STEP (Short TErm Prediction)

Workpackage 5:
STEP Project Evaluation Report

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Executive summary

The ERA-NET ROAD Mobility research project "STEP" implemented short term prediction within traffic management centres to support traffic management decisions and ultimately improve network performance. STEP aimed to establish a better understanding of the operational short term prediction requirements of traffic managers at interurban and urban traffic management centres in Europe. STEP has explored the gaps between the state-of-the-art and requirements of operators in terms of functional application, data requirements, interfacing and the success of existing tools that are used. Central to the project were real-life trials conducted in an operational traffic management centre environment, testing the tools against user requirements while learning valuable (practical) lessons during implementation. This report summarises the key stages of the project as well as the results including lessons learnt about the state-of-the-art, operational user requirements in terms of short term prediction, and implementing and deploying predictors for live traffic management operations.

The project "STEP" (Short TErm Prediction) has explored issues relating to the implementation of short-term traffic prediction in TCCs. The project results are aimed to be transferable. The project started in 2011 and its field trial in the regional TCC in Utrecht has recently been completed. The short-term predictor was operational for five months, and used by staff managing the motorway network in the Netherlands' congested centre. Separately, a test-bed was similarly developed for the South West of England, although this was not used in operations.

The actual predictor that was tested was developed by Fileradar , and the principal objective was not to test the quality of a single predictor in a real-life situation or to compare between alternative predictors. Instead, the intention was to make a predictor available for actual TCC staff to use in their day-to-day work, to investigate what the obstacles are to its success, and to gain a better understanding of whether we could remove some of these issues.

An initial state-of-the-art overview of short-term forecasting systems was undertaken including a literature review of current traffic prediction models and short-term forecasting models. This included a review of multiple applications of short-term prediction systems in Europe focusing on a number of EU cities. It should be noted that it was not easy to find information about the practical applications. The majority of applications so far have focused on providing current state information to users. Although many existing software applications can detect incidents, often they cannot distinguish between recurrent and non-recurrent congestion. Moreover, there seems to be an insufficient insight into the relation between data quality (accuracy, reliability, timeliness, completeness) and estimation / prediction quality, that requires further attention to increase acceptance of short term prediction in TCC operations.

This close co-operation with the TCC management and users helped to provide a clear indication of the essential aspects of short-term prediction that affect its use and acceptability. These include the following:

- It is important that the actual traffic flow prediction is of a very high quality, as TCC staff considered only the first 15 minutes to be of adequate quality to serve their needs. (The deterioration after longer lapse times were found to prevent the predictions being used for longer term forecasts);
- The preferred option for the presentation of prediction results selected by TCC staff was found to be through use of a split screen with actual traffic levels and animated predicted situation shown side-by-side;
- Data transfer latency is critical when implementing short-term prediction tools, with TCC staff often comparing predictions with existing real-life data that they are used to seeing on their screen. The data volumes are significant when compared with real-time traffic

data because each updated prediction contains not just a single snapshot in time but a series in time from now into the future. Considerable time was spent on streamlining communications elements of the system so that staff felt comfortable with the outputs.

- Non recurrent traffic congestion and quantitative descriptions of that (in terms of minutes delay, length etc) were the most interesting, but also the hardest to achieve; and
- The provision of an aggregated graph showing the average and current total km network queue.

This report sets out the background to the project itself covering the key outcomes of each of the different elements and conclusions from these. It also sets out the dissemination activities that have been undertaken thus far and others planned to share the experience of the project with those who have a direct interest in short-term prediction approaches to managing traffic.

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1 Introduction

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the EC. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR this joint research project was initiated. The funding National Road Administrations (NRA) in this joint research project are Belgium, Switzerland, Germany, Netherlands Norway and United Kingdom.

This report describes the process and the results of the different work packages within the research project and draws conclusions on the key requirements for the development and implementation of successful short-term prediction systems within a TCC environment.

STEP aimed to establish a better understanding of the operational short-term prediction requirements of traffic managers at interurban and urban traffic management centres in Europe.

The project has explored the gaps between the state-of-the-art and requirements of operators in terms of functional application, data requirements, interfacing and the success of existing tools that are used.

Central to the research work has been the delivery of a real-life trial conducted in an operational traffic management centre environment, testing the prediction tool against user requirements while learning valuable practical lessons during implementation.

