INTELLIGENT TRANSPORT SYSTEMS

Abstract

The introduction of the Traffic Management Act 2004 (TMA2004) set out Government’s vision to tackle congestion and disruption on the UK road network. The Act places a duty on local authorities to ensure the expeditious movement of traffic on their road networks and the interface with surrounding authorities.

In Essex, EssexITS (a joint partnership of Essex County Council, Atkins and Siemens), has taken a hands-on approach to assist the County Council in carrying out its responsibility under TMA2004. EssexITS has developed a number of Integrated Urban Traffic Management and Control (UTMC) strategies to manage Essex’s road network, tackle congestion and proactively prevent or reduce the effect of congestion.

UTMC systems are designed to allow the different technologies to be used within single platform management systems, enabling communication and interaction of different applications and systems. EssexITS has deployed a number of UTMC systems in the last decade, together with the implementation of the UTMC Common Database and have developed innovative traffic control strategies using a combination of UTMC technologies.

This paper presents a case study on the practical use of various UTMC systems and integrated strategies to tackle congestion. It looks into a particular congestion hotspot in Chelmsford, the Army and Navy roundabout, on the major route linking Chelmsford town centre to the A12 and A130. The traffic flow across this roundabout is often disrupted causing delay to traffic going into and leaving Chelmsford town centre.

The case study looks into how a combination of UTMC systems works together to deliver the most appropriate traffic control at this site.

Background of the site and the scheme

The site

The Army and Navy Roundabout is one of the most important interchanges in Chelmsford, it is situated south east of Chelmsford town centre see Figure 1. The roundabout connects the town centre with major destinations around Essex:

- The A1060 Parkway connects the roundabout with the town centre
- The A138 Chelmer Road is connected with the A12 junction 19 for Colchester, Ipswich and the coastline of Suffolk and Norfolk
- The A1114 Essex Yeomanry Way connects Chelmsford with the A414 to Maldon and the A130 to Basildon, Southend and Canvey Island. The A1114 also connects to junction 17 and 18 of the A12. Although not the natural route for traffic from/to the A12, it is often used as an alternative route

Figure 1 - The Army & Navy Roundabout
The A414 Princess Road links to the south of Chelmsford and A12 for Brentwood, M25 and London.

The B1009 Baddow Road connects to Great Baddow, a residential area near the outskirts of Chelmsford. There is a single lane one-way flyover connecting Parkway with Essex Yeomanry Way, allowing a dedicated straight ahead movement above the roundabout. The one-way flyover operates in tidal mode, opening ‘inbound’ allowing commuters from Essex Yeomanry Way to travel into the town centre in the morning and ‘outbound’ in the afternoon and the evening.

**Congestion hotspot**

Due to the location of the Army and Navy roundabout peak hours are normally heavily congested. The morning peak traffic flows into the roundabout from Essex Yeomanry Way towards the town centre. Minor traffic flow from Chelmer Road has priority over traffic not using the flyover. This causes tailbacks and more than doubles the journey time for vehicles. The reverse happens during the evening peak hours.

The dominant traffic flow on Parkway is helped by the flyover which has been changed to ‘outbound’ for Essex Yeomanry Way and the dedicated left turn lane for Chelmer Road, however, it is still usually congestion during evening peaks. Any long tailback on Parkway will have a severe knock on effect on traffic flow in the town centre causing other junctions and roundabouts to exit block.

There is also a large flow of traffic on Essex Yeomanry Way towards the roundabout in the evening, and because the flyover is used by vehicles leaving Chelmsford in the afternoon and evening, Essex Yeomanry Way is also always congested in the evening.

**Congestion scheme**

The ‘Essex Works’ campaign has set amongst its many objectives, to tackle traffic congestion. As a result, EssexITS has initiated a number of congestion schemes, one of them being at the Army and Navy roundabout.

The objective of this scheme is to tackle congestion and proactively prevents traffic accessing Parkway and Essex Yeomanry Way, allowing more efficient flow of traffic from Essex Yeomanry Way, and preventing tailbacks on Parkway causing congestion to spread to other junctions and roundabout.

To achieve this, EssexITS have installed part-time traffic signal on Parkway circulatory and the Chelmer Road circulatory as a part of an integrated UTMC control strategy for this site see Figure 3.

**Integrated UTMC strategy**

The integrated UTMC strategy for the Army and Navy Roundabout was to be rolled out in stages:

- Stage 1 – Implementation of part-time traffic signals
- Stage 2 – Timetable switch on of part-time traffic signals
- Stage 3 – UTMC Integration (Manual dynamic switch on)
- Stage 4 – Automated UTMC strategy (Automated dynamic switch on)
- Stage 5 – Pollution Control Strategy

**Stages 1 and 2 - part-time traffic signal and operations**

The first stage of the roll out was to install traffic signals on the Parkway circulatory node and the Chelmer Road circulatory node of the roundabout, allowing a certain level of control of the roundabout. Both sets of signals operated in part-time mode.
Integrated urban traffic management and control strategies

The Parkway circulatory traffic signals will allow the clearance of Parkway traffic when congestion is severe. Although the operation of the traffic at a roundabout might introduce inefficiency to its operation, the part-time traffic signal can be switched on only when it has a beneficial effect to the traffic and its adjacent network.

