Minimising incident related congestion with dynamic diversion plan generation

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Abstract

Incidents account for about 25% of the total delay on UK roads [1]. One way to reduce their impact is to implement a diversion plan with an aim to make the most efficient use of the surrounding road network. Currently where plans exist diversion plans are constructed manually and stored in a fixed plan library for reference when incidents occur. Manually compiling, agreeing, and maintaining a fixed plan library is a costly and labour intensive exercise and plans can become neglected and out of date. This paper describes a prototype automatic diversion plan generation system created by TRL for the SSR directorate of the Highways Agency. The system can be used in real-time to generate diversion plans for immediate implementation, and also to help generate and maintain fixed diversion plan libraries.

Keywords

Incident, Congestion, Diversion, Road Network, Planning

1 Introduction

A quarter of all congestion on the Highways Agency road network is the result of incidents [1]. One way to reduce the impact of an incident is to divert traffic away from the incident location and onto the remaining network; however an inappropriate diversion plan can make the situation worse. Currently where plans exist diversion plans are constructed manually and stored in a fixed plan library for reference when incidents occur. Manually compiling, agreeing, and maintaining a fixed plan library is a costly and inefficient exercise and plans can become neglected and out of date.

TRL has recently delivered a prototype Diversion Plan Generation (DPG) system for the Highways Agency. The prototype system automatically generates diversion plans for the Kent road network intended for implementation on roadside message signs. The DPG system can be used in two ways: (1) in conjunction with a live traffic management system and (2) in a standalone system.

This system forms part of a suite of potential network management tools for use in the Agency’s Regional Control Centres (RCCs). These are traffic modelling tools which are able to predict network conditions and provide operational support to network operators.
This paper describes the proposed applications of the core DPG system and the advantages of using DPG over current practices. The steps the DPG system takes to automatically generate diversion plans are summarised and the ability to tailor the system to the different needs and priorities of stakeholders such as Local Authorities is discussed. Finally some future developments are considered.

2 Current and proposed diversion plan systems

In this section current diversion plan systems and proposed applications for the core DPG system are described and compared.

Single fixed plans

Current diversion plan systems are based on a fixed library of static plans each responding to a specific incident location. Figure 2 illustrates an actual diversion plan from the Kent static plan library [2], plan number 2C/38, to be implemented in case of a closure to the eastbound M20 between J8 and J9. The plan consists of two separate diversions, one sending traffic close to the incident on a small diversion along the A20, the other acting further in advance of the incident and diverting traffic along the M2. Note that the more local diversion makes use of a pre-marked diversion route using fixed symbol signing (in this case a circle).

Figure 1: Example Diversion Plan 2C/38
**MOLA**

The Motorway On-Line Advisor (MOLA) software was developed by TRL for the Highways Agency and is currently installed in the South East Regional Control Centre. MOLA’s primary function is to provide dynamic decision support to network managers, advising on the ‘best’ diversion strategy to adopt in the event of an incident, given the current and predicted traffic situation. The system is based on a traffic model which uses real time traffic flow data to simulate the effect of a diversion plan on the flow of traffic on the network. Currently MOLA selects a number of diversion plans from a fixed library, depending on the location of the incident. The operator is then presented with estimates of delay on the network for each of the plans and recommends the most appropriate plan from the set of fixed plans to implement. MOLA will always consider a “do nothing” scenario, and will suggest this as the most appropriate plan if necessary. This situation may occur if the impact of diverting traffic through local roads is worse than keeping traffic queuing from the incident.

**Live DPG MOLA**

In the Live DPG MOLA system (proposed), the core DPG system (based on a traffic model) would be totally integrated into MOLA. In the event of an incident MOLA would pass all the information regarding the incident, the current state of the network and the traffic conditions to DPG. The DPG system would identify which variable message signs would have the largest influence on the current traffic and would then generate diversion routes in real-time and corresponding diversion messages suitable for display on the selected VMS. These diversion plans would then be passed back to the MOLA system for appraisal and recommendations, and from there to the network operator for immediate implementation.

**Standalone DPG**

The Standalone DPG system (proposed) would be used to assist network managers in quickly developing a set of suitable diversion plans in an efficient manner. In the Standalone DPG application the core DPG system would use historic traffic data to incorporate time-of-day effects into the plan generation process, thus providing an advantage over the conventional method of generating plans.

