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Queens Cross Roundabout
Option Appraisal

Aberdeen City Council
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Prepared by: ..... Approved by: .....
Chris Menzies Gordon Rendall
Senior Consultant Associate Director

Queens Cross Roundabout

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Lower Ground Floor, 3 Queens Terrace, Aberdeen, AB10 1XL
Telephone: 01224 627800 Fax: 01224 627849 Website: http://www.fabermaunsell.com

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1 Introduction

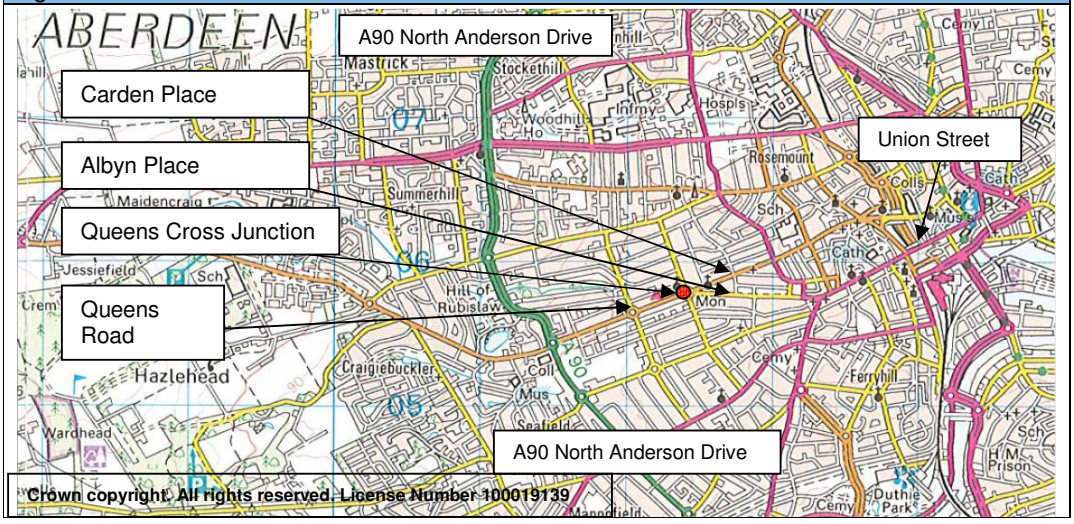
1.1 Background to Study

Faber Maunsell are commissioned by Aberdeen city council to consider options that would address operational issues associated with the Queens Cross roundabout junction, located to the west of Aberdeen's City centre. Anecdotal evidence suggests that there is a perceived safety issue amongst drivers when using this junction arising from poor lane discipline and uncertainty when approaching the junction. Observations of the junction in operation confirm that confusion arises when approaching and entering the roundabout, in particular from the Albyn and Carden Place arms, leading to hesitation and delay. This behaviour is considered to have a detrimental effect on the junction's capacity and safety, the latter of which is confirmed following analysis of the safety statistics of the junction.

The junction is a major five arm roundabout junction located within one of Aberdeen's main businesses and residential areas, which also supports a number of secondary schools. The junction identified in Figure 1.1 below, lies on a major commuter route into the city handling over 5500 vehicle trips in both the am and pm peak periods*. As with any major commuter route, there are a high proportion of public transport services that operate along this corridor serving both the residential and business areas, which further emphasises the importance of this route.

*2005 Turning Count Survey Undertaken by Aberdeen City Council

Figure 1.1 – Location of Junction – Aberdeen



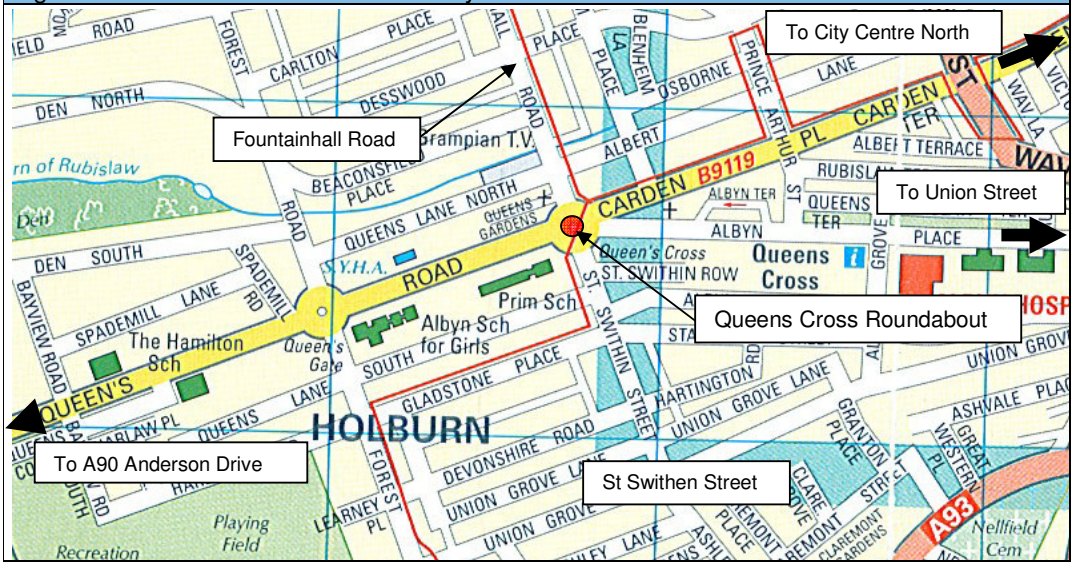
This study aims to identify the key issues associated with the junction and the constraints within which it operates. A number of outline design solutions have been identified and considered during the course of the study all of which have been subject to appraisal and option sifting.

It is intended that the findings of this report will inform the decision makers when considering the junction improvements necessary to address the problems associated with the Queens Cross junction.

1.2 Site Location and Description

The roundabout lies on the main route linking the A90 Anderson Drive, a key distributor route across the city, and Aberdeen City Centre. Located to the west of the city centre on the B9119, the roundabout has five entry arms; Fountainhall Road to the north, Carden Place to the north-east, Albyn Place to the east, St Swithen Street to the south, Queens Road to the west and an exit only lane onto Queens Gardens to the north-west. Figure 1.2 below identifies the roads which form the major arms of the junction.

Figure 1.2 – Location of Junction - Locally



1.3 Scope of Study

The junction accommodates in the region of 5500* AM and PM peak hour traffic movements into and out of the city centre and has been observed to experience minor delays and queuing during the peak periods; the Queens Road and Carden Place arms of the junction being particularly susceptible to AM and PM queuing. However, it is not the capacity but the safety of the junction that has been identified as the key problem; the poor junction geometry at the Carden Place and Albyn Place entry arms potentially leading to conflicts between vehicles accessing the roundabout.

In an effort to improve the safety of the junction, the study aims to identify a number of options for improvement that will be considered for implementation at a later date. Although capacity is not the main issue, it is recognised that while improving safety, there may be resultant capacity benefits.

In order to arrive at the recommendations, the existing junction and the surrounding area are examined to appraise and assess the road and infrastructure requirements. This includes conducting traffic surveys at junctions that are likely to be impacted on by any potential re-development and updated queue length surveys at the roundabout junction. The client team from Aberdeen City Council have provided comment on the current junction arrangement and any associated historical issues which required consideration as part of the assessment.

As part of this process, fourteen different initial options have been considered which have been sifted following appraisal and consultation with Aberdeen City Council. The appraisal process considered road safety issues, build-ability, cost, capacity, pedestrian and public transport issues. Following an option sifting process preferred options were taken forward for a more detailed assessment including swept path analysis, traffic modelling and minor design refinements.

The assessment of the final recommended options will provide information on the likely improvements to general safety and capacity as well as considering the implementation of the proposals from a build-ability and cost perspective.

The findings and recommendations of this report are presented in the following chapters:

- Chapter 2, Existing Junction Appraisal
- Chapter 3, Option Generation
- Chapter 4, Option Development

*2005 Turning Count Survey Undertaken by Aberdeen City Council

2 Existing Junction Appraisal

2.1 Introduction

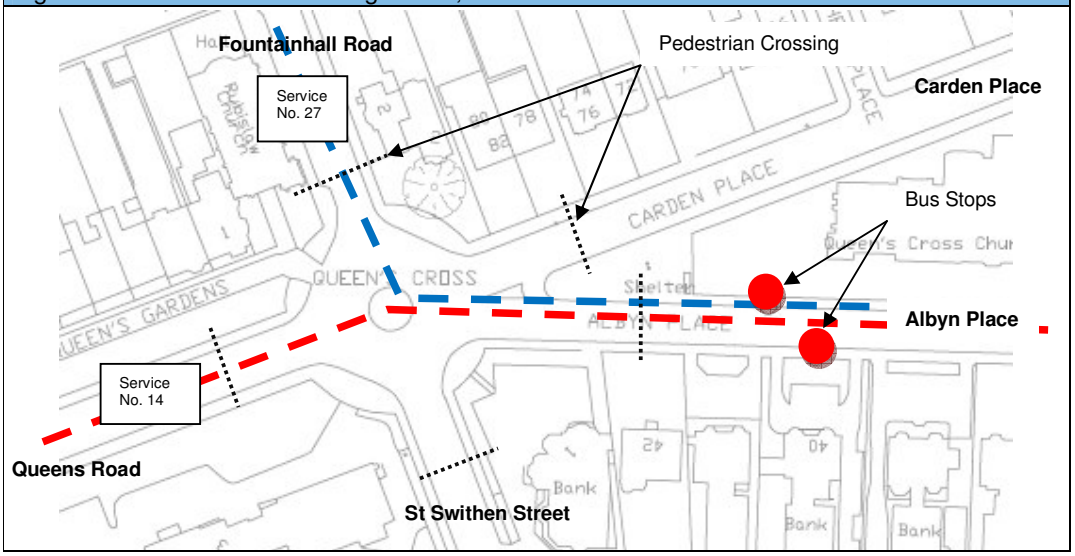
An initial site assessment of the roundabout was undertaken to note the existing infrastructure and traffic behaviour through the junction. The assessment considered the junction geometry, pedestrian crossings and included general observations relating to traffic behaviour and flow. A queue length survey was undertaken at this time to determine areas where excessive queuing was likely to be problematic.

Public utility apparatus, street lighting and hard landscaping features were noted during the surveys and consideration was given to the existing drainage of the junction by noting gully points and typical carriageway cross fall. The following paragraphs discuss the findings of the assessment.

2.2 Site Observations

The existing junction effectively operates as a five arm roundabout with two lane entries and single lane exits on all arms onto the roundabout. Pedestrian movements are facilitated by formalised crossings located on all arms of the roundabout typically set back by approximately 13 to 40m, as illustrated in Figure 2.1 below.

Figure 2.1 – Pedestrian Crossing Points, Bus shelters and Bus Routes.



Although this is a key route into the city centre and business areas of Aberdeen, with the exception of a short length of cycle lane on Albyn Place, there are no dedicated facilities for cyclists on either the approach roads or on the roundabout; however, the carriageway widths on Queens Road and both Albyn Place and Carden Place are sufficient to allow general shared road use for cyclists.

Bus services 14 and 27 operate along Albyn Place, Queens Road and Fountainhall Road via the roundabout junction and within the direct vicinity of the junction; bus shelters are located on Queens Road and Albyn Place.

Figure 2.1 illustrates the pedestrian crossing points, the main bus service routes operating via the junction and bus stops within the vicinity of the junction. Figure 3.1, Section 3, illustrates the pedestrian crossings in greater detail.

With a large residential population located to the north and south of the junction and four schools located within 600m of the junction, there is a high pedestrian demand during the am peak period in particular and the signalised crossings are called at regular intervals.