The traffic signal on this node was only be switched on when congestion is severe on Parkway causing tailback into the town centre. This requires an Urban Traffic Control (UTC) engineer to run a cast in UTC for the switch on of the signal when required.

The primary function of the Chelmer Road circulatory node traffic signals is to create opportunities for traffic on Essex Yeomanry Way to enter the roundabout during ‘inter-greens’. The diagram in Figure 4 below demonstrates the operation.

Figure 3 - Signal approval drawing for the Army and Navy congestion scheme and description of operation

Figure 4 - Clearance of traffic on Essex Yeomanry Way during inter-green periods
The traffic signal also has a consolidating effect on traffic flow on Chelmer Road, instead of ‘drip feeding’ traffic onto the circulatory, they are compacted and released as a solid platoon when the signal is green. This allows better flow from Essex Yeomanry Way onto the circulatory. The Chelmer Road circulatory traffic signal node is timetabled to be switched on during the evening peak from 15:45 to 18:00 to ease congestion on Essex Yeomanry Way. The effects of the signal can be seen from the CCTV images in Figure 5 and journey time graph in Figure 6.

Stage 3 – UTMC Integration (manual dynamic switch)

UTMC systems and strategies

The introduction of the Siemens UTMC common database, “COMET”, which links up with several UTMC compatible systems opens a vast range of new applications and strategies for traffic control. The link up of COMET with various UTMC systems enables the interactions between systems and integration of control strategies. An illustration of the EssexITS UTMC setup and example of such UTMC strategies can be found in Figure 7.

UTMC strategy example 1: Galleys Roundabout part time signal switch on by video detection

The Galleys roundabout part time signal is designed to ease congestion on the A120 during the evening peak hours on weekdays and at noon during weekends or holidays. The part time signal uses an innovative automatic on/off switch. A video detection system (using digital video processing) was installed on the A120 approach approximately 250m from the Galleys roundabout to visually detect queuing traffic. This system, Traficon, then passes on the real-time data from site to COMET. A number of automation logics are defined in COMET for the on/off switch of these signals, when the real-time traffic data from Traficon meets any pre-defined conditions. When this happens, COMET interacts with UTC for the on/off switch of the part-time signals. COMET will also interact with SieSpace (a variable message sign and car park guidance control system) to display messages on the variable message sign (VMS) informing drivers of the operation of the part time signals.

As traffic patterns change throughout the year the automation strategy ensures the signals are on, whenever required. Regular revalidation of the signal switch on/off times is no longer required and the signal operation is always responsive to the real-time conditions on site, including any exceptional condition such as incidents or accidents. The integration of three UTMC systems (UTC, Video detection and VMS) ensures a high level dynamic control of traffic which was not possible before.
Integrated urban traffic management and control strategies

UTMC strategy example 2:
Waterhouse Lane
SCOOT automation

Split Cycle Offset Optimisation Technique (SCOOT) is a centralised computer automated method of controlling traffic and is designed to implement synchronised control for multiple traffic signal sites to optimise traffic flow through a region. Under low traffic flow condition SCOOT can be unresponsive and drivers can experience delays in a SCOOT region. The Waterhouse Lane SCOOT scheme automates the switching of control modes of traffic signals, allowing drivers to benefit from the most efficient method of control in the region at anytime.

Strategies are defined in COMET to react to flow data for the region from UTC, and when certain pre-defined conditions defined in COMET are met, COMET interacts with UTC and switches the mode of control of the traffic signal region from vehicle actuation (VA) to SCOOT or vice versa. The switching of control mode of traffic signal is traditionally done via timetables and the automation of such ensures the most efficient mode of control is select based on real-time traffic condition and will not require constant re-validation of timetable entries.

Manual Dynamic Switch On of Part-Time Signals

As discussed earlier, the use of part-time signals is only beneficial under certain traffic condition and is traditionally switched on/off via pre defined entries in the signal controller or UTC timetable. As traffic patterns differ from day to day, reacting to temporary changes (incident/accidents) or permanent (road widening, new traffic signals etc.) changes to the road network, the operation of a fixed timetabled part-time signal is unresponsive and can be inefficient. It also required regular re-validation of the timetable to ensure the traffic signals operate at the optimal times.
For dynamic switch on operation the traffic signal is put under UTC (or Remote Monitoring System – RMS) control where it “listens” to UTC commands for the switch on/off. Two ‘casts’ are setup in UTC, one that switches the signal on and the other that switches it off and these pre-defined ‘casts’ can be directly actioned by an UTC engineer running the ‘cast’ command on the UTC terminal.

It is inappropriate for a UTC engineer to constantly monitor traffic flow and manage the switch on of the traffic signals or for any control centre operators to have direct engagement with the UTC system. This is where the COMET UTMC common database bridges the gap in providing an easy to use operator interface for various UTMC systems including UTC with pre-defined access levels see Figure 8. Corresponding strategies are defined in COMET for the switch on and off of the traffic signals, these can be action via the a symbol on the COMET map interface see Figure 9. When actioned, COMET will interact with UTC and action the corresponding “casts” in UTC for the switch on/off.

With the help of CCTV images, operators at Essex Traffic Control Centre (ETCC) can remotely switch on/off the signals, via COMET client terminals situated in the ETCC, on the Parkway circulatory node when traffic is queuing back into town and on the Chelmer Road circulatory node when congestion on Essex Yeomanry Way occurs.

**Manual Dynamic Switch On with VMS control**

The signal switch on/off strategies in COMET are also linked in with a VMS situated on the Parkway approach. A message is displayed informing drivers when the part time signals are in operation when the switch on strategy is actioned. When this happens, COMET also sends a pre defined command to SieSpace, another UTMC system that controls VMS, car park counters and car park guidance VMS. This strategy integrates the control of two completely different traffic systems and operates them via a single control strategy see Figure 10.

**Stage 4 - Automated Dynamic Switch On**

Images from CCTV can often be deceiving and manual strategies rely on control centre operators’ manual interventions in a busy and multi-tasking environment. This is often affected by operator’s perception and judgment which relies on attention, discipline and skill of individual operators, imprecise actioning of strategies and human errors are sometime unavoidable.

In order for precise and unbiased activation of UTMC strategies, EssexITS has taken an extra step to automate UTMC strategies.

**Site condition based activation**

During the installation of the traffic signal site, additional inductive loop detectors were installed on Parkway and Chelmer Road, these are linked to the traffic signal controller. These detectors do not have any direct input to the signal controller’s operation and are only relayed to UTC. There are also existing inductive loop detectors on the Essex Yeomanry Way approach, these are connected into another set of traffic signals (Essex Yeomanry Way bus gate) and traffic flow data is also relayed to UTC.
When this raw traffic flow data from the loop detectors is transmitted into UTC, it is analysed and converted into flow and congestion figures. Flow is the rate of vehicle movement across the detector, while congestion is the percentage of congested time (when a vehicle is present on a detector for 4 seconds). These data are then forwarded to COMET and are stored in the UTMC database.

An understanding of how the flow and congestion data reacts to traffic conditions is required. For example, the decrease in flow and increase of congestion following a high flow state suggests the start of a flow breakdown and queuing on site. The relation of this data to traffic condition could slightly differ between sites, but can be further understood by the study of historic data together with data from other systems such as CCTV and the journey time measurement system.

With the knowledge of the relation between these data parameters to the true traffic conditions on site, trigger points can then be carefully selected for the activation of strategies see Figure 11. For example, if the congestion is above 80% for more than 10 minutes on Parkway, and the flow is below 20 minutes, this suggests that there is serious congestion on site which could start tailing back into the town centre, spreading the congestion into other areas. When this condition occurs, the automated strategy will be activated and COMET will action a list of predefined commands, turning on the Parkway/Circulatory signals via UTC and setting the approaching VMS sign on via SieSpace see Figure 12.

The Chelmer Road/circulatory traffic signal node is automated in a similar way. When flow on Essex Yeomanry Way reaches a certain level, the signal will switch on to deal with the heavy flow, but since this is likely to have a negative effect on Chelmer Road there is another rule in the strategy that prevents the signal from switching on, or off, when congestion is excessive on Chelmer Road.
The automation of these strategies means that human intervention is not normally required in the management of the dynamic switch on/off of the signal. This enables more reliable and robust management of the signals switch on/off, however, the effectiveness of this automated system depends on having the appropriate triggers and conditioning logics defined and will often require a trial period to optimise.

Real-time performance based control

Traditionally, it has been difficult to quantify or measure the performance of signal control operation using available detection technology. Technical data such as flow, congestion, occupancy, headway and speed can be converted into performance indicators but this often requires complex modelling and is often difficult to generate in real-time. A more simple indicator of traffic performance that can be generated in real-time, with the current UTMC setup in Essex is “vehicle seconds”.

This is the journey time difference from the profile (benchmarked) journey time multiplied by the number of vehicles making that journey. The indicators allow the ‘effect’ of the traffic signal operation to be quantified in numeric terms. This enables performance based strategies that offers extra efficiency and effectiveness over the condition based (flow and congestion data) strategies. To understand this, we need to first understand how profiling works.

Profiling is a function in COMET that allows five minute slot profiles to be built up using real-time data, with a weighted moving average. For example, on Monday at 09:30, a journey time of 450 seconds is recorded, this will then be averaged (10% weighted) with Monday 09:30 profile journey time. Profiling happens every 5 minutes, therefore individual profiles exist for a Monday 09:30, Monday 09:35, Monday 09:45 etc. Profile is also based on day types, therefore the profile journey time data for Monday 09:30 will be different to the one for Tuesday 09:30, Sunday 09:30 etc (Figure 12). Profiling allows the build up of historic data in a way that enables direct comparison with real time data. Profile data is often understood as “what the data should be generally under normal conditions, at a certain time, on a certain day type”.

The comparison of real time journey time with profile data allows a measurement of journey time against normal average conditions and is useful in quantifying effects of new projects such as part-time signal installation, congestion plans and events such as incidents and accidents. Figure 12 shows a journey time on the Essex Yeomanry Way approach into town on the day when the part time signals were first switched on, showing the journey time reduction on the Essex Yeomanry Way approach.

EssexITS has deployed more than 80 Automatic Number Plate Recognition (ANPR) sites around the county over the last few years for measurement of journey times on major inter-urban and radial routes.
With the Army & Navy roundabout being one of the most important junctions in Chelmsford, journey time measurement is available on Chelmer Road and Essex Yeomanry Way across the roundabout see Figure 13. With the Army and Navy roundabout being the only major roundabout across these journey time routes any changes to the roundabout operation (e.g. part time signal operation) will be reflected in a change of the journey time.

When the Essex Yeomanry Way circulatory part-time signals are switched on, one would expect a decrease of journey time on the Essex Yeomanry Way route and an increase on the Chelmer Road route. However, if there are 20 vehicles suffering from the 10 seconds delays on approach A (200 vehicle seconds) and a 100 vehicles benefiting from a 3 seconds journey time reduction (-300 vehicle seconds), there is an overall improvement of -100 vehicle seconds justifying the operation of the part-time traffic signal.

EssexITS is proposing to install pollution monitors on approaches to the Army and Navy roundabout. These monitors will be UTMC compatible and will be able to be linked into COMET. These pollution monitors will enable pollution clearance strategies to be developed and triggered based on real time pollution levels on site. Any pollution clearance strategies can be operated in parallel with congestion strategies they may, however, conflict and, as such, strategy priorities will need to be defined.

EssexITS is proposing further automated strategies at the Army and Navy roundabout, not to tackle congestion but to control the level of pollution. The junction is within an Air Quality Management Area (AQMA) and as such it is essential for Essex County Council to reduce the pollution level at this location.

Emissions from vehicles are especially poor in start-stop traffic, the use of traffic signals on queuing approaches to the roundabout could reduce vehicle emissions by compacting traffic into platoons and transporting them in batches, by running long green/red timings at the traffic signal on the roundabout. This will reduce the amount of start-stop movement and smooth the travel approaching to the roundabout; however drivers might experience longer waiting periods for the red signal due to the long green stage timings on other approaches.
Conclusion

The implementation of the UTMC framework in Essex allowed different traffic technologies to communicate and to be used within a single platform. Together with the introduction of the UTMC common database, different traffic system with different purposes can interact enabling new and innovative network management applications.

Unlike most other traffic systems such as UTC, the UTMC common database offers a user friendly graphical interface for traffic operators, enabling control centre operators to indirectly engage with traffic systems that are traditionally only used by traffic engineers.

Simple strategies can be predefined in the common database for functions such as the display of legends on VMS or the switch on/off of traffic signal via the click of a button. More complex strategies involve logics where a vast range of real time data from various UTMC systems can be used as triggers, whether it is flow data from a UTC site, ANPR journey time data, pollution data or car park occupancy etc. The resulting control from a UTMC strategy can also exist in many forms, whether it is the display of messages on VMS, traffic signal timings, plans or mode of traffic control, change of car park status etc. As such, any real-time data from any UTMC systems can have an influential effect on the operation of other UTMC systems. For example, traffic signal can now use real time journey time data, pollution levels, and data from other traffic signal sites as inputs that enable the optimal control to be implemented on site.

As demonstrated in this case study of the Army and Navy Roundabout congestion scheme, the linkage of the UTC, ANPR-JTMS, SieSpace with COMET has opened up vast opportunities for innovative network management strategies for the optimisation of network performance. Many of these strategies are developed to give a co-ordinated high level control across different traffic control platforms based on real time traffic condition and performance on site.

UTMC has opened up a new chapter for the industry, and innovative UTMC strategies are rewriting conventional methods and tactics used in traffic signal control and network management.