How technology influenced and aided in the redesign of the M1 Motorway at Lissenhall Interchange, Dublin

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1. Introduction

A large Motorway Interchange in Dublin was suffering from significant congestion during both peak periods. The roundabout controlled junctions were installed as a dumbbell interchange in 2003 as part of the construction of the M1 motorway which links Dublin with Belfast. These roundabouts quickly required partial signalisation due to the congestion being experienced almost from the day it opened due to dominating flows from some arms. However the signalisation only partially alleviated the problems with significant congestion still evident on many arms. In addition this congestion was growing rapidly as traffic on some arms do not have alternative route options to Dublin, and some of these areas are predicted to grow rapidly in the coming years.

The Dublin Port Tunnel, which opened in December 2006 at a cost of €752 million to the exchequer, adjoins the southern extent of the Motorway as it enters Dublin City approximately 10Km south of the Lissenhall Interchange. This section of motorway also provides the principal access to Dublin Airport as well the northern extent of Dublin City's radial motorway, the M50.

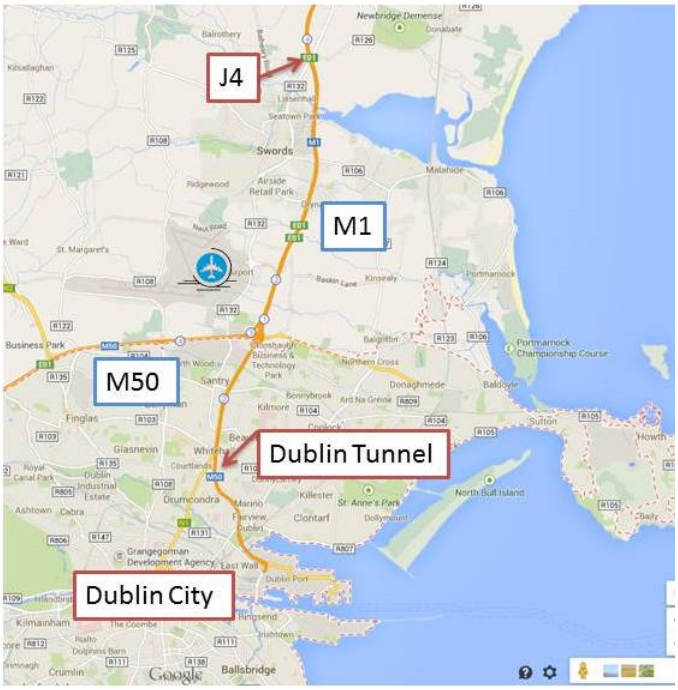


Figure 1: Scheme location

In 2010 the National Roads Authority and Fingal County Council commissioned a redesign of the junction as part of an overall upgrade of the M1 Motorway to protect and ensure the efficient operation of one of the most significant links on the National highway network.

As part of this design process an innovative solution was proposed, and was initially met with significant scepticism. In order to aid the stakeholder consultation process the designers created detailed LINSIG and VISSIM models and proposed how the relatively new concept in Ireland of a Linked Mova system could be used to control a complex junction such as this in a semi-rural location.

The micro-simulation model and the details of the traffic control system soon convinced people that the solution is viable and sceptics soon became advocates of the scheme with construction commencing in 2012. The novel solution, including a "Jug Handle" route through one roundabout, became operational in the middle of 2013 and had an immediate impact, with congestion eliminated on all arms throughout the day.

The paper will look at the delivery process and will detail how the technology we have available to us now makes it much easier to develop and promote innovative schemes that can have a dramatic impact on a locality.

Figure 2: Lissenhall Interchange before scheme

Section 2 of this short paper discusses the baseline traffic conditions, Section 3 outlines the traffic modelling undertaken, and Section 4 presents an overview of final junction layout. Section 5 sets out features of the configuration of the linked MOVA signal control and Section 6 summarises the paper.

