Robinson Transportation Consulting

Royal Oak Roundabout Safety Improvements

Road Safety Review
Scheme/Preliminary Design

May 2018

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s7(2)(a) Privacy

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	Bruce Robinson			Bruce Robinson		18/05/18
B						
C						
D						

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1. Introductory Statement

1.1 Introduction

This report presents the findings of a scheme/preliminary design stage safety review of the proposed safety improvements to the Royal Oak roundabout intersection in Auckland.

The project extent is indicated on Figure 1. The proposed preliminary design has been prepared by GHD, Auckland on behalf of the Auckland Transport (see Appendix A: Roundabout Improvements Concept Design). The primary proposed improvements to the existing roundabout is to add raised pedestrian crossings across all legs of the roundabout, reshaping of the central island, extensions to the splitters islands, additional spiral markings within the circulatory roadway and advanced directional signs.

Figure 1 Approximate extent of project

1.2 Reviewer

This safety review is the first for the proposed intersection improvements. It was suggested by NZTA prior to safety funding assistance with any design changes. Given that it is a review of one concept design drawing, together with crash records and traffic surveys, the safety review team comprised of a single experienced[1] roundabout safety auditor:

Bruce Robinson	Pr.Eng. (RSA), M.Eng., B.Sc.Eng. (Civil) Robinson Transportation Consulting, Tauranga

It is understood that a more formal safety audit will be required in due course.

1.3 Methodology

The review generally follows the guidelines contained within the NZ Transport Agency document "Road Safety Audit Procedures for Projects, Guidelines, Interim Release, May 2013" and is complemented by the reviewer's experience with other complex multi-lane roundabouts.

This review should not be regarded as a complete "quality check" of the project. It focuses essentially on safety issues that are considered significant regarding the proposed design.

The review has identified road safety concerns and made recommendations about corrective actions. Whilst these recommendations may indicate the nature or direction of a solution, they do not necessarily provide specific details of how to address or resolve that concern. Responsibility for the solution of any safety issue identified remains with the designer.

1.4 Project documentation, briefing meeting and site visit

The reviewer was provided with the following materials:

1. A preliminary design plan. A copy of this drawing is contained in Appendix A.
2. Swept paths tracking rubbish trucks and buses. An example drawing is provided in Appendix B.
3. "Royal Oak Roundabout – Analysis and Summary" background document.
4. Traffic surveys of peak hour multi-modal origin-destinations, approach queue lengths, pedestrian crossings.
5. Sidra operational capacity analyses.

The reviewer carried out a desk-top audit of these documents.

A site tour during the AM peak period and briefing meetings were held with the GHD traffic engineers (Jason Chow and Inho Lim) and the Auckland Transport project manager (Winston Gee), on 13th April 2018 followed by a detailed site inspection on the same afternoon. The weather was fine for the site visit.

[1] *Principal Investigator, "Roundabouts: An Informational Guide" (First Edition), U.S. Federal Highway Administration, 2002.*

1.5 Ranking system

The potential road safety problems identified have been ranked as follows:

The probable crash frequency is qualitatively assessed based on expected exposure (how many road users will be exposed to a safety issue) and the probability of a crash resulting from the presence of the issue. The likely severity of a crash outcome is qualitatively assessed based on factors such as expected speeds, type of collision, and type of users involved.

Reference to historic crash rates or other research for similar elements of projects, or projects as a whole; have been drawn on where appropriate to assist in understanding the likely crash types, frequency and likely severity that may result from a particular concern. The frequency and severity ratings are used together to develop a combined qualitative ranking for each safety issue using the Concern Assessment Rating Matrix in **Table 1** below. The qualitative assessment requires professional judgement and a wide range of experience in projects of all sizes and locations.

Table 1: Assessment Matrix

Likelihood of Fatality or Serious Injury	Probability of a Crash Occurring			
	Frequent	Common	Occasional	Infrequent
Very Likely	Serious	Serious	Significant	Moderate
Likely	Serious	Significant	Moderate	Moderate
Unlikely	Significant	Moderate	Minor	Minor
Very Unlikely	Moderate	Minor	Minor	Minor

While all safety concerns should be considered for action, the client or nominated project manager will make the decision as to what course of action will be adopted based on the guidance given in this ranking process with consideration to factors other than safety alone. As a guide, a suggested action for each concern category is given in **Table 2** below.

Table 2: Categories of Concern

CONCERN	Suggested Action
Serious	Serious concern that must be addressed and requires changes to avoid serious safety consequences.
Significant	Significant concern that should be addressed and requires changes to avoid serious safety consequences.
Moderate	Moderate concern that should be addressed to improve safety
Minor	Minor concern that should be addressed where practical to improve safety.

In addition to the ranked safety issues it is appropriate for the safety reviewer to provide additional comments with respect to items that may have a safety implication but lie outside the scope of the safety review. A comment may include items where the safety implications are not yet clear due to insufficient detail for the stage of the project, items outside the scope of the review such as existing issues not impacted by the project or an opportunity for improved safety but not necessarily linked to the project itself. While typically comments do not require a specific recommendation, in some instances the reviewer may give suggestions.

1.6 Disclaimer

The findings and recommendations in this report are based on an examination of available relevant plans, the specified road and its environs, and the opinions of the reviewer. However, it must be recognised that eliminating safety concerns cannot be guaranteed since no road can be regarded as absolutely safe and no warranty is implied that all safety issues have been identified in this report. Safety reviews do not constitute a design review or an assessment of standards with respect to engineering or planning documents. Readers are urged to seek specific technical advice on matters raised and not rely solely on the report.

While every effort has been made to ensure the accuracy of the report, it is made available on the basis that anyone relying on it does so at their own risk without any liability to the safety reviewer or their organisation.

2 Safety Review Findings and Recommendations

The following safety review findings may pertain to either the existing condition or the proposed design modifications. The category of concern has been indicated in each sub-heading, based on the exposure probability x severity likelihood. It is left to the parties involved to respond appropriately, according to their separate or shared responsibilities for each of the safety concerns that have been identified. In some cases, the timing of safety improvements may be triggered by re-development of land on the various frontages of the roundabout intersection.

2.1 Speed management and consistency (C.U=Moderate)

The site currently has a 50 km/h speed limit on the urban approach roads. However, roundabout entry speeds should ideally be less than 40 km/h, with sought-after speed consistency criteria (relative speeds) of no more than 20km/h and less than 10km/h desirable between consecutive geometric elements or conflicting traffic streams. When bicyclists are required to share lanes with general traffic, as is the case at this site, then an even slower circulatory roadway speed is considered appropriate to maintain relative speed consistency, thus making "claiming" or the lane and circulating safer.

The required speed reduction on entry and circulatory roadway negotiation is usually achieved through horizontal deflection in greenfield sites. As has been noted in this retrofit environment, however, there is little scope for provision of additional horizontal deflection given the constrained land-uses and rights of way. In fact the "urban village" environment that has developed around this intersection, with intense multi-modal activity has led to a need to consider sharing space between these conflicting local and through trip desire lines. In this regard, it is notable that only 5 of the 17 injury or fatal crashes were vehicle-vehicle crashes with the majority of crashes involving more vulnerable users: either pedestrians, bicyclist, motorcycles or mopeds. In such a situation transitioning to a lower 30km/h speed limit zone with 300-500m of the roundabout and prior to the shops and crosswalks may more appropriate to consider.