2.2.1 *Queens Road*

Queens Road approaches the junction from the west with a two lane approach to the junction. Although not formally delineated, the nearside lane is generally utilised for vehicles travelling to Fountainhall Road as well as Carden Place while the offside lane accommodates vehicles travelling to Albyn Place as well as St Swithen Street. On this informal basis, traffic is distributed evenly along both lanes and appears to function without observed excessive delay during the am peak period. Photographs of the Queens Road looking from the roundabout and towards the roundabout can be seen in Figures 2.2 and 2.3 respectively. Because of poor lane delineation there is confusion amongst drivers causing safety issues.

Figure 2.2 – Queens Road looking west	Figure 2.3 – Queens Road looking east

Both the offside and nearside lanes are approximately 3m in width while the westbound exit lane from the roundabout is approximately 5.5m in width. There is a pelican crossing located approximately 28m from the give-way which provides pedestrian access across Queens Road.

2.2.2 *Fountainhall Road*

Fountainhall Road is the northern approach arm of the junction which flares into two lanes after the pedestrian crossing as shown in Figure 2.4 below. Again with no formal designation, drivers generally use the nearside lane when proceeding to Carden Place, Albyn Place and St Swithen Street while the offside lane is used for vehicles travelling to Queens Road. Site observations note that this operation distributes the traffic unevenly with the majority of the traffic moving into the nearside lane. Long queues have been observed in the AM peak periods with the majority of traffic heading southbound or into the city centre.

Figure 2.4 – Foutainhall Road looking north	Figure 2.5 – Foutainhall Road looking south

Each approach lane is approximately 15 m in length and approximately 2.5m in width. The northbound exit lane onto Fountainhal Road is approximately 3.2m in width with a pelican crossing located approximately 13m from the give-way. Figures 2.4 and 2.5 illustrate this arm looking north from the roundabout and south onto the roundabout respectively.

2.2.3 *Carden Place*

Carden Place forms one of the main approaches to the junction from the north-east and consists of two approach lanes. Following site observations, the nearside lane would appear to be used most heavily for vehicles travelling to St Swithen Street and straight ahead onto Queens Road. The offside lane is typically used for movements to Fountainhall Road and a small proportion of straight ahead movements. This layout distributes the traffic unevenly with the majority of the traffic moving into the nearside approach lane. This has led to excessive queues when the junction has been observed in the pm peak periods with the majority of traffic travelling westbound.

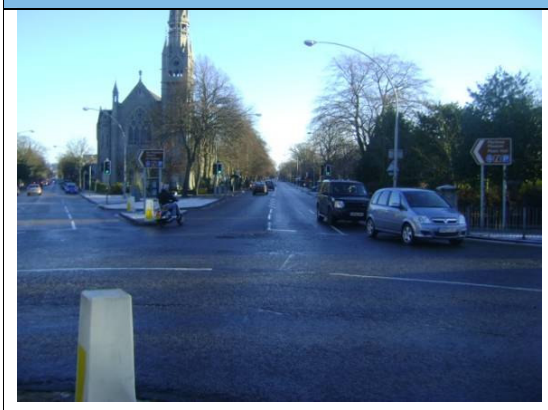
Figure 2.6 – Carden Place looking north-east	Figure 2.7 – Carden Place looking south-west

A minor slip road has been provided in advance of the junction allowing a left turn onto Albyn Place from Carden Place. This ‘by-pass’ has been provided as a result of poor alignment of the Carden and Albyn Place approach arms, which would make this manoeuvre difficult to achieve.

Both approach lanes are approximately 2.7m in width while the exit lane is approximately 5.2m in width. There is a pelican crossing located approximately 25m from the give-way which provides pedestrian access across Carden Place. Photographs of the Carden Place looking from the roundabout and towards the roundabout can be seen in Figures 2.6 and 2.7 respectively.

2.2.4 *Albyn Place*

Albyn Place is the main approach from the east with two approach lanes; the nearside lane typically used by vehicles turning left to St Swithen Street and straight ahead on to Queens Road while the offside lane is commonly used for vehicles travelling to Fountainhall Road and Carden Place. Again as with the approaches of the other arms of the roundabout, this layout distributes the traffic unevenly with the majority of the traffic moving into the nearside lane. As with the Carden Place approach, peak period observations note that this leads to excessive queues in the peak periods with the majority of traffic heading westbound. Figures 2.8 and 2.9 below provide reference to the approach from the roundabout and onto the roundabout.

Figure 2.8 – Albyn Place looking east	Figure 2.9 – Albyn Place looking west
	

Each approach lane is approximately 2.6m in width with an eastbound exit lane measuring approximately 4.7m in width. There is a pelican crossing located 36m from the give-way which provides pedestrian access across Albyn Place and is noted to be well used during the am peak period in particular. There are road markings for a westbound cycle lane on this road however they stop just short of the pedestrian crossing and do not continue beyond the roundabout.

2.2.5 *St Swithen Street*

St Swithen Street approaches the junction from the south and flares beyond the pedestrian crossing to provide two approach lanes. Observations suggest that the nearside lane is commonly used for left turning vehicles travelling to Queens Road and Fountainhall Road while the offside lane is used by right turning vehicles travelling to Carden and Albyn Place. Used this way, traffic is not distributed evenly with the majority of the traffic moving into the offside lane. With a lack of clear lane discipline this has led to long queues being observed during the peak periods when the majority of traffic is travelling westbound.

Figure 2.10 – St Swithen St looking south	Figure 2.11 – St Swithen Street looking north

The approach lanes are approximately 2.5m in width while the exit lane is approximately 5.3m in width. There is a pelican crossing located 24m from the give-way which provides pedestrian access across St Swithen Street.

2.3 Junction Geometry

The geometric parameters of the junction were surveyed and annotated onto an existing O.S Landline base map. The survey recorded the inscribed circle diameter of the roundabout, the circulating carriageway width, the junction approach widths and effective flare lengths. With reference to DMRB 6:2:3 'Geometric Design of Roundabouts' it was possible to review the surveyed junction parameters alongside the prescribed design criteria. On this basis, a number of issues regarding the design of the junction became apparent. These included the flare length, width of entry into the junction and deflection. The surveyed parameters have been tabulated alongside the design guidance in Table 2.1 below for reference.

When classifying the roundabout, the Queens Cross junction does not fully fit the characteristics of either a normal or compact design; however due to the number of arms, multiple lane entries and slight flaring of the approach arms, the junction has been classified as normal when determining design parameters.

Table 2.1 – Existing and DMRB design criteria for a 'normal' roundabout		
Parameter	Existing	DMRB
Inscribed Circle Diameter (ICD)	36m	28m to 100m
Circulating Carriageway Width	12.5m*	1.0 to 1.2 x max entry width
Max Entry Width	6.3m (two lanes 3.15m)	3m – 3.5m multi lane
Central Island Diameter	11m	4m minimum

On the basis of the DMRB design criteria, with a maximum entry width of 6.3m, the existing design exceeds the prescribed circulating carriageway width which would allow for a 7.5m circulating lane.

Many of the safety issues associated with the junction could be attributed to the non-standard junction geometry. The poor approach deflection generally leads to greater approach speeds while the wide circulating carriageway results in lane confusion and 'weaving' on the roundabout.

2.4 Traffic Analysis

As discussed in Chapter 1, the Queens Cross roundabout handles major traffic movements along a well-used commuter and public transport corridor into Aberdeen and is generally well

utilised throughout the day. Data from a 2005 classified turning count survey has been analysed to determine peak periods and turning movements and a queue length survey was undertaken in March 2009 to provide an indication of the typical queues experienced during the am and pm peak periods. The following paragraphs examine the traffic behaviour at the existing junction and will form the basis upon which subsequent improvements will be measured against.

2.4.1 Traffic Flows

Traffic count information for the Queens Cross roundabout was obtained from a 2005 traffic survey provided by Aberdeen City Council. The information provided illustrated that the junction handles peak period traffic flow in the region of 5500 pcu's with 36 different turning movements. The AM peak hour was established to be 0800 – 0900 and the PM peak 1645 – 1745. The 2005 data was factored using a central growth factor of 1.064* to provide estimated turning counts for 2009. The existing traffic survey data was further supplemented with new traffic counts undertaken at the near-by junctions of Carden Place / Prince Arthur Street and Albyn Place / Prince Arthur Street.

On the Queens Cross roundabout the major flows in the AM and PM peak periods are eastbound from the Queens Road arm to the Carden Place arm of the roundabout with factored 2009 flows of 440 vehicles in the morning and 362 vehicles in the afternoon peak periods. The major movements at the junction are generally equally split between Queens Road and Albyn Place and Queens Road and Carden Place. Appendix A provides the turning count data for the AM and PM peak periods.

Similarly at the Carden Place / Prince Arthur Street junction the major flows in the AM and PM peak periods are eastbound along Carden Place with a flow of 727 vehicles during the AM period and 439 vehicles during the PM period. At the Albyn Place / Prince Arthur Street junction the major flows in the AM and PM peak periods are westbound along Albyn Place with a flow of 491 vehicles in the mornings and 388 vehicles in the afternoons.

Following consultation with the client team a design year of 2012 for the junction improvements was determined. The 2005 base year flows and the factored traffic flows are contained in Appendix A for reference. In order to improve the clarity of the data, the turning count information is provided in a colour coded origin and destination format.

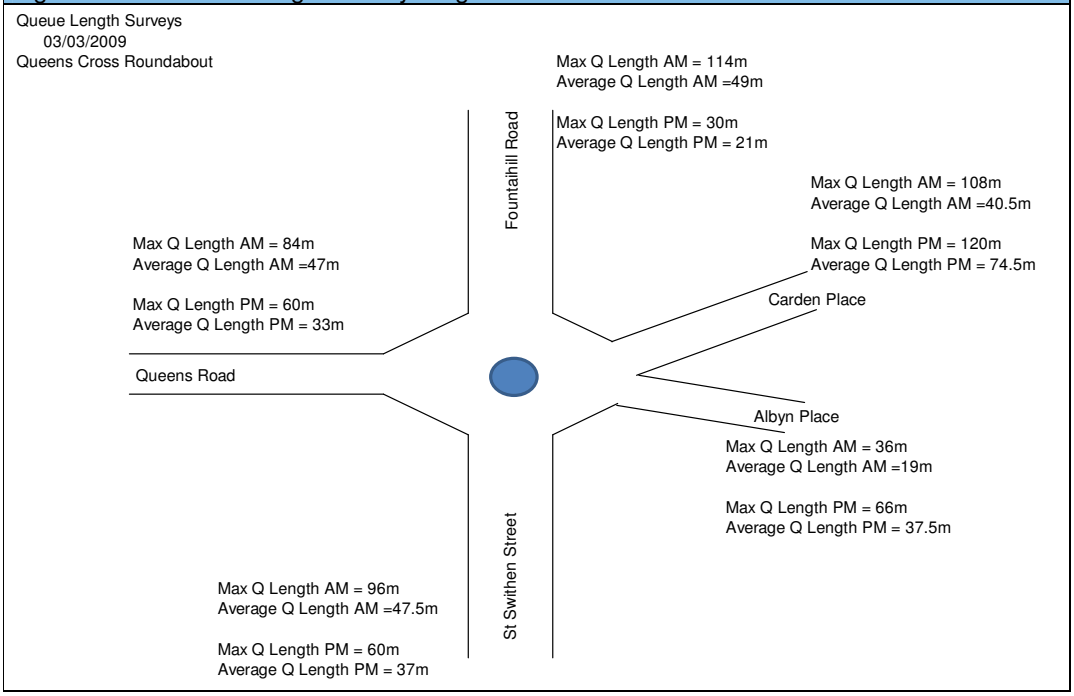
* Dft National Road Traffic Forecasts (Great Britain) 1997

2.4.2 Operational Performance

As a result of the non standard nature of the roundabout junction in terms of geometric alignment, the junction does not operate in a way that would be expected of a standard roundabout. The wide circulating carriageway, the minimal deflection on the approach arms and the poor separation between the Carden and Albyn Place approaches are all contributing factors.