2. Baseline Traffic Conditions

M1 Junction 4, locally known as Lissenhall Interchange, forms a junction between the M1 motorway and the old Dublin – Belfast Road (R132) and is the focal point for motorists commuting between Dublin City Centre and North County Dublin towns of Donabate/Portrane, Rush, Lusk, Skerries and the northern end of Swords.

The townlands of Rush, Donabate and particularly Lusk experienced exponential growth in population during the 'Celtic Tiger' boom years from the turn of the millennium until the economic crash in 2008. For example, Lusk's population more than doubled in this time. Public transport facilities in these areas are not of a high standard with commuter train services the most reliable form of public transport between Dublin City Centre. As such, the car retains a strong modal share for this region with Lissenhall interchange transferring the vast majority of these trips between the R132 and the M1.

Swords is the largest town in County Dublin with a population in excess of 40,000 recorded in 2011, the most recent Census. Further to this, Swords has been identified as an 'emerging city' in National Planning Policy with a population projection of 100,000 envisaged by 2035. With the vast majority of development potential existing to the north and west of Swords. As a result congestion at the Lissenhall Interchange was expected to increase exponentially as the economic recovery in Ireland takes hold.

Traffic surveys conducted in 2009 recorded Average Annual Daily Traffic (AADT) volumes of approximately 100,000 vehicles between J1 (M50) and J2 (Airport). An AADT of approximately 50,000 vehicles was recorded just north of Lissenhall Interchange (J4). As such, the volume of traffic using the M1 halves between Junctions 1 (M50) and Junctions 4. Further interrogation of these figures, shows that Lissenhall Interchange specifically carries approximately 17,000 vehicles to and from the M1 motorway each day.

Figure 3: Approximate AADT on M1 (2009)

The principal issues associated with the northern roundabout prior to the upgrade were extensive queuing on the R132 SB and the R126 (Hearse Road) in the AM peak period as commuters looked to join the M1. These movements competed with one another for green time as well as the M1 SB off ramp movement. Despite both roundabouts operating under MOVA control before the works there was still an imbalance in the apportioning of green time which would either lead to extensive delays and queuing on the R132/R126 or a compromise of flow on the M1 southbound off ramp as queues could block back onto the mainline.

In the PM peak, the short stacking space between the R132 NB and SB arms on the interchange frequently blocked the R132 NB movement leading to queuing across the bridge and back down the M1 NB off ramp and onto the M1 mainline.

Figure 4 Conflicting Movements at Northern Roundabout

Finally, at the southern roundabout, the R132 NB suffered from lack of green time at the M1 NB off ramp and R132 SB traffic dominated traffic flow at this junction, again resulting in backup towards and onto the M1 mainline

As congestion was expected to grow there was concern that the strategically important M1, the primary cross-border route, would be significantly impacted by congestion at this interchange.

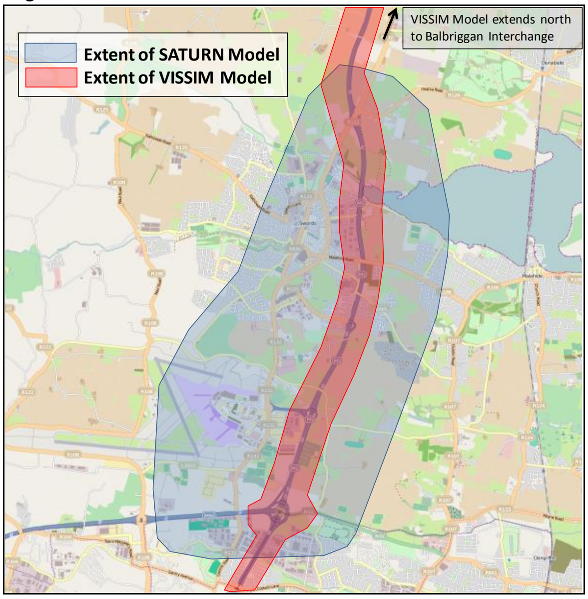
3. Traffic Modelling

In order to comprehensively assess the impact of the proposed scheme, it was necessary to review the effects both locally and strategically. This assessment encompassed impacts to traffic currently using the M1 motorway as well as traffic diverted to/from local roads directly adjacent to the M1 and to/from national roads within the M1/N2/M3 corridor, which are located nearby and can be used as an alternative route.