Although vertical deflections such as entry and/or exit speed humps or tables can be a safety concern in high speed environments, they are generally considered acceptable in speed-constrained and lower traffic flow situations such as on roundabout legs to local or collector roads, such as Campell Road in this case. However, they are not usually found on arterial roads, such as Mount Albert Road, Mount Smart Road or Manukau Road due to the inconvenience to higher traffic flows and heavy vehicles including buses and emergency vehicles. Consideration could be given to a more sinusoidal speed hump profile[2,3] on the leading edges, that would be more comfortable to traverse for bicyclists and bus passengers. It is understood that this safety-focused project may be followed by an urban design investigation that could more fully explore some shared-space concepts, including a raised intersection or street blocks.

[2] *'Traffic Calming - Sinusoidal, `H' and `S' Humps | TRL'. (https://trl.co.uk/reports/TRL377) Accessed 15 May 2018. .*

[3] *https://at.govt.nz/media/807636/ATCOP-Drawing-set-Chapter-8-Traffic-Calming.pdf*

At this site a fatal crash involving a pedestrian crossing has resulted in a raised crosswalk being installed on Mount Smart Road, with a supplementary in-pavement active road stud system which are activated by pedestrians present at the crossing. The active road studs have also been implemented on the Campbell Road leg, albeit without a raised crosswalk. During the site visit, it was noted that these road studs tended to de-activate quite a while after pedestrians had passed through the crosswalk. Many of them are also becoming pressed into the asphalt concrete surround, possibly making them less visible. It is important that their operation is tuned and maintained so that, over time, drivers do not become de-sensitised and disregard such warning lights as seemingly unresponsive to actual conditions at the crosswalks. As a result of these retro-fitted treatments, there are now a variety of inconsistent pedestrian and driver user experiences across the various legs of this roundabout. The proposed design aims to provide greater consistency at these crosswalks.

Figure 2 Vertical deflection at raised pedestrian crossing of Mount Albert Road

Recommendations

a) *Consider the appropriateness of the 50km/h posted speed limit on all roundabout legs though the Royal Oaks commercial area and whether it should be reduced to encourage safer crossings and consecutive roundabout entry and negotiation speeds that are safe and consistent with the road environment.*

b) *Design raised crosswalks to be adequately signed and marked, longitudinal profiles of the vertical deflection zones that are comfortably traversable by buses and emergency vehicles, appropriate to the flow function of an arterial street.*

c) *Ensure that active road studs are correctly timed and maintained to maximise their effectiveness. For consistency consider installing them on all crosswalks to the roundabout.*

2.2 Intersection and network form (Comment)

In the current configuration (Figure 1), the circulatory roadway is variable with 3 lanes in front of three of the splitter islands, and 1 lane in front of the other two splitter islands. The safety record of roundabouts with multiple entries or exits and three circulatory lanes is mixed with increased risk of entry- or exit-path overlap and side-swipe crashes and depends on careful coordination of the various roundabout design elements that control entry speeds and path overlap within the circulatory roadway. The proposed design includes a modification of the circulatory roadway lane configuration, reducing it to 2 lanes in front of two splitter islands and a single lane in front of the other three splitter islands (Appendix A). This should reduce the number of lane change conflicts that are possible within the roundabout as well as slowing the circulating speeds (possibly trading off some capacity).

At a conceptual design stage, it is also appropriate to consider alternative forms of access or control and their relative safety performance. For example, other treatments could include reconfiguration to a signalised intersection, alternative roundabout configurations or alternative routes and way-finding measures to bypass this site and divert some traffic demand.

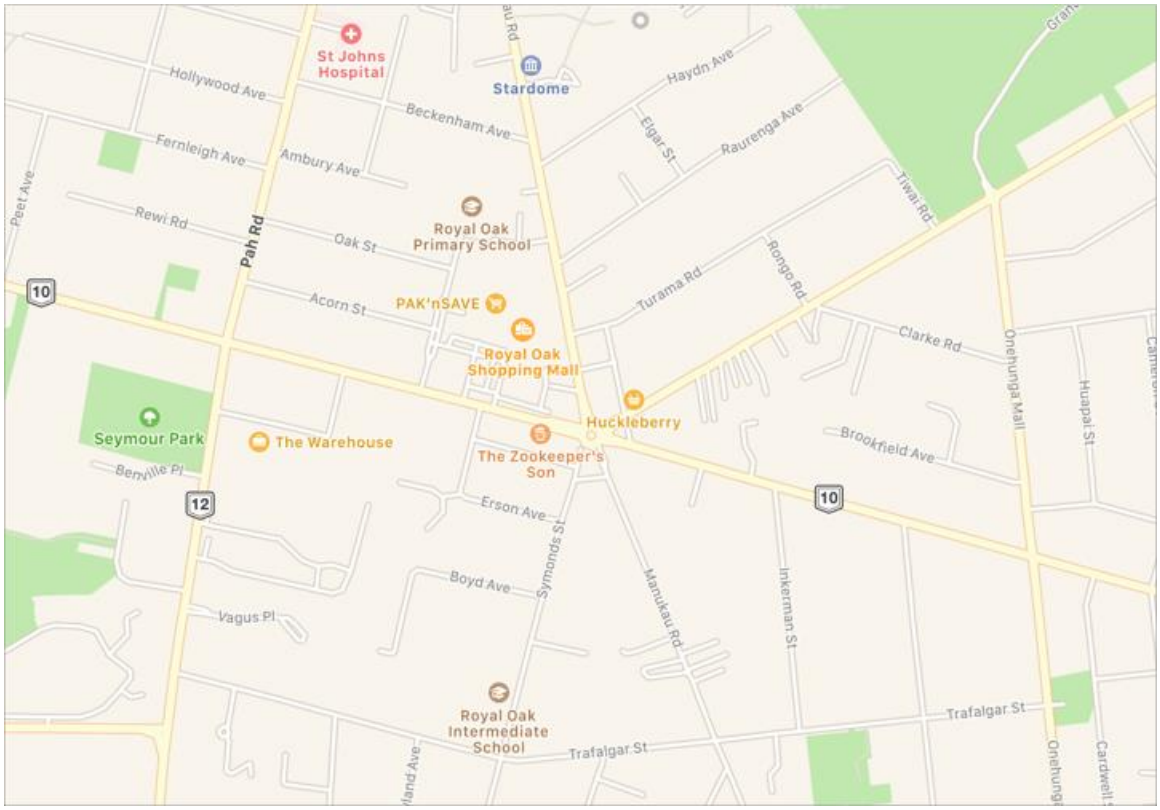


Figure 3 Vicinity map showing wider network route options

In the project briefing meeting it was mentioned that other central island shapes have been considered, as well as removing an exit lane on Mount Albert Road, a turbo-roundabout treatment with kerb-separated circulatory lanes, and staggering the pedestrian crossings. The possibility of a subsequent urban design study that included consideration of a raised shared space on Campbell Road leg with a driveway apron treatment at the roundabout was also discussed, as well as possible bypass alleys or streets.

