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Understanding Linsig in the Real World

"All models are wrong but some are useful" George Box, Statistician, 1978

Introduction

For many years now, Linsig has been the go-to tool for traffic signal modelling. As it has developed over the years, it has increasingly secured a role both as a traffic model and as a design tool. It has also spread, quite literally, as the ability to model complex networks has been introduced and refined. On an isolated junction, the results from a Linsig model are easy to understand, making it a powerful design tool. The more complex the model, the more difficult it is to understand the results in the context of the real world.

In this paper we look at how Linsig is used to model complex networks in a 'useful' way. In particular, how to use and understand the model to get information relevant to the real world of network management, planning and I.T.S. It examines techniques to get the most reliable and useful model data, as well as helping to explain what the data means and the implications it can have.

Firstly, we should define what we mean by a 'complex network'. There is no hard-and-fast definition, but the phrase is used here to describe the types of network that are traditionally difficult to model and understand in Linsig, and used to be (and still often are) referred for microsimulation. They tend to have at least one of the following characteristics:

- Circular routes;
- Multiple valid routes between the same origin and destination;
- Restricted lane lengths between junctions or nodes.
- Interference between nodes caused by queuing – "Sliver Queues"

All these characteristics can be modelled and allowed for in Linsig, but the input and interpretation of the results is, to a greater or lesser extent, variable and difficult. In differing circumstances, all four characteristics may – or may not – be relevant. Tools are available in Linsig to automatically disable circular routes; flows are automatically assigned across routes and restricted lane lengths can be entered. None of these tools offer a 'correct' way to model these features though – the real world is just too messy!

Instead, we can (and should) focus on how to build the model to be as useful as possible, and to interpret the results in the real world. Future versions of Linsig may make our models more useful and accurate, but they will only ever be a model, not the real thing.

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Challenges

The first complex characteristic we have identified above, is the appearance of 'circular routes' in our model. This happens wherever our network provides a closed loop, in which traffic could theoretically pick a route from origin to destination that passes through similar parts of the network more than once – and potentially an indefinite number of times. The easiest example to understand is a driver circling around a roundabout, without turning off.

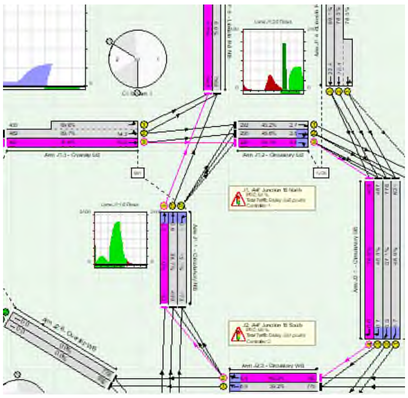

Figure 1. Circular route in Linsig

It is easy to identify this and Linsig removes most of these routes by default. In some cases though, drivers may actually use circular routes to avoid sitting in excess queues. In other cases, in town centre environment, there may be genuine circular routes used for dropping off and picking people up at specific points, often by taxis or buses. Both of these situations need to be identified and allowed for, if they occur.

The second characteristic, multiple valid routes, poses a basal challenge to the model – the problem of assigning traffic to lanes within a network. The Linsig assignment model by default allocates traffic based on delay, sharing the traffic out across all valid routes. But we know that different features affect driver lane (and therefore route) choice in different ways; a lane merging after a junction will discourage offside lane use on the approach. A well-used bus stop on the same approach will encourage use of the offside lane though. Neither of these will be automatically picked up or considered.

Figure 2. Nearside lane can technically be used for all ahead traffic, but is only really used by buses and taxis.

Probably the most difficult feature of all to model is the effect of restricted lane lengths between junctions or nodes. There are currently no automatic facilities to recognise and control a model to take short lanes into consideration, as the reasons for short lanes and consequences vary so dramatically. Fundamentally though, Linsig uses a 'vertical queueing' model, which assumes traffic in a queue has no physical length. This is due to the statistical nature of all the versions of Linsig so far, as the queues are calculated rather than measured. The queue length results are all statistical estimates of average values, based on uniform arrival, and so a true physical queue length at any given time cannot be derived.

