Digital Data for Traffic Signal Controllers. DCIS – the traffic signal controller information standard

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Introduction

This paper will provide an overview of the current position of the Transport Technology Forum's Digital Controller Interface Standard (DCIS) project, its objectives, the rationale for why the project is being undertaken and its current position in a continually developing arena.

The focus will be on the technical content of the suite of files that allow digital representation of signal-controlled locations on the road network (a "digital twin") but there will be some consideration of how the data may be used, and how it may be created as a by-product of normal traffic engineering processes.

Background

Up until recently, there was no need for the details of a traffic controller to be shared for other users. Traffic modellers and other parties had a sporadic interest in how a controller was configured, thus controller configurations could be stored and managed locally.

As we move to a connected digital future, there is a need to make this data available more widely in a standardised form. The use cases for this are around building a "digital twin" of the entire road asset that can be shared, for example to:

a) enable better planning of others' works e.g. utilities – by knowing detector locations and lane allocations, and by working with digital twins of the utilities under the junction
b) support emerging connected vehicle services such as Green Light Optimal Speed Advise (GLOSA) as they roll out from pilots to national services
c) simplify the data collection effort needed for better modelling of traffic networks, especially across authority boundaries
d) build better sat nav routing through knowledge of controller attributes, as well as permitted route options for all modes
e) enable new data driven services that need to know the characteristics of traffic signals across the nation

As well as connecting to today's vehicles and enabling new services, future highly automated vehicles will need to know far more than humans do about the configuration of a controller. These vehicles will need to know the "rules of the road" in terms of lane allocation, timing periods and real time status. To do this, each signal site in the UK will need a unique location reference from which these new services can find the data they need.

As the "digital twin" movement continued to expand, DfT were keen to ensure that signals were neither omitted or developed by people without signals knowledge. Hence the DCIS project was started through the Transport Technology Forum (TTF), mixing a team of seasoned signal experts with data and connected vehicle expertise.

The DCIS project also has a key role for Local Authorities and maintainers, as it will help move towards more digital processes and sharing of information. We are currently collecting a set of use cases for these stakeholders.

As an example, the DfT asked how many signal-controlled junctions and crossings exist in the UK? There was a level of concern when it was realised that this was not easily accessible and regularly updated. At a time when the quantity, resolution and functionality of available data sets is an entrenched characteristic of how our connected world works, this was felt in need of a solution. Site unique numbering, classification and identification, site layout, site control 'logic' were then identified as key elements within the scope of the DCIS project of value to external users and data providers alike.

When this was coupled with the emerging need for connected vehicles to respond correctly to traffic signals, and to support future highly automated vehicles, it became apparent that the UK needed to put in place structures for the standardisation and management of data relating to signalised locations on the network – as part of the "Digital Twin" approach.

Those who have awareness of the connected and autonomous vehicle (CAV) sector will know that many elements of information generated or consumed by these vehicles have already been standardised, (or are going through that process). However, in much the same way that, while the UK follows the BSEN50556 and BSEN 12675 standards for traffic signalling systems and traffic signal controllers respectively, we still also require TOPAS2500 to define those traffic engineering methodologies that are specific to the UK. Subsequently, we need standards for how information about signalised junctions is presented that recognises these UK-specific needs.

So the DCIS project was commissioned by DfT via the TTF to occupy that space in the array of applicable standards. It defines a digitisation not only of what a signalised location is, but also how it is laid out and what it does in a set of JSON (JavaScript Object Notation) files.

In developing these JSON files, we have given thought to the lifecycle of signalised locations. This is from definition of original need through planning and modelling to procurement, installation and commissioning, then through to operation and maintenance and ultimately to the end-of-life upgrade or removal. The files need to remain relevant and accurate throughout the lifecycle of the site. The content of the files has to be broad enough to support the many stakeholders who are involved in this lifecycle while remaining sufficiently bounded to be manageable.