Therefore, without further information the reviewer is reluctant to opine on whether the form and location of the roundabout is the best solution in terms of a safe system design for this specific location. However, in general terms, it should be noted that a well-designed multi-lane roundabout can provide an appropriate safe system design for an intersection.

Recommendation

At an appropriate time, consider a project scoped to focus on urban design and the relative merits of alternative roundabout configurations and/or alternative network options and/or control, to improve safety performance.

2.3 Approach lane pre-segregation and entry curve design (C.U=Moderate)

The proposed design shows that all of the current double-lane entry lanes only serve between 1 and 3 of the possible 5 exit legs and the circulatory roadway lane is restricted to two lanes at most. This makes it even more important than in the current design that vehicles are correctly pre-segregated into the correct entry lanes, even prior to the pedestrian crosswalks so that unsafe late lane changing is minimised. In this regard, Advanced Directional Signs with individual lane origin-destinations have been proposed. Also, three approach lanes downstream of the crosswalks have been marked with solid lines to indicate that no lane changing should occur. Three of the 5 approaches have repeated the entry lane turn arrows upstream of the crosswalks.

However, the positions of the ADS in terms of upstream location distance appear to be shorter than optimal, given the extensive queuing that occurs on the approaches during peak periods. Ideally, drivers should not be required to change lanes in-queue but rather be forewarned with enough time and space in terms of lane changing indications or gaps to pre-segregate their vehicles prior to joining the back-of-queue.

Figure 4 Queue backup on Mount Albert Road

Particularly on multi-lane arterial routes, drivers reasonably expect to continue through an intersection in either lane. Specifically, on Mount Albert Road which is four lanes wide, the design lane arrangement would result in a left lane "trap" for drivers who may expect to optionally proceed straight through the roundabout to Mount Smart Road from this lane (although Mount Smart only has one exit lane). This could cause unsafe late lane changes to avoid the trap. Of note is that the proposed design extends the raised splitter island on Campbell Road into the currently white-hatched circulatory roadway which more clearly differentiates the Campbell Road exit from the Mount Smart Road exit for Mount Albert Road and Manukau Road (southbound) entrants. While eliminating this acute-angled adjacent exit confusion, it also foreshortens the room for late lane changes, thus accentuating the need for clear and timely lane per-segregation cues on Mount Albert Road and Manukau Road (southbound).

Figure 5 Trap lane from Mount Albert Road entry to Campbell Road exit

Recommendations

a) *Re-locate the ADS signs as far upstream on each approach as required to allow for safe lane changing prior to joining the back of queues during peak periods;*

b) *Provide repeated turn lane markings upstream of peak period queues on each approach to encourage pre-segregation;*

c) *Extend solid lane lines on Mount Albert Road approach upstream of the pedestrian crosswalk to discourage late lane changes.*

2.4 Deflection and path overlap through the roundabout (O.U=Moderate)

The entries into the roundabout appear to be perpendicular to the central island and have relatively low deflection. Thus, it is possible for drivers to enter the roundabout at inappropriately high speeds and they may then be forced to slow quickly into the circulatory lane. This could increase the likelihood of loss of control. Specifically, the inside entry lanes closest to each splitter island are not oriented tangentially to the central island truck apron. At unconstrained sites, best practice is to offset the approach entry paths to the left of the central island (including any apron) to manage entry speeds into the circulatory roadway with the minimum vehicle speed being achieved at the roundabout limit line. This can generally be achieved geometrically by resetting of the splitter island leading edge and the

kerb radius, re-shaping the entry curve radius to offset to the left of the central island. In conjunction with this kerb geometry, the entry lane markings should be targeted toward their matching circulatory lane in front of the next downstream splitter island.

On Campbell Road and Mount Smart Road each with adjacent "through" entry lanes both destined to exit at Mount Albert Road, this lane geometry can encourage drivers in adjacent shoulder lanes to take the shortest path through the circulatory roadway, with their path overlap into the inside lane cutting off the inside lane vehicles during circulation. It is perhaps noteworthy that a full Dutch "turbo-roundabout" design with kerb separated lanes would eliminate the possibility of path overlap on the circulatory roadway and also help to manage speeds.

Fast tangential exit speeds increase the likelihood of loss of control type crashes and the potential for higher speed crashes involving pedestrians crossing the road near the exits. This could be a safety issue at the Campbell Road exit as well as at the Manukau Road south exit leg Therefore, the detailed design should include the consideration of the speed path profiles through the roundabout to demonstrate safe speeds, through both the circulatory path and on the higher speed through lane entries and exits.

On the other hand, on multi-lane exits, perpendicular exits can cause exit path overlap, particularly for heavy vehicles. For example, the double lane exit to Mount Albert Road has a severe left turn on exit arrangement which adjacent trucks or buses are unable to negotiate without crossing the exit lane markings (see swept paths in Appendix B). This will lead to side-swipe conflicts and crashes.

Figure 6 Constrained exit to Mount Albert Road

The roundabout central island also includes an apron. Any vertical kerb "nib" between the inner circulatory lane and the apron next to roundabout islands can be hazardous for motorcyclists, particularly if the entry path offsets, referred to above, have not been provided. The crash record includes that 4 of the 17 injury or fatal crashes involved motorcyclists/mopeds (Appendix C).

Recommendations

a) *At detailed design stage, assess the speed path profiles through the roundabout and provide for safe speeds: through both the entry and circulatory path, with the inner entry lanes being sufficiently offset from and as tangential to the central island as possible; to reduce path overlap for through traffic entering at Campbell Road and Mount Smart Road, and to reduce speeds on the tangential exit lanes at Campbell Road and Manukau Road south exit.*

b) *Design the mountable central island apron kerb to be sufficiently offset from the fastest travel paths and flush with the pavement surface to minimise the tripping hazard for motorcyclists;*

c) *Correct the geometry to avoid an exit lane path overlap conflict point for heavy vehicles at Mount Albert Road exit;*

2.5 Central island conspicuity (O.U=Moderate)

The central island currently consists of a small diameter, relatively wide mountable apron, with a lamppost in the centre and street name signs indicting each exit leg. However, it is evident from the lack of wheel tracks that the apron is not used much and indeed the whole island is very inconspicuous and unreadable with no target value, being almost flush with the circulatory roadway.

Figure 7 Inconspicuous central island

The proposed design will increase the central island and reshape it with two "cams" to develop right turn spiral lanes from. The exact shape has been determined from the non-traversable "remnant" as indicated by the inside track requirements of the design vehicle swept paths (Appendix B).

Reconfiguration of the central island provides an opportunity to increase its target value by incorporating heightened visual elements (e.g. vegetation, mounding, artwork) that would provide a terminal vista so that drivers notice the presence of the central island rather than having their gaze distracted across to the far side of the intersection.