With this in mind, it is difficult in many cases to predict what the effect of the queue will be. The average may be well within the available queueing space, however the 'peak queue' could exceed it. Again, this may, or may not, be a problem. There are features within Linsig that allow us to limit queuing, by penalising the capacity if the average queue exceeds a value. The penalty is arbitrary though, and the end result can be either ineffective, or overly harsh.

Because of the potential for queueing, often short links require good progression through coordination. As many experienced traffic engineers can testify, getting good progression on one route is easy, getting good progression on every (overlapping) route is not so easy.

Finally, sliver queues are one of the most common, but least understood phenomena to occur both in real life and appear in models. Many people ignore them, or 'de-sliver' their models without examining the cause. However anyone who while driving has found themselves in a queue for no apparent reason, only for traffic to speed up again, has experienced a real sliver queue. These can be real and can cause real problems. Linsig can identify them, but assessing the potential impact is a matter of judgement, not one that a computer can make.

Case Study – Queuing around A47 Junction 20 Interchange

The Interchange between the A47 Soke Parkway, and A15 Paston Parkway, in Peterborough, had long standing problems of queueing and delays on the Northern and Southern slip roads from the A15. The largest traffic flows by far are a dominant A47 East-West and West-East flow, at-grade. The interchange had not previously been signal controlled, but signals were considered to alleviate the existing delays and to enable growth. Many people in the local area, including some working for the local highway authority, had concerns about the potential for worse queues to form as a result of signalling the interchange.

Figure 3. A47 Junction 20 Southern off-slip queueing during off-peak

In modelling the proposed junction, we quickly established that there was no optimal 'minimalist' solution, involving only two or three nodes signalled. Quite simply, the Easterly and Westerly flows always dominate. Signalling just the off-slips would quickly create a queue back to the previous un-signalled nodes. Signalling just the A47 approaches, the queue on the circulatory would quickly block. An acceptable solution was found by signalling all four nodes, however we first had to be sure that we had understood the effect of queuing.

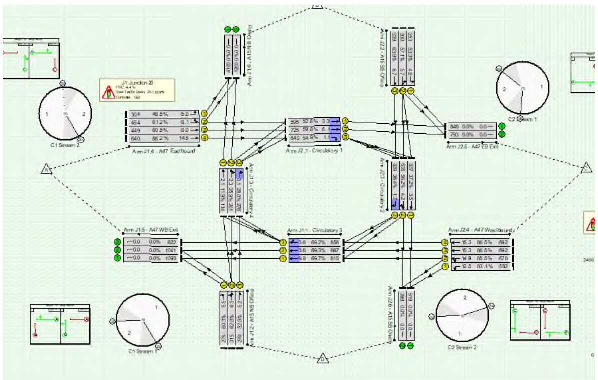

Figure 4. A47 Junction 20 Network Layout, four signalled nodes

The model results suggest that the proposed junction has positive Practical Reserve Capacity, and that the mean-maximum queue of all lanes is within the physical limits of the site. Before going any further, we 'normalised' the model, to more accurately reflect how the junction would operate in 'real life'. We firstly manually checked and optimised the busiest routes for progression, adjusting offsets using timing dials, while watching the time-distance diagrams and checking the mean-max queues.

Having achieved good progression, we then manually reduced the green times for external (i.e. approaching) phases to achieve a degree of saturation close to or slightly below 90%, giving the spare green time to the circulatory phases. This distorts the Practical Reserve Capacity results for the network, which now show close to 0% PRC, but mimics how most roundabouts and interchanges are conventionally configured in practice. Progression was then re-checked.