The Standalone DPG system will also provide a method of easily updating the diversion plan libraries (for use either as single fixed plans or within MOLA) should there be a change to the network, e.g. addition of VMS or a change to traffic patterns.

There are two major factors that should be considered when comparing traffic model-based diversion plan generation systems to conventional methods: the involvement of necessary stakeholders, and the ability of the system to operate in real time. These factors are discussed below.
**Stakeholder agreement process**

Stakeholders include organisations like the Highways Agency, the Department for Transport, Local Authorities, and the Police who are responsible for different types of roads (motorways, A-roads, urban roads, etc), and/or have different fundamental interests (e.g. safety, operational efficiency, etc). With static plan libraries, the stakeholder group must agree the actual diversion plans. The process of deciding fixed diversion plans involves much debate, which makes the process lengthy and expensive. Also, over time changes occur to the road network (e.g. carriageway widening, new Variable Message Signs (VMS) installed and general changes to traffic patterns). Because of this, fixed diversion plans need to be reviewed and new ones generated on a regular basis which means repeating this complex process. Because of the complexities involved in developing and maintaining a fixed library of diversion plans, experience has shown that it can become neglected and the plans become out-of-date.

Using the DPG system to generate diversion plans, both for immediate use and for maintaining plan libraries, will ensure that the plans are up to date. Stakeholders would agree on the rules and parameters governing the diversion plan generation within the DPG system, such as maximum road capacities and time-of-day variations, rather than individual plans. This has an advantage over the current systems since once the rules are agreed then changes to the network would require minimal re-agreement amongst the stakeholders.

The DPG system also allows a greater flexibility in the diversion plans for temporary changes in the network. For example, if a VMS is out of order this information can be incorporated into the plan generation process, as opposed to the fixed case which doesn't account for changes to the network.

**Real-time effects**

Incorporating real-time effects into diversion plan generation creates more effective and appropriate diversion plans which make best use of the surrounding network. Taking into account the current state of the network and time-of-day effects reduces the risk of diverting traffic onto an already congested road. The remaining capacity of the surrounding roads is taken into account and links are assessed as to whether they could cope with the increased traffic a diversion would impose. This would not simply be a measure of the actual remaining capacity on a road, but also the desirability of filling that road, at that time, with diverting traffic. The desirability of a particular road can also be affected by other factors, such as the environmental impact. This issue will be discussed further in Section 4.

MOLA currently provides an advantage over a single fixed plan in that a range of fixed plans are appraised in real-time and the most appropriate is implemented taking into account the current and predicted future traffic conditions. The proposed Standalone DPG system would take into account time-of-day effects on the network, allowing more effective diversion plans to be generated. Live DPG MOLA would further improve the plan generation process by also creating the diversion plans in
real-time. The Live DPG MOLA system will be the optimal solution providing the most efficient and appropriate diversion strategies for the network.

Other diversion planning tools
The DPG system considers the most appropriate diversion routes for the benefit of the entire driving population and the surrounding environment. This highlights a fundamental difference between the DPG's strategic plans and those generated by in-car navigation systems which provide advice to improve the journey for an individual driver; these may not result in the most efficient and appropriate use of the remaining road network.

3 The core DPG system

The core DPG system will produce diversion messages for display on VMS in response to an incident on the network. The system identifies the VMS that will be most influential in diverting traffic away from the incident location, produces suitable diversion routes for the traffic which make the best use of the surrounding network and creates the messages to be displayed on the selected VMS. In this section this process is described in more detail (for full details see [3])

Inputs

The DPG system uses a previously generated CONTRAM (a traffic assignment model) network and routes file. The network file defines the structure of the network, and the routes file contains the journeys that modelled traffic would take on a typical day. If DPG was integrated with the MOLA system then this routes file would provide real-time assignment data for the current state of the network. DPG also requires, as input, a database containing information on the VMS, the destinations and the roads. Specifically, the database contains:

- the VMS locations and characteristics (such as size)
- the destinations and relative destination groups (where several destinations can be referred to in a message using a group description – such as M25 for M25 South and Dartford Tunnel – when the VMS is a considerable distance away)
- destination importance multipliers (values that are assigned to destinations or destination groups so that important destinations such as London will be preferentially selected for message generation rather than local destinations such as Swanley)
- individual link information including road name, link capacity, link length and link “cost”, (the link cost is based on a number of factors and is discussed further in Section 4).
The Plan Generation Process