The existing junction was modelled using ARCADY, and a queue length survey was undertaken to validate the base model. The queue length survey identified the maximum queuing lengths on each arm of the junction. The surveys were conducted during the morning and evening peak hour periods on Tuesday 3rd March 2009. The results of the survey are summarised in Figure 2.12 and tabulated in Tables 2.1 and 2.2. The full results are contained in Appendix B for reference.

Figure 2.12 – Queue Length Survey Diagram



The results in Figure 2.12 indicate that the longest queues form on Fountainhall Road (114m) in the AM peak period and on Carden Place (120m) in the PM peak period. There are also long queues on Carden Place during the AM peak period as well as the PM peak period.

Table 2.1 shows the maximum queue lengths recorded over the AM peak period in five-minute increments. The table indicates that the queues vary over the peak hour and that the longest queues occurred typically towards the end of the peak hour. It can be seen that Carden Place experiences a peak queue towards the middle of the peak period reaching 108m or 18 vehicles at 8:25am before quickly falling towards the end of the survey period.

Table 2.1 – AM Queue Length Survey Results

8am – 9am	Queens Road	Fountainhall Road	Carden Place	Albyn Place	St Swithen Street
Time	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)
08:05	54	6	0	12	42
08:10	48	36	24	12	36
08:15	36	36	60	18	18
08:20	36	48	18	12	42
08:25	54	54	**108**	18	42
08:30	24	66	78	18	48
08:35	30	72	90	18	42
08:40	48	30	42	30	54
08:45	30	36	6	**36**	66
08:50	72	**114**	6	12	42
08:55	**84**	60	36	30	42
09:00	48	30	18	12	**96**
Average Queue Length	47	49	40.5	19	47.5

Table 2.2 below shows the maximum queue lengths recorded over the PM peak period in five-minute increments. The table indicates that the queues are relatively consistent during the peak hour with the longest queues typically occurring during the middle of the peak hour. It can be seen that as with the AM period, Carden Place experiences the most excessive queuing, with queues generally over 50m or 8 vehicles queuing during the hour.

Table 2.2 – PM Queue Length Survey Results					
16.45pm – 17.45pm	Queens Road	Fountainhall Road	Carden Place	Albyn Place	St Swithen Street
Time	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)	Max Q Length (m)
16:50	12	**30**	48	30	12
16:55	18	24	84	18	48
17:00	30	24	78	24	24
17:05	48	12	**120**	48	42
17:10	42	**30**	114	54	**60**
17:15	30	**30**	60	**66**	54
17:20	36	12	78	24	48
17:25	18	18	36	54	18
17:30	30	18	24	30	30
17:35	24	**30**	36	24	24
17:40	**60**	18	**120**	48	42
17:45	48	6	96	30	42
Average Queue Length	33	21	74.5	37.5	37

Referring to Tables 2.1 and 2.2 above it is apparent that the greatest queues occur on Carden Place during both the AM and PM peak periods. The queues build up to a peak of 108m, 18 vehicles, during the AM period before dissipating to less than 50m, 8 vehicles, in a fifteen minute period. During the PM peak period, the queue length is relatively constant at over 50m, peaking at 120m at 17:05.

With the exception of the maximum queue lengths, during the AM and PM periods, the remaining arms of the junction experience queues in the order of approximately 12-70m or 6-12 vehicles. Considering the average queue lengths over the one hour period Tables 2.1 and 2.2 above show that Fountainhall Road has the highest average queue length in the AM peak period and Carden Place has the highest average queue length in the PM peak period. Fountainhall Road has an average 49m queue length, approximately 8 vehicles, during the AM peak period peaking at 114m. Carden Place has an average 74.5m queue length, approximately 12 vehicles, during the PM peak period peaking at 120m on two separate occasions during the survey.

From the tables above, it can also be clearly seen that during the AM peak period, queuing in excess of 75m occurs on all arms with the exception of Albyn Place. However, during the PM peak period, vehicle queuing is more acute on the Carden Place arm. This suggests a more dispersed arrival profile during the AM period and more localised profile during the PM period.

2.4.3 Pedestrian Movements

Pedestrian routes across the junction are accommodated by signal controlled junctions on all approach arms typically set back between 13m and 30m from the junction giveaway lines. Figure 3.1 of Section 3, illustrates the crossing locations. The crossings were observed to determine the major pedestrian routes within the vicinity of the junction and establish any low or particular high levels of usage. From the casual observations made, it was apparent that all crossing points are well utilised particularly during the am peak periods. The Carden Place and

Albyn Place crossings in particular appear to cater for a large proportion of school children crossing as this is a main route between the residential areas to the north of the junction and the schools located to the east on Albyn Place.

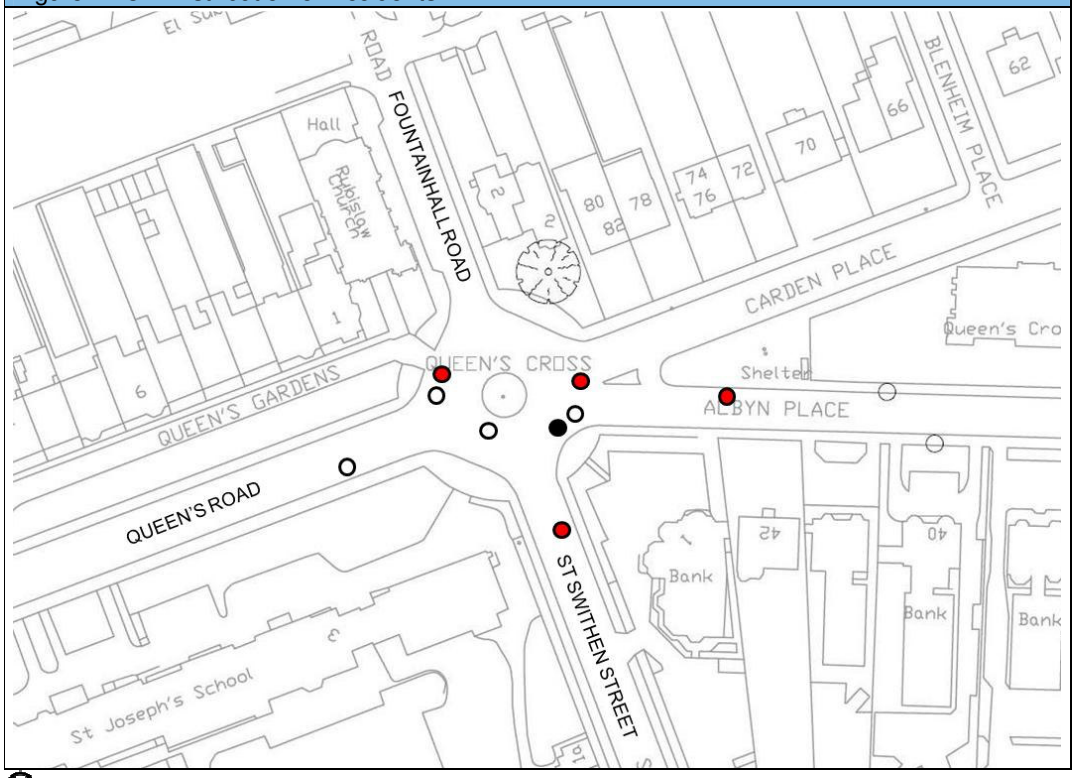
2.5 Safety Considerations

Chapter 2 of the DMRB 6:2:3 discusses the relative safety of a roundabout when compared to alternative forms of junction. Table 2/1 of the DMRB presents the findings of a 2004 TRL study which considered the accident statistics of a sample of 1,162 roundabout junctions. It was concluded from this study that as the number of junction arms increases, so too does the frequency of accidents. From the study it was calculated that of the sites considered, a 5 arm roundabout with single carriageway approach roads would have an accident frequency of 1.72.

Accident data for the Queens Cross junction provided by Aberdeen City Council, illustrates graphically all accidents from slight to fatal during a three year period between July 2005 and July 2008. The data indicated that 15 accidents in total were recorded during this period; an accident frequency of 5. When making the comparison with the findings of the TRL study, this would suggest that accidents at the Queens Cross junction are almost three times more likely to occur than the average of the junctions studied by the TRL. The sample sized used by the TRL is limited, however this does provide some basis for comparative purposes although this should be used with some caution.

When analysing the Queens Cross accident statistics, ten were recorded as damage only, four accidents were slight, one was recorded as serious and none were fatal. Because the data was recorded graphically, each accident location was noted on an annotated junction layout plan, it was possible to determine particular areas where accidents occurred more regularly. Figure 2.13 below illustrates this distribution.

Figure 2.13 – Distribution of Accidents



Location of one accident
Location of two accidents
Location of three accidents

The data highlighted that of the 15 accidents recorded; six accidents were located at the Albyn Place entry/exit with the remaining accidents recorded at various locations across the junction, in no particular grouping. Considering the entire junction as a whole, this illustrates that 40% of all accidents during this time were occurring in one concentrated location.

Reviewing the accidents at the Albyn Place entry/exit, the following characteristics were recorded:

- Five accidents were during the day in dry and fine weather conditions.
- Three were caused as a failure to judge the other persons path or speed and did not observe the junction properly.
- Four accidents were within the evening peak period.

From the above, it is interesting to note that the majority of the accidents were not caused as a direct result of any adverse weather conditions and took place during the peak period traffic movements. Half of the incidents at this location were as a result of poor observation of the junction and traffic movements on it.

From the documented accident data provided by Aberdeen City Council, it is clear that there is some basis for the perceived safety issues raised by drivers regarding the junction. Site observations suggest that driver behaviour when using the Albyn and Carden Place approaches is typically hesitant suggesting driver uncertainty leading to a potentially higher risk of accident. The accident data provided by Aberdeen City Council, which includes details on the nature of the accidents, can be seen in Appendix H of this report

3 Option Generation

3.1 Introduction

Prior to generating improvement options, a review was undertaken of the information gathered during the site assessment process. The information gathered typically considered:

- Traffic movements;
- Turning counts;
- Accident data;
- Queue length survey data;
- Street landscaping;
- Street furniture;
- Access arrangements; and
- Pedestrian crossing facilities.

In order to provide a successful design for junction improvement, the problems, issues and constraints associated with the current junction were used to form the basis of Planning Objectives against which design options would be appraised.

The following paragraphs discuss the option generation process and provide an account of the problems, issues and constraints that were considered in the process of determining the final recommended design options.

3.2 Problems, Issues and Constraints

3.2.1 Problems

Referring to the data collated and presented in section two, the key issues regarding the junction predominantly relate to the approach alignments from Carden Place and Albyn Place. With the existing arrangement, the geometric layout is such that there is limited separation between the entry arms from both the Albyn Place and Carden Place links. The issue of both approaches merging at the roundabout with no island separation is further exacerbated due to the proximity of the exit lane from the roundabout onto Albyn Place.

The lack of separation raises issues relating to gap acceptance and confusion regarding priority when entering the roundabout from either Albyn Place or Carden Place. As a result of this, site observations suggest that there is hesitation when emerging from either access onto the roundabout, often with traffic emerging onto the roundabout from both Albyn Place and Carden Place at the same time and utilising the same gap in the circulating flow. The result of this driver behaviour leads to underperformance of the junction and importantly raises the likelihood of vehicle conflict issues. Further uncertainty comes from eastbound drivers mainly approaching from Queens Road unsure of which lane to enter for exiting onto either Carden Place or Albyn Place.