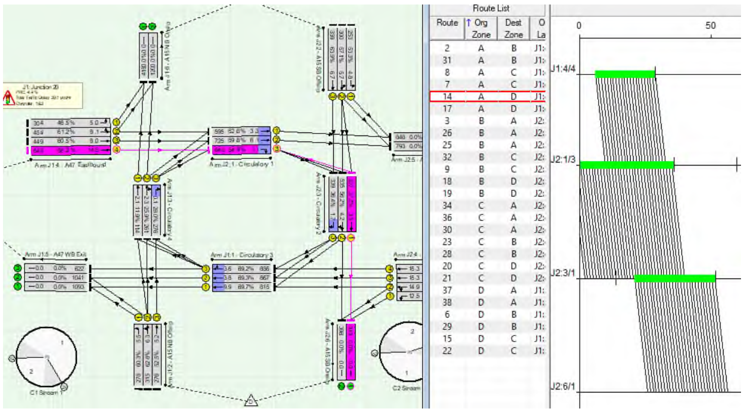

Figure 5. Manually optimising for progression using time-distance diagrams

The queue lengths on the shortest circulatory links now need to be looked at in detail. Linsig assumes a uniform arrival rate at all entries to the network, however in practice arrival rates vary, sometimes dramatically. On an approach lane with unlimited queueing space and assuming fixed time, the queue would be averaged out over the measured period, resulting in the predicted mean-max queue. The circulatory lanes do not have unlimited queuing space though, and if a queue forms over the previous up-stream stop line, these drivers could be 'cut off', failing to get green and resulting in a quick forming, excess queue.

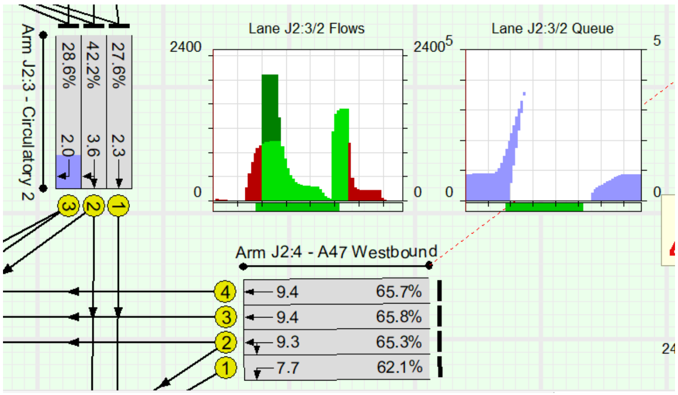

Figure 6. Examining MMQ, flow and queue profile

Where the upstream flow into the circulatory phase is limited to less than the available capacity at the downstream circulatory phase, the excess queue will form upstream – and not cause a problem. In this case however, the upstream phases (both the approach and first circulatory phase) receive long green times, several times longer than the short circulatory phase. Any variation in arrival rate will not be noticed at the first or second stop line, but would be noticed at the third, if there were an increase in traffic travelling West-to-South or East-to-North. The flows for these routes were predicted to be very low, but already used a significant amount of the potential queueing space. Low flows are less certain and subject to higher deviation than higher flows. It was therefore likely that these minor routes could cause significant queues, despite the initial indications of the results.

Using the model we predicted when each route was most likely block, when the mean-max queue was predicted to be highest. The progression was then altered by time of day to ensure that on these routes, the upstream phases kept right of way after the 'blocking phase' downstream gained right of way. Within the controller specifications, facilities were included to allow this, both in MOVA linking, and the CLF plans. The MOVA linking also included several additional features to detect queues forming at the upstream phases, in lanes associated with the short circulatory phases, and to hold these links, to clear the queue if it occurs.

In practice, the interchange operated as foreseen – to the model and as interpreted. Queues form quickly on the short circulatory phases in response to high variations in traffic arrival patterns – we suspect related to shift change times at large employers locally. The signals respond as fast as a queue forms, displacing the increased volume of traffic on to external approaches and holding green on the routes with a queue forming, relieving the queue before it has caused any problems, and giving good progression.