Recommendations

a) *Incorporate heightened visual elements into the enlarged central island to provide a terminal vista from each roundabout approach to improve legibility and recognition that this is a roundabout intersection as well as clearly demarcating the location of the island that must be circulated.*

b) *Provide the minimum truck apron or vertical elements that are necessary to provide adequate forward stopping sight distance on the circulatory roadway.*

2.6 Circulatory roadway markings (C.VU=Moderate)

The design has circulatory lane markings spiralling out from the cams on the central island to the Mount Albert Road exit and the Campbell Road exit. As critical as ensuring the correct exit paths are taken is ensuring that the correct entry paths from the giveway lines to the correct circulatory lanes are made. Therefore the design could be improved by providing these guide markings for the inside lanes leading from all entries expect Manukau Road northbound where it is not needed.

As a further visual cue, the inner circulatory lane could benefit from having the turn arrows repeated opposite splitter islands where there are two circulatory lanes at Manukau Road north and south. The exclusive left exit lanes to Mount Albert Road and Campbell Road would also benefit from repeater directional markings on the outer circulatory lanes between the entry and exits. A graphical summary of these lane marking recommendations is provided as Appendix E.

The proposed design shows solid lane markings in the southwest and northeast quadrants of the circulatory roadway, similar to the raised kerbs in a Dutch "turbo" roundabout design. These lane markings are intended to be mandatory and enforce lane-discipline. As such they should be bold, and possibly treated with a different colour or possibly using audio-tactile pavement markers.

Recommendations

a) *Consider providing guidelines for the median entry lanes from the giveway line into the correct inside circulatory lane for critical movements.*

b) *Consider providing turning lane arrow markings in front of the splitter islands in the multi-lane circulatory roadway.*

c) *The solid spiral lane markings in the southwest and northeast quadrants of the circulatory roadway could be made more conspicuous through a combination of wider and different colour and/or by including audio tactile pavement markings.*

2.7 Pedestrian crossing points at roundabout splitter islands (C.L=Significant)

Pedestrians have been involved in 5 of 17 injury or fatal crashes (Appendix C). Furthermore, the traffic surveys (Appendix D) indicate that there is significant pedestrian activity throughout the day and early evening. Two of the legs (Campbell Road and Royal Albert Road) currently have active road studs at the crossings. At four of the five legs there are currently ramped kerbs off the sidewalk at pedestrian crossing points and flush pedestrian refuges through the splitter islands.

The proposed design plans to replace these with 100mm raised pedestrian crosswalks, similar to the ones on Mount Albert Road, but painted red with white zebra stripes. As well as providing vertical deflection for vehicles crossing them, they will be flush with the sidewalks making it easier for all non-vehicle users to cross comfortably. It is not clear whether ative road studs are being considered at the other crosswalks, but these should be considered for consistency and safety enhancement.

On Manukau Road north and south legs there are some parking spaces either within the functional area of the intersection between the crosswalks and the giveway lines, or upstream that are limiting pedestrian sight distance and resulting in conflicts (side-friction) with through traffic when parking or leaving. It is suggested that any parking spaces that are within the functional area of the intersection or limiting sight distances to the crosswalks be removed (Appendix E).

Figure 8 Car parking obfuscation

Finally, during the site visit, it was noticed that the busy crosswalk at the Manukau Road north leg was frequently causing car queues in the single exit lane to back up into the roundabout, thus blocking other movements. This operational matter is resulting in a safety concern by causing vehicle-vehicle conflicts in the roundabout. It is left to the designers to investigate possible solutions which may include some combination of a signalised crossing; dual exit lanes (shown in Appendix E); or re-location of the crossing point.

A Sidra 95th percentile queueing analysis of this crossing during the PM peak estimates a 107m queue northbound, which would block the upstream roundabout and a 1304m queue southbound. If there were dual northbound exit lanes from the roundabout, tapering back to a single lane 60m after the crossing, then the northbound queue would reduce to 41m (and the southbound queue would remain 1304m, as before).

Recommendations

a) *Remove all parking spaces within the functional intersection areas between the crosswalks and giveway lines on Manukau Road exits and Manukau Road northbound entry.*

b) *Provide adequate dynamic sight distance of pedestrians by removing any parking space within 1 car length from the crosswalk on each approach on Manukau Road north and south.*

c) *Retrofit the existing Mount Albert Road crosswalks to have a consistent design and marking treatments to the new raised crossings on the other legs.*

d) *Consider providing active road studs at all crosswalks for safety and consistency.*

e) *Design a solution for the queue spillback from the Manukau Road northbound exit due to the high pedestrian crossing activity during peak periods.*

2.8 Bicycle path continuity and wayfinding (O.VL=Significant)

The crash evidence indicates that 5 of 17 crashes involved bicyclists, also noting that a further 4 involved motorcycles or mopeds (Appendix C). Multilane roundabouts are difficult for less confident cyclists to negotiate in the general traffic lanes, particularly if they have more than 4 legs as occurs at Royal Oaks. Therefore, recommended practice is to provide an alternative off-road path for less confident cyclists as multi-lane roundabouts. In this case, the variable circulatory roadway also makes it difficult for cyclists to pre-segregate into the correct lanes to negotiate the intersection by requiring them to claim an inside lane rather than a shoulder lane to certain destinations.

The sidewalks on some corners of the intersection are quite narrow so off-road bicyclists should be instructed by supplementary signs at the shared path “begins” points to dismount or otherwise give way to pedestrians. This should also apply at the crossings.

For the more confident on-road riders, there should be signs after the ADS signs and upstream of the crossings instructing them to “claim the lane” to negotiate the roundabout

as a vehicle would, to their destination. In some cases, for right turns a lane change from the shoulder to the inside entry lane may also be necessary.

A possible solution to provide protected entry into either of the roundabout entry lanes when a bicycle approaches (e.g. in a short shoulder bicycle lane) could be to briefly stop other vehicles at crosswalk signals when a bicycle actuates a sensor. These crosswalk signals could also be actuated by pedestrians rather than the current "on-demand" pedestrian priority crossing, thus bunching pedestrians to cross in groups during their own green phase. Metering the roundabout legs may also provide more positive control to optimise roundabout performance during peak periods.

Recommendations

a) *Provide an alternative off-road shared path and wayfinding provisions for less confident cyclists to cross the roundabout;*

b) *Provide optional bicycle ramps to and from shared crossings through the roundabout intersection to provide a safe off-road crossing.*

c) *Provide supplementary signs at the beginning of the shared paths and crossing points requiring off-road bicyclists to dismount or give way to pedestrians.*

d) *Provide signage upstream of the crossings of the need for on-road bicyclists to claim the general traffic lane appropriate to their destination and proceed through the roundabout as a vehicle.*

e) *Consider a signal metering solution at each crosswalk approach that provides bicycle priority into the roundabout entry lanes and possibly protected signalised crossings for pedestrians.*