In addition to the entry issues associated with Albyn Place and Carden Place, the roundabout alignment is a departure from that which would be developed for a standard roundabout. The existing Inscribed Circle Diameter (ICD) is measured at 36m and with a central island diameter of 11m; the resultant circulating carriageway width is 12.5m. When referring to chapter 7 of DMRB 6:2:3, this exceeds the maximum recommended width, which is a factor of the maximum entry widths. The wide circulating carriageway in combination with a lack of carriageway markings leads to driver uncertainty and poor lane discipline, which leads to a greater risk of conflict issues.

Considering the approach lanes onto the roundabout, none of the five arms exhibit any great level of deflection onto the roundabout, which further influences driver behaviour on approach to the junction. Where no queuing traffic is present, it was observed that drivers do not significantly alter approach speeds and enter the junction at higher than expected speeds.

3.2.2 Issues

The main issues to consider relate to providing a solution that maintains the operation for all non vehicle option users such as pedestrians, cyclists and public transport while improving the situation for vehicular traffic. No design should be taken forward that while improving the junction for vehicular traffic would be at the detriment of the aforementioned users.

In this regard, given the large residential population, options that would significantly alter the pedestrian desire lines should be avoided where possible. Accordingly, any interruptions to pedestrian flow should be considered carefully when formulating any options.

It has been noted that buses route through the junction and there are bus stops located on Albyn Place. Junction improvements need to consider maintaining this route both during and post construction where possible.

Hard and soft landscaping issues factor highly as there exists a high level of hard surfacing in an area that has a significant visual impact. The current roundabout provides a location for a statue of Queen Victoria and design options need to be mindful of relocation of this feature.

Public utilities and associated infrastructure are major areas to consider as diversion of services and relocation of service apparatus could have significant cost implications. It has been noted that there are telephone boxes located within the vicinity of the junction which may require relocation.

Physical issues to consider include surface runoff and drainage tie-ins, the location of approach signage that may require relocation, traffic signals equipment and any significant level changes that would need to be accommodated.

3.2.3 Constraints

The main constraining factor relates to the extent of the area within which options could be considered. Aberdeen City Council have provided a redline boundary plan which illustrates the area which is adoptable. From this plan, copy included in Appendix C it can be seen that the boundary is to the rear of the footways on all approaches and extends to the boundary of the church to the east of the junction.

3.3 Design Considerations

In order to assess the options, it is necessary to set out the considerations against which the options can be appraised. The design considerations have been prepared following a review of the main problems which are to be addressed and the key issues to be overcome. It has been possible to develop the design considerations with reference to the key categories applied to STAG appraisals namely; Technical, Safety, Environment, Economic issues.

These main headings have been subdivided such that the design considerations relate to;

- Public utilities;
- Drainage;
- Design compliance;
- Landscape;
- Pedestrian Routes;
- Pedestrian Safety ;

- Traffic Safety;
- Design Cost; and
- Whole life cost.

The design considerations are noted on Table 3.1 of Appendix D which presents the generated options against the design considerations.

3.4 Objectives

In addition to the design considerations, it was determined that each option must address the key areas that form the main problems and issues associated with the junction. These objectives serve to provide a benchmark against which all options that have been generated can be measured. By referring to the problems and issues identified following the site appraisals, data review and client consultation, the following objectives have been established:

- Objective 1 – Reduce the likelihood of vehicular conflict
- Objective 2 – Improve where possible junction flow and network operation
- Objective 3 – Enhance or maintain existing pedestrian provision

From the Objectives identified above, it is possible to broadly measure the options to sift out those that do not fully address the requirements and focus attention on the stronger options.

By comparing baseline data for the existing junction which considers existing queue lengths, a comparison can be made against the modelled queues for the design options.

In terms of vehicular conflicts it has been determined via the review of the accident statistics where the points of conflict arise. On this basis, a subjective approach has been taken where options are evaluated considering ease of use of the junction, and subsequently potential conflict issues.

Pedestrian provision is measureable against the existing situation. Options that increase the number of crossing points or relocate crossings away from the existing desire lines will be considered negatively in the assessment.

3.5 Option Generation

Initial options were developed following a team workshop session with a small group of experienced traffic engineers. The workshop session involved a site walkthrough in order to gain an appreciation of the operation of the junction, establish the parameters within which any design would be constrained and identify areas where improvements could be made.

Following the site walk through, a session was held where the previously observed issues and constrains were discussed and broad design options for improvement were identified. From the session, it was apparent that the following key areas, in no particular hierarchy needed to be addressed:

- Improved lane discipline by new road markings and directional signage on all approaches
- Reduced circulatory carriageway
- Improved deflection on approach
- Increased separation between Carden Place and Albyn Place arms.

As a result of the workshop session, it was determined that the improvement options would typically fall into a number of high level categories of which there would be associated sub options. The categories within which options would be developed were:

- Double Roundabout options;
- Larger Roundabout options;
- Lining and signage options;
- Signalisation options;

- Traffic Management options; and
- Localised Geometric Improvements.

On this basis a number of outline options were developed some of which incorporated ideas from the several of the high level categories.

3.6 Initial Options

The developed options are summarised in Table 3.1 of appendix D which presents the options and sets them out against the design considerations that were developed and discussed in section 3.3. The following paragraphs provide a brief outline of each option and a sketch plan of each option is provided for reference under each option. Appendix E contains larger scale plans for reference.

It should be noted that option 1 considers the base approach to any of the improvements. With this option the geometry of the roundabout is improved to reflect the guidance set out in the DMRB. Subsequent options that relate to general roundabout improvements will adopt this more standardised roundabout design alongside any other improvements for the junction.

The following option summaries provide a review of the typical improvement, a general layout plan and a tabulated summary of the relative strengths and weaknesses of each option.

3.6.1 *Option 1*

The design of this option aims to amend the existing layout to create a more 'standardised' form of roundabout as per the design guidance set out in DMRB 6:2:3. The design incorporates a reduced circulating carriageway, amended island layout to incorporate an over run area and improved entry deflection. The design includes:

- Lining and signing on all approaches
- Carriageway realignment to achieve a narrowed circulation lane
- Single lane approach on Albyn Place
- Two lane exit onto Queens Road

Figure 3.1 – Option 1 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Does not address safety issues

3.6.2 *Option 2*

As with Option 1 there is an amendment to existing layout to create a more 'standardised' form of roundabout. However in an attempt to remove points of conflict, the exit onto Albyn Place is removed and a two lane approach is provided from Albyn Place. The improvements incorporate those of Option 1 and the following:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road

Figure 3.2 below illustrates the proposal.

Figure 3.2– Option 2 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Removes conflict issues when exiting onto Albyn Place ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Does not address all safety issues ▪ No direct entry onto Albyn Place ▪ Increased eastbound traffic on Carden Place

3.6.3 *Option 3*

This option considers amendment to existing layout to create a more elongated roundabout in an effort to set back the approach arms from Carden and Albyn Place. However with this alignment, it becomes increasingly difficult to achieve an adequate exit lane onto Albyn Place and the design essentially becomes unworkable. The design incorporates:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road

Figure 3.3 below illustrates the proposal.

Figure 3.3 – Option 3 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Major safety issues when considering Albyn Place exit ▪ Exacerbates conflict issues when exiting onto Albyn Place

3.6.4 *Option 4*

This design is essentially a double roundabout and aims to increase the separation between the Carden and Albyn Place approaches. This is achieved by having a three arm roundabout to the east which allows Carden Place and Albyn Place traffic to merge onto ont approach to a new four arm roundabout to accommodate Queens Road, St Swithen Street and Fountainhall Road and the Carden/Albyn Place traffic flows. The improvement aims to:

- Create one four and one three arm roundabout
- Two lane entry from Carden Place
- Two lane entry from Albyn Place
- Increase separation between Carden Place and Albyn Place entry arms

Figure 3.4 below illustrates the proposal.

Figure 3.4 – Option 4 Layout

Strengths and Weaknesses

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to east roundabout from west ▪ Limited queuing capacity on approach to west roundabout from east

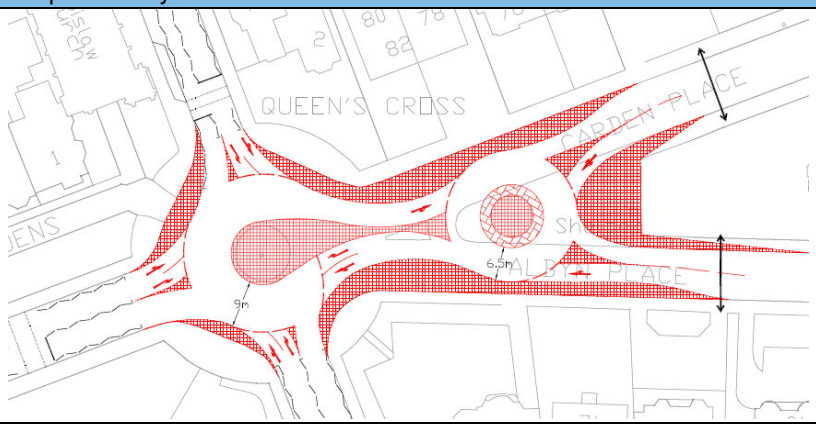
3.6.5 *Option 5*

This option is essentially a double roundabout as per option 4 above however circulation on the Queens Cross roundabout to the west is not facilitated and all southbound traffic movements are directed onto the second roundabout to the east. The design incorporates:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- Creates one four and one three arm roundabout
- Single entry lane from Carden Place
- Single entry lane from Albyn Place
- Increased separation between Carden Place and Albyn Place entry arms
- No straight ahead on Fountainhall Road-St Swithen Street

Figure 3.5 below illustrates the proposal.

Figure 3.5 – Option 5 Layout



Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to east roundabout from west ▪ Limited queuing capacity on approach to west roundabout from east ▪ Increased journey time for straight ahead on Fountainhall Road-St Swithen Street ▪ Non standard layout may lead to driver confusion ▪ Additional curved alignments may present difficulties for larger vehicles

3.6.6 *Option 6*

As with the previous option, this is essentially a double roundabout design with no circulating flow on either of the two roundabouts. The design is in effect an elongation of a standard roundabout with longer circulating lengths; these could in themselves prove problematic by creating higher speed traffic flows. The design incorporates:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- Creates one 'elongated' roundabout
- Two entry lanes from Carden Place
- Two entry lanes from Albyn Place
- Increased separation between Carden Place and Albyn Place entry arms
- No straight ahead on Fountainhall Road-St Swithen Street

Figure 3.6 below illustrates the proposal.

Figure 3.6 – Option 6 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to west roundabout from east ▪ Increased journey time for straight ahead on Fountainhall Road-St Swithen Street ▪ Non standard layout may lead to driver confusion ▪ Additional curved alignments may present difficulties for larger vehicles ▪ Risk of higher circulation speeds

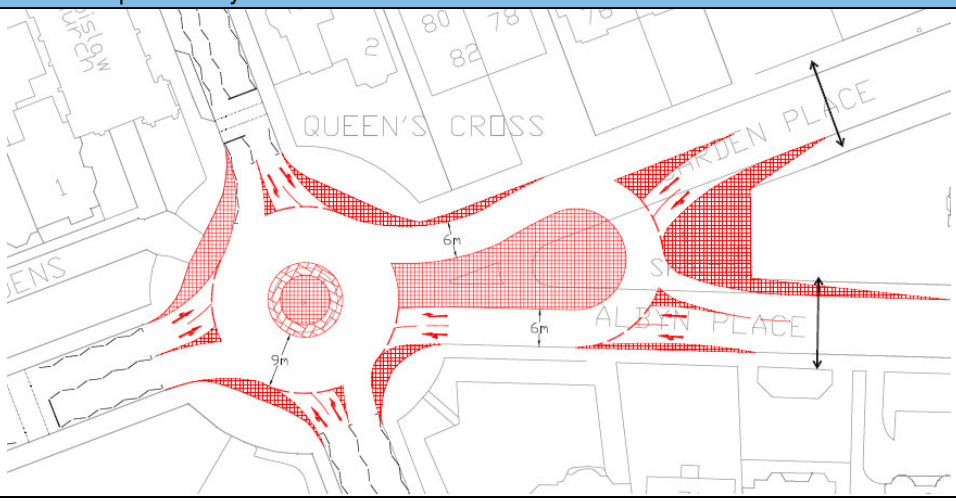
3.6.7 *Option 7*

Option 7 maintains the ideals of a two roundabout design but with the circulation removed from the eastern roundabout. This effectively maintains the west roundabout with full functionality while using roundabout principles to manage the integration of the Carden Place and Albyn Place approaches. The design provides:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- Two entry lanes from Carden Place
- Two entry lanes from Albyn Place
- Increased separation between Carden Place and Albyn Place entry arms

Figure 3.7 below illustrates the proposal.