It would not be possible to assess all of the impacts outlined above in one model and as such it was necessary to use three models. The existing M1/N2/M3 Corridor assignment model was used to assess the strategic reassignment effects between the M1 and both N2 and M3.

An assignment model is also more appropriate in order to understand local reassignment effects. As such a SATURN model was used to model strategic reassignment of trips from the R132 (Old Dublin – Belfast Road) and other local roads onto the M1. On the M1 corridor itself, micro simulation modelling is the most appropriate tool for assessing on-line impacts associated with the introduction of various elements of a proposed upgrade. A VISSIM model of the M1 corridor was therefore developed to quantify such impacts.

Figure 5 – Extent of SATURN & VISSIM Models



Linsig models were also produced to develop the most optimum staging plans for the proposed upgrade but also to gain an understanding of the issues associated with the previous arrangement. As mentioned above, the junction was operating under MOVA control which was a retro fit to the original dumbbell layout. The staging plan for this signal control evolved over a period of time and maximised the efficiency of the existing geometric layout which was found to be the principal constraint on the interchanges performance.

The extent of the VISSIM model developed for the study is illustrated in Figure 5 above and comprises of the section of the M1 from the M1 Turnapin Interchange (southern extent of the motorway) to north of Lissenhall Interchange.

It was found that the AM peak period was the critical period as motorists travelling from Rush, Lusk, Skerries & Donabate suffered considerable delays in accessing the M1.

The 2010 AM base model showed extensive queueing (900m) on the R132 southbound approach to the northern roundabout as was the prevailing issue at Lissenhall at the time and as discussed in Section 2 above.

Figure 6: 2010 Base AM VISSIM Model

A pronounced peak queue (180m) was also noted on Hearse Road (R126) between 08:45 & 09:00. Hearse Road operated under a 'give – way/flashing amber' prior to the upgrade and was not afforded appropriate gaps in traffic for queues to disperse at this peak time.

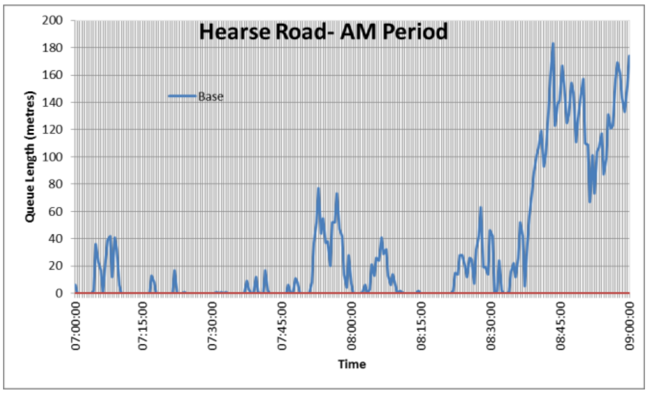


Figure 7: Queue Lengths on Hearse Road (R126) AM Peak.

The PM peak base model was found to be less turbulent with queues of 120m noted on the M1 northbound off ramp and 130m on the R132 NB approach to the Interchange.

The base model was calibrated and validated in accordance with the NRA Project Appraisal Guidelines and satisfied the relevant stakeholders (NRA & FCC) of its accuracy to the prevailing traffic conditions.

VISSIM was found to be of great benefit in demonstrating and agreeing the modelling parameters and also gaining stakeholder 'buy in' of the preferred solution. The graphical interface and video footage that VISSIM provides is an invaluable tool in pitching proposed schemes particularly innovative schemes such as the subject scheme when the initial disposition is one of scepticism. Driver behaviour is demonstrated and understood in way that network statistics cannot be grasped.