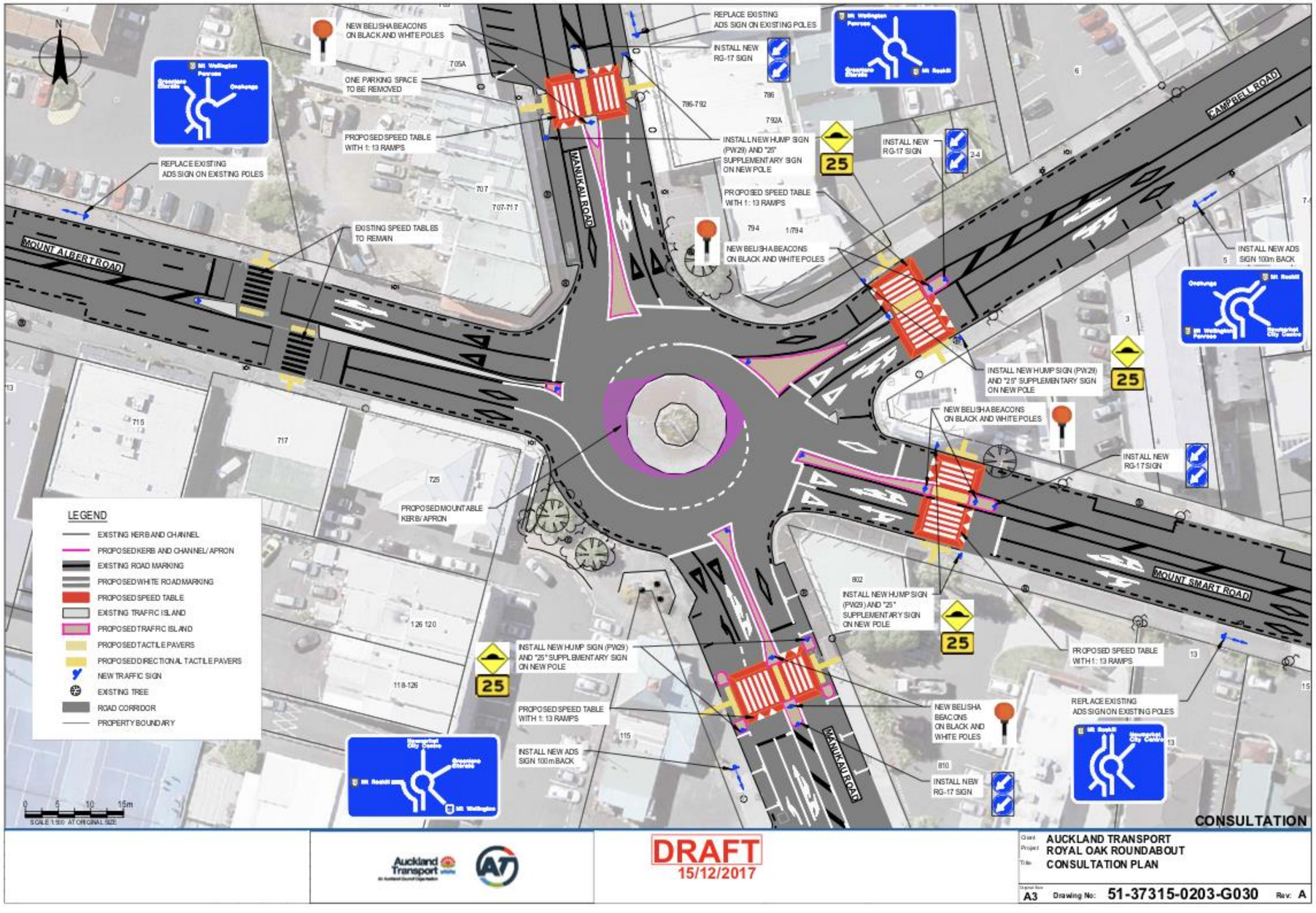
3 Review Statement

I certify that I have used the available plans, and have examined the specified roads and their environment, to identify features of the project that I have been asked to look at that could be changed, removed or modified in order to improve safety. The problems identified have been noted in this report.

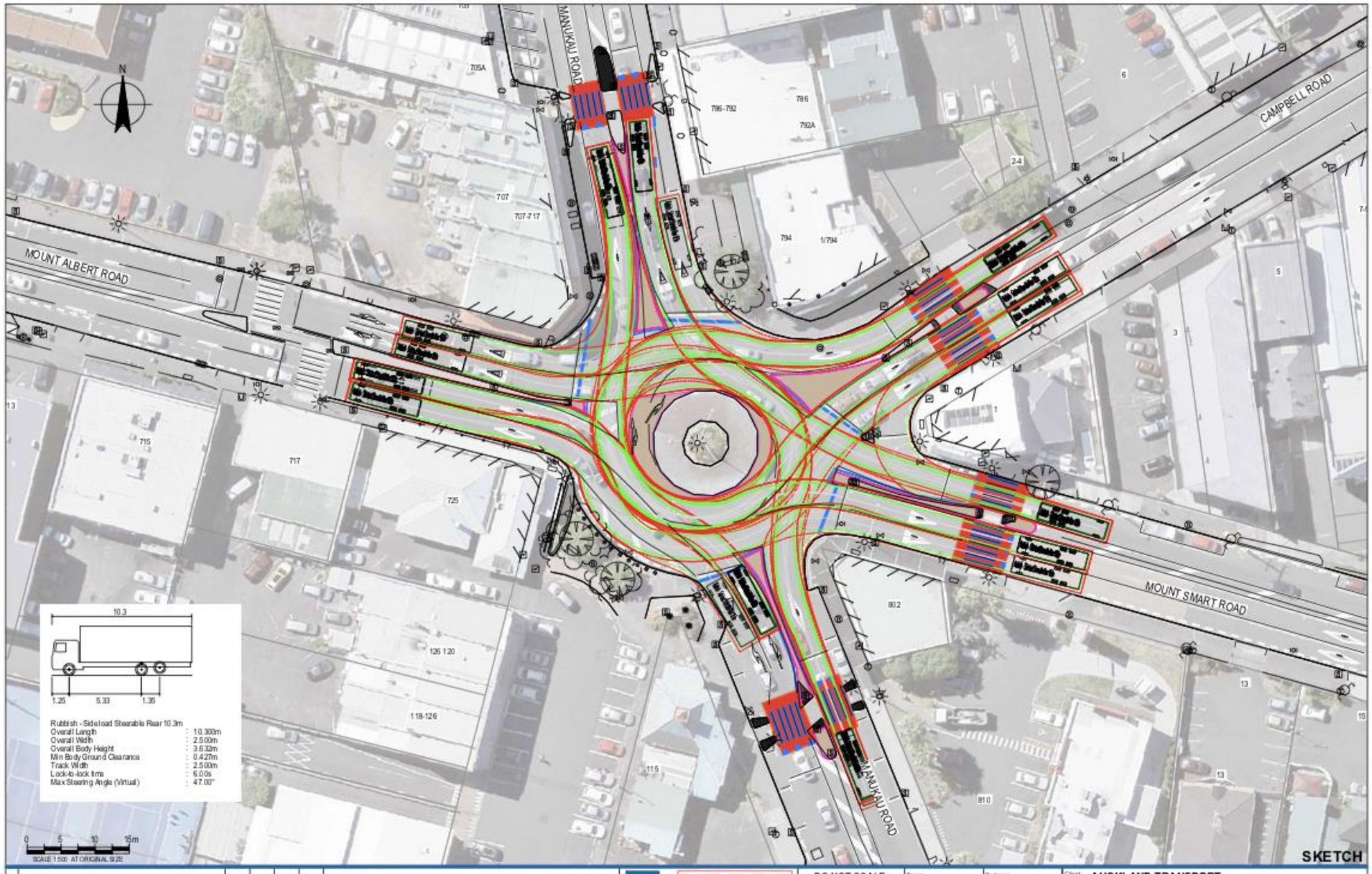
Signed:..... Date: 18/05/2018

Bruce Robinson, Pr.Eng. (RSA), M.Eng., B.Sc.Eng. (Civil)
Robinson Transportation Consulting, Tauranga