For many of these stakeholders, for example sat nav providers and CAV services, there will be benefits in receiving standardised information about a junction and in adding or developing the content and passing on standardised data to the next stakeholders in the lifecycle. It is however acknowledged that for the content creators – typically Local Authorities (particularly in the initial seeding phase support is required to ensure benefit can be derived later as their uses cases mature).

As examples of these use cases, standardised data allows better comparison of sites and their attributes and parameters across a whole estate for maintenance, as well as between different users. It also allows users to extract dedicated knowledge relevant to their needs, whether it is easing the burden of unpacking stages to phases when optimising or refreshing UTC strategies, supporting, more realistic emulation of controllers in network models, or providing an indication of pedestrian facilities for the disabled community. And in the longer term, standardised data enables a connected and then automated vehicle to know everything it needs to about the crossing or junction that it is approaching, and supplement its on-board sensing and data resources with specific roadside data to ensure the smoothest and most efficient movement through the junction.

What? Structure of the JSON file suite

In defining a signalised site, it is crucial that we know where it is and important to understand what it is and who owns or is responsible for it. We need to know the layout of the site, the signals on the site and the detection, and lastly, if we are to understand how the site will respond to traffic then we need a set of information about how the site is configured.

After taking a look at portable and temporary sites and considering the effect of their short-term presence on the network, the processes required to oversee their placement, set up, use, and removal, we parked this more challenging problem and settled on developing a workable system for permanent signal-controlled sites.

The following sections of this paper look at the data format employed as well as the parts of the proposed JSON file suite including unique site identification, intersection summary document, site layout information and at the controller facilities and how they are set up for each site. An overview is shown in Figure 1.

