

Kirklees Traffic Signal Maintenance AI Project

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Abstract

This paper is based on the experience of deployment of an AI based traffic control support system in Kirklees. It will outline the challenges and opportunities created by introducing a new form of traffic control based on the Simplifai control approach. The points that will be covered will be:

- How to create an AI readable digital twin for traffic control
- How to set a goal for traffic control and can be understood by machines
- The skills needed to use new control techniques
- The outcomes from the deployment in Kirklees

The project has been funded by the Department of Transport as part of the Traffic Signal Maintenance Fund

Simplifai Control is protected by patent pending GB2110405.4 and Simplifai is a registered trade mark.

Keywords:

Artificial Intelligence

Data Integration

Digital Twin

Introduction

In May 2021 the Department of Transport initiated a competition to improve the maintenance of traffic signals in England. Local authorities submitted proposals to the competition and 39 were awarded grants to implement the proposed projects. Kirklees Council was successful with its proposal in the maintenance competition and this project is to deliver the AI element of that proposal.

Kirklees Traffic Signal Maintenance AI Project Objectives

The original concept formed between KAM Futures (Simplifai Systems predecessor) and Huddersfield University was to develop “Autonomic Road Transport Support Systems”. The concept was initially tested in Manchester using the TfGM Aimsun traffic model which proved the concept. This work resulted in the filing of the patent pending GB2110405.4 . The solution was updated to provide a solution for the post Covid recovery and this was proposed for a as part of the Kirklees application for the DfT Traffic Signals Maintenance fund proposal. The overall strategy for the AI element of that application was to collate create a series of tools would be delivered to allow traffic operators to manage the network to achieve defined criteria and would include:

- Web-based tool that allows dynamic Inspection of traffic data from available sources,
- Integrate new traffic sources such as traffic surveys, weather, bus open data and air quality data, and
- Creation of traffic plans for planned and unplanned disruptions to the road transport network

The desired outcome was to demonstrate that, through better access to data and analytics related to traffic use, improvements can be made to reduce transport’s impact on the environment and improve the reliability of the transport network. A series of products were planned to be delivered for use by traffic operators in Kirklees. These are:

- Prediction tool
- Database
- Analytical tool
- Managing planned events tool
- Managing real-time operations tool
- AI model representation

The Global Pandemic resulted in dramatic changes to the way we work, shop, and spend leisure time that have resulted in unprecedented changes to the daily, weekly and monthly travel patterns. While traffic volumes overall are now similar to what they were pre pandemic, the traffic profiles for individual locations and times of day can still be dramatically different. In the past there would be a regular pattern that changed by a single digit percentage over a number of years, now with changes to purpose of travel and mode use

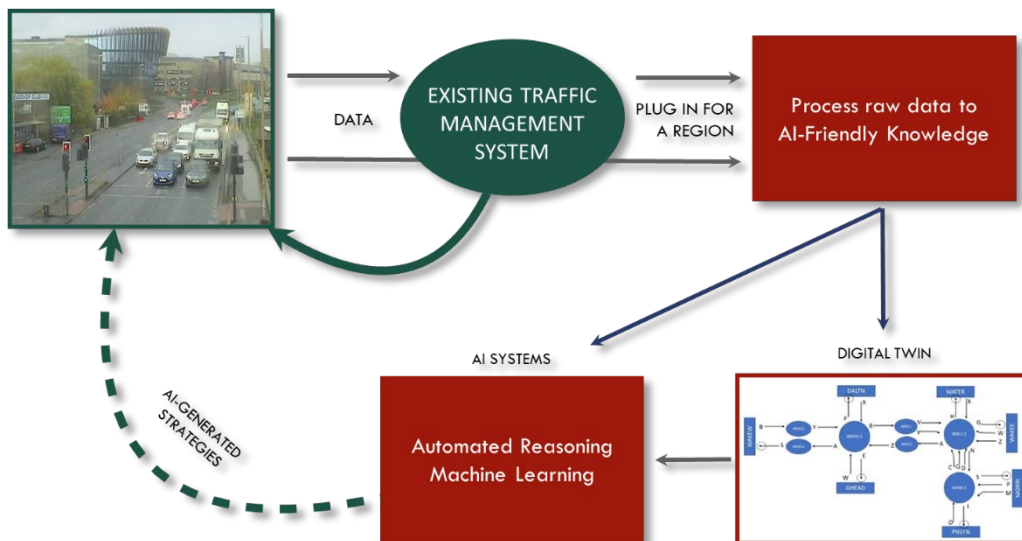
on a daily basis no two days appear to be the same. Whereas previously the difference between non recurrent and recurrent delay might be a 50/50 split, the dominance of non-recurrent congestion has made networks generally more unreliable. In this project we are delivering tools that focus specifically on non-recurrent congestion to enable Authorities to make best use of their existing assets at a time when budgets for maintenance and upgrades are being stretched.