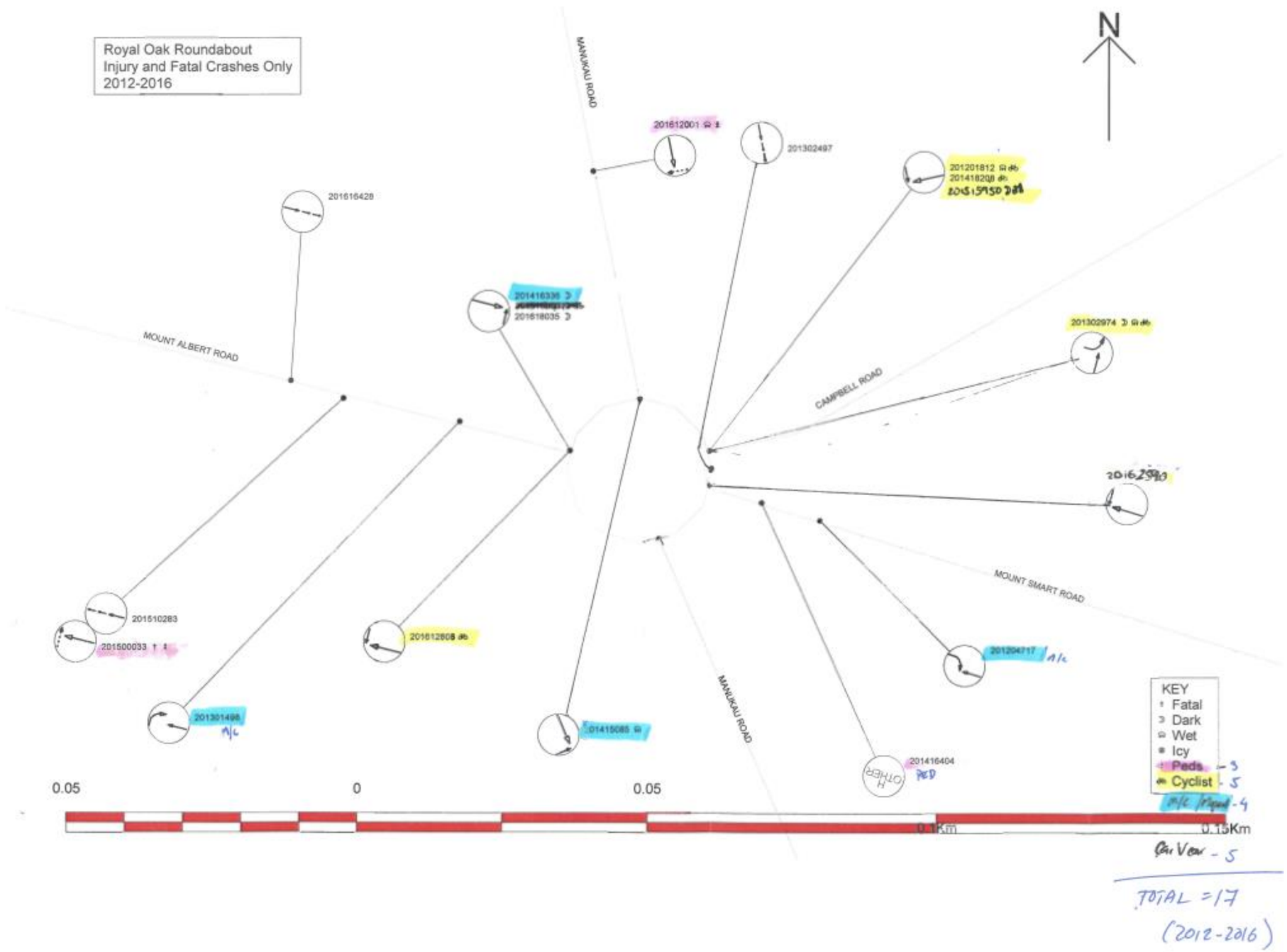
Appendix A: Roundabout Improvements Concept Design



Appendix B: Tracking Curves (Rubbish Trucks)



Appendix C: Crash Record (2012-2016)



Appendix D: Traffic Surveys

Client GHD
Location Royal Oak Roundabout
Date Thursday, 19 October 2017
Survey Time 07:30 - 09:30 & 15:00 - 18:00
Description Royal Oak Roundabout Pedestrian Crossing Survey

MATRIX Traffic and Transport Data

N

Hour Starting	Pedestrians Type
8:00	All Classes

Zone 1	AM Peak	8:00	to	9:00
	PM Peak	15:00	to	16:00
Zone 2	AM Peak	8:15	to	9:15
	PM Peak	15:15	to	16:15
Zone 3	AM Peak	8:15	to	9:15
	PM Peak	16:15	to	17:15
Zone 4	AM Peak	8:00	to	9:00
	PM Peak	16:15	to	17:15
Zone 5	AM Peak	7:45	to	8:45
	PM Peak	15:00	to	16:00

Figure 9 Pedestrians 8-9am

Client GHD
Location Royal Oak Roundabout
Date Thursday, 19 October 2017
Survey Time 07:30 - 09:30 & 15:00 - 18:00
Description Royal Oak Roundabout Pedestrian Crossing Survey

MATRIX Traffic and Transport Data

N

Hour Starting	Pedestrians Type
16:00	All Classes

Zone 1	AM Peak	8:00	to	9:00
	PM Peak	15:00	to	16:00
Zone 2	AM Peak	8:15	to	9:15
	PM Peak	15:15	to	16:15
Zone 3	AM Peak	8:15	to	9:15
	PM Peak	16:15	to	17:15
Zone 4	AM Peak	8:00	to	9:00
	PM Peak	16:15	to	17:15
Zone 5	AM Peak	7:45	to	8:45
	PM Peak	15:00	to	16:00

Figure 10 Pedestrians 4-5pm

Figure 11 Queues

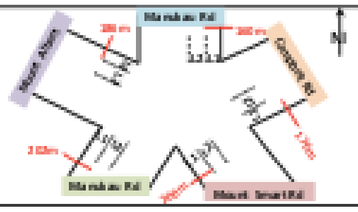
Client: ID HD

Location: 1 - Manukau Rd / Mount Smart Rd / Campbell Rd / Mount Albert Rd

Date: Thu, 28 Oct 2017

Survey Time: 7:00-9:00 & 15:00-18:00 (5 hours)

Description: Queue Length Survey (in cars per 5 min blocks)