The site was validated in MOVA and CLF over two weeks and revisited after two months. During the validation, only two CLF timings needed adjustment and the MOVA linking was slightly relaxed. Additional facilities for queue clearance, including stricter MOVA Linking and Hurry Call overrides, included due to concerns over the potential for queues, have never been needed and are not enabled.

Case Study – Late Lane Changing at A47 Junction 18

Several miles West of Junction 20, lies A47 Junction 18, north of Peterborough City Centre. This junction is another grade-separated interchange, although with limited access to and from the A47 to the West via Junction 17. The junction has been under signal control for many years, and equipment is old and has become unreliable.

Since the parkway network was built, pedestrians have been able to cross the junction using a series of footbridges and an underpass. The concrete footbridges have reached end of life, and a scheme is in progress to build at-grade pedestrian facilities into the signals, including new footways, to enable the bridges to be demolished.

The junction has been congested for many years, and there has been a lot of concern about the impact of the scheme on traffic at a critical part of the city. We were asked to design and model the junction, to incorporate pedestrian facilities, while improving traffic flow. To aid the modelling process and give confidence, we had an external team from Atkins available to provide VISSIM microsimulation based on the existing VISSIM City-wide model of Peterborough. Together we designed a modelling process to iterate between Linsig and VISSIM, identifying problems, addressing them and testing against each other, comparing both against the current traffic conditions.

Key to the scheme was the ability to demonstrate any capacity loss or increase through various design options. To do this with accuracy though, it is essential to have a robust Base Model. The initial iteration of the Base Model in both Linsig and VISSIM was simple in construction of the model, and relatively conventional. The flows for both were taken from a recent origin-destination survey commissioned for the scheme.

When compared though, the initial results of both not only failed to match, but were at extremes on several arms, either side of the expected benchmark. The Linsig model showed high levels of saturation on several internal links, with a degree of saturation substantially in excess of 100%, while approach lanes known to queue showed as under-saturated. The VISSIM model showed none of the queues at all.

The problem in Linsig clearly starts on the links with greater than 100% saturation. In a base model, using traffic count data (not predicted or derived flows), it should not be possible to achieve a degree of saturation more than 100%, although a small margin of error is permissible and to be expected. This is because beyond 100% saturation, all remaining traffic should exist as excess traffic in a queue, and not be counted across the stop line.

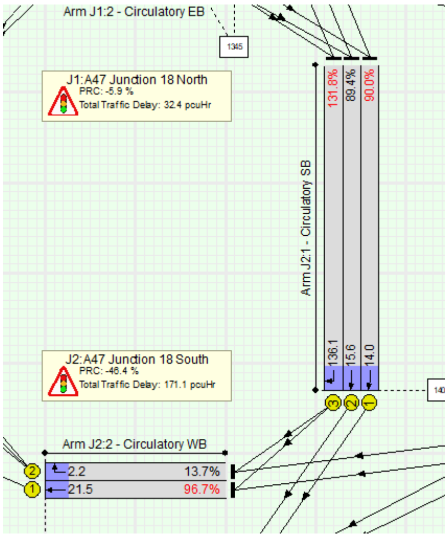

Figure 7. Base Model saturation unbalanced and significantly exceeding 100%

Other problems in the Linsig model could be attributed to queueing from the internal links. Assuming the links are at 100% saturation, with an excess queue, the standing queue would prevent traffic joining the circulatory even when they have right of way. This would result in undercounting in the traffic survey, and therefore a low degree of saturation on the lane on the model, as Linsig cannot predict interaction between the queue and upstream stop lines.