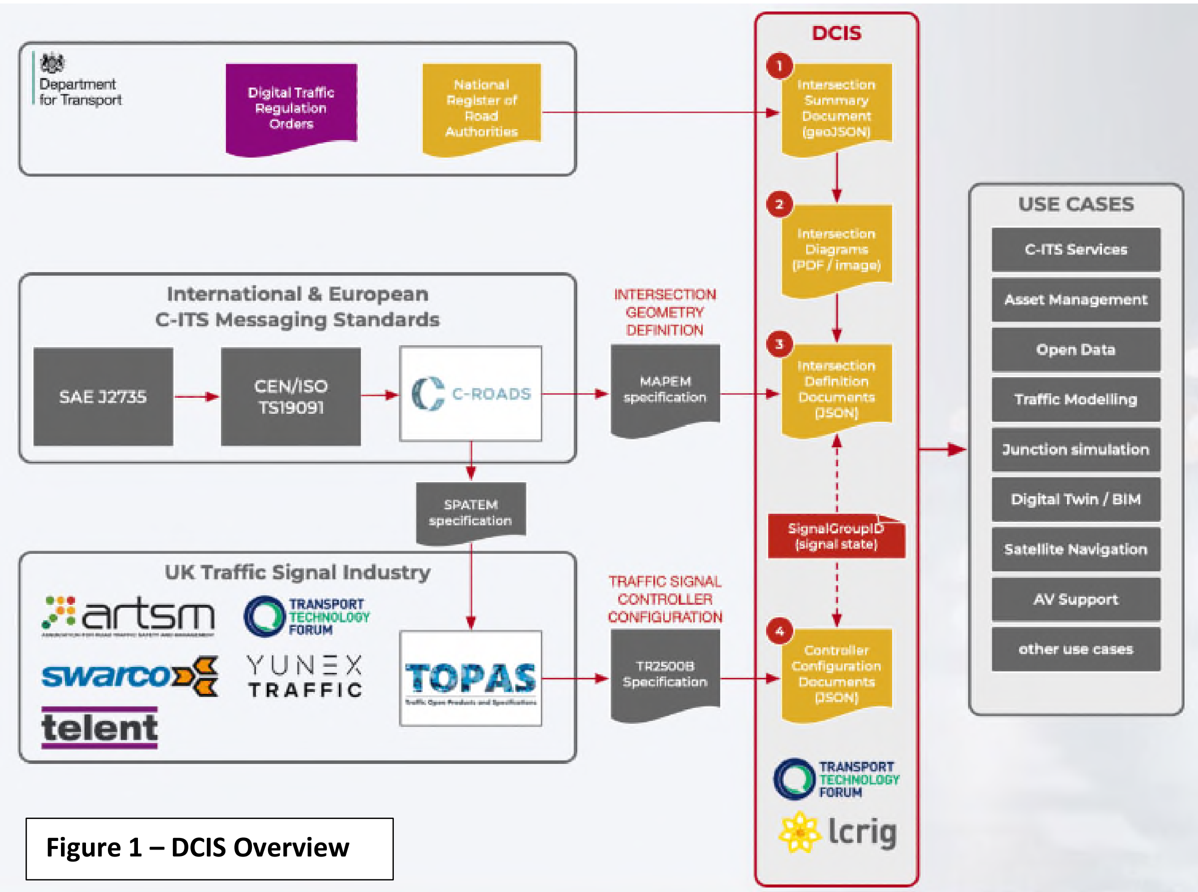

Figure 1 – DCIS Overview

Data Format

Why JSON? In determining the need for a standard consideration has been given to the optimum data for storing, sharing and processing the data. The data needs to be easily exchangeable, platform agnostic and ultimately an open format. Both JSON and XML (eXtensible Markup Language) were valid candidates however JSON was selected in the end as it:

a) Doesn't require a dedicated parser
b) Is arguably both simpler and more flexible
c) Results in smaller files

The need for a unique site number

Traffic signal numbering across the UK has historically been undertaken at a 'local' signals team context, typically within a defined geographical area aligning with authority or wider operational boundaries. The style of numbering employed varies greatly. Some use UTC style notation with other areas using locally bespoke schemas incorporating attributes such as local region identifier, site type attributes etc typically combined with a unique numeric value.

Historically, there has been little need to avoid conflict or overlap between discrete 'areas'. However, to support endeavours that require 'Country- (and continent-) Wide' datasets, a unique numbering system needs to be developed in order to ensure each site can be identified (and data accessed) uniquely.

We emphasise strongly that this number is an additional reference and in no way edits or changes the ID schema that is in use for day-to-day operation.

The 'how' of numbering - LA Level / Site level

Fortunately, we are not setting out to create a standard of how to uniquely number sites as this has already been undertaken by C-Roads (https://www.c-roads.eu/) who are a cross European consortia of authorities and road operators aiming to harmonise standards across Europe.

Within the standard the number (intersectionreferenceID) is made up of two parts:

- Authority level (RoadRegulatorID). This denotes the area in which the site 'belongs' and will be also incorporate a country code component. This is assigned from a central register and not within an Authorities' gift to dictate
- Site level. This is the point at which data set creators allocate an ID to their sites. This is undertaken at a stream (conflict area) level in order to align with how MAPEM files are created

Site ownership and operation is not always clear cut which may impact on how a site is numbered. A key part of the DCIS project is to ensure that a suite of guidance documentation is created to support both the simpler numbering end of the spectrum through to the more complex cases.

Intersection Summary Document

At the simplest level, the data model provides a standardised method for capturing the Intersection ID along with geographic location. However, there is also the opportunity to capture a simple site ontology e.g. the 'high level' site type junction, Crossing etc as well as more detailed attributes including types of crossing facility. It is considered that this approach yields great benefit for relatively little effort and will provide a unique reference that works not only within the DCIS space but the wider digital twin of the built environment.