The DPG process can be broadly divided into four stages:

(1) Identify a VMS

For every relevant VMS, ‘VMS-destination pairs’ (pairings of a VMS and an associated destination) are formed, based on modelled journeys which pass through the specified VMS and the incident, and end at the specified destination. These VMS-destination pairs are each scored according to two different factors: a measure of the total amount of traffic that would have passed through the VMS link and the incident link, and ended at the destination and a consideration of the distance of the VMS to the incident, since it is assumed that fewer drivers will follow a diversion from a VMS situated further away from an incident. These two scores are combined to create a Potential Traffic Influence (PTI) score for the particular VMS-destination pair. Individual VMS are scored by summing the individual PTI scores for each VMS-destination pair. The VMS with the highest score (the most “influential” VMS) is used to display the first diversion message.

(2) Identify diversion routes

Having identified the top-ranked VMS, possible diversion routes are generated from the VMS to various destinations. Diversion routes are generated using a shortest paths algorithm that calculates a ranked list of lowest cost routes. The “cost” of diverting traffic down a particular link is made up of a number of factors including the remaining capacity of the link and the length of the link. The choice of cost values has an enormous effect on the diversion routes generated and this issue will be discussed further in Section 4. Possible routes are then passed to step (3).

(3) Create a diversion message

For the top-ranked VMS, there are several diversion routes to different destinations. The DPG ranks the destinations and destination groups according to the combined PTI score of the relevant VMS-destination pairs and the destination importance multipliers. For the most influential destination or destination group, the DPG takes the diversion route with the lowest cost and generates a diversion route message. If the message is not suitable (e.g. too long) the process continues with the next ranked route until a suitable message is generated. Diversion messages by DPG for display on VMS contain 3 fundamental parts: a description of incident e.g. Accident Ahead; a description of the destination for which the diversion is intended e.g. For London, and the intended diversion route e.g. Use A260, M2. For more restrictive VMS (e.g. where only two lines are available) the DPG system omits the incident description.

(4) Repeat from stage (1) for next VMS

The process is then repeated for the next VMS. However, before returning to step (1) the traffic routes previously taken from the CONTRAM output file are updated to take into account the diversion route from the top-ranked VMS. The corresponding
link costs are also updated. This is a vital step of the DPG system, and helps ensure that subsequent diversion routes take into account the reduced capacity on roads used by previous diversion routes.

Outputs

As output, the DPG system returns the VMS included in the diversion plan and their associated diversion messages and routes. Figure 3 & 4 show two diversion messages generated by the DPG system in response to a total closure of the eastbound M20 between junctions 8 and 9. (The incident link is shown in red.) The modelled links are shown in blue and the VMS locations in orange, with the VMS selected for the current diversion message marked in yellow. In figure 3, traffic bound for the East Coast is diverted off the M20 well in advance of the incident and directed to use the M2. In figure 4, the selected VMS is closer to the incident and directs Channel Tunnel traffic to take a smaller diversion along the A20 before rejoining the M20 further on. Figure 5 shows part of this second diversion at a more detailed level.

![Figure 3: Example diversion route generated for Eastbound M20 closure](image-url)
Figure 4: Example diversion route generated for Eastbound M20 closure

Figure 5: Zoomed in view of the incident link and part of the diversion route
The diversions shown in figures 3, 4 & 5 are essentially similar to the static plan shown in Section 2 for an incident on the same link, although the DPG system generates four additional VMS messages and diversion routes (not shown). In this case the costs of the individual links are mostly based on link capacity and are calibrated to produce similar results to the existing static plans. The diversion routes generated are highly dependent on the weightings applied to the links and the system can be calibrated differently, according to different priorities. This issue is discussed further in the following section.

4 Rules and calibration

Key to the DPG’s performance are the rules it follows to generate and assess its own diversion routes. The actual parameter values that make up the rules (like the remaining capacity, priority of major/minor roads etc) will be dictated by the preferences and priorities of the stakeholders such as Local Authorities.

Changing the main parameters in the DPG system can have an enormous effect on the VMS selected and the messages created for them to display. Two sets of parameters that have a particularly significant effect on the diversion routes and messages are discussed below.