The cause of this problem was looked for during a routine site visit to validate the model. As well as measuring cruise times between nodes, lane designation and driver behaviour were observed. During this visit we identified driver behaviour and misuse of lanes as the cause of the error. The manoeuvre predicted by Linsig to have a degree of saturation in excess of 100% was indeed, at times, fully saturated. During these times though, some drivers would instead use an alternative lane, marked to a different destination. Having avoided the queue on the approach and first circulatory phase, they would then turn around the 'outside' of the roundabout, using a small area of hatching to merge back in to the correct lane, before the downstream stop line. In this way, more traffic was able to turn around the roundabout, than would fit in the single designated lane as modelled.

Figure 8. Driver changing lanes over hatching

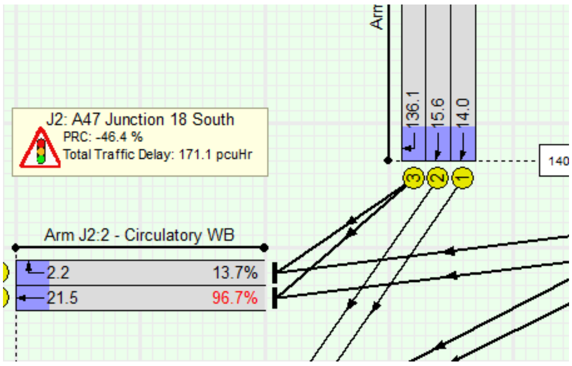

Figure 9. Lane Connectors configured as marked on-street.

This is not an easy situation to model in either Linsig or VISSIM. The obvious options are to only allow correct behaviour in the model, resulting in a large negative error, or to allow the unauthorised behaviour, by adding link connectors to create a valid route. Assigning traffic to this though, the Linsig assignment model distributes far too much traffic to the 'incorrect' lane, making the degree of saturation in the 'correct' lane disproportionately low and creating queueing in other lanes, where it has not been observed. Furthermore, Linsig cannot model the interaction between vehicles as they merge.

To solve this problem, a balance had to be struck in allocation of vehicles between the two possible routes – 'correct' and 'incorrect'. The observations we had made confirmed that this route was indeed saturated during the peak. We could therefore determine that a correct Base Model should show these lanes as being at or close to 100% Saturated. We could also assume that drivers would not choose to use the 'incorrect' route if the correct route has less delay. Having added the links, and locking the flow in the 'incorrect' route, we manually added traffic to it, before assigning the remaining traffic flow. Using the two assumptions above, it was possible to iterate through each scenario until reaching a point where the correct route was

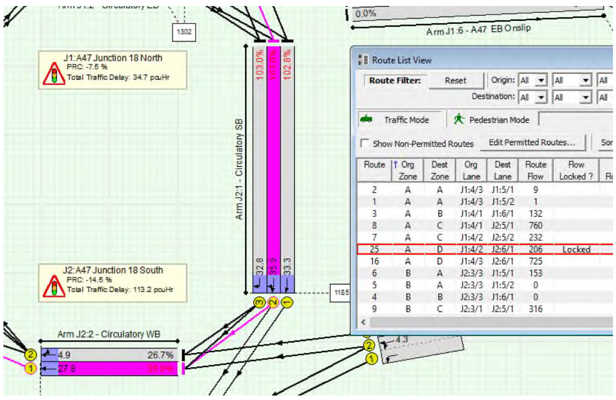

Figure 10. Additional Lane Connectors added, flows manually entered and locked. Degree of saturation balanced.

approximately fully saturated, and higher than or balanced with the lanes on the other route.

This approach, while based on judgement, allowed us to build a Base Model which correlates with real life observations. As a result we can be confident in using the results as a baseline to compare future models against. We would be concerned about the validity of this approach in predicting future performance, but the hatched area used for vehicles to merge is removed in all future design options, meaning that the models built to evaluate the proposals can be built using conventional techniques.