Future year models were developed for 2015, 2025 and 2040. These models considered background traffic growth rates as well as the future expansion of Swords as an 'emerging city'. The performance of the junction upgrade will be discussed in Section 4 below.

4. Final Design Layout

The key issues to be addressed in the final upgrade design were clear following a combination of on – site observations and the development of the base traffic models discussed above.

a) Queuing on the R132 and R126 SB in the AM Peak
b) Queuing on the R132 NB and across the bridge in the PM peak

The overarching objective in addressing these issues was to preserve and ensure the continued efficient operation of the M1 mainline.

Figure 8: Aerial Photograph of Final Layout

In resolving issue (a), the fundamental obstacle to be overcome was the volume of southbound traffic exiting the M1 in the AM peak competing with the R132 (SB) and R126 for green time at the northern roundabout. The final design proposed a novel solution whereby, the significant majority of traffic using the M1 SB off ramp was accommodated via a free flow ‘jug handle’ slip through the island of the roundabout. This traffic, which is mostly destined for Swords, no longer competes with the R132 (SB) and R126 for green time, thereby affording these arms more green time.

A free flow slip onto the M1 southbound was also introduced for the R126 to improve accessibility for this arm whilst also reducing the green time it requires. This also resulted in greater green time, reduced delays and queuing for the R132.

The separation of M1 southbound traffic exiting at Lissenhall to access Swords from those accessing the R126 and R132 has also helped resolve issue (b) above. The reduction in traffic using the short stacking space between the R132 NB & SB arms resulted in less potential for blocking of the R132 NB movement which is heavily demanded in the PM peak. This in turn reduced the potential for queues building back onto the bridge, through the southern roundabout and onto the M1 NB off ramp.

As a further upgrade measure, the southern roundabout was amended to a ‘hamburger’ arrangement with R132 SB traffic travelling towards Swords bisecting the old roundabout. Traffic travelling SB from the R132 towards the M1 NB was separated and now performs a ‘left to go right’ movement at the junction. This movement is relatively lightly demanded, however, it was affecting the amount of green time afforded to the R132 NB in particular under the previous staging plan. This intervention has resulted in reduced queuing on the R132 SB approach to the junction as well as the M1 NB off ramp.

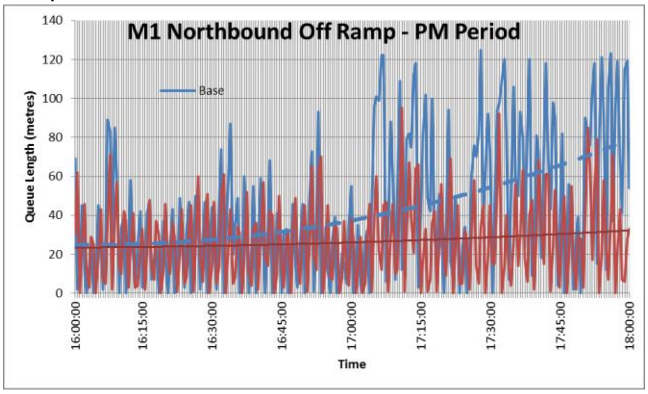


Figure 9: Pre & Post Scheme Queuing on M1 NB off ramp

5. Signal Control Design

As mentioned above, the previous interchange layout had been operating under signal control which had evolved from partial signalisation to MOVA control on both roundabouts. However, the subject upgrade presented an opportunity to install completely new and modern traffic signalling equipment including Imtech’s first deployment of their Chameleon unit and Extra Low Voltage equipment in Ireland.

The general signalling arrangement has a separate controller on either side of the motorway. All phases on each side including entry and exit Toucan crossings are controlled in a single stage stream, partly for simplification and to provide coordination with appropriate use of demand dependent stages and phase delays. This also allows MOVA to have knowledge of all demands for all phases on each side and optimise the signal timings accordingly without the need for complicated linking. This is particularly useful if oversaturation occurs on any link, where complicated multi-stream MOVA sites sometimes suffer, as MOVA cannot necessarily compensate easily for the oversaturated link by adjustments elsewhere around the junction.