Figure 2 shows a sample Intersection Summary Document.

```
{
  "type": "FeatureCollection",
  "version": "20230621000000",
  "roadAuthorityId": 2741,
  "features": [
    {
      "type": "Feature",
      "id": 10540,
      "properties": {
        "location": "Green Lane / Front Street",
        "altSiteId": "YK2254",
        "siteType": "Junction",
        "subType": [
            "Farside Pedestrian"
        ]
      },
      "geometry": {
        "type": "Point",
        "coordinates": [
          -1.12529400,
          53.95517000
        ]
      }
    },
    {
      "type": "Feature",
      "id": 10620,
      "properties": {
        "location": "Boroughbridge Road / Beckfield Lane",
        "altSiteId": "YK2262",
        "siteType": "Junction",
        "subType": [
            "Nearside Pedestrian",
            "Nearside Toucan"
        ]
      },
      "geometry": {
        "type": "Point",
        "coordinates": [
          -1.13350153,
          53.96985801
        ]
      }
    },
    {
      "type": "Feature",
```


Figure 2 – Intersection Summary Document

Site Layout

An important part of the effective operation of any signal-controlled site and communication of that to other digital stakeholders is an awareness of the approaches to and exits from the conflict zones. Knowledge of factors such as how many side roads or filter lanes are there into or out of which traffic may be gained or lost, what flares are there on the approach to the stop line for additional queue storage and many other layout considerations all affect the choices of control strategy and the specific set up of each site.

Similarly, the placement of signals and other roadside equipment and of loops or detection zones also affect traffic engineering decisions and are of potential use e.g. to a connected vehicle, signals maintainer or another entity such as a utilities contractor.

Within the suite of JSON files, most of this information is held in the MAPEM file. For the DCIS team the MAPEM file is perhaps the most straightforward file, as it is fully defined in the library of C-Roads documents and this paper will only provide a simple summary of the file.

The file is tied to the other files in the DCIS suite by the intersectionreferenceID which appears in the numbering file and the controller data file as well. The topicality of the file is defined by its version numbering and related content on keep-alive time before seeking a fresh copy of the content.

Layout - CEN/ISO TS19091 – MAPEM

The format and content of MAPEM files is defined in the C-Roads standards and related document set. This is still a work in progress and the DCIS team are working to confirm that this is applicable to the range of UK signal-controlled sites.

The essence of the MAPEM file is that a single nominal location is defined at or close to the centre of the crossing or junction. The lanes (which can be attributed to modes) into and out of a conflict zone are defined by a series of nodal points placed along the central axis of each lane. Each nodal point is defined by offsets from the reference point. Nodes are placed so that the deviation of the interpolated lane centre line does not exceed a permitted level of error. Both offset referencing and sparse node placement minimise the file size, important for wireless transmission of the content from the roadside to vehicles but less so for other use cases.

Nodes on ingress and egress links are numbered upwards from the edge of the conflict zone. Ingress nodes numbered 1 are then mapped to egress nodes 1 for the permitted turning movements. A vehicle traversing a junction will follow node numbers counting down to the stop line, then have a permitted trajectory to its desired (and permitted) egress lane and will then follow the node numbers on that lane starting a 1 and counting upwards. (While DCIS is not concerned about roads between signalised locations, these are also mapped by lanes and nodes that abut the ingress and egress lanes). Figure 3 shows key MAPEM characteristics overlayed onto a simplified site plan.

Lanes may have attributes associated with them, for example bus lanes or cycle lanes. Pavements and pedestrian crossings also have lane definition by nodes and numbering so that all types of road user can be catered for.

Similarly, the attributes of lanes may be set for certain periods of the day or according to other controlling criteria. Bascule bridges are a good example of a situation where the road is only useable when the bridge is in the lowered position and traffic can flow.

MAPEM files also support information on the location and identity of traffic signals, allowing the signals on each lane to be correctly assigned.