Case Study – A complex urban network, Peterborough City Centre

Peterborough City Centre is undergoing rapid change in recent years as retailers are moving into previously industrial areas, and urban dual-carriageways increasingly need to cater for pedestrians. Changes have included new junctions and crossings, as well as street scene enhancements. While these changes have been modelled and investigated individually, the overall combined effect had not been studied. With yet another signalled junction due to be built relatively close to a large unsignalled roundabout, a detailed model was commissioned, using both VISSIM and Linsig, to investigate the potential impact of the new junction, and to identify any opportunities for improving network coordination.

One of these potential opportunities was thought to be the ability to indirectly control the roundabout by coordinating junctions on each of the three main approaches.

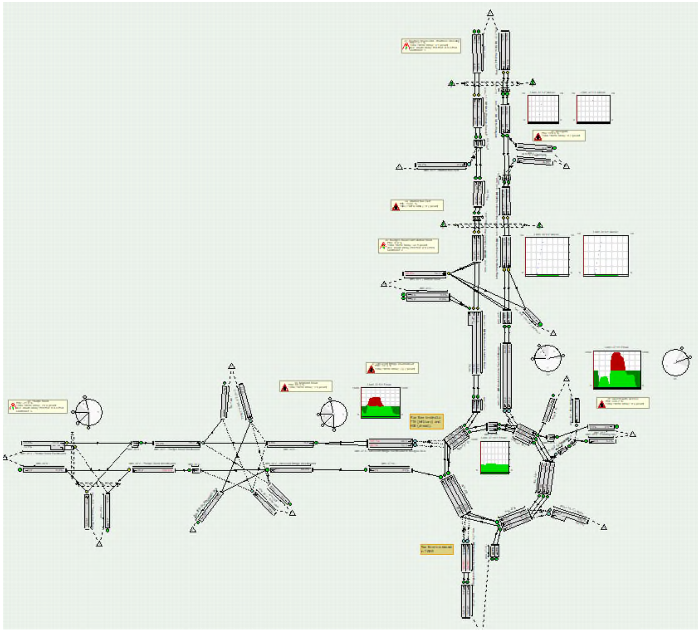

Figure 11. Crescent Bridge Network, Base Model

The approach taken was to build parallel models in both VISSIM and Linsig, again validating between the models in iterative steps. Several 'check' measurements of queues were made on site, specifically to compare the queue lengths from the VISSIM model. Turning count data from all junctions was collected and assigned to an origin – destination matrix using the Linsig Turning Count tool, and standard route allocation, before comparing lane counts against VISSIM.

Very quickly, a significant problem with traffic lane allocation appeared in Linsig. Using the normal allocation of traffic, around the large busy priority roundabout at the centre of the network, traffic appeared to choose unusual routes. By analysing the route times and delay, we can see this is due to (real) delay in one particular lane. As the roundabout has conventional markings requiring drivers to change lanes, link connectors allow this movement. Linsig is identifying these as opportunities for routing traffic with lower delay though and is allocating traffic accordingly. While some drivers may be doing this, the vast majority are not.

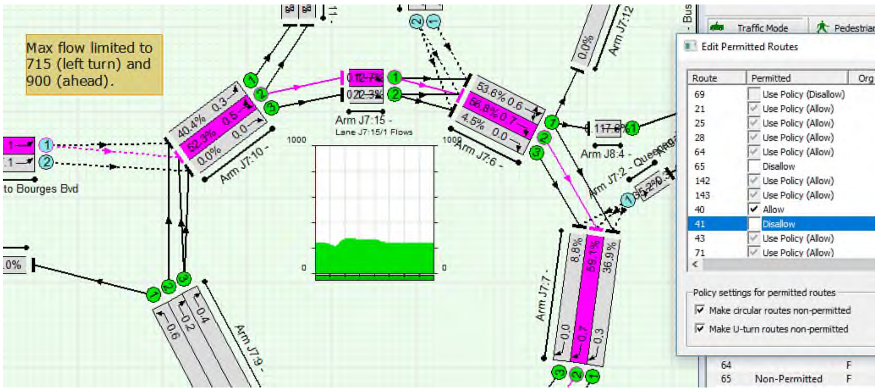

Figure 12. Routes manually disallowed

In order to solve this problem, the routes were analysed manually and routes involving multiple lane changes not seen on site were disallowed manually. The give-way characteristics of one approach lane was also modified away from typical ‘roundabout’ values and towards ‘left turn’ values, reflecting an unusual geometry and matching more closely what happens on site.