Capacity Cost Coefficients (CCCs)

The CCCs are used as weightings on each link in the network so that, for example, motorways are preferred over minor roads when producing routes. In general the CCC values are broadly based on road type e.g Major A road, Minor B road etc. However, decreasing and increasing the CCC values of the links of individual roads can cause significant differences in the diversion routes generated. This means that values can be altered to obtain routes that favour more environmentally friendly links or avoid high-speed roads etc. This enables the DPG system to be tailored towards specific objectives, like reducing congestion, minimising environmental impact, maximising safety etc, or any combination of the above. Additionally, temporary changes to the network can be reflected in the CCC values; for example, if roadworks are present on a specific link then the CCC value of that link can be increased for the duration of the works.

No one set of CCCs will give the ‘best’ calibration providing the ‘best’ diversions since classifying one route as better than another is a subjective process. The absolute values used for each road are arguably less important than the relative values; for example, provided the weightings of the major A roads are, in general, more than motorways links and less than B road links then reasonable routes will be produced in most cases (where the higher the weighting the less likely a road will be used for a diversion route). Provided that the CCC values are always based on a solid underlying concept, such as weightings dependent on road type, then they are
all equally valid; the set of CCCs chosen depends entirely on preference and on priorities.

*Destination Importance Multipliers (DIMS)*

The DIMs allow weightings to be given to destinations and destination groups so that (strategically) more important locations (such as London) are more likely to be picked for VMS message generation than small localised destinations (for example, Biggin Hill). These multipliers can have a significant effect on the VMS messages displayed. As with the CCCs the relative values rather than the absolute values are important. For example, destination group names should have a higher or equal importance weighting than the destination names that make up the group. – This ensures an appropriate message is selected which is a recognisable destination to the majority of road users (rather than placing village names on the national network etc).

The choice of multipliers is otherwise entirely dependent on exactly what the system is being calibrated for. As before, there is no ‘correct’ set of values. These multipliers can also be altered for different real-life situations. For example, if there is an event at Brands Hatch on one particular day then the importance multiplier for Brands Hatch can be increased for that one day only.

Both the capacity cost coefficients and the destination importance multipliers can be changed by the user through DPG’s interactive front end\(^1\). Clicking on individual (or groups of) links and destinations allow the parameter values to be easily modified. A detailed calibration study has been undertaken for roads in Kent. The study has shown that the CCC values and DIMs can be calibrated to meet different user requirements [4].

### 5 Future Development of DPG

The DPG system that has been developed is a prototype system. The next stage is to engage with the necessary stakeholders, and produce a reliable operational system tailored to the needs of the network operators. The following proposed developments have been agreed with the Highways Agency.

The first objective will be to establish the needs of key stakeholders. A series of meetings will be held with all interested parties to describe the features and capabilities of the DPG system and how the DPG can be used to help improve existing traffic management systems, such as MOLA. The meetings will also establish any additional requirements of the DPG system for its use as a traffic management tool.

As previously mentioned the DPG could be used both as a stand-alone fixed plan generation system and incorporated into a live traffic management system. The

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\(^1\) This functionality is not currently included but will be available in the next release version of the DPG system.
operator requirements from the stakeholder consultation will be used to develop these two applications of the DPG system.

Specifically, the DPG system will be incorporated into MOLA for use in Godstone RCC. In the long term, MOLA and DPG as traffic management tools could be rolled-out to other Regional Control Centres. To achieve this, a number of enhancements and additions will be required by the DPG system to enable MOLA and DPG to closely interact both in real time and as a static system.

The other main focus of development of the DPG project is further research and development into the core DPG engine. The prototype DPG system has been built to a high specification; however, there is a need to improve its internal core engine, especially in the way it models traffic and diversions in order to improve the quality of its output. The additional features will be identified by the internal developers, as well as the key external stakeholders.

6 Conclusions

This paper has described a prototype automatic diversion plan generation system on the Kent road network developed for the Highways Agency. It is designed for presentation to key stakeholders and decision makers, and will be fundamental in aiding the future design and development of the next generation of diversion planning systems. The DPG system can be used in a number of applications, both as a standalone plan generator for creating and maintaining fixed plan libraries and in real-time to create diversion plans for immediate implementation. In either situation the implementation of an operational DPG system will result in more efficient use of the UK road network and lead to an overall reduction in congestion.

References


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