2 Short Term Prediction Tools and Approaches

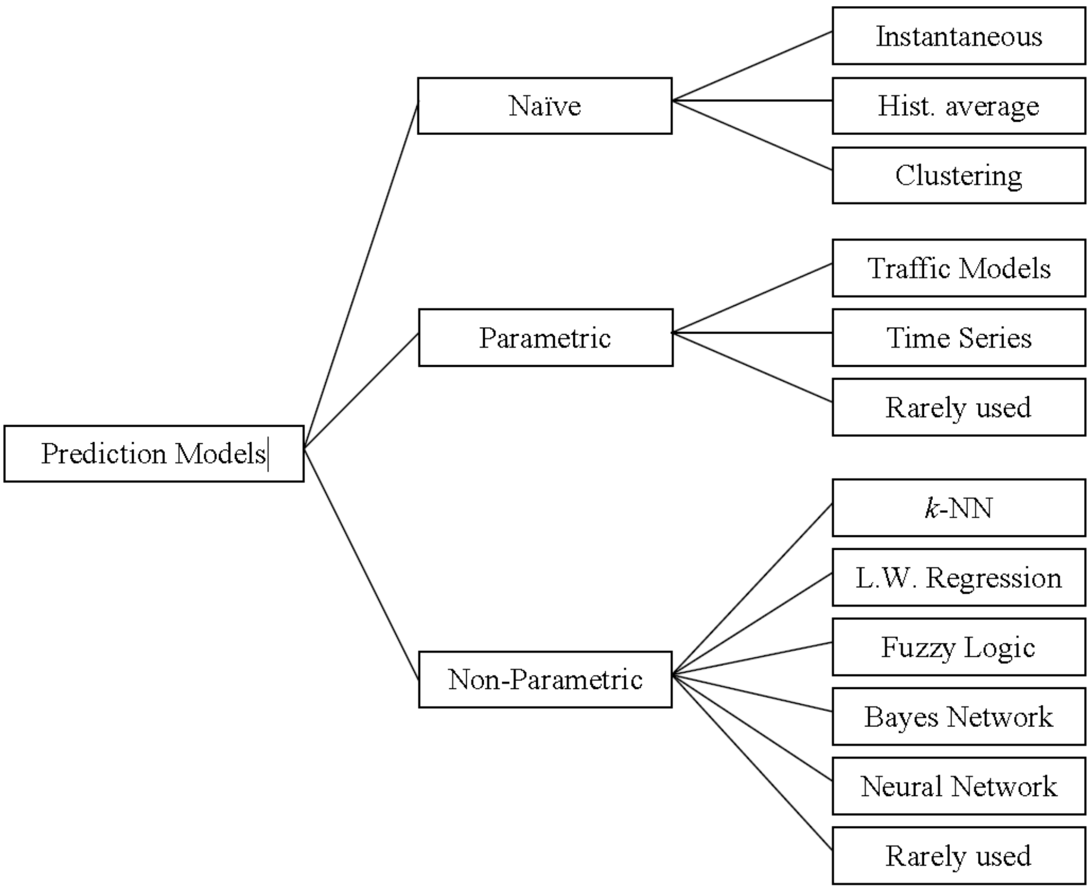
2.1 Introduction

This section sets out the background on the key requirements necessary for short-term traffic prediction engines. As further background, a brief informative summary of short-term prediction methods is also provided. Aspects of user interface, system architecture, interface protocol specification and deployment are discussed more fully below.

2.2 Summary of Short Term Traffic Prediction Models

The contents of Workpackage 1 provides details of the literature review undertaken on the different approaches to short-term traffic prediction, with prediction models can be subdivided into three main categories: naïve methods, parametric models and non-parametric models, and further subdivided after that (see Figure 2.1 below for further details).

Figure 2.1: Overview of the Different Short-Term Prediction Models Available



Source: Hinsbergen et al, “STEP workpackage 1: State-of-the-Art: Review of Best Practice”

2.2.1 Naive Methods

The term ‘naïve’ is rather subjective, but can be interpreted as ‘without any model assumption’. Naïve methods are widely applied in practice because of their low computational effort and easy implementation. The accuracy however is usually very low. Generally any parametric or non-parametric method was found to have a higher accuracy than these methods.

2.2.2 Parametric Models

The term ‘parametric’ indicates that only the parameters of the model need to be found using data; the structure of the model is predetermined. Knowledge on the traffic processes can be implemented in these structures, especially in traffic simulation models, which can aid in understanding traffic processes. Also, unforeseen cases such as incidents can be modelled. Another advantage of these methods is that usually less data is needed compared to non-parametric models. Some parametric models have shown good performance, in accuracy as well as computational effort.

Within the traffic model category, there are two main subcategories: online full dynamic traffic assignment models, and online traffic flow models. The former explicitly model demand, route choice and flow propagation through the network, whereas the latter only simulate flow propagation, while treating time-dependent demand and route choice implicitly as dynamic parameters or boundary conditions.

2.2.3 Non-parametric models

The term non-parametric does not imply that these models completely lack parameters, but rather that the number and nature of the parameters are flexible and not fixed in advance. Model structure as well as model parameters need to be determined from data. Therefore, usually more data is required than for parametric models. The advantage of these models is that the difficult, dynamic and non-linear processes found in traffic can be modelled without knowledge on the underlying processes being required. Unforeseen cases such as incidents and potential traffic management responses however pose a problem as the model structure is derived from data.

2.3 Key Requirements for Short-Term Prediction Engines

The STEP user research and live trials have established the following key requirements for short-term traffic prediction engines.

- In practice reasonably accurate predictions on a horizon of at least 20 minutes are needed in order for the predictions to support decisions made by traffic managers.