MATRIX

AM	North East Leg (Campbell Rd)		North Leg (Manukau Rd)		South Leg (Manukau Rd)		West Leg (Mt Smart - Albert Rd)		South East Leg (Mount Smart Rd)	
	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
7:00	0	1	0	1	0	1	6	9	0	1
7:02	1	2	1	1	0	7	6	1	0	15
7:04	2	4	0	9	1	4	6	8	2	1
7:06	2	4	1	8	0	1	1	6	1	1
7:08	2	7	0	1	2	1	7	11	1	4
7:10	1	2	1	11	1	7	1	7	6	1
7:12	2	6	1	1	2	6	14	18	1	8
7:14	1	11	1	7	0	7	10	13	1	1
7:16	4	3	1	4	0	6	16	14	0	2
7:18	1	2	2	6	1	7	7	7	4	4
7:20	1	9	2	4	2	6	1	7	1	1
7:22	2	6	2	1	1	9	7	20	1	4
7:24	1	1	1	7	1	9	20	20	2	1
7:26	1	2	1	11	1	1	9	9	2	4
7:28	1	1	1	8	0	1	4	7	1	1
7:30	2	4	1	8	1	1	14	13	1	2
7:32	2	4	1	4	0	7	8	7	1	4
7:34	1	4	1	2	0	1	6	13	1	1
7:36	1	1	1	1	1	1	6	7	1	4
7:38	7	6	1	1	2	8	7	6	2	4
7:40	2	2	1	11	0	7	6	13	1	4
7:42	1	1	1	4	0	4	6	6	1	1
7:44	6	7	2	1	0	7	4	1	2	2
7:46	1	6	1	16	2	1	10	9	2	2
7:48	4	4	1	17	2	9	1	6	1	1
7:50	1	1	1	11	0	7	7	6	4	1
7:52	2	1	1	18	2	1	10	13	1	2
7:54	2	2	1	17	1	6	7	8	1	1
7:56	4	6	0	13	1	4	7	7	4	6
7:58	11	8	1	1	0	1	11	8	1	4
8:00	11	9	0	1	2	4	6	7	1	1
8:02	13	21	0	13	2	4	6	1	1	1
8:04	14	17	2	14	1	8	13	8	2	1
8:06	11	17	0	8	1	15	11	7	1	1
8:08	13	17	1	1	1	16	8	10	7	4
8:10	8	17	1	2	0	15	10	10	1	1
8:12	6	10	1	2	2	16	7	6	1	4
8:14	8	10	1	1	0	17	1	20	4	4
8:16	9	13	2	4	0	17	8	20	1	1
8:18	2	6	0	2	1	20	10	7	1	1
8:20	1	1	2	7	1	1	13	13	1	1
8:22	1	1	1	6	0	1	5	6	1	1
8:24	2	2	1	7	2	2	7	4	1	4
8:26	2	6	1	10	0	1	6	6	2	1
8:28	4	10	1	17	1	1	6	1	1	1
8:30	1	4	1	20	2	2	1	1	1	1
8:32	2	4	1	16	0	1	6	13	1	1
8:34	4	7	1	1	0	1	1	10	1	4
8:36	6	7	1	2	1	1	10	13	1	1
8:38	2	4	1	1	1	1	1	6	1	1
8:40	1	2	0	7	1	4	1	1	1	2
8:42	1	1	1	6	1	1	14	9	1	4
8:44	1	1	1	1	0	1	13	17	1	6
8:46	2	11	0	17	2	4	8	6	1	4
8:48	1	13	0	16	1	4	1	7	1	6
8:50	1	0	0	1	2	7	1	16	2	1
8:52	1	1	1	1	0	1	4	11	2	1
MAX	14	21	2	20	2	20	16	20	8	15
MIN	0	1	0	1	0	1	1	1	0	1

With Clearway - 7:45-8:45										
cycle	13.0	17.0	1.0	16.0	2.0	18.7	17.1	20.0	5.0	5.0
queue veh	8.4	10.9	1.0	9.9.3	1.2	11.3.6	10.2.6	1.20	11.9	3.0

audible	20.3	21.9	2.1	17.1	3.1	21.8	17.8	19.1	5.3	5.4

Calibration: 1.01 1.32 1.27 1.14 1.26

PM	North East Leg (Campbell Rd)		North Leg (Manukau Rd)		South Leg (Manukau Rd)		West Leg (Mt Smart - Albert Rd)		South East Leg (Mount Smart Rd)	
	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
15:00	2	1	1	1	0	10	16	9	1	10
15:02	1	2	0	1	2	9	20	16	4	8
15:04	6	7	1	2	1	7	16	13	4	9
15:06	1	7	1	6	2	6	4	6	1	1
15:08	7	9	1	13	1	4	1	1	6	7
15:10	0	11	2	1	1	1	6	1	1	1
15:12	6	12	1	10	1	1	1	6	4	4
15:14	10	10	1	10	1	11	1	1	1	10
15:16	10	11	0	10	2	6	6	14	4	10
15:18	8	14	0	10	1	17	1	6	4	9
15:20	9	12	0	10	1	11	6	1	4	7
15:22	7	8	2	13	2	7	10	6	1	1
15:24	6	7	0	11	1	7	20	20	1	4
15:26	6	6	0	13	1	4	9	20	4	6
15:28	1	6	1	9	1	4	16	14	1	7
15:30	1	7	0	6	1	1	6	1	4	6
15:32	1	1	4	10	1	4	9	11	2	2
15:34	4	2	1	16	2	7	9	13	2	2
15:36	1	4	2	8	0	9	6	12	0	2
15:38	6	4	0	10	1	1	7	14	2	1
15:40	9	11	1	11	2	2	4	9	1	7
15:42	6	11	1	11	1	1	6	9	1	7
15:44	7	14	1	13	2	1	4	7	10	10
15:46	9	11	0	11	0	6	8	8	9	8
15:48	6	8	1	14	1	1	7	8	1	1
15:50	6	8	2	16	0	1	9	1	1	8
15:52	1	11	0	10	1	1	10	1	6	11
15:54	2	9	2	10	1	1	7	9	2	16
15:56	1	8	1	10	1	2	7	4	1	9
15:58	1	7	1	10	1	2	1	1	2	6
16:00	6	10	0	20	1	4	1	10	4	4
16:02	10	20	1	10	0	9	0	10	1	1
16:04	10	14	0	10	2	6	9	17	7	7
16:06	17	17	0	10	1	11	6	13	13	9
16:08	15	14	0	10	1	8	6	6	13	13
16:10	10	17	1	10	2	8	4	7	6	1
16:12	17	17	1	16	0	9	7	9	6	4
16:14	14	14	1	10	2	6	1	8	11	10
16:16	13	21	0	10	1	1	10	9	6	11
16:18	14	17	0	10	1	2	9	6	14	10
16:20	15	13	1	10	1	1	6	1	12	17
16:22	10	19	2	15	1	1	6	8	14	15
16:24	10	14	0	9	1	2	8	7	11	10
16:26	13	15	0	10	1	1	1	6	10	14
16:28	10	10	1	19	2	1	1	1	12	10
16:30	11	17	0	11	2	2	7	1	10	11
16:32	16	11	0	10	1	0	0	0	0	11
16:34	15	10	1	16	0	4	1	7	4	11
16:36	19	14	0	15	4	1	7	8	7	14
16:38	14	15	0	10	1	10	7	7	4	11
16:40	11	11	0	10	2	1	10	0	0	12
16:42	14	17	0	15	1	0	1	1	1	11
16:44	17	17	0	17	1	1	1	1	1	1
16:46	17	17	1	17	2	4	4	1	1	7
16:48	17	17	0	10	1	1	1	1	0	7
16:50	17	13	1	10	0	1	1	1	1	6
16:52	17	10	1	10	0	1	1	1	1	3
16:54	19	17	1	17	0	1	1	1	2	0
16:56	17	17	1	17	2	4	0	0	7	0
16:58	15	17	0	16	0	4	1	7	0	0
17:00	13	15	1	0	2	2	1	1	1	0
17:02	10	17	0	16	2	4	1	1	0	11
17:04	15	17	1	17	1	1	1	1	1	7
17:06	13	17	0	15	2	13	1	1	0	0
17:08	17	11	0	15	2	20	1	1	1	7
17:10	19	17	1	16	2	20	1	7	11	13
17:12	10	17	0	14	0	20	1	1	7	13
17:14	17	10	0	17	2	20	1	7	0	10
17:16	12	20	0	16	2	1	1	6	1	0
17:18	17	15	1	13	1	20	7	7	6	6
17:20	15	17	0	15	1	20	1	7	1	6
17:22	17	16	0	9	0	20	1	1	1	1
17:24	15	17	0	17	2	20	1	7	1	0
17:26	17	16	1	14	1	20	1	1	1	0
17:28	17	16	0	14	1	13	1	1	1	10
17:30	17	17	1	15	1	1	1	1	0	13
17:32	17	15	0	13	1	1	1	1	0	11
17:34	17	11	0	7	1	1	1	1	0	11
17:36	14	17	0	11	1	10	1	1	1	14
17:38	10	17	0	16	7	0	1	1	1	10
17:40	13	17	0	10	1	1	1	1	0	17
17:42	17	10	0	16	1	7	1	1	7	0
17:44	10	17	1	13	1	1	1	1	0	0
17:46	13	19	0	10	1	1	1	1	0	14
17:48	17	11	1	13	1	6	1	1	1	13
17:50	10	14	1	12	1	1	1	1	0	12
17:52	14	13	1	11	1	1	1	1	1	14
17:54	11	17	0	10	1	1	1	1	1	13
17:56	10	17	0	14	1	1	1	1	1	17
17:58	12	17	1	10	1	0	1	1	1	12
MAX	17	17	4	11	7	20	16	16	14	11
MIN	0	1	0	0	0	1	1	1	1	1