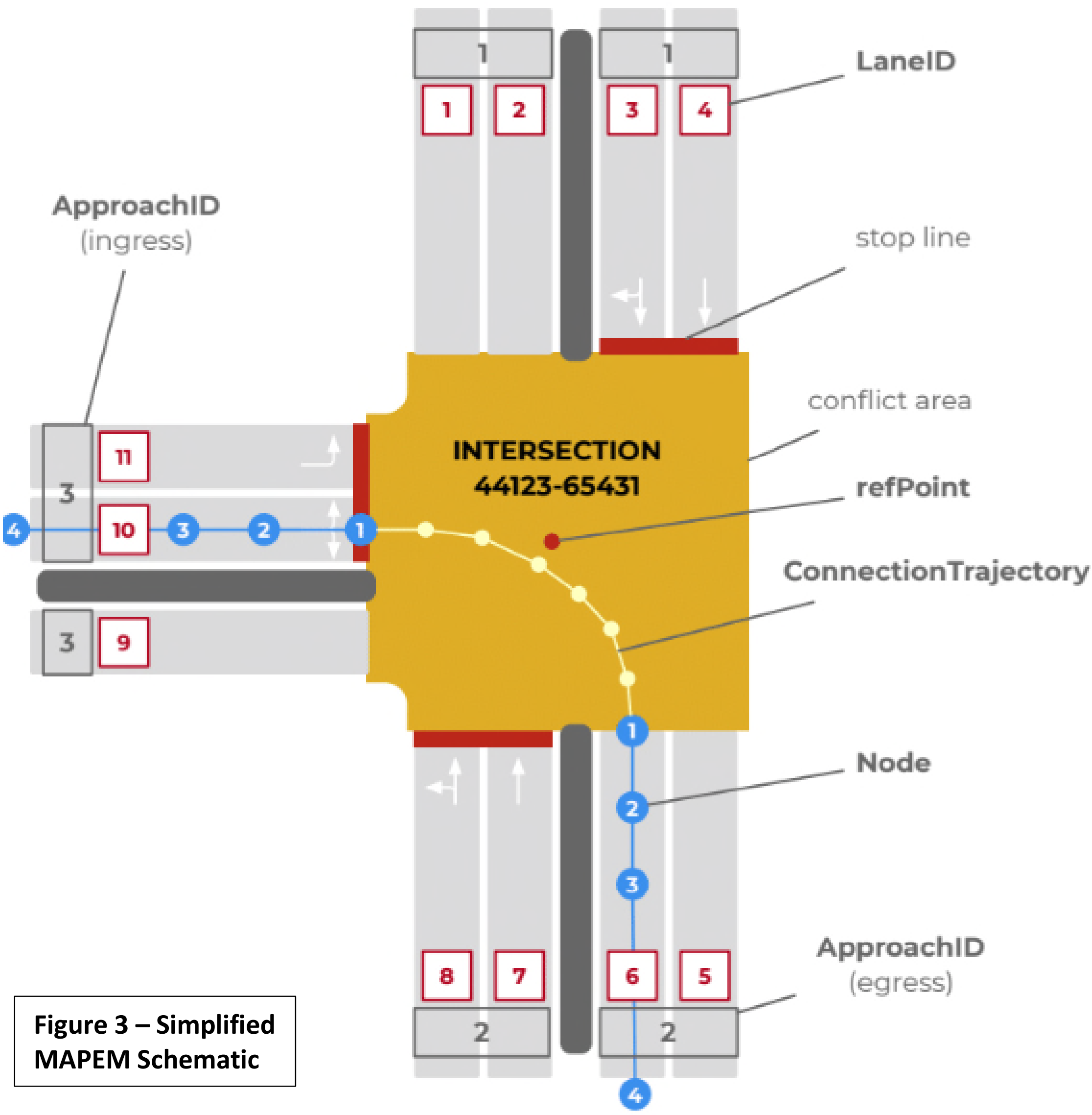

Figure 3 – Simplified MAPEM Schematic

MAPEM Creation

Up to now, UK projects that have required MAPEM files (for example those deploying GLOSA) have relied on the manual implementation and checking of the content. This is not a viable option for every site in the UK. However, in common with other digitisation activities such as the location of sub-surface assets, cable runs, ducts, pipework, etc., the availability of CAD drawings goes a long way towards supporting automation of MAPEM file creation. Pragmatically, if there is an intervention at an old site where the records may not be compatible with this type of automation then there is a strong possibility that reason for needing to provide these files is that the site is being included in a scheme or project and as a part of that work sufficient changes are occurring to lead to the creation of CAD and thereby the creation of MAPEM. That is, the process will be a need-driven one so it can be swept up in project activities.