The junction layout on the north side allows the two major approaches (phases B and D) to be green concurrently substantially increasing capacity and reducing delays.

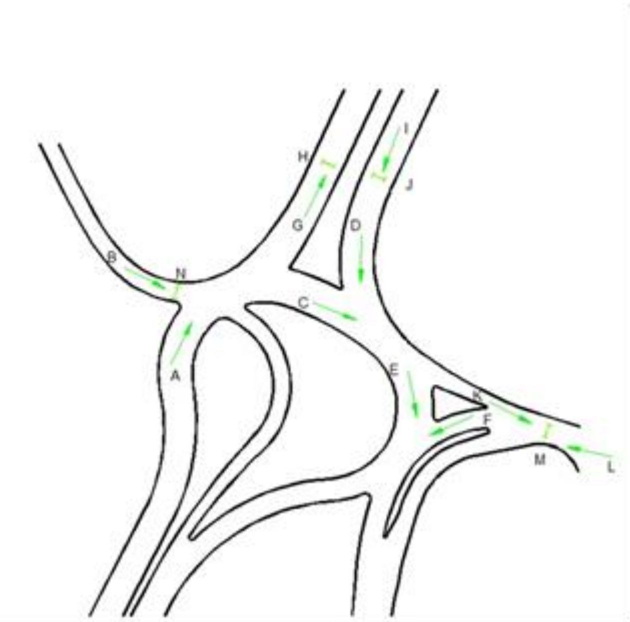


Figure 10: North Side Staging Diagram

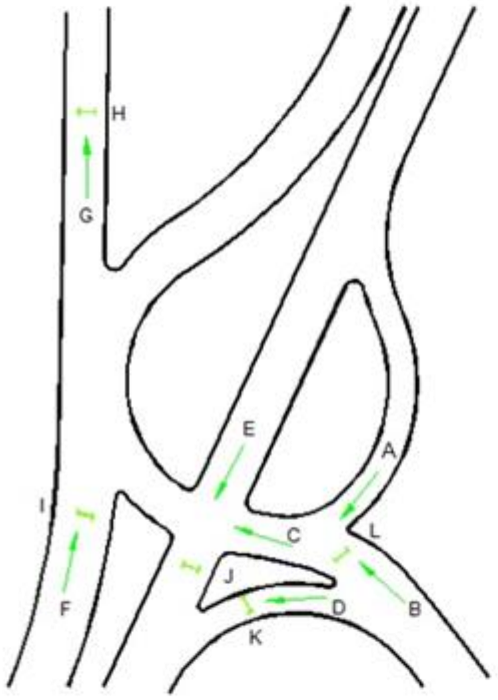


Figure 11: South Side Staging Diagram

Both sides were configured for MOVA to be the primary method of control with CLF and VA as fallback options. There are a number of alternative stage selection options for MOVA, CLF and VA modes depending on the exact pattern of demands especially for Toucan phases.

The North side internal circulating links (phases C and E) were configured with phase ending delays following specific upstream phase greens and did not need to be directly controlled by MOVA links and lanes. However, for occasions when queues form on these internal links, queue loops are placed at the maximum storage length to demand and extend relevant circulatory clearance stages. This was chosen as it had been used very effectively at signal controlled roundabouts in the UK.

Queue detectors are also used on the motorway exit slip roads on both sides, on the bridge links connecting the two sides of the motorway, and on the west side turn-off for right turners (phase A), as these are considered to be the critical links for safety and efficiency.

To minimise delays to traffic from longer intergreens, walk with traffic Toucan phases are configured to appear only if demanded at any point during the stage and to terminate at the end of minimum green. Further to improve efficiency for traffic, phase M on the north side has a shorter controller minimum green time plus a phase delay to ensure an appropriate street minimum.

The start-up and reversion stages are the circulatory on the north side and turn-off for right turners on the south side, so major high speed approaches are generally on red at quiet times particularly overnight to encourage lower speeds and improve safety.

