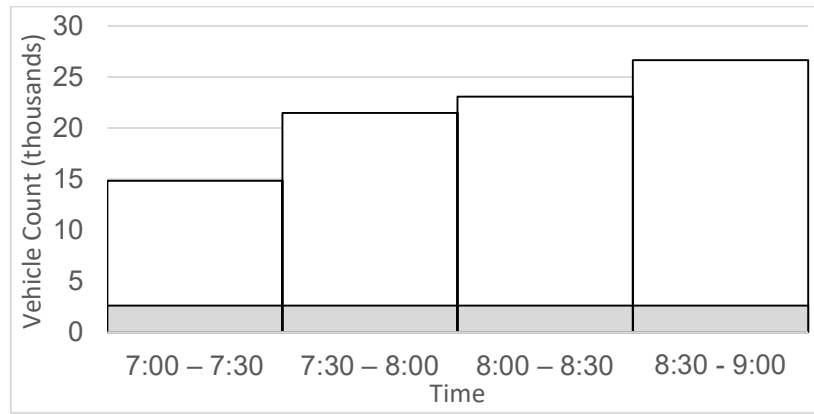


Figure 8: Demand profile from 7 to 9 AM (Cars in white and bikes in grey)

## RESULTS

### Overview

Two Aimsun simulations were undertaken to evaluate the traffic performance of the Christchurch network under two modal conditions:

1. A baseline model of only cars and buses, and
2. A second model, including cars, buses, and bicycles, to assess the impact of introducing cycling demand on network performance

Each model was simulated eight times, and the results presented below represent the average values across all runs to minimise the effect of random variation and ensure consistent network performance comparison. Key network performance indicators, including average speed, travel time, delay, density, and flow, were extracted from both models.

### Model 1 – Cars and Buses

The baseline model demonstrated typical peak-period conditions dominated by private vehicle use. Table 1 summarises the network-level results.

Table 1: Average results of the baseline model

	All Vehicles	Cars	Buses
<b>Average Speed (km/h)</b>	31.20	31.23	16.46
<b>Total Travel Time (h)</b>	11135	11,075,86	50
<b>Total Travel Distance (km)</b>	296157	295175	982
<b>Delay Time (sec/km)</b>	70.35	70.39	54.96
<b>Density (veh/km)</b>	5.47	5.43	0.04
<b>Flow (veh/h)</b>	33290	33217	73

The results indicate that the average car speed was approximately 31 kilometres per hour. In comparison, buses operated at a lower average speed of 16 kilometres per hour, most likely due to frequent stops and lower priority in mixed traffic. The network exhibited moderate levels of congestion, reflected in an average delay of 70.35 seconds per kilometre and an average density of 5.47 vehicles per kilometre.

### Model 2 – Cars, Buses, Bicycles

The inclusion of bicycle demand, derived from 2023 Census data for SA3 areas, introduces an additional mode of transport into the network. Table 2 presents the average results for this scenario.

Table 2: Average results for model 2, including bicycle demand

	All Vehicles	Cars	Buses	Bikes
<b>Average Speed (km/h)</b>	28.67	29.02	16.22	16.01
<b>Total Travel Time (h)</b>	11,083.90	10,546.66	48.85	488.29
<b>Total Travel Distance (km)</b>	260,958.00	252,832.52	804.24	7,321.24
<b>Delay Time (sec/km)</b>	84.65	85.35	55.62	60.29
<b>Density (veh/km)</b>	7.14	6.75	0.05	0.34
<b>Flow (veh/h)</b>	30,198.88	29,389.31	65.63	743.94

Compared to the baseline model, average car speeds decreased slightly to 29.02 km/h, while overall network density and delay increased, reflecting the redistribution of space and interactions between modes.

### Comparison Between Scenarios

A comparison of the two models highlights the effects of introducing bicycle demand on overall network performance. When bicycles were included, the average car speed decreased from 31.23 km/h to 29.02 km/h, representing a 7.1% reduction. This decline reflects the additional interactions and minor delays caused by bicycles sharing space with vehicles, particularly at intersections. The average network delay increased from 70.35 seconds per kilometre to 84.65 seconds per kilometre, representing an approximately 20% increase, indicating slightly slower traffic progression throughout the network. Similarly, network density increased from 5.47 to 7.17 vehicles per hour, a 30.5% rise, indicating higher occupancy levels and reduced flow efficiency due to the introduction of the additional mode. The overall vehicle flow rate decreased from 33,290 to 30,199 vehicles per hour, consistent with the reduction in average speed and the increase in congestion levels. Despite this, bicycles contributed a total of around 744 vehicles per hour across the network, operating at an average speed of 16.01 km/h, which aligns with expected commuter cycling behaviour. Overall, the inclusion of bicycles led to a modest reduction in performance but provided a modal split, demonstrating that the network can accommodate cycling demand with manageable impacts on vehicular efficiency.