The DCIS project has not yet reached the stage of addressing how this will occur, but given the level of work on the digitisation of assets and availability of CAD, we do not foresee significant disruptions to normal project processes and methods being necessary to generate 90% of the content of MAPEM files. We anticipate that there may be more work in identifying and mapping specific traffic signals on specific phases to the right locations.

Additionally, although not in the scope of DCIS, a project is being overseen by ARTSM for a TOPAS specification on detection protocols which will specify the location and nature of detection zones and their mapping to controller inputs, it is anticipated that this will sit alongside the DCIS datasets and consideration is actively being given to ensure appropriate 'touch points' exist.

eTOPAS

At the core of the DCIS information pack, we propose to provide a representation of control logic used to 'run' a site i.e. a mirror of the static data within the configuration. This is not something that currently exists and there are no European (or wider standards) that can represent UK traffic control logic.

Furthermore, the current UK standard for a traffic signal controller TOPAS2500 (and formally TR2500) dictate the 'what' but not the 'how' of how controllers are designed and built by manufacturers. This 'open' strategy promotes innovation and subsequently different ways of achieving the same end however due to this 'openness' this does not lend itself to a standardised model for how controllers actually operate. If we come at this from the other end of the process, the customer requirements, these can vary wildly and must be 'processed' by a configuration engineer in order to produce a configuration that works on a specific manufacturer's hardware thus these are not considered a viable process for producing a standardised data model.

We must also be aware of historical context. Automated traffic control is not a new concept and proposing a 'controller logic' data model long after the first controller was deployed on street, combined with the low 'churn' rate of equipment consideration is not without issue. Any standardised structure needs to be created, developed and maintained in such a way to capture the current and recent history (of control logic) as well as providing a platform for the future - there will be compromises.

In order to facilitate adoption and understanding, we are proposing to call this JSON file the 'eTOPAS' this embodies the historic tradition of the customer requirement documents being referred to as 141 files, TR2500 etc with the 'e' to denote the 'standardised' electronic outcome of a configuration.

eTOPAS Concept

The data structure itself will be based on normalising key attributes contained within controller configurations as far as possible from supplier configurations while reducing/converting supplier specific methods and facilities to common structures. For example, it is proposed to number phases from 0 with a label attribute, this approach will allow differences relating to dummies to be ironed out.

The approach to develop the DCIS eTOPAS has been based on an existing configuration for a MOVA T-junction with configurations created by the main UK controller suppliers for their hardware. This has allowed the DCIS team to explore how the customer requirements document is translated into a configuration within a supplier's toolset in order to identify the commonalities as well as the differences, be they subtle or dramatic.

One of the key areas of work that has taken place while developing the data structure is to attempt to understand attributes within a configuration that are implicit or only accessible within the controller as a derived state as these are likely to be core to site operation and are not likely to be directly contained within a configuration file.

Going forward, the plan is to further extend the test site configuration by creating further derivatives to allow additional features and facilities to be added (crucially to increase the complexity not necessarily to accurately mirror a real-world site) in order to understand the impact on the controller configuration in order to extend the eTOPAS JSON structure. This will then lead onto creating eTOPAS files for additional sites in order to further test and refine the structure.