Figure 3.7 – Option 7 Layout



Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Simple distribution onto Albyn and Carden Place ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to west roundabout from east

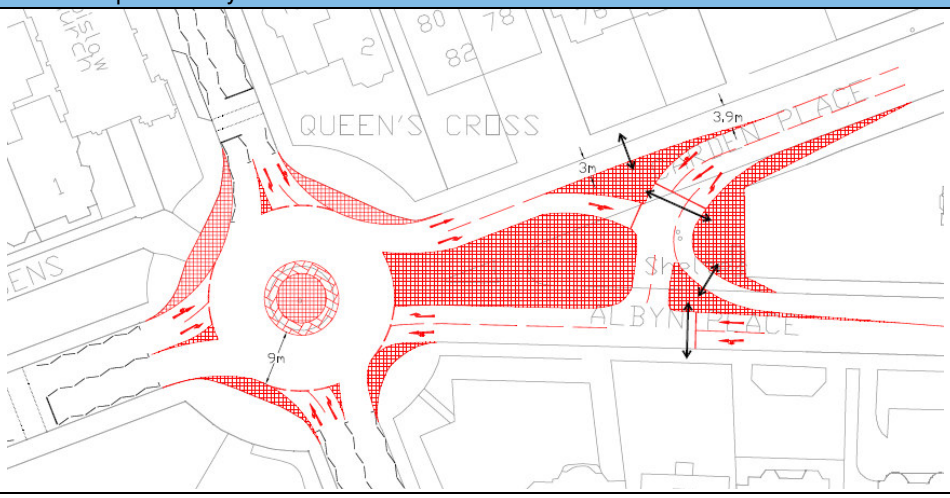
3.6.8 *Option 8*

With this design, the improved roundabout is maintained and traffic signals are introduced to manage the merging traffic flows from Carden and Albyn Place. A two lane exit east is provided from the roundabout onto Carden Place which allows free flow onto Carden Place and diverges to allow access onto Albyn Place. The Albyn Place access is managed through the signal controlled element of the design which also incorporates a separate slip route onto Albyn Place from Carden Place. The design option incorporates:

- Two lane approach to signals and roundabout on Albyn Place
- Two lane exit onto Queens Road
- Two entry lanes from Carden Place and one left turn slip onto Albyn Place
- Two entry lanes from Albyn Place
- Signal controlled exit onto Albyn Place from Carden Place exit
- Traffic management of Carden and Albyn Place entry flows.

Figure 3.8 below illustrates the proposal.

Figure 3.8 – Option 8 Layout



Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place	▪ Limited queuing capacity on approach to east signalised junction from roundabout ▪ Four pedestrian crossing points required ▪ High cost option

3.6.9 *Option 9*

As with the previous option, a standardised roundabout design is adopted and the merging traffic from Carden Place and Albyn Place is managed by traffic signals. The fundamental difference with this option relates to how traffic exits the roundabout to enter Albyn Place. Unlike the previous option, this design provides a separate exit land from the roundabout onto Albyn Place while the traffic exiting onto Carden Place is free flowing. The design incorporates:

- Two lane approach to signals and roundabout on Albyn Place
- Two lane exit onto Queens Road
- Two entry lanes from Carden Place onto Albyn Place no left turn slip
- Two entry lanes from Albyn Place
- Signal controlled exit onto Albyn Place from dedicated roundabout exit arm

Figure 3.9 below illustrates the proposal.

Figure 3.9 – Option 9 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to east signalised junction from roundabout ▪ High cost option

3.6.10 *Option 10*

Essentially an amalgamation of options 8 and 9 this option goes further by removing Albyn Place as a destination from the roundabout. In this design, all eastbound traffic is directed onto Carden Place. While this arrangement would improve the junction, the impacts of this restriction would be observed within the wider network as eastbound traffic attempting to manoeuvre onto Albyn Place is forced to undertake a right turn across Carden Place further downstream of the junction. The design provides:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- Two entry lanes from Carden Place onto Albyn Place with left turn slip
- Two entry lanes from Albyn Place
- No exit onto Albyn Place from roundabout

Figure 3.10 – Option 10 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ No exit onto Albyn Place ▪ Potentially higher eastbound traffic flow on Carden Place ▪ Traffic impact on other network junctions further east. ▪ High cost option

3.6.11 *Option 11*

Building upon the traffic restrictive approach of Option10, this option considers removing the approach from Carden Place which would effectively merge all westbound traffic onto the Albyn Place approach. No signals would be required of this option, however as with the previous option, the implications of this restriction would be felt further east on the network. The design of this option would deliver:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- No entry from Carden Place
- Two entry lanes from Albyn Place
- Single wide exit from roundabout with split lanes to Albyn and Carden Place.

Figure 3.11 – Option 11 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Minor relocation of pedestrian crossing points ▪ Shorter crossing time on Carden Place	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Greater westbound traffic flow on Albyn Place ▪ No entry from Carden Place ▪ Conflict potential at diverge point for Carden Place/Albyn Place on exit from roundabout ▪ Traffic impact on other network junctions further east. ▪ High cost option

3.6.12 *Option 12*

As with Option 10, entry from the roundabout onto Albyn Place would not be possible. The merging traffic flows from Carden and Albyn Place are managed via traffic signals located in closer proximity to the junction than previous options. The exit onto Carden Place is less direct and in an attempt to reduce vehicle speeds making this manoeuvre, a higher degree of deflection is incorporated into the design for this movement. Key elements of the design include:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- No entry from Carden Place
- Two entry lanes from Albyn Place
- Single exit onto Carden Place
- No exit onto Albyn Place

Figure 3.12 – Option 12 Layout

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place	▪ Extremely limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Greater likelihood of pedestrians following desire lines across Carden Place after crossing at Albyn Place. ▪ Exit from roundabout onto Carden Place could be problematic for larger vehicles ▪ High cost option

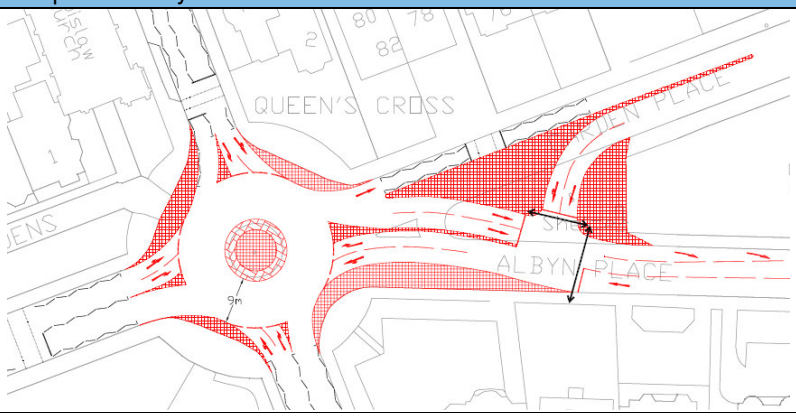
3.6.13 *Option 13*

Option 13 builds upon Option 9 to provide a roundabout and signal controlled access from Albyn and Carden Place. Incorporating a single eastbound exit from the roundabout, traffic with a Carden Place destination is free flowing while traffic for Albyn Place is filtered off into two lanes on approach to the traffic signals. The fundamental difference of this design relates to increased queuing capacity for eastbound traffic onto Albyn Place. In order to achieve this two lane exit with a merging taper from the signalised junction onto Albyn Place is required. This is onoy achieved by reducing the approach from Albyn Place to a single lane. Key elements of this design include:

- Two lane approach to the roundabout on Albyn Place
- Two lane exit onto Queens Road
- No direct entry from Carden Place
- Two entry lanes from Albyn Place
- Single eastbound exit from roundabout and split to Albyn Place
- Single approach lane to signalised junction from Albyn Place

Figure 3.13 below illustrates the proposal.

Figure 3.13 – Option 13 Layout



Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Requires merge lane on Albyn Place eastbound ▪ High cost option

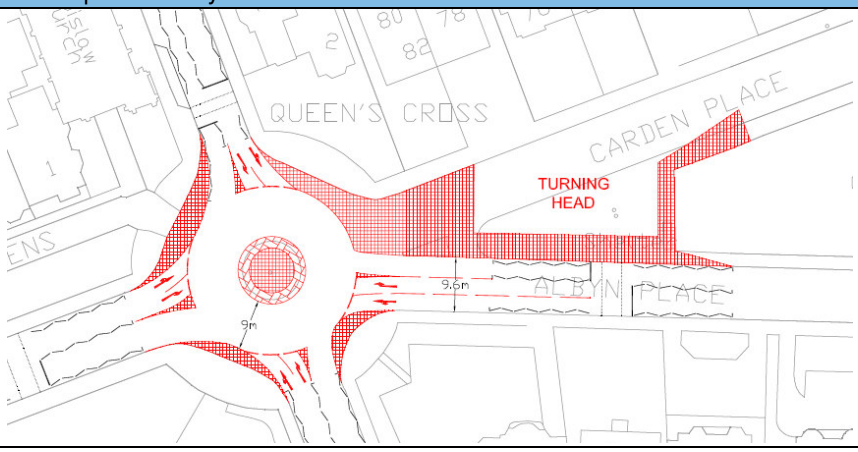
3.6.14 *Option 14*

This final option takes traffic restrictions to a conclusion by considering no entry or exit available at Carden Place. This restriction would essentially stop up a major approach to Aberdeen and would direct all traffic onto Albyn Place. The implications of this option would be realised on the wider network and there would be the danger that re-routing of traffic could create rat-running problems. The design considers:

- Two lane approach on Albyn Place
- Two lane exit onto Queens Road
- No entry from Carden Place
- No exit to Carden Place
- Two entry lanes from Albyn Place
- Single eastbound exit from roundabout onto Albyn Place

Figure 3.14 below illustrates the proposal.

Figure 3.14 – Option 14 Layout



Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Improved pedestrian movement with one less crossing ▪ Medium cost option	▪ Single exit for all eastbound traffic onto Albyn Place would be likely to create delay at the roundabout ▪ Greater traffic volumes on Albyn Place ▪ Major traffic rerouting likely to occur including rat running on adjacent streets ▪ Traffic impact on other network junctions further east ▪ Subject to successful traffic regulation orders

3.7 Option Sifting

The 14 options that arose from the option generation process were taken forward for review by the project team for further detailed consideration. The options were tabulated against the design criteria determined in section 3.3 to aid the evaluation and sifting process. The options were also considered against the planning objectives set out in section 3.4 and using a comparative appraisal it is possible to quickly sift out those options that do not satisfy the majority of the planning objectives.

Table 3.1 below identifies the options against the planning objectives and includes the pros and cons associated with each option. The strongest options to fall out of this appraisal process are identified for further detailed review.

The options are scored such that no improvement or negative benefits would generate no score or zero. Positive improvements where the design offers benefit are recorded as 1.