Factory Acceptance Testing

Specific issues arising during the FAT related mainly to the prohibited / alternative stage moves and CLF plans. The CLF plans had to be simplified and could not make use of every demand dependency that MOVA is capable of using due to the extensive special conditioning that this would have required. Following this simplification, the prohibited / alternative stage moves required separating by method of control.

MOVA

The MOVA version M6.0 datasets for each controller share a common approach, and this section highlights some of the features used for the efficient operation of the two controllers and so they coordinate well together without explicit linking. To assist in achieving this, TOTALG and stage MAX times have been constrained as appropriate without being too restrictive to maintain flexibility. However, MOVA rarely needs to extend green times and cycle times to the maximum values.

The stage demand codes (SDCODE) mainly use a mix of 1X, 3X, 1XX and 3XX codes as appropriate for demanding the most appropriate stages for the current demands on-street. The priority facility (PFACIL) codes are set to 4 for all stages, as it was found that this provides an effective balance between immediate truncation of stages and considering oversaturation for links green in the potentially truncated stages. It also assists in clearing queues quickly without excessive detriment to other links around the junction and avoiding other queue detectors being activated for conflicting links and the resulting oscillation that can sometimes be observed at other MOVA sites.

To provide a higher level of priority to pedestrians and cyclists through shorter wait times when traffic conditions permit, the pedestrian priority facilities available in MOVA version M6.0 (PEDMAX1) have been used with shorter stage MAX times when Toucan demands exist.

Challenges in site commissioning

The south side was originally configured to have phases A, B and C each associated with a stop line and signals. However, after installation it was decided that the phase C stop line and signals were causing confusion and safety concerns due to their close proximity and limited storage space between them. Therefore the phase C stop line and signal heads were removed, however to reduce the effort involved in changing the controller and associated cabling on-street, phase C was altered to a dummy phase with adjustments to the conflicts, phase intergreen timings and phases in stages accordingly.

Aside from the safety concerns above requiring changes to the south side controller configuration and street installation, it was also found that the operation of the MOVA CRB differed from standard practice and that the cabling of the queue detectors for MOVA bypassed the call/cancel processing of the controller resulting in priority demands in MOVA control from normal vehicle movements. These were all quickly resolved by Imtech.

Post-commissioning it was found that a MOVA divide error was frequently occurring on the east side during quiet times of day. This was discussed with TRL who identified a potential issue with the interstage timing (CHANGE) values in the dataset due to the way in which pedestrian links are configured to operate in the controller. Therefore adjustment was made to the CHANGE values to account for the highest possible rather than the most usual interstage timings and this appears to have resolved the issue.

6. Conclusions

The junction upgrade was completed in June 2013 and has delivered reduced queuing levels and shorter journey times on all approaches. The most significant improvement has been achieved on the R132 SB approach to the northern roundabout with typical queues of less than 90m recorded in the critical AM peak. This has resulted in a considerable decrease in journey times for motorists commuting to Dublin City Centre.

The VISSIM model predicted that queueing levels would decrease to an average 60m across the critical R132 SB approach lanes in the AM peak following completion of the works. Queue length surveys conducted in November 2013 recorded an average queue length of 54m during the AM peak period. This is a considerable decrease when compared to the queue lengths noted prior to the scheme.

It is our opinion that this innovative type of upgrade would not have been realised were it not for the technological tools, such as VISSIM and advanced traffic signal control, we have at our disposal today. These tools helped allay initial scepticism and demonstrate conclusively that the design proposals could be successful.

This paper has described the benefits of using a combination of inventive geometric design, traffic modelling, traffic signal control, and demonstrated its practical application in Dublin. These tools facilitate the realisation of lateral thinking and helped foster new approaches in traffic engineering and highway design.

Acknowledgement
The AECOM team would like to thank Fingal County Council & the National Roads Authority for commissioning this scheme and our alliance partners Roughan & O'Donovan for working in partnership with us on this project. We would also like to thank Imtech for their contribution to this paper.