Developing the Solution

Simplifai adopted the agile Dynamic Solutions Development Method (DSDM) to manage and control the solution development which, by using a defined methodology, we demonstrated a robust approach to development and change control. This method also has the benefit of being able to generate a set of documentation to permit scaling of the solution. This enables the solution to easily grow from deployment in a small number of locations to be deployed across a local authority covering all of its traffic signal network without any additional hardware.

The solution comprises the network data, two data models, an Automated Reasoner (the planning engine) to provide strategies and a Simulator to model results.

In simple terms the solution collates and processes the data to be useful for modelling and simulating the network (the Digital Twin) and generating Plan Options through an Automated Reasoner planning engine. This system uses the goal led approach to evaluate and select the most appropriate plan, or plans, for the desired goal outcome.



Visibility of real time and historical network performance was inhibited by the lack of API access to the relevant data from some existing systems. The project engaged directly with a number of suppliers to identify and evaluate the most appropriate data source and content and then manage access to that data. The project resolved these access requirements and put in place a methodology to support continual access that will ultimately become a fully automated process.

The data sources are:

1. Urban Traffic Control data from the deployed Swarco SCOOT UTC system. The available data was analysed for suitability and a formal process established permitting access to the live system. At present the system does not have a suitable API permitted automated retrieval of the data which is current manually gathered a daily basis (our understanding is that the API integration is currently being developed and rolled out across existing systems). The SCOOT data used comprises:
 - a. M02 providing flow, delay and congestion data
 - b. M08 which provides saturation and congestion data
 - c. M20 data providing relationship between flow and green time
 - d. M37 providing details of changes over time
2. Traffic survey data – this was used to provide detailed information on turning movements and analysed to validate the traffic counts from the SCOOT data (any errors were then automatically taken into account when using the data)
3. Now Wireless air quality data is used to identify the periods of time when air quality has historically been poor and give a real time indication of current air quality levels at a range of locations.
4. Drakewell journey time data is used to quantify the impacts of disruptions to the transport network and validate the performance of the existing systems, quantify the impact of the maintenance interventions and the inventions that have been created by the Simplifai System.
5. Weather data from Vaisala is used in conjunction with the air quality and traffic data to understand the changes to air quality and network performance as a result of changing weather conditions.
6. Bus Open Data (BODs) providing bus position data and has been analysed in reference to the green stages of the traffic signals over the course of a journey through the project geography.

During the project, Simplifai had to determine the method of data ingress and build extractors to insert the data into a data lake. The raw data is initially stored on a secure cloud environment. An automated Java process has been developed to take the data and store it in the relevant database files. A cloud based database has been used as this is good for handling structured data. Data is used to create two models based on the Simplifai Systems patent pending approach to creating digital twins of traffic networks:

- a Domain model that deals with the stated data – the set of rules and dynamics that control the movement of traffic and how things move within a region, and
- a Problem model that uses dynamic data to manage the specified goal or goals. Manages current state and future state to determine solution to achieve the goal

Simulation and Prediction Tools

The technique provides a methodology for enhancing existing traffic control systems without the high costs of new hardware to extend their useful life in a more complex urban world. The Simplifai digital twin is invoked to deal with an identified issue and given a corresponding goal to be achieved. When invoked, the system uses the patent pending methodology to pull data from a data lake to generate a symbolic and formal knowledge model describing the current status of the traffic network. The model also encodes knowledge of what is currently possible using existing techniques as well as what might be possible using all options allowable within defined safety and regulatory constraints including, for instance, time constraints or controllable traffic lights.