Table 3.1 - Option Sifting						
Ref.	Obj. 1	Obj. 2	Obj.3	Strengths	Weakness	Carry Forward
1	0	0	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Does not address safety issues	No
2	0	0	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Removes conflict issues when exiting onto Albyn Place ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Does not address all safety issues ▪ No direct entry onto Albyn Place ▪ Increased eastbound traffic on Carden Place	No
3	0	0	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ No changes to pedestrian crossing points ▪ Low cost option	▪ Does not address issues associated with close proximity of Carden Place and Albyn Place entry arms. ▪ Major safety issues when considering Albyn Place exit ▪ Exacerbates conflict issues when exiting onto Albyn Place	No
4	1	1	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to east roundabout from west ▪ Limited queuing capacity on approach to west roundabout from east	Yes
5	1	0	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit	No

				▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Limited queuing capacity on approach to east roundabout from west ▪ Limited queuing capacity on approach to west roundabout from east ▪ Increased journey time for straight ahead on Fountainhall Road-St Swithen Street ▪ Non standard layout may lead to driver confusion ▪ Additional curved alignments may present difficulties for larger vehicles	
6	1	0	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Increased public amenity space ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to west roundabout from east ▪ Increased journey time for straight ahead on Fountainhall Road-St Swithen Street ▪ Non standard layout may lead to driver confusion ▪ Additional curved alignments may present difficulties for larger vehicles ▪ Risk of higher circulation speeds	No
7	1	1	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Simple distribution onto Albyn and Carden Place ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to west roundabout from east	Yes
8	1	0	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty	▪ Limited queuing capacity on approach to east signalised junction from roundabout ▪ Four pedestrian crossing points required	No

				▪ Completely removes conflict issues between Albyn Place and Carden Place	▪ High cost option	
9	1	1	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to east signalised junction from roundabout ▪ High cost option	Yes
10	1	0	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ No exit onto Albyn Place ▪ Potentially higher eastbound traffic flow on Carden Place ▪ Traffic impact on other network junctions further east. ▪ High cost option	No
11	1	1	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Minor relocation of pedestrian crossing points ▪ Shorter crossing time on Carden Place	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Greater westbound traffic flow on Albyn Place ▪ No entry from Carden Place ▪ Conflict potential at diverge point for Carden Place/Albyn Place on exit from roundabout ▪ Traffic impact on other network junctions further east. ▪ High cost option	Yes
12	1	0	0	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place	▪ Extremely limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Greater likelihood of pedestrians following desire lines across Carden Place after crossing at Albyn Place. ▪ Exit from roundabout onto Carden Place could be problematic for larger vehicles ▪ High cost option	No

13	1	1	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Requires merge lane on Albyn Place eastbound ▪ High cost option	Yes
14	1	0	1	▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Improved pedestrian movement with one less crossing ▪ Medium cost option	▪ Single exit for all eastbound traffic onto Albyn Place would be likely to create delay at the roundabout ▪ Greater traffic volumes on Albyn Place ▪ Major traffic rerouting likely to occur including rat running on adjacent streets ▪ Traffic impact on other network junctions further east ▪ Subject to successful traffic regulation orders	No

Planning Objective 1 – Reduce the likelihood of vehicular conflict

Planning Objective 2 – Improve where possible junction flow and network operation

Planning Objective 3 – Enhance or maintain existing pedestrian provision

From the table above, it is clear that none of the options fully address all of the Planning Objectives. However a number of the options do address two out of the three objectives and have subsequently been identified for further consideration.

3.8 Options considered or further development

The junction options have been evaluated using the design criteria set out in Table 3.1 of Appendix D and further appraisal has been undertaken by reviewing each option against the planning objectives and where similar options exist, the stronger of that particular type of option has been considered.

The findings of this assessment were raised and discussed with the project team where the relative merits and dis-benefits associated with each option were discussed. Following this review, it was agreed that the following options would be considered for further evaluation to determine modelled traffic behaviour and design refinement using a swept path analysis to ensure design compatibility with a designated design vehicle.

- Option 4
- Option 7
- Option 9
- Option 11
- Option 13

The performance of each of these options is further assessed and the findings detailed in the following Section.

4 Option Development

4.1 Introduction

Following the option appraisal and sifting process, it has been possible to identify the strongest options to carry forward for a more detailed review. It has been demonstrated that the options, noted below are likely to reduce vehicular conflict and improve the operation of the junction in compliance with the planning objectives in paragraph 3.4.

- Option 4
- Option 7
- Option 9
- Option 11
- Option 13

The five options to be carried forward have been subject to a swept path analysis to determine feasibility in terms of geometric design and a traffic modelling assessment to determine likely operational performance.

The following paragraphs present the findings of the swept path analysis and subsequent design modifications required to accommodate the design vehicles. Following the design modifications, a Traffic Modelling assessment was undertaken and this information is provided with a brief discussion of the findings.

4.2 Traffic Appraisal

In order to confirm the suitability of the generated options, an auto tracking assessment was undertaken to ensure that proposals for the Queens Cross Roundabout would allow Large Articulated Vehicles and Bendi-buses to manoeuvre through the junction. Appendix F contains the tracking drawings for all vehicles from which the layouts to the proposals were re-aligned to better suit the vehicles sweeps.

From the swept path appraisal, it was possible to amend the design geometry of all the options to accommodate the design vehicles. The amended junction parameters have been therefore used in all subsequent models. Following the swept path appraisal, it was apparent that there remains scope within the adopted roads area to incorporate further minor amendments should these be required at a later stage.

Further to consultation with Aberdeen City Council, it was agreed that 2012 would be the year of assessment for the analysis. Traffic growth for the Queens Cross roundabout was calculated using ‘central’ growth National Road Traffic Forecasts (NRTF), obtained from the Department of the Environment, Transport and the Regions. As a result the survey flows from 2005 and turning count data from surveys conducted in 2009 were factored up to give the 2012 weekday flows. This data can be seen in Appendix A of this report.

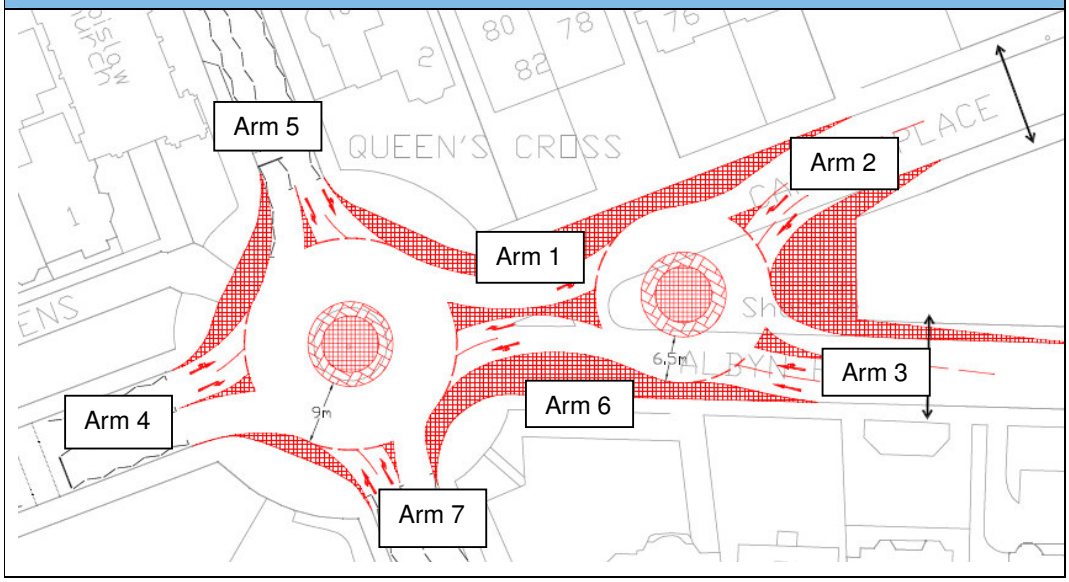
The Transport Research Laboratory’s (TRL) computer programmes Visual ARCADY 6 and Visual PICADY 4.1 have been used to assess the capacity of each option for the junction. JCT Consultancy software LINSIG v2 has been utilised for all options that included traffic signalisation. The performance of the junctions has been assessed using three industry standard outputs; Ratio of Flow to Capacity (RFC), Maximum Queuing (Q) and Inclusive Queuing delay (IQD). The results of the capacity assessment for the junctions have been tabulated and are contained alongside the output files within Appendix G.

An important outcome of the modelling was the requirement for both lanes on arm 6 of the options tested to exit into arm 4 (Queens Road). To accommodate this, two exit lanes would therefore be required on arm 4 (Queens Road). This is common to all five options being tested and the results discussed below take account of this requirement.

Sensitivity testing was also undertaken to review the impacts of a single lane of traffic accommodating the main traffic flow on arm 6 in an effort to assess the impacts of this scenario. The sensitivity test is further detailed in section 4.3.

4.2.1 Option 4 – Double Roundabout

Figure 4.1 – Option 4



From the tables below, it is apparent that Arm 1 of the junction would experience significant queuing that would impact upon the west roundabout. It is likely that excessive queuing occurs as a result of drivers giving way onto the second easterly roundabout. The entry width of this arm is designed at 4.5m to increase deflection onto the roundabout. However, this has a negative impact on the ability of the modelled traffic to exit onto the roundabout. Attempting to increase the entry width to improve capacity is not feasible as this would reduce the amount of deflection on approach to the roundabout and subsequently create a safety issue.

Table 4.1a - ARCADY 6 Results – Option 4: East Roundabout

Time Period (2012)	Arm 1 Albyn Place(West)		Arm 2 Carden Place		Arm 3 Albyn Place(East)	
	RFC	Queue	RFC	Queue	RFC	Queue
AM	1.298	220.1	0.360	0.6	0.303	0.4
PM	0.842	5.0	0.538	1.2	0.443	0.8

Table 4.1b - ARCADY 6 Results – Option 4: West Roundabout

Time Period (2012)	Arm 4 Queens Road		Arm 5 Fountainhall Road		Arm 6 Albyn Place		Arm 7 St Swithen Place	
	RFC	Queue	RFC	Queue	RFC	Queue	RFC	Queue

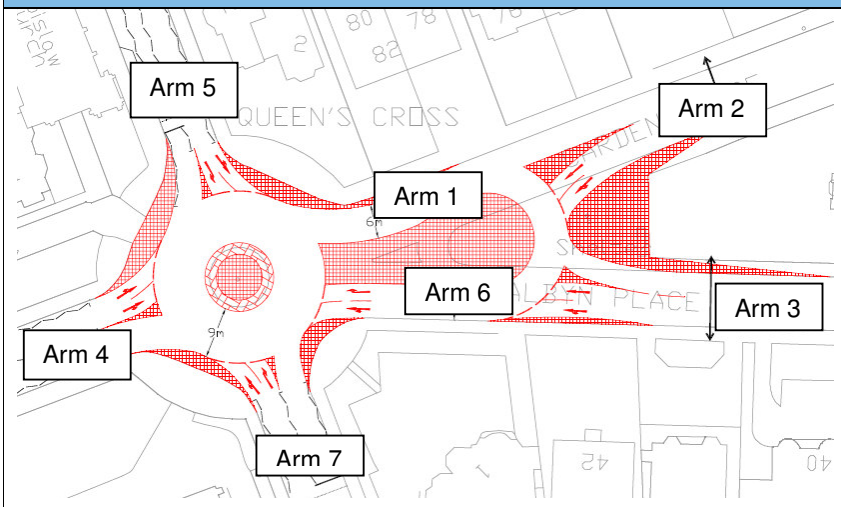
AM	0.834	4.7	0.773	3.2	0.547	1.2	0.798	3.8
PM	0.757	3.0	0.658	1.9	0.903	8.1	0.593	1.4

The issues associated with arm 1 apply to arm 6 of the junction. In this instance 8 pcu's are noted to queue on the approach to the west junction from the east. With a stacking capacity of approximately 20m, traffic would back up onto the east roundabout junction with an entry width of 6.5m it is unlikely that any increase to entry width would be possible. The overall performance of the junction is therefore directly limited by queuing capacity on arms 1 and 6. To summarise, this option should not be taken forward for the following reasons:

- Exceeds capacity on Albyn arm of west roundabout during am peak period
- With queuing of 8 vehicles there is the risk of queue back onto east roundabout
- Excessive queuing in the order of 220 vehicles is displayed on approach link between west and east roundabout.