Figure 4 shows the header section of the current version of a sample eTOPAS.


```
{
    "overview": {
        "_comment": "Digitised TOPAS2500 in JSON concept mapping. including
            Control (4.4) and reply (4.5) of TOPAS2523B",
        "version": "1.0",
        "created": "2021-05-28T09:40:23.000Z",
        "disclaimer": ""
    },
    "site": {
        "uId": "4401310410",
        "lhaId": "NLC-1-041",
        "generalDescription": "A18 Queensway / Dudley Road, Scunthorpe",
        "type": "Junction"
    },
    "versionHistory": {
        "0": {
            "issue": "0.0.2",
            "description": "Original configuration",
            "created": "2020-09-16T16:41:51.000Z"
        },
        "1": {
            "issue": "1.0.1",
            "description": "Continued",
            "created": "2020-09-16T16:45:04.000Z"
        }
    },
    "environment": {
        "configuratorVersion": "IC4 15.0.3",
        "controller": "ST950ELV",
        "firmwareType": "46059",
        "firmwareIssue": "16",
        "configRef": "E82763",
        "configChecksum": "4CB048B2",
        "configIssue": "1",
        "created": "2020-04-30T00:00:00.000Z"
    },
    "dimming": {
        "dimmingRequired": true,
        "dimmingVoltage": 27.5,
        "dimmingCallDelay": {},
        "dimmingCancelDelay": {}
    },
    "facilities": {
        "masterTimeClock": true,
        "holidayClock": true,
        "ftToCurrentMax": true,
        "startingIntergreen": 11,
```


Figure 4 – eTOPAS (part)

eTOPAS Creation

It is considered (at least in the short to midterm) that the only viable mechanism of creating the eTOPAS JSON will be as an output from the software tools created by traffic signal controller manufacturers to create their own controller configurations, as they are the only parties with the internal knowledge of how their tooling produces an outcome.

Dialogue is already under way between the DCIS team and key parts of the supply chain in order to understand how a standard can be created that delivers the largest amount of data from the configurations for the minimal effort. However, it is understood that changes will be required both in data supplied by the 'client' e.g. intersectionID and the software used to create the configurations in order to ensure an outcome that makes the best use of existing processes and data without significantly increasing the time to create (and specify) configurations.

It is also acknowledged that there will be areas that cannot be reasonably represented within the JSON these include areas such as special conditioning which is unique to a single manufacturer's toolset. In this case it is proposed to include this within a special field with appropriate warnings and notes as to the nature of the content. If we try and do everything, we will invariably achieve nothing!

DCIS – Getting along with the neighbours

It is also crucial to note that the DCIS data will not exist in isolation! There are other projects within the highway space looking at developing and improving digital twins. These include:

a) the Digital Traffic Regulation Order (DTRO) approach which includes digitising existing TROs both for road closures and banned turns (amongst others) and storing them in a standard model (as for DCIS) in a central government run store for use by interested parties including LAs, sat nav and service providers to support more flexible future for elements such dynamic kerbside allocation
b) Other digital twin projects looking at the roads that feed into a junction and works by Geoplace to create a much-improved underground asset register for the space underneath them
c) STREETMANAGER, which holds permits for temporary works and will provide a link to temporary signals
d) The National Parking Platform, a centralised repository for parking details using DTROs which will show the value of centralised nationally available data to users by allowing payment for all parking via a single app
e) Connected vehicle services that need to know signal configurations – for example to route HGVs to avoid left turns for cycle safety, and to support the wider roll out of GLOSA with its environmental benefits
f) As part of the data suite needed by automated vehicles to safely navigate the UK's complex roads

Summary

The UK Government wants the entire UK highway network digitised for consumption by current and future users. This paper merely highlights one small thread of a much wider tapestry in an effort to set out the evolving thinking that is being employed.

We believe that each part of the DCIS file suite has the potential for great value and when fused together has the capability to provide an outcome that is greater than the sum of its parts. We have identified use cases which we believe will benefit signals teams in authorities, signal companies, navigation providers and modellers through savings in time, improvements in accuracy and previously unachievable scale. We also see opportunities for delivery of focussed services e.g. in Active Travel which have previously relied on implied or inferred data.

The benefits of the proposed approach can then be further extended by incorporating other datasets that were typically discrete e.g. mapping TROs at traffic signals and being able to easily incorporate these within a model of the junction itself or the wider road network, or checking each banned turn in a signal controller has an accompanying Order in law.

This project (and its outcomes) cannot work without continuing engagement and feedback from the UK traffic signalling community. There is no intention of steamrolling parties into adoption this must be an approach that fits in with business-as-usual processes in order to deliver the necessary scale for benefit to be realised.

The end. So far…