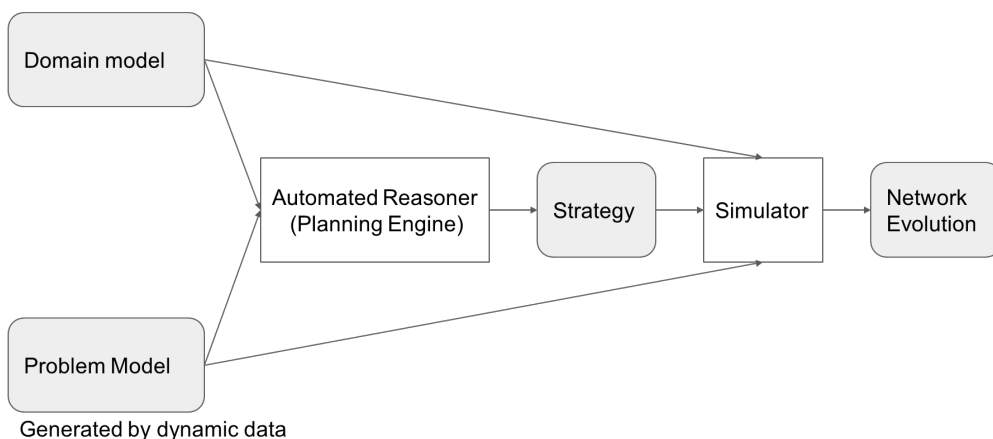
The system, based on the patent pending methodology, is the first system of its kind in the UK that when solving the problem, creates two core modules, a high level abstracted one for exploring the different states within the Automated Reasoner (Planning Engine) and a highly detailed one for the Simulator.

- The Simulator is an analytical tool to determine impacts on the network from chosen strategies
- The AI model is the high-level Prediction tool to evaluate multiple options in a rapid time to support near real time plan selection and implementation

A knowledge model is then provided as input to an Artificial Intelligence (AI) Automated Reasoner that, leveraging on Automated Planning PDDL (Planning Domain Definition Language) techniques, generates detailed traffic light strategies that can demonstrate, in simulation, achieving the defined goal conditions. The strategies can then be sent to the involved traffic lights to be implemented using existing control systems UTC and/or UTMC. The Automated Reasoners uses a version of an Expressive Numeric Heuristic Search Planner. In addition to this, Simplifai are currently testing heuristics for the next generation of the AI Automated Reasoners.

Using the AI model, we can extend or reduce the length of stages and extend the length of a stage (trading such time with another one).

The domain model permits the engine to extend or reduce the length of stages by some given fixed amount per cycle and also provide awareness of the max cycle time, so to extend the length of a stage, it would “trade” such time with another one.



To achieve the outcome desired, there needs to be a causal relationship between the network knowledge (data) and the method of analysing and controlling the network (model & control mechanism) to manage a specified goal.

One of the challenges with near real time modelling has been the time taken to effectively model scenarios which has exceeded the time window in which to implement a strategy to have a worthwhile effect on the network and prevent the issue occurring. During the project we have implemented a methodology based on our patent pending technology that permits this to be achieved within seconds when previously it could exceed an hour. The use of an automated reasoner and simulator approach delivers an effective traffic modelling solution from which traffic signal plans can be extracted and implemented.

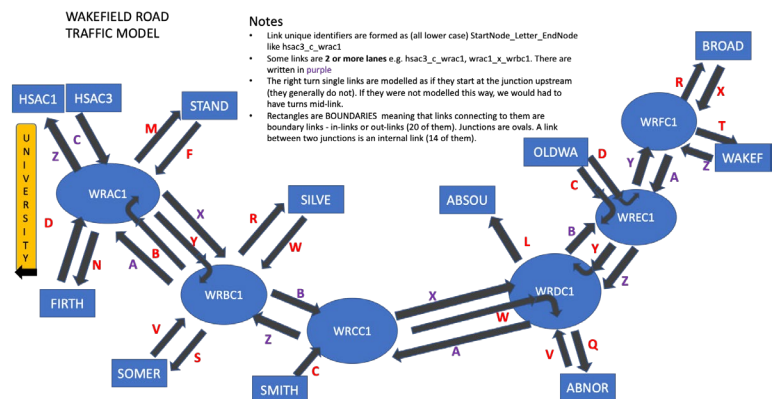
The simulation model is based on the knowledge gained from the existing traffic control systems. The calculation of turn rate from the partial data available from traditional flow data was validated on the project for one of the regions chosen for implementation.

The figure opposite shows the measured values (presented by letter A-F and W-Z) and the calculated values (represented by values G-U) for a typical location used for implementation.

We also used the traffic survey data to validate the traffic count data from the traffic control system which is the raw data used for timing calculations for the existing system. The validation process highlighted a number of errors in the data (that at the time were not flagged as faults) that resulted in suboptimal operation of the signals.

These issues were then corrected as part of the DfT Traffic Signal Maintenance Fund project resulting in improved operation using the existing systems. This methodology is being used as part of the optimisation process for the signals as part of the maintenance project.