4.2.2 Option 7 – Modified Double Roundabout

Figure 4.2 – Option 7



From the tables below, it can be seen that PM peak period queuing would be the main issue associated with this option. The exit from arm 2 is controlled by traffic flows onto Albyn Place as is the current situation. However, due to increase separation between arms 2 and 3 and greater gap acceptance, less queuing is exhibited when this junction option is modelled.

Table 4.2a - ARCADY 6 Results – Option 7: East Junction

Time Period (2012)	Arm 1 Albyn Place(West)		Arm 2 Carden Place		Arm 3 Albyn Place(East)	
	RFC	Queue	RFC	Queue	RFC	Queue
AM	0.793	3.7	0.392	0.6	0.295	0.4
PM	0.521	1.1	0.541	1.2	0.434	0.8

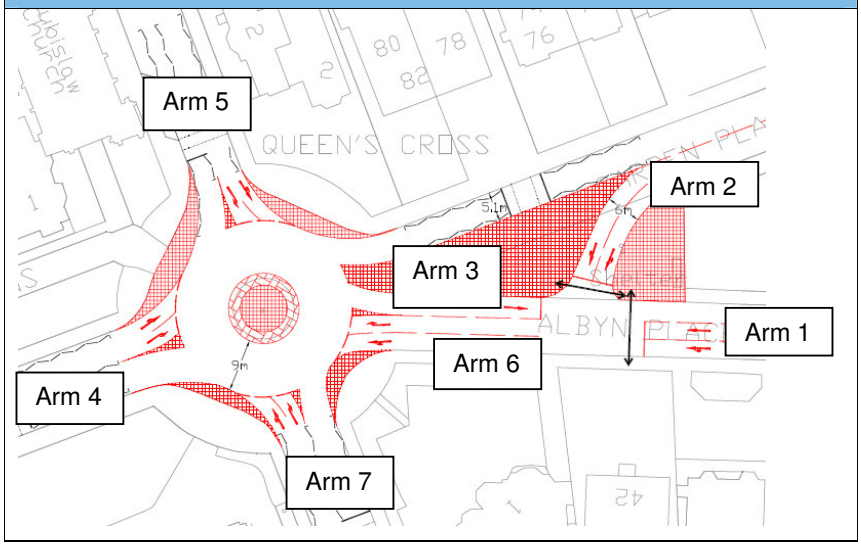
Table 4.2b - ARCADY 6 Results – Option 7: West Junction 2012 AM & PM								
Time Period (2012)	Arm 4 Queens Road		Arm 5 Fountainhall Road		Arm 6 Albyn Place		Arm 7 St Swithen Place	
	RFC	Queue	RFC	Queue	RFC	Queue	RFC	Queue
AM	0.851	5.3	0.807	3.7	0.479	0.9	0.815	4.2
PM	0.770	3.3	0.676	2.0	0.766	3.2	0.608	1.5

On the basis of the modelling results, it is recommended that this option is carried forward for the following reasons:

- When tested with the model parameters amended to reflect a 'free flow' condition, there is little impact on the queuing on Carden Place and the model suggests that the impacts on the Carden Place arm are negligible.
- The junction provides a free flow movement from arm 1
- Modelling indicates that the queue lengths on arms 2 and 3 would be improved. However at worst case scenario queuing would be no worse than current conditions as the priorities remain unchanged.
- Arms 4,5 and 7 would exhibit reduced queue lengths

4.2.3 Option 9 – Signalised Option a

Figure 4.3– Option 9



When modelling the roundabout element of the junction, the ARCADY modelling combines the total generated flows from Albyn Place and Carden Place and does not account for the traffic release generated by the signalised element of the junction. It is therefore likely that queues on arm 6 of the junction could be managed by the traffic signals at Albyn and Carden Place.

Table 4.3a - ARCADY 6 Results – Option 9: Roundabout element								
Time Period (2012)	Arm 4 Queens Road		Arm 5 Fountainhall Road		Arm 6 Albyn Place		Arm 7 St Swithen Place	
	RFC	Queue	RFC	Queue	RFC	Queue	RFC	Queue
AM	0.851	5.3	0.807	3.7	0.479	0.9	0.815	4.2
PM	0.770	3.3	0.676	2.0	0.766	3.2	0.608	1.5

The traffic modelling results considering the traffic signal controlled element of the junction are presented in Table 4.3b below. Initial modelling runs of this junction considered a left turn movement from Carden Place onto Albyn Place eastbound over a three stage cycle. Improvements to signal efficiency were made by removing the left turn movement to create a two stage operation.

Table 4.3b - Linsig Results – Option 9: Signalised Element

Time Period (2012)	Arm 1 Albyn Place(Wstbnd) L1		Arm 1 Albyn Place(Wstbnd) L2		Arm 2 Carden Place L1		Arm 2 Carden Place L2		Arm 3 Albyn Place(Estbnd)	
	Deg Sat	Q	Deg Sat	Q	Deg Sat	Q	Deg Sat	Q	Deg Sat	Q
AM	40.1	2.4	3.4	0.0	78.6	4.5	9.9	0.3	83.1	7.7
PM	65.0	4.9	5.8	0.0	72.5	5.8	11.6	0.6	76.2	6.2

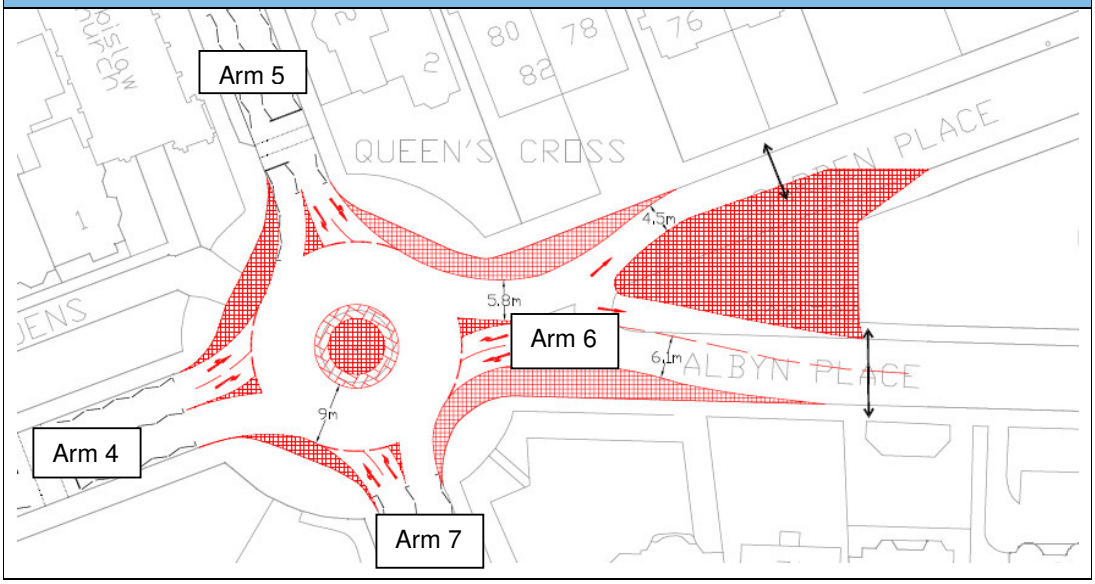
*Mean Max Queue in pcu's

The main issue associated with this option relate to the predicted queuing on arm 3 of the junction. As a result of excessive queuing, there is a risk that traffic would queue back onto the roundabout element for the junction. To counter this, arm 3 would require a second lane, which in turn requires a two-lane exit onto arm 1. Due to limited carriageway space a two lane exit is not feasible with this option. This option is not recommended for the following reasons:

- Considering the signalised element of the junction, a queue of approximately 8 vehicles is identified on the Albyn Place approach on exit from the roundabout (arm 3). With this arrangement, there are issues with regard to queue back onto the roundabout.
- The option requires a two lane approach on arm 1. As a result of this it is not feasible to add a second lane on the exit to this arm which would be necessary to enable this option to work.
- Further consideration is not recommended for this option.

4.2.4 Option 11 – No entry from Carden Place

Figure 4.4 – Option 11



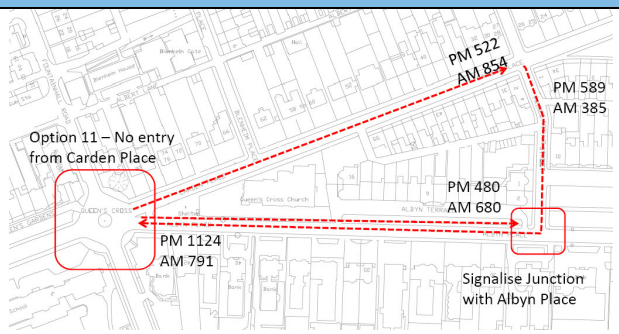
Reviewing the modelling results for the roundabout junction, it is apparent that the main queues would form on arm 6 of the junction. This is as a result of all westbound traffic being directed onto a single arm. The modelling results are detailed in table 4.4a below.

Table 4.4a - ARCADY 6 Results – Option 11

Time Period (2012)	Arm 4 Queens Road		Arm 5 Fountainhall Road		Arm 6 Albyn Place		Arm 7 St Swithen Place	
	RFC	Queue	RFC	Queue	RFC	Queue	RFC	Queue
AM	0.851	5.3	0.807	3.7	0.479	0.9	0.815	4.2
PM	0.770	3.3	0.676	2.0	0.766	3.2	0.608	1.5

Due to the amended traffic routing associated with this option, the main diversion route has been identified and is illustrated in Figure 4.4b below. Although there are other routes for diverting traffic to follow, in order to perform a robust worst case assessment, all diverted trips have been assigned to this route.

Figure 4.4b – Option 11 Diversion Route



The Picady modelling for the Prince Arthur St / Albyn Place junction, table 4.4a below, confirms that the junction would not accommodate the additional traffic in its current form. Queues in the order of 181 pcu's are predicted which would clearly be unacceptable

Table 4.4b - Picady Results – Option 11: Priority Junction (base)						
Time Period (2012)	Arm 1 Albyn Place(West)		Arm 2 Prince Arthur Street		Arm 3 Albyn Place(East)	
	RFC	Queue	RFC	Queue	RFC	Queue
AM	na	na	1.439	91.2	0.119	0.1
PM	na	na	1.774	181.1	0.094	0.1

In order to address the impact at the Prince Arthur St / Albyn Place junction, the junction has been assessed considering a traffic signal installation to accommodate the traffic flows. The Linsig results below suggest that the junction operates within capacity and would exhibit queue lengths in the order of 14 vehicles. The Linsig modelling results are presented below for reference.