### Time-dependent network performance

To further understand how traffic conditions evolved, the total delay and average speed were analysed across the simulation period (7:00-9:00 AM). Figures 4.1 and 4.2 illustrate these results for both the baseline model (Model 1) and the model including bicycles (Model 2). As shown in Figure 9 (left), both models exhibit a buildup of delay as demand increases toward the peak during the morning commute. However, model 2 demonstrates a consistently higher delay than model 1 at all-time points. This represents a significant increase in congestion, confirming that the introduction of bicycles, under the current network, contributes to reduced vehicular efficiency. The right side of Figure 9 clearly shows that the average speed of all vehicles across the network is lower in Model 2 throughout the whole simulation period. While both models experience a decline in speed as congestion sets in, model 2 starts from a lower base and remains approximately 5-10 km/h slower than model 1. The convergence of the two lines towards 9:00 AM suggests that the network begins to recover as demand subsides.

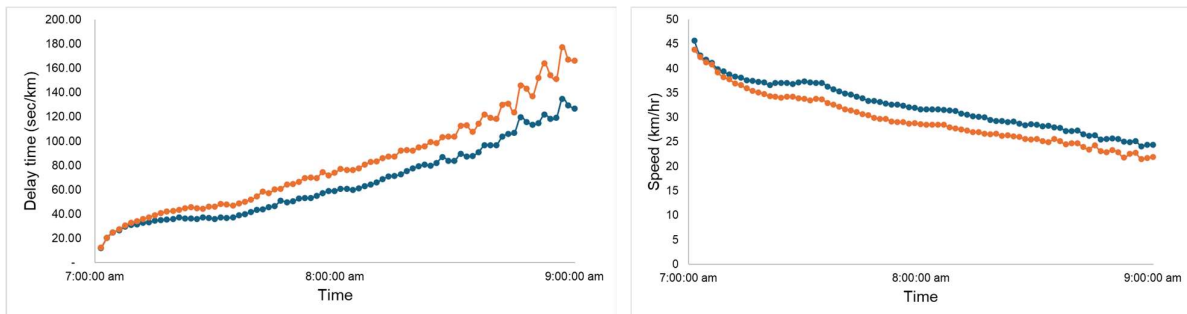


Figure 9: Average delay time over simulation period (left), and average speed over simulation period (right), model 1 in blue and model 2 in orange

## DISCUSSION

### Findings

The introduction of bicycle traffic into the Christchurch transport network produced relatively modest impacts on overall network performance. Comparing the two simulated conditions, one with only cars and buses and the second including bicycles, reveals that the presence of cyclists results in a slight reduction in vehicle operating speeds and network efficiency. Specifically, average car speed decreased by approximately 7.1%, while overall delay increased by around 20%, and network density rose by nearly 30.5%. These findings suggest that, while the inclusion of bicycles introduces some additional conflicts into mixed-traffic conditions, the current cycling infrastructure is capable of accommodating cycling demand without severe deterioration in overall network performance.

The corresponding reduction in total vehicle travel distance (11.9%) across the network implies that including cycling demand has decreased the trip length, as cycle routes are typically shorter than those for vehicles, aligning with broader transport sustainability goals. Although this substitution led to slightly lower speeds and higher delays for motorised traffic, it also reflects a diversification of network use that supports active transport initiatives within the city.

From a network design perspective, the observed increase in delay and density highlights the need for improved integration of cycling infrastructure. Shared lane operation, as represented in the model, tends to create minor conflicts at intersections and along constrained links, particularly where bicycles and vehicles compete for limited space. This suggests that dedicated cycling facilities, such as segregated lanes or protected intersections, could reduce modal interference and help maintain smoother flow for all users.

The time-dependent performance data, illustrated by the delay and speed graphs, provides a nuanced view of the congestion dynamics. The consistently higher delay and lower average speed in the multimodal scenario (model 2) throughout the entire 7:00 -9:00 AM period confirm that the introduction of bicycles creates a measurable and persistent effect on network congestion. This pattern underscores that the interaction between bicycles and motor vehicles, particularly at intersections, systematically reduces traffic flow efficiency during peak hours.

Notably, the simulated impacts remain within a manageable range for an urban network of Christchurch's scale. The moderate decline in performance metrics demonstrates that encouraging cycling is unlikely to compromise overall network functionality if accompanied by targeted infrastructure improvements. Furthermore, the environmental and social benefits of increasing cycling, such as reduced emissions, lower congestion over the long term, and improved public health, likely outweigh the small reductions in vehicular performance observed.

Overall, these findings reinforce that integrating bicycles into the Christchurch transport network can be achieved with limited negative operational impacts, particularly when supported by thoughtful planning and design. The time-dependent analysis also highlights the importance of evaluating performance over time, as static metrics alone may not fully capture the dynamic interactions between modes during peak travel hours. These results support the continued prioritisation of active transport modes as part of Christchurch's broader sustainable mobility strategy.

### Limitations

Due to time constraints, the cycleway design closely followed the OSM imports. As a result, only separated cycleways and shared paths were modelled. Although some paths viewed in Google Maps did not appear to be shared, the OSM layout was used unless any major discrepancies were found. Consequently, the OSM determined which pedestrian crossings were included, often resulting in an intersection with only one modelled crossing. The purpose of this project was initial model construction; it was out of our scope to validate cyclist routes or to model every traffic light, pedestrian crossing, signal plan, and connecting path centroid. Refining the model to include these features is an area for future/ongoing research work.

While many people associate cycleways with on-road cycle lanes, these were not part of the OSM import and would have required manual modelling from aerial imagery. Therefore, in areas where on-road cycle lanes exist, the model may have overestimated the impact of cyclists on vehicle traffic, as realistically, cyclists would not be travelling in the same vehicle lanes. Similarly, advanced stop

boxes at intersections, allowing cyclists to advance over vehicles, were not modelled, which would have slightly increased both cyclist and vehicle travel times in the simulation.

Aimsun assumes a deceleration rate of 3 m/s for bikes, which is the same as the deceleration rate for cars. As bike deceleration data was not available, this was left as the default. An additional limitation is that the expanded Christchurch network results in errors on specific predefined bus routes. Some services, such as the Orbiter, could not operate correctly in the simulation, which slightly reduces the accuracy of public transport representation and potentially underestimates total bus travel time and modal interaction. Finally, although many errors from previous versions of the model have been corrected, undetected issues may remain, which could impact the results.

## CONCLUSION

This study examined the impact of bicycle traffic on Christchurch's transport network using a detailed microscopic simulation in Aimsun. By comparing a baseline model of cars and buses with a model that also includes bicycles, this research quantified the impact of introducing cycling demand on network performance indicators, such as speed, delay, density, and flow.

These results indicate that incorporating bicycles results in a modest reduction in vehicle speeds, an increase in delay, and a higher network density, reflecting the interactions between modes in a shared environment. Despite these effects, the network maintained a high level of functionality, demonstrating that Christchurch can accommodate current cycling demand without severe deterioration of vehicular efficiency. Bicycles contributed a meaningful modal share, highlighting the importance of including active modes in transport network models.

These findings underscore the importance of integrating dedicated cycling infrastructure, such as segregated lanes, to minimise conflicts and optimise flow for all users. Overall, this research supports promoting cycling as a sustainable transport mode, providing evidence-based guidance for future infrastructure planning and policy development to improve network efficiency, reduce emissions, and enhance mobility options in Christchurch. Future work should explore improved modelling of cyclist behaviour and signal coordination to enhance realism and further support multimodal transport planning.

## ACKNOWLEDGEMENT

Most of the modelling guidance and technical advice that shaped this work was provided by our advisors, Mehdi Keyvan-Ekbatani and Cameron Davis, to whom we are sincerely grateful. We also acknowledge the Christchurch City Council for providing access to their macroscopic SATURN model, which was instrumental in supporting our analysis.

## AUTHOR CONTRIBUTION STATEMENT

Ashley Thomson and Billy Goble are the main authors and have carried out the research (including literature review, data collection, data analysis, modelling, simulation and interpretation of results) under the supervision of A/Prof. Keyvan Ekbatani (providing overall research guidance, development of research ideas, and interpretation of findings) and co-supervisor Cameron Davis (providing support in research discussions, data analysis, and review of modelling approaches).

## REFERENCES

CASAS, J., FERRER, J.L., GARCIA, D., PERARNAU, J. and TORDAY, A. (2010). Traffic simulation with Aimsun. In: BARCELÓ, J. (ed.) *Fundamentals of Traffic Simulation*, Vol. 145, International Series in Operations Research & Management Science, Springer, New York, pp.173–232. Available from: [https://doi.org/10.1007/978-1-4419-6142-6\\_5](https://doi.org/10.1007/978-1-4419-6142-6_5)

CHALERMWONGPHAN, K. and UPALA, P. (2019). Comparing the traffic operation, fuel consumption, and pollutant emission of bike lane pattern design with AIMSUN microscopic simulation model: A case study of Nakhon Sawan Municipality in Thailand. *The Open Transportation Journal*, 13, pp.182–193. Available from: <https://doi.org/10.2174/1874447801913010182>

CHRISTCHURCH CITY COUNCIL. (2024). *Draft Long-Term Plan 2024–2034, Volume 1*. Christchurch, New Zealand. PDF document, 439 pp. Available from:

<https://ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/Long-Term-Plan/LTP-2024-2034/Draft-LTP-2024-34-document-VOL-1.pdf>

HAJIDAVALLOO, M.R., ZHAOJIAN, L., CHEN, D., LOUATI, A., FENG, S. and QIN, W.B. (2023). Mechanical system inspired microscopic traffic model: Modelling, analysis, and validation. *IEEE Transactions on Intelligent Vehicles*, 8(1), pp.301–312. Available from: <https://doi.org/10.1109/TIV.2022.3146313>

HALL, M.D., VAN VLIET, D. and WILLUMSEN, L.G. (1980). SATURN—A simulation-assignment model for the evaluation of traffic management schemes. *Traffic Engineering and Control*, 21(4), pp.168–176.

JAFARI, A., BOTH, A., SINGH, D., GUNN, L. and GILES-CORTI, B. (2022). Building the road network for city-scale active transport simulation models. *Simulation Modelling Practice and Theory*, 114, 102398. Available from: <https://doi.org/10.1016/j.simpat.2021.102398>

KUTSCH, A., KESSLER, L. and BOGENBERGER, K. (2025). Analyzing bicycle riding characteristics based on naturalistic urban drone observations: Free riding, following behavior, and overtaking maneuvers. *Transportation Research Record: Journal of the Transportation Research Board*, 2679(9), pp.900–914. Available from: <https://doi.org/10.1177/03611981251341354>

LEE, H.S., OH, K., KEYVAN-EKBATANI, M., NGODUY, D. and JOHARI, M. (2020). *Multi-modal traffic dynamics of Christchurch CBD*. Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand.

MOUSAVIZADEH, O., & KEYVAN-EKBATANI, M. (2024). On the important features for a well-shaped reduced network MFD estimation during network loading and recovery. *Transportation Research Part C: Emerging Technologies*, 161, 104539. Available from: <https://doi.org/10.1016/j.trc.2024.104539>

MOUSAVIZADEH, O., & KEYVAN-EKBATANI, M. (2026). Multi-reservoir traffic dynamics: Outflow network MFD and state estimation with sparse traffic data. *Transportation Research Part C: Emerging Technologies*, 184, 105504. Available from: <https://doi.org/10.1016/j.trc.2025.105504>

PÉREZ CASTRO, G. (2023). *Towards microscopic models for bicycle traffic simulation*. Available from: <https://doi.org/10.3384/9789180752497>

STATISTICS NEW ZEALAND. (2025). *Main means of travel to education for Christchurch City* [Online]. Government of New Zealand. Available from: <https://tools.summaries.stats.govt.nz/places/TA/christchurch-city#main-means-of-travel-to-education> (Accessed 18 August 2025).

ZENG, Z., SONG, B., ZHENG, X. and LI, H. (2019). Changes of traffic network and urban transformation: A case study of Xi'an city, China. *Land Use Policy*, 88, 104195. Available from: <https://doi.org/10.1016/j.landusepol.2019.104195>