Once the simulator has been created and validated using the process outlined above it can then be used in conjunction with the AI System to create new sets of timing to address a particular goal. This goal can be set in advance to address a known problem that is likely to occur in the future (roadworks and event or other known disruption). The process can also be used to address a problem in real time (incident, crash, emergency lane closure, etc) to create timings in real time to meet a specific goal (preventing gridlock, gating traffic upstream of an incident, prioritising alternative routes and modes)



Kirklees Traffic Signal Maintenance AI Project Outcomes

Data Visualisation

With the creation of the Data Lake and the adaptation of the data format into a format that permits use in terms of visualisation and modelling we are able to visualise what has mostly been previously hidden real time data on the traffic flow, delays and congestion and compare this in tandem with other forms of related data. With the data in the repository in a format that can be used, the Visualisation Tool enables the data to be evaluated and compared based on a chosen goal as well as to visualise the data to identify network insights.

The visualisation and analysis of the data provides the ability to source insights into traffic movements on the network as well as providing the source data to monitor the performance of the network. Through data aggregation we can evaluate separate sources of data to provide greater insight into the nature and form of issues on the network. Highlighting that network constraints that the systems are experiencing may be a consequence of problems at peripheral locations on the network. Thereby enabling more effective strategies and interventions to be applied.

Inductive Loop Performance

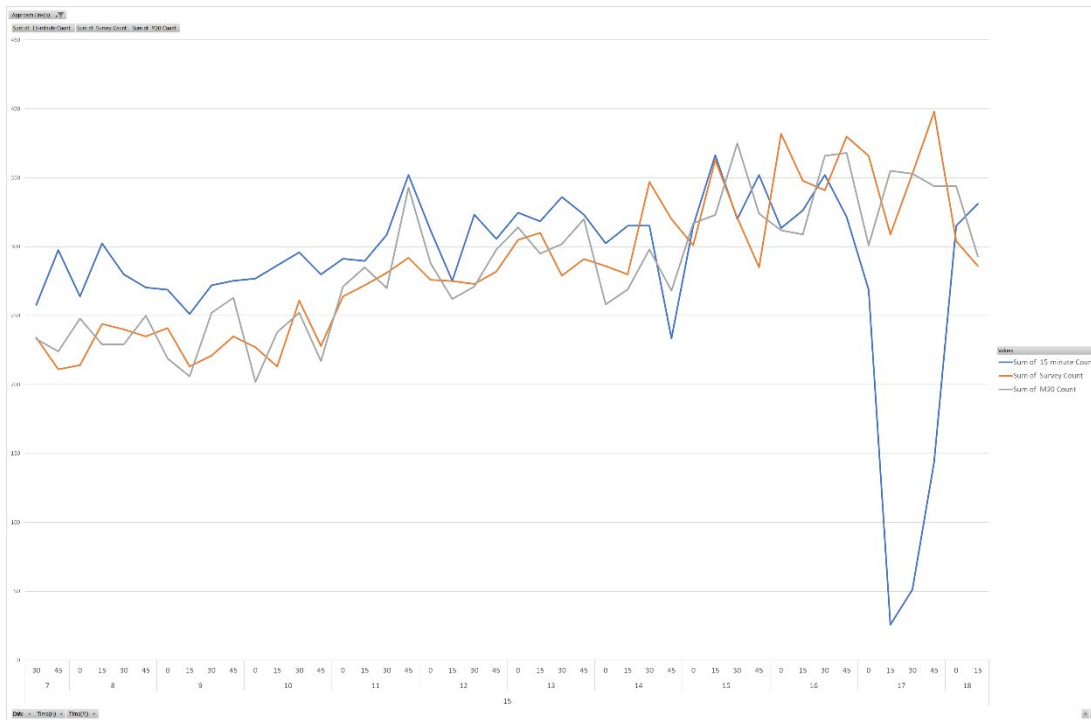
Through the visualisation and analysis, we have been able to identify inductive SCOOT loops that have failed or are performing below the expected requirement. In one instance the loop was found to work satisfactorily during periods of normal traffic flow but at the point of high flows it began to work against the volume of traffic. This can be seen as the sudden drop on the right of the graph below.

There are potential causes for this, either the congestion limits flow across the loop deceiving it to think there are low volumes or there is one loop across the three lanes (or three loops acting as one) that due to the slow-moving congestion falsely believes that there are few vehicles.

The loop analysis has also been able to identify the performance of individual loops and with the overall AI analysis of the geography permitting the models to 'in-fill' where inductive loops have failed or are performing sub-optimally without the need for physical intervention.

The advantage of this analysis lies in the ability to target sites that would benefit from current or future Traffic Signal Maintenance Funding for physical upgrades.