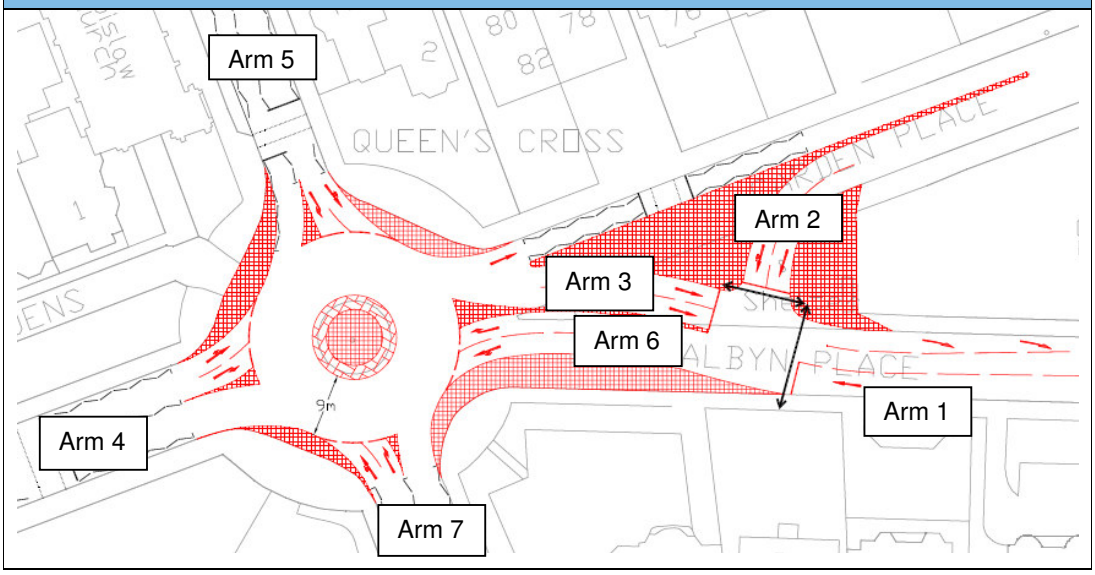
Table 4.4c - Linsig Results – Option 11: Signalised Junction (prop)						
Time Period (2012)	Arm 1 Albyn Place(West)		Arm 2 Prince Arthur Street		Arm 3 Albyn Place(East)	
	Deg Sat	Queue	Deg Sat	Queue	Deg Sat	Queue
AM	69.5%	12.5	76.8%	12.1	68.8%	8.4
PM	64.8%	10.1	79.1%	14.5	69.5%	10.0

The main issues with this option relate to the capacity of the Albyn Place / Prince Arthur Street junction further east on the network. However, when considering any major traffic rerouting, there is a greater risk that rat-running could become an issue along adjacent streets. The above option is recommended for further consideration for the following reasons although there are some concerns identified below.

- No anticipated queuing or capacity issues at the roundabout.
- With the entry onto the junction from Carden Place removed, the issues of capacity are removed to Prince Arthur Street/Albyn Place junction
- Further testing confirms that with signalisation, the Prince Arthur St / Albyn Place junction operates within capacity at a 90 second cycle time with mean maximum queues in the order of 12 vehicles.
- This option carries a risk that rat running may increase on the adjacent wider network.

4.2.5 Option 13 – Signalised Option b

Figure 4.5 – Option 13



With this junction arrangement, it is clear that the modelling results indicate that the roundabout element of the junction would work within capacity without generating excessive queues. When referring to the observed queue length data obtained from the queue length survey, it is noted that this design option potentially reduces the queue lengths. In addition to the two lane exit onto Queens Road, there would be a requirement to merge two lanes into one on Albyn Place. Initial evaluation suggests that this is feasible, however a safety audit should be undertaken to confirm that this would be acceptable.

Table 4.5a - ARCADY 6 Results – Option 13

Time Period (2012)	Arm 4 Queens Road		Arm 5 Fountainhall Road		Arm 6 Albyn Place		Arm 7 St Swithen Place	
	RFC	Queue	RFC	Queue	RFC	Queue	RFC	Queue
AM	0.851	5.3	0.807	3.7	0.479	0.9	0.815	4.2
PM	0.770	3.3	0.676	2.0	0.766	3.2	0.608	1.5

The traffic modelling results are presented in Table 4.5b below. Initial modelling runs of this junction considered a left turn movement from Carden Place onto Albyn Place eastbound. However, to allow this movement, it was necessary to adopt a three-phase operation, which resulted in subsequent delays. In order to address this it was concluded that this movement would be removed and all traffic from Carden Place with an Albyn Place destination would be routed through the junction. With this arrangement in place, it was possible to reduce the operating stages to two thereby improving the efficiency of this junction option.

Table 4.5b - Linsig Results – Option 13: Signalised Element								
Time Period (2012)	Arm 1 Albyn Place(Wstbnd))		Arm 2 Carden Place L1		Arm 2 Carden Place L2		Arm 3 Albyn Place(Estbnd)	
	Deg Sat	Queue	Deg Sat	Queue	Deg Sat	Queue	Deg Sat	Queue
AM	53.4	3.1	38.1	1.5	42.5	1.7	51.5	4.5
PM	59.4	5.0	59.9	3.4	62.5	3.7	36.8	3.4

*Mean Max Queue in pcu's

On the basis of the modelling results, it is recommended that this option is considered for further evaluation for the following reasons:

- The traffic modelling suggests that queues would be in the order of 5 vehicles during the PM peak period.
- When assessing the traffic signal element of the junction, the design allows for a two lane exit from the roundabout on the approach to the signalised junction. With this arrangement, the modelling identifies a predicted queue length of 4 vehicles.

4.3 Sensitivity Testing

Sensitivity testing was undertaken for the junctions discussed above to account for disproportionate lane allocations which are not applied by ARCADY. In the modelling, ARCADY cannot allocate traffic flows to a relevant lane but instead evenly distributes traffic flows over the whole lane width. Therefore, the ARCADY programme will assign traffic onto roundabout approach lanes evenly and not as on-site observations would suggest with the majority of traffic utilising one lane. As equal lane distribution is unlikely to occur sensitivity tests undertaken considered the main traffic flows only and allocated these flows to a single approach lane. In reality vehicle drivers would have the option of two lanes however, this analysis would present a worst case scenario. The five proposed options assessed in paragraph 4.2 were originally designed with at least one approach lane on each arm of the roundabout for westbound traffic onto Queens Road and with one exit lane on Queens Road. However, it was apparent from an early stage that the junction would not perform as required without the provision of two approach lanes on Albyn Place assigned to westbound traffic and supplemented by two exit lanes on Queens Road.

4.4 Detailed Option Appraisal

Following the swept analysis and the traffic modelling it is apparent that there are strengths and weaknesses associated with each. Table 4.6 below summarises the strengths and weaknesses associated with each option.

Table 4.6 - Summary of Preferred options			
Option	Strengths	Weaknesses	Comments
Option 4	Operates without traffic signals	Excessive queuing and queue backup between roundabouts	No further consideration recommended
Option 7	**Operates without the need for traffic signals**	**Non standardised from of junction**	**Recommended for future consultation**
Option 9	Opportunities to controlled flow between Carden and Albyn Place	No sufficient stacking on approach to signalised junction from roundabout. Queue back onto roundabout	No further consideration recommended
Option 11	**The design option works well at this location**	**Major traffic rerouting required. Detrimental effect and issues associated with Prince Arthur Street / Albyn Place junction.** **Rat running more likely to occur**	**Recommended for future consultation**
Option 13	**Opportunities to controlled flow between Carden and Albyn Place**	**Junction operation is tied to operation of traffic signals.**	**Recommended for future consultation**

5 Summary and Conclusions

5.1 Summary

This report presents the findings of a study to identify options that would primarily address safety issues associated with the Queens Cross roundabout junction, located to the west of Aberdeen's City centre. Anecdotal evidence suggests that there is a perceived safety issue amongst drivers when using this junction arising from poor lane discipline and uncertainty when approaching the junction. Observations of the junction in operation confirm that confusion arises when approaching and entering the roundabout, in particular from the Albyn and Carden Place arms, leading to hesitation and delay. This behaviour is considered to have a detrimental effect on the junction's capacity and safety, the latter of which is confirmed following analysis of the safety statistics of the junction.

The junction is a major five arm roundabout junction located within one of Aberdeen's main businesses and residential areas which also supports number of secondary schools. The junction, lies on a major commuter route into the city handling over 5500 vehicle trips in both the am and pm peak periods. As with any major commuter route, there are a high proportion of public transport services that operate along this corridor serving both the residential and business areas which further emphasises the importance of this route.

By adopting a workshop approach to generate options, fourteen outline options were identified that would, in principle, aim to address the issues associated with the junction.

The options were evaluated against a set of planning objectives that were determined during the study which made it possible to 'sift out' the weaker options and focus attention onto five preferred schemes.

These five options were then subject to further analysis considering build ability in terms of geometric design and operational performance. Following a swept path analysis considering a specified design vehicle, it was apparent that all of the options could be developed within the constraints of the land available. It was also noted that further to the design amendments, within the design boundaries, there is sufficient scope to amend and develop the designs further should that be required.

Following the traffic modelling appraisals, it was clear that the modified roundabout design, common to all options, did not display any detrimental results and improved the junction in terms of queuing. However, it was clear that queuing on the link between the east and west elements of the junction were critical with a number of the options unable to accommodate the 'linking' traffic.

Considering the strengths and weaknesses of the five preferred options, three options have been selected for further evaluation and review. It is therefore recommended that the following options are carried forward for a Traffic Safety Review:

Option 7 – Modified Double Roundabout

Option 7 provides a simplified approach to addressing the issues associated with the existing junction which does not require any signalisation. Although the traffic modelling suggests that the Albyn Place approach onto the roundabout would exhibit excessive queuing during the PM peak period, it may be possible to increase entry width to accommodate this. It should also be noted that the queues on Albyn Place and Carden Place should be comparable to those currently observed as there is no real change in the priority for exit onto the junction from these

approaches. However there is likely to be a benefit in terms of safety of users at these approaches.

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Minor changes to pedestrian crossing points ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Simple distribution onto Albyn and Carden Place ▪ Medium cost option	▪ Reduction of traffic flow past Albyn and Carden Place entry points may lead to fewer gaps for Albyn place exit ▪ Limited queuing capacity on approach to west roundabout from east

Option 11 – No Entry from Carden Place

The improvements associated with option 11 are based upon a revised priority for west bound travel from Carden Place onto Queens Road. The option delivers queuing and safety improvements at the roundabout although the rerouted traffic does create new issues at Prince Arthur Street/ Albyn Place junction. However traffic modelling for this junction suggests that this additional traffic could be managed with traffic signals. For the purposes of this assessment, all diverted trips were routed through this junction while in reality fewer trips would be expected. In this regard there may be implications relating to increased levels of rat running.

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Minor relocation of pedestrian crossing points ▪ Shorter crossing time on Carden Place	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Greater westbound traffic flow on Albyn Place ▪ No entry from Carden Place ▪ Conflict potential at diverge point for Carden Place/Albyn Place on exit from roundabout ▪ Traffic impact on other network junctions further east. ▪ High cost option

Option 13 – Signalised Option

From the results provided, it is apparent that junction 13 appears to work satisfactorily and does not lead to any excessive queuing. However, it should be noted that the two components of the junction have been modelled separately and while the modelling parameters have been amended to reflect some synergy between the junctions.

Strengths	Weaknesses
▪ Improvement to general roundabout design ▪ Improved lane discipline should remove driver uncertainty ▪ Completely removes conflict issues between Albyn Place and Carden Place ▪ Maintains Carden Place pedestrian crossing	▪ Limited queuing capacity on approach to roundabout junction from Albyn Place ▪ Requires merge lane on Albyn Place eastbound ▪ High cost option

5.2 Conclusions

Subject to the findings of any further detailed traffic modelling and any amended design resulting from the safety review, the options should be costed and presented for public consultation. It is recommended therefore that the next stage of the assessment should therefore be undertaken in the following stages:

- Stage 1 Undertake Traffic Safety Review.
- Stage 2 Adopt design to take into account findings of safety review.
- Stage 3 Outline costing review.
- Stage 4 Public consultation exercises.
- Stage 5 Review findings of public consultation with Aberdeen City Council and adopt a final design solution.