Queues throughout the network were examined in the Base Model, and compared with observations. The Linsig model appears to show throughout most of the dual carriageway network, that mean-maximum queues are within the physical restraints of the site. Local coordination through the dual carriageway section of the model also means that internal links should never be able to exit block as a result of main-road traffic, although additional traffic can join from a range of minor priority side roads.

While the modelled mean-max queues are within physical limits, and coordination means that any random excess queue is held on the approaches, not the internal links, Linsig did give warnings of multiple ‘Sliver Queues’. These queues form for a number of reasons, normally when traffic on a high-saturation flow lane is discharged into a queue on a lane with a lower saturation flow, after the start of the downstream green, but before the queue has cleared. In many cases these sliver queues are irrelevant and caused by statistical anomalies.

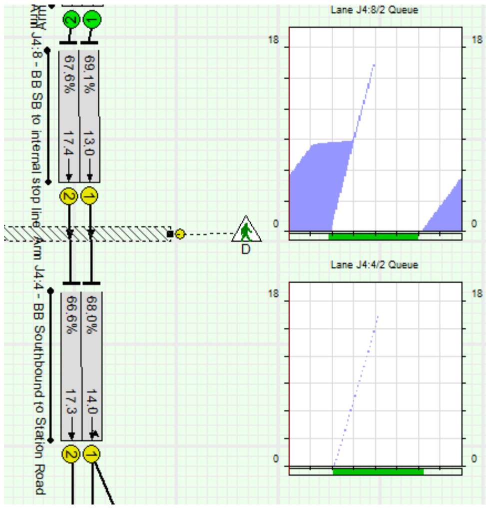

Figure 13. Sliver queues forming at start of green

Before disregarding it, the queue and its cause should be checked. By examining the queue profile diagrams, we can see in this case that the sliver queue reflects the lead vehicle from the upstream stop line joining the downstream queue as it clears the stop line. The front of the platoon then creates a further sliver queue as it reaches the next stop line at the start of green. This is highly efficient, as it results in maximum traffic discharge over the downstream stop lines. In these cases, Linsig has a ‘de-sliver threshold’ that can be set to ignore the phenomena and to clear the warning, although we should be aware that in this case, this is likely to be a real and observable.

Figure 14. Platoon of traffic passing through the same lanes.

Comparing the results to site observations, they can be seen to match closely. First observations indicated that this section of the network was oversaturated and queuing as a result. Closer observations though show that the road remains free flowing for extended periods – the queues within the network are being cleared. The queues within the network are actually platoons, moving through the network, passing each successive stop line at saturation flow, shortly after the start of green. In these circumstances, we can legitimately consider revising our model to reduce or remove the starting displacement on the shortest internal links, and on links with only a single controlled entry point and rigid coordination, random queueing can be ignored.

Ultimately, the development and new junction has been allowed to proceed. The concept of controlling the central roundabout by using the junctions on each arm was shown not to work, as the lower maximum saturation flow onto the roundabout causes each main arm to act as a reservoir, storing the end of a platoon as a queue. There is then insufficient time between the back of the queue clearing and the next platoon arriving to allow a meaningful increase in the flow at the next roundabout node. Some other options were shown to provide potential benefits, however the benefit was too low and uncertain, while disruption and cost was too high for the options to be feasible. While not identifying any improvements, the modelling work did allow the local authority to make an informed choice and to avoid costly and disruptive works, which may have provided no significant benefit.