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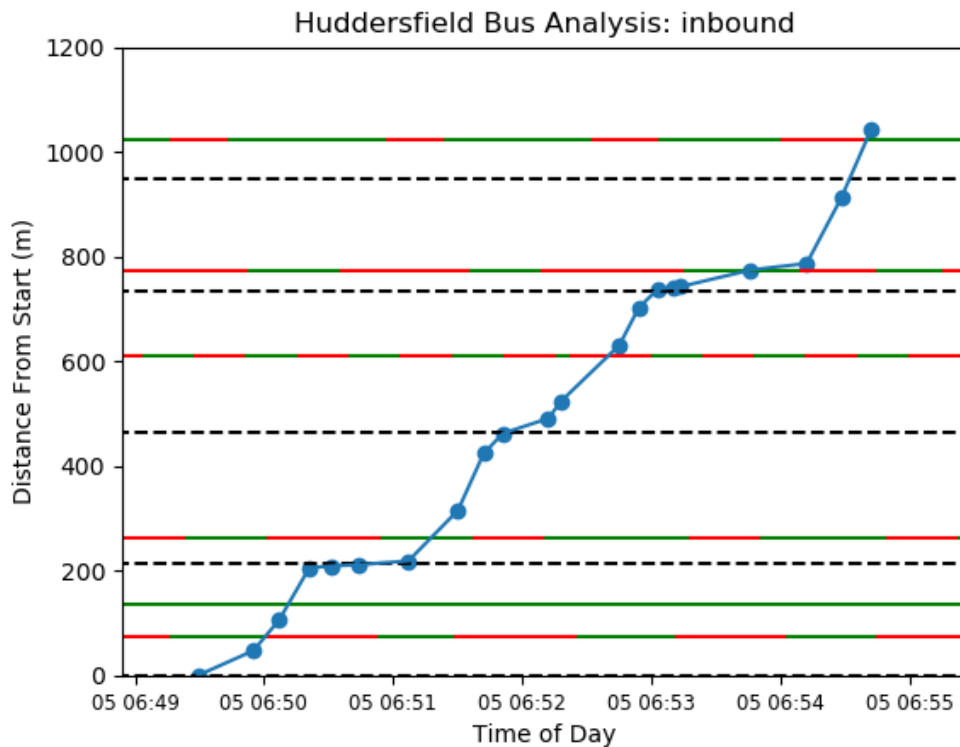
Bus Open Data

The Bus Open Data (BODs) was analysed to evaluate the quality of the data and its use for identifying the performance of the bus movement along one of the geographic areas of the AI project. We identified that there are times when the BODs data appears to group transmission of the bus location data which has been attributed to temporary loss of telecommunications signal.

The BODs data was analysed over time as it passed through the five junctions along the AI project geographic area. By aligning this data with the stage times of the traffic lights it is possible to identify where the bus was held-up when it encountered a red signal.

In the graphic below:

- The Red and Green bars show the different traffic signal junctions and the phasing of the appropriate signals
- The blue line shows the geo-position data from the bus as it passes along the route



Traffic Flow Analysis and Improvement

By creating accessible network performance data, we are able to analyse it to identify issues and constraints that can inform the nature of the goal we wish to set the AI Engine.

On the project we analysed how the existing systems managed large regular sporting events of different sizes and created plans that met specific goals immediately prior and in the aftermath of particular events. The simulator was then used to test the effectiveness of these alternative plans that could be created quickly for each individual event. In this example flow, delay and congestion data applicable to a day were analysed across the region to identify the impacts of the congestion and the variances across the network region. The evaluation was undertaken by route and location. Flow, delay and congestion are all discernible. In this analysis several outcomes were observed:

- The significant delays to traffic before the event occurred on a stretch of road that is a primary feeder into the region
- One primary post-event exit route did not reflect the expected delays
- There was a significant evening peak on one of the days

The analysis supported the setting of an AI Goal of reducing delays in the stretch of road feeding the region it also shows that there is a need to also understand other interventions that may be in place and ensure they are also reflected in the simulation, e.g. temporary road closure to permit pedestrians to leave the event.

Kirklees Traffic Signal Maintenance AI Project

The traffic signal maintenance project is ongoing and other results from the project will be presented at the conference.

References

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- 2 Leveraging Artificial Intelligence for Simulating Traffic Signal Strategies Bhatnagar, S., Guo, R., McCabe, K., McCluskey, L., Scala, E. & Vallati, M., 16 Jun 2022, (Accepted/In press) 2022 IEEE 25th International Conference on Intelligent Transportation Systems (ITSC). IEEE, 6 p.