With Clearway - 16:15-17:15										
cycle	17.0	17.0	1.0	10.0	1.0	20.0	0.0	0.0	13.1	10.0
queue veh	10.2	10.2	1.1.3	11.1.3	1.0	1.20	17.0	1.4	10.0	10.0

audible	20.1	17.1	1.0	10.1	1.0	10.0	0.1	0.9	10.1	10.1

Calibration Factors: 1.01 1.14 1.4 1.1 1.25

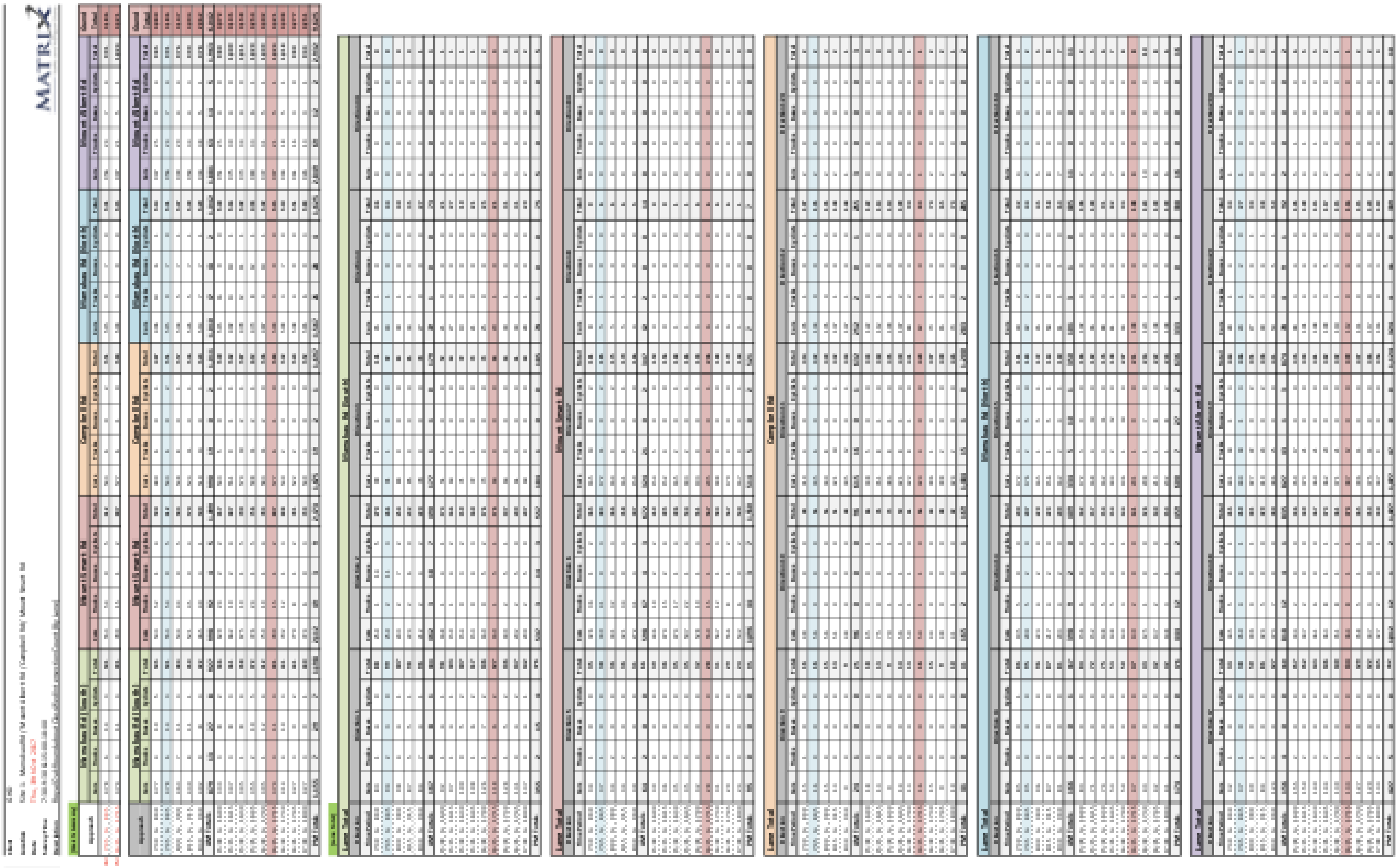


Figure 12 Traffic Turning Counts

Appendix E: Review Markup* of Roundabout Improvements Concept Design

* Please consult relevant text for context (for discussion purposes only, not for final design)