Other Tools for Complex Networks

Some of the most significant errors in a complex Linsig model come from inaccurate input and assignment of traffic flows. Other than the standard origin-destination tables, Linsig also has an option for adding turning count data, as it is often collected. This can then be estimated into the standard OD matrix, with the error shown for each movement.

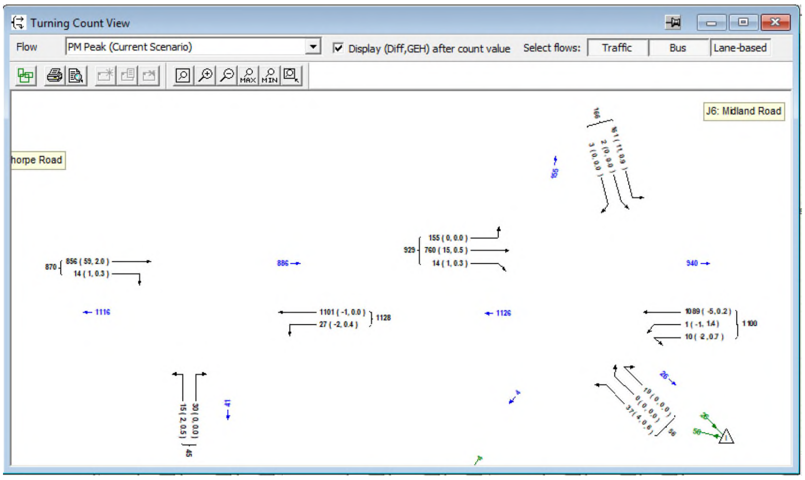

Figure 15. Traffic flow data entered as turning counts.

Another useful tool is the Lane-Based flow entry mode. Although there are fewer occasions when it is needed, this allows the user to add lane counts, potentially from automatic count points. Using Lane-Base Flows, traffic can be assigned to layers, allowing routes to be effectively managed based on traffic type, potentially making it easier to allow moves for some vehicles (such as buses, taxis and motorcycles), while prohibiting them for others (cars and vans), such as in the photo in Figure 2. This also has the advantage that it can be used at the same time as an OD matrix. The two in combination can be used to add data from different sources, although great care must be taken not to omit or duplicate any data. It can also be difficult to understand some of the results, as the input data is split.

In some circumstances, basic parameters through a complex model may change, either by time of day, or depending on the route of traffic (or nature of traffic). A bus station or HGV access may present vehicles that are substantially slower in real life than the average used in the model. When looking for the effects of this on coordination over successive stop lines, the margin of error multiplies. To improve the accuracy, it is important firstly to ensure that the travel times or speeds used on Lane Connectors is accurate, by measurement if possible. Where values may change significantly, the Lane Connector values may be overridden, by flow group, route or layer. Cruise times on the Lane connectors can be weighted to encourage more or less traffic onto the link during delay-based assignment. Platoon dispersion can also be removed where distances are short and coordination is fixed.

Conclusion

Linsig has a wide variety of tools and data which at times come in useful for complex networks, particularly the most difficult and error prone tasks. It is important to remember that a model is only as accurate as the data it starts with. The more layers of manipulation or extrapolation that data is put through, the higher the rate of error that should be expected. Likewise, as the size of a model increases, any inherent errors are magnified.

It is essentially a balancing act to keep models as small and simple as possible, while including as much detail as necessary to make the model useful. As the size and complexity of the model grows, it becomes increasingly important to use the tools available in Linsig to counter any errors.

Remember that Linsig (and all traffic modelling software) only provides an estimate, based on previous observations of typical behaviour, an assumption that behaviour will be the same everywhere and that this will remain true in the future. In reality, driver behaviour changes between regions, between sites and even by time of day. In most cases, not enough to substantially change the results, but all sites are unique, so there is always the potential. Be aware of this, measure anything unusual that can be quantified, and adapt the model if necessary.

More importantly than anything else, always interpret the results and if possible, compare the model against real life. If they don't match, the model is not useful.

Acknowledgements.

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