  Traffic managers desire the capability to predict from 30 minutes to 90 minutes into the future, but the performance of predictors will decrease rapidly as the time horizon moves into the future. The above requirement for 20 minutes is not intended to deny the strength of the aspiration for 30-90 minute horizons, it simply emphasises that if the predictions are not reasonably accurate at least as far as 20 minutes in advance, they will almost certainly be of little use to traffic managers;

- The prediction model needs to be able to predict the effect of non-recurrent situations such as incidents or road works, because it is especially around those situations where traffic manager really can make a difference by taking the optimal actions. Predictions based solely on historic averages are therefore not very useful for traffic management;

- Both speed and travel time should be predicted. Delays also represent a very useful viewpoint;

- The accuracy of the predictions should be expressed in both the predicted length of the queues (determines whether spillback is correctly predicted) as well as the predicted speed of traffic (determines whether delays are correctly predicted). If both the length of future queues and the speed of future traffic are accurately predicted, the traffic managers can make good decisions on which dynamic traffic management measures to apply;

- Timeliness is a critical factor, as generally traffic controllers need to respond swiftly to emerging traffic congestion. The predictions need to be available to the end users within minutes (e.g. 2-5 minutes or less); and

- It is highly desirable that a predictor should be able to simulate potential traffic management scenarios to support decisions. Predictors without this capability should have some benefit, but the overall benefit is greatly increased if the predictor can inform “what-if” questions.

2.4 Conclusions

The research undertaken as part of the STEP project has revealed that there is clearly a requirement for short-term forecasting and that the benefits of using predictions are recognised with improved information provided for both road authorities as well as road-users. However the selection between scenario-based (or case-based) approaches and optimisation approaches is seen as difficult as both approaches have particular drawbacks/benefits.

The relationship between the quality of the data and quality of estimations/predictions is not clear and it is recommended to investigate this further, as well as the extent to which data quality can be increased by advanced estimation and data fusion techniques. The more complex the model is, the more accurate the predictions it provides although it is uncertain what appropriate levels of predictive accuracy are available for the different applications of short-term prediction models.

The model has been proven in many scientific studies, but the hard part is to calibrate the model for a large-scale network. Despite the model’s simple form, there are many thousands of parameters to find: the demand at each on-ramp at each time of the day, the average route choice at each intersection or off-ramp in the network, the capacity of each section of the road, the average distance between vehicles when flow is at capacity, etc. To make matters even more complex, these parameters are stochastic and dynamic by nature because they depend on human driver behaviour, weather, lighting conditions, road works and incidents.

The STEP live trials used predictions generated by a combination of algorithms and models. The core model used is a traffic flow propagation model in which traffic is modelled as a fluid stream. The STEP tool employed additional algorithms to perform the entire calibration automatically. As presented in Workpackage report 4B most of these provided excellent results, but the capacity calibration algorithm has not yet been able to fully account for the complex traffic congestion patterns involving spillback over intersections, interaction between different bottlenecks and moving jams. This will be further explored by Fileradar as part of their ongoing research work to develop the short-term prediction tool, outside the scope of this project.

3 User Requirements and Interface Issues

3.1 Introduction

In this section the main conclusions are presented based on the experiences gained before and during the pilot. The main goal of the STEP project was to investigate how to successfully apply short-term predictions in a traffic control centre. The conclusions are presented from different perspectives on how to answer this question: user acceptance and trust, the user interface, technical deployment and the prediction quality.

3.2 User Interface Issues – Feedback from TCC Operators

The work undertaken as part the consultation exercise with TCC operators provided a good understanding of the operational short term prediction requirements of traffic managers at Interurban and Urban Traffic Control Centres (TCC's) in Europe. One of the key objectives was to explore the gaps between the state-of-the-art and requirements of operators in terms of functional application, interfacing and the success of existing tools that are currently being used by TCCs.

Between January and March 2012 a series of meetings and discussions took place with Traffic Control Centre contacts in the UK, Netherlands and Belgium to understand how real-time traffic controllers are setup, including practical operational and data requirements as well as to gather views on traffic prediction tools that are currently available to improve network performance and how these are used in practice. Our main objective was to understand the key issues that need to be addressed when developing practical traffic prediction tools and to maximise the potential for their application to support traffic control centre operations. An online questionnaire was developed. We also distributed hard copies to key contacts, which elicited a total of 15 responses from TCCs. A summary of the key points from this feedback is provided below:

Issue	Feedback and Assessment
Tasks, Goals and Measures Of Traffic Control Centres	▪ Overall TCCs agree on the importance of improved journey time reliability and reduced disruption in the case of major incidents; ▪ TCCs are mainly concerned about the efficiency of the system (i.e. the throughput of the road network) that they manage, mostly in irregular situations; ▪ The most important measures that they apply during their daily operations to influence traffic operations are providing information and incident management; and ▪ Concerns about to deal with irregular situations (eg. random incidents on the network etc.) also indicate a potential application area for short-term prediction model.
General Response of TCCs To The Issue of Short-Tern Prediction	▪ A total of 80% of TCC respondents stated that they were optimistic about the use of short-term predictors to address problems of congestion; and ▪ TCCs indicated that the staff in many cases is unaware of the possibilities of traffic prediction, and that they should be taught about the application more fully.
User Requirements For Short-Term Prediction	▪ Just over half respondents stated that the accuracy of the predictions themselves was a key issue; ▪ Nearly 75% or TCCs stated that they wanted to see evidence of successful application by other TCCs and also experience

	of real-life trials; and ▪ 75% of respondents stated that the cost of setting up short-term traffic predictors in their daily operations was a key consideration.
Visualisation of Short Term Prediction	• In terms of how to present information to users the use of colour-coded links overlaid on a map view was most popular response, accompanied by alerts or alarms in case of abnormal conditions; and • It was considered important that the level of manual intervention when using the tool should be kept to a minimum, and automation should be provided to help the operators.
Scenario Generation	• Predictors should be linked to traffic management scenario generation, so that the system can predict the traffic conditions that will arise with and without traffic management intervention. • The use of short-term prediction without scenario generation is already seen as an important asset by many TCCs. • Still, over 50% of TCC respondents felt that predictors that have the ability to apply scenario generation are considered most useful.
Horizon and Accuracy of Short Term Prediction	• A total of 40% of respondents felt that in terms of the accuracy of outputs of prediction tools and information on future travel times and the speeds a target of 80% was desirable; • It was noted that the desired horizon for prediction tools depends on both the user and the specific situation, as for traffic controllers a shorter horizon is required, while for traffic engineers a long horizon is needed; and • In the case of inter-urban incidents or peak periods, a 1 hour look-ahead was considered as appropriate, while for urban networks a period of 15-30 minutes was seen as a good horizon. This is because in urban environments the traffic flows can change much more quickly.
Experiences With Short Term Prediction:	• Only 4 of the 15 TCCs interviewed have any experience with short term prediction tools, and the feedback provided revealed that they are only partially dissatisfied with their current systems; and • Early stages of development and application – dissatisfaction with accuracy of the system. However, in some cases it was too early to evaluate their systems fully.

3.3 Summary of User Interface Requirements

The project’s dialogue with the Traffic Control Centres followed by operational experience in live prediction trials (as summarised in Chapters 4 and 5), have helped to establish the relative importance of the following techniques for presenting predictions to users:

- the benefit of colour-coded links overlaid on a map view which are considered by most respondents as essential to support TCC functionality;
- the use of alerts or alarms to highlight abnormal conditions which are seen as being very useful for TCC operators;
- showing colour-coded quantities in a tabular list, again considered useful for TCC’s; and

- detailed graphs for a single selected link or section which are regarded as being quite useful to support operational needs.

The following have also been mentioned by operators as being desirable features within any short-term prediction system:

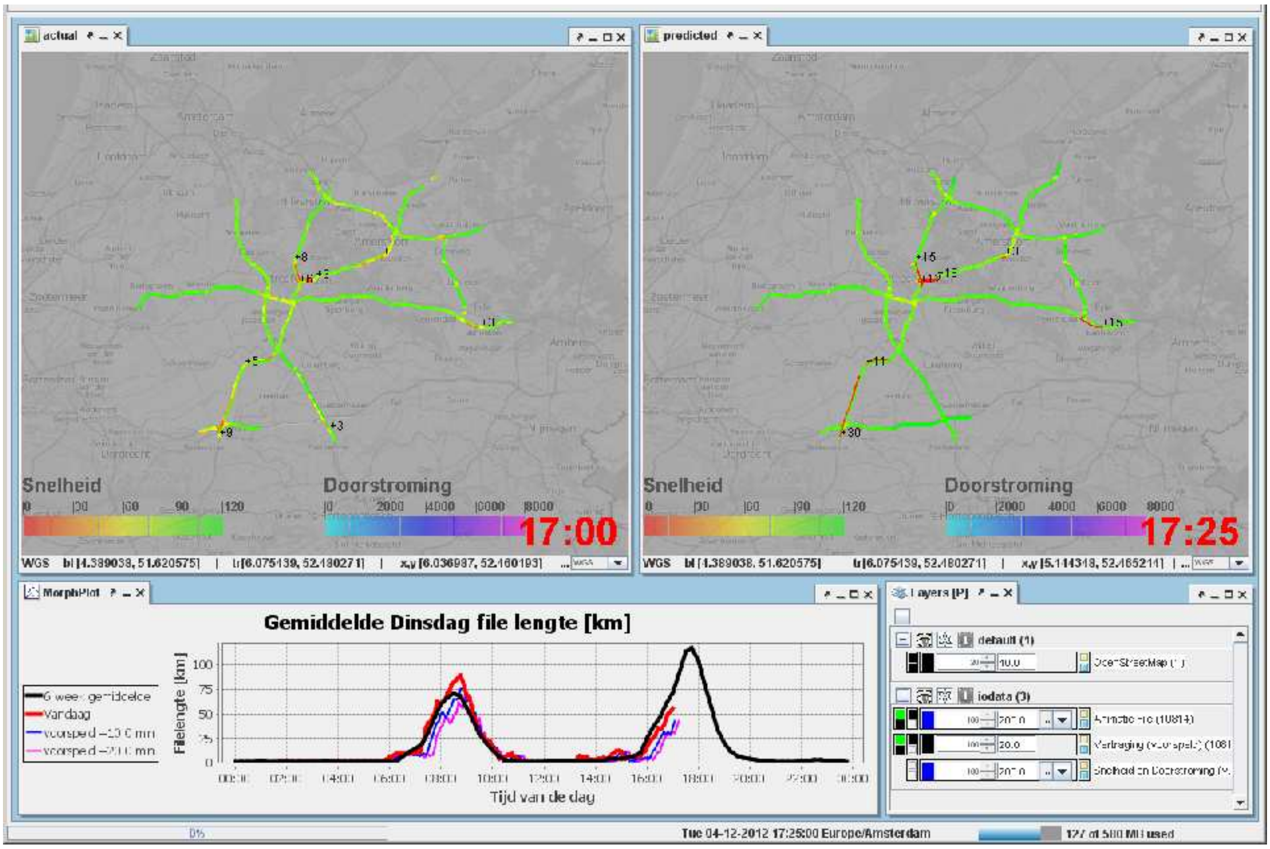
- the inclusion of regular reports on the accuracy achieved; and
- use of visualisation of the remaining capacity on corridors.

The experience of live prediction trials has helped refined the best practice for presenting map-based views as follows:

- It is beneficial to present the predictions in a split screen showing two maps, one highlighting the current situation with the other presenting the animation of the predictions.

An example of this style of presentation is shown in Figure 3.1 below:

Figure 3.1: Example of dual display with current and predicted traffic states



Source: Screenshots captured from live STEP operation December 2012

Rather than the animation showing only predictions it can also be useful to include information on the recent history at the start of the animation before moving into the future situation – therefore the distinction between past and future can be clearly distinguished (e.g. by changing colour of the displayed time).

- It is important to allow the user to select the quantity displayed on the maps, for example switching between speed, flow, travel time and delays;
- The data displayed on the user interface should be updated frequently in order to support

traffic management decisions. From the research it is recommended that five minutes is a suggested maximum time between data updates of both current and predicted maps;

- Alerts of predicted congestion should be displayed on a geographic map and/or a dashboard-style summary; and
- Screen "real-estate" is a precious commodity within traffic control centres. A predictor user interface should not require a dedicated display monitor as it should be capable of running on monitors already in use by the traffic manager, and ideally should be fully integrated with the traffic management system user interface.

3.4 Conclusions

The STEP project's research of a total of fifteen traffic control centres in Europe revealed that the majority are interested in deploying short-term prediction to improve their management tasks, and expect that there would be tangible benefits of deploying short-term prediction in urban, regional and national traffic control. However, their preference was to see more evidence of successful real-life trials elsewhere before adopting any particular approach themselves.

Almost all of them stated that they expected that costs of setting up a short term predictor in their own centre would also pose a major problem. The outputs of this work fed directly into the real-life trial undertaken in the Netherlands, testing the STEP prediction tool against specific user requirements and helping to identify the best option for presenting the outputs of the short-term prediction tool.

Over 80% of control centres surveyed stated that they were optimistic about the use of short-term predictors to address problems of congestion. Predictors that can simulate potential traffic management scenarios are seen as providing significant additional benefit – while 50% of control centres rated a basic prediction capability as "very useful" or better, this rose to 80% if scenario simulation capability is included.

Nevertheless, the experience of TCCs with the practical use and application of these models bring their daily routine/operation is certainly limited. TCC representatives are interested in short term predictions in regular conditions, which is seen as a means to deal with variability/reliability of traffic conditions. Ultimately however, and consistent with most TCC's considering management of their networks in irregular conditions is a key objective, predictions of irregular conditions would be most useful, as one can then rely less on experience. This raises particular challenges to developers of such tools, since the state-of-the-art does not provide readily applicable traffic prediction tools with proven predictive power in incidental conditions. Obviously, the reason for this is the inherent conceptual difficulty of predicting unforeseen events, as well as drivers' response (demand side) to non-repetitive irregular traffic conditions.

In general traffic managers consider that predictions could be used to support decisions regarding:

- answering 'what-if' questions to efficiently apply the right traffic management scenario - currently there is no good decision support system available to the control centre for answering 'what-if' questions and evaluation of different traffic management scenarios;
- replacing fixed hardware by mobile hardware that is deployed at locations where predictions indicate that congestion problems will arise; and
- efficiently sending road inspector / traffic officers to the right locations where predictions indicate that problems will arise.

The research indicated that the most important reason holding back network managers from deploying short-term predictors today is a lack of clear and convincing evidence of successful application by other network managers.

4 Development of Tools for Scenario Development – Preparing the Pilot Software

4.1 Introduction

Workpackage 3 focused on the development of the proposed User Interface that will be presented to potential users of the short term predictors in the UK Pilot (WP4A) that will enable more detailed assessment and evaluation to be undertaken on how potential users might use the interface to support decision making in their strategic management of the road network.

The Traffic data Interface specification finalised between MM and Fileradar (Deliverable 3A) in July 2012 and approved by PEB. Interface Specification for the STEP tool was finalised and approved by PEB in August 2012. On the basis that we canvassed a number of potential users of short term prediction data on key attributes that they wish to see incorporated into the specification of prediction tools it was considered important to ensure that these were reflected in the development of draft specifications that were used in the development of the prediction tool and interface for both UK and Dutch trials. These documents were developed to support the pilot phases of the project in detailing the initial user interface that will be presented to users to display and highlight road sections where it is predicted that traffic congestion might occur based on the calibrated historic data and the Fileradar prediction model. The User Interface was designed to meet the key requirements identified in WP2: User Requirements report, and the user interface concentrates on providing an alerting mechanism and information graphing to support decision making by TCC operators.

Whilst users appear somewhat divided on the type of different user interface there is interest in developing an alerting type interface as well as graphical representation of the predictions that are made. In developing and testing the tool and interface both the UK and Dutch trials aim to investigate both mechanisms. In terms of visualisation, in general the feedback identified that the use of colour-coded links overlaid on a map view was a popular option, accompanied by alerts or alarms in case to show abnormal conditions. Importantly, TTC operators revealed the level of manual intervention when using the tool should be kept to a minimum and a degree of automation should be provided to help the operators in their daily operational duties.

As part of the work to develop user interface specifications within WP3A it is envisaged that an alerting type mechanism to advise operators when traffic conditions are predicted to be different from usual, with minimal disruption to operators duties. The primary objective is to develop a user interface based on the short term prediction mechanisms required by operators, as opposed to the development of new tools to support the trials themselves.

There are various possible system architecture permutations with two main variables:

- Integration – whether the predictors are fully integrated with the traffic management system (desirable) or whether they require their own separate user interface; and
- Hosting – whether the predictors are hosted alongside the traffic management system or whether they are hosted separately, for example by a prediction service provider. Both are reasonable patterns.

A number of different permutations are illustrated below but the overall preference is for the fully integrated options presented in Figures 4.1 and 4.4.

Figure 4.1: Fully integrated predictor components

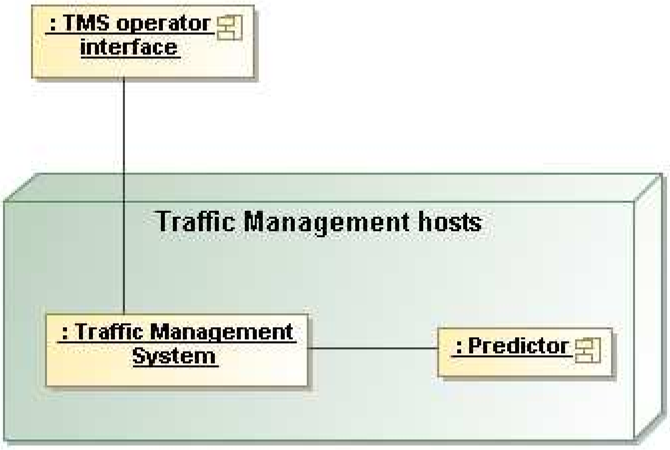


Figure 4.2: Partially integrated predictor component requiring its own user interface

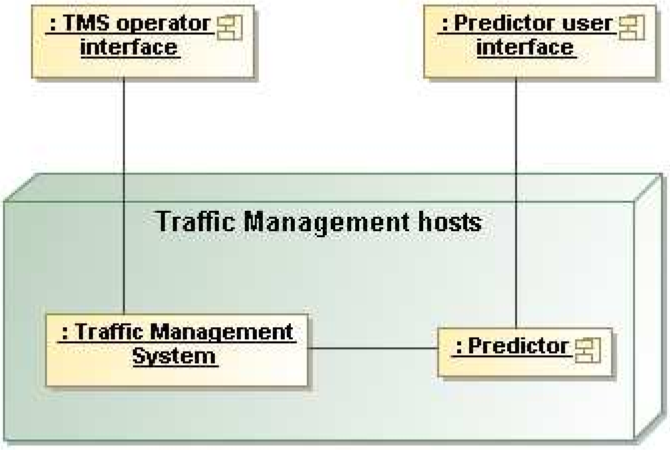
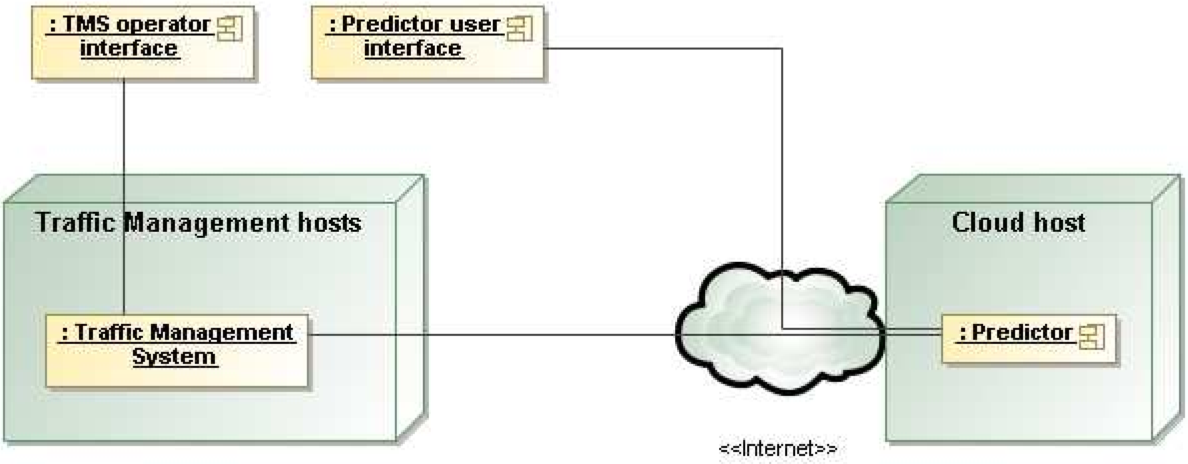


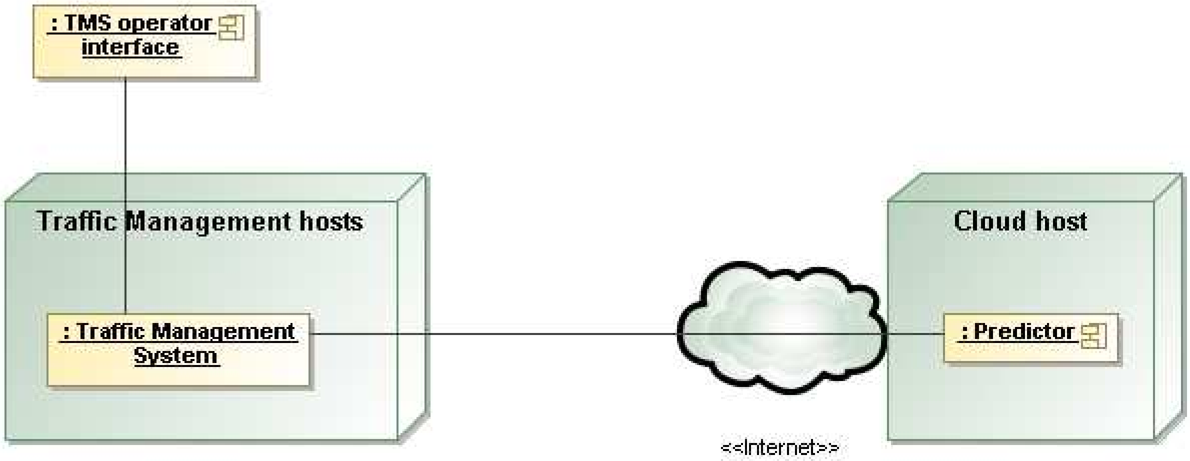
Figure 4.3: Predictor running in separately arranged hosting and requiring its own user interface



Where the predictor has a dedicated user interface, the presentation technology and underlying communications should obviously fit with IT policies of the authority. Typically a solution based on communication over standard HTTP produces the fewest deployment issues.

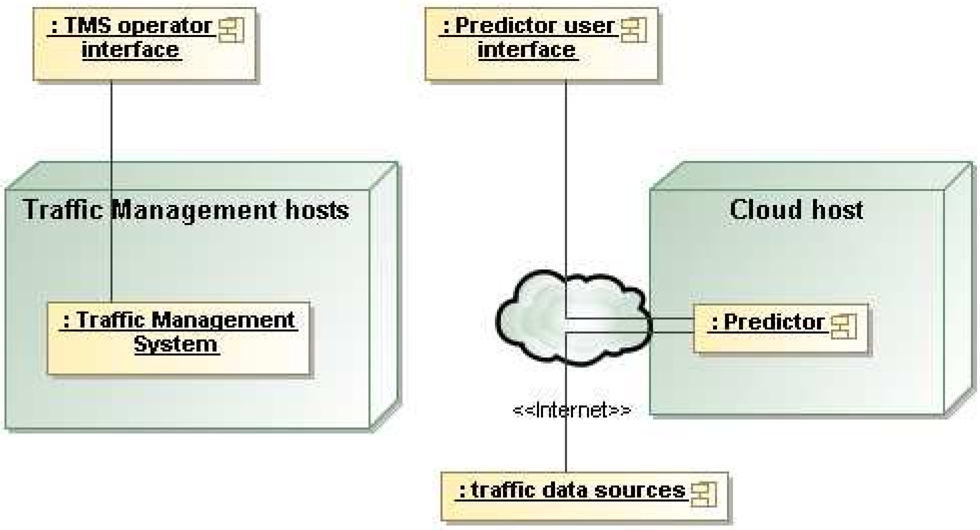
The STEP project implemented two different patterns for two separate trials. The architecture for a UK trial followed the pattern of Figure 4.4, with the Fileradar hosted prediction engine being integrated into Mott MacDonald's Osprey traffic management system. A live trial in the Netherlands followed the pattern of Figure 4.5, which enabled an operational trial to go ahead quickly without requiring any change to existing traffic management systems.

Figure 4.4: Integrated predictor running in separately arranged hosting



As a further detail, traffic data sources may be routed to predictors directly rather than through the traffic management system – in that case there is no need for integration at all. This pattern, shown in Figure 4.5, is not preferred for operational use but it can be a practical way to establish a trial.

Figure 4.5: Non-integrated predictors



Another architecturally significant factor is the required scale – for data sizing, throughput and performance. Traffic management systems suppliers are used to the raw traffic data being the largest and most frequent data source, but predictions can potentially be an order of magnitude larger because within every fresh prediction dataset there can be a snapshot at each time interval between now and the horizon. For example a predictor may be configured to provide a full dataset for each of 5 minutes ahead, 10 minutes ahead, etc up to 60 minutes ahead, and deliver this every 5 minutes, so that the total prediction data set is 12 times larger than the current traffic data set. Furthermore the road segments used in traffic flow propagation models may be finer-grained than the links currently monitored in traffic management systems. System architects must plan for this extra level of scale.

5 The STEP Live Pilots

5.1 *Introduction*

A key element of the project is the real-life trials conducted in operational traffic control centres in the UK and in The Netherlands, testing the tools against user requirements, with the outcomes of the trials helping to identify key requirements for implementation in Traffic Control Centres across Europe, including the design of user-friendly interfaces easing the understanding of dynamic information. This chapter describes Workpackages 4A and 4B.

5.2 *Overview of the UK Pilot*

The original proposal for Work Package 4A involved utilising Mott MacDonald's Integrated Network Management system previously installed in the Highway Agency's South West Regional Control Centre (SWRCC) to initiate a pilot project. This pilot would also involve providing the Area 2 management team (Mott MacDonald and Balfour Beatty) with predictive capability. A series of steps were set out in the original WP4A pilot programme and work initiated including following:

TASK	STATUS
• Preparing data and mapping:	• Historic data was obtained from HA for all relevant MIDAS sites and from TRADS for all relevant trunk road TMU sites. All road links have been mapped from NTIS and HA referencing schemes onto ITN road links for overlay onto standard map products.
• Undertaking dynamic model calibration:	• Historic data from 2010 and 2011 has been used to provide an initial calibration of the prediction model.
• Developing appropriate interfaces (with predictor and with users):	• Preparation of easy to understand STEP and interface-use material for RCC/Area 2 staff to reduce thresholds. A draft version of the interface has been produced but this has not been tested in an operational setting yet.
• Undertaking user engagement :	• During the preparation work to develop the pilot initial discussions took place with HA staff and the Area 2 team to gain a better understanding of their operational requirements and to test initial views/feedback on the development of the STEP application.

After discussions with the Area 2 team, it became evident that engagement with the RCC operators was also needed in order to gain the complementary view of how predictors might be used in a strategic road operations environment.

5.2.1 HA Structural Changes and Plans and Impact on WP4A

Discussions with the HA during the preparatory phase of WP4A revealed a number of significant impacts on the original plans for the UK pilot trial proposed for WP4A. These included the following:

- The role of the SWRCC changing to become more responsive, with the strategic role being fulfilled by a newly created National Traffic Operations Centre in Birmingham. This meant that the value of obtaining views from the SWRCC was significantly reduced;
- Current plans for the development of the HA's National Traffic Information Service involving a significant amount of work on traffic data collection and analysis, as well as traffic prediction to manage traffic incidents on the network with some duplication on the STEP work tasks; and
- Ongoing work within the HA's Traffic Management Directorate (TMD) who are developing their own approach to short-term prediction, which presents a risk of confusing

users/operators within the HA in terms of piloting the independently developed STEP prediction tool in an operational capacity.

- The changing management of Area 2 to a joint venture of Atkins/Skanska with effect from 1 July 2012, which reduces the value of introducing the STEP tool within the SWRCC.

There was also an added complication presented by the HA's key role as strategic partner during both the Olympic Games (27 July – 12 August 2012) and Paralympic Games (29 August – 9 September 2012). During this period, a significant amount of key operational staff would be heavily engaged in traffic management duties and would not be available to participate in the UK trial during the period of the games.

Reflecting these key issues set out above a new approach for delivering WP4A needs to be developed which will still enable the core objectives of the STEP project to be met. As TMD already have had short term prediction capability at NTOC since 2003, the STEP project would provide greater benefit to the HA if the focus was to focus on undertaking user engagement within the HA to inform the future TMD desktop service provision for different parts of the HA who will use to manage traffic on the network by obtaining feedback on the interface and presentational aspects of the application.

By focusing on the HA's current NTIS Enhanced Desktop tool, it was considered beneficial that participation in the user engagement work would help underpin its development and subsequent roll-out across the HA as well as provide a good platform for understanding key requirements relating to the interface and functionality of the tool. Thus, there were considered to be clear benefits to such an approach in terms of providing a better understanding of user interfaces and what operators "like" in preparation for NTIS desktop development as well as the importance of having a clear understanding of the different agencies within the HA that may be able to participate in any qualitative assessment of the tool/interface guidelines.

Unfortunately, ongoing discussions with the HA continued to focus on the issues raised in terms of the changing role of the organisation and this ultimately meant that the pilot could not take place within an HA TCC.

5.2.2 Approach to Traffic Wales

Due to difficulties in resolving the delivery of a UK STEP Pilot within an HA TCC an alternative option has been pursued, with Traffic Wales approached to help with our engagement activities. During December 2012 a final option was considered to text the STEP application within Traffic Wales, which is the public face and link to the Traffic Management Centre (TMC) operations which work to underpin the key responsibilities of the Welsh Government's transport responsibilities – namely to 'develop a world-class transport system to provide safe, affordable and sustainable transport for all.' The organisation is actively striving to improve the quality of information provided, either through simple methods such as information exchange agreements or investing in Intelligent Transport Systems (ITS).

Traffic control and management services are delivered by Amey/URS under a Welsh Transport Technology Consultancy (WTTC) contract, as well as the Welsh Government's Trunk Road Agencies. Staff are based within Traffic Management Centres (Coryton, Cardiff on the M4 in South Wales and Conwy on the A55 in the North). The Traffic Management Centres in Cardiff and Conwy form the hub of Traffic Wales' communications and information dissemination network.

In parallel with feedback obtained from TCC staff in the Netherlands on the operation of the tool, it was considered beneficial to get views from Traffic Wales personnel, to help identify the strengths and weaknesses from a different perspective of standard operations and general data availability and in particular how it meets the needs of operators elsewhere. It was felt that by drawing together the feedback from both Dutch and Welsh control centre personnel will then help us inform how short term prediction tools such as STEP can be further developed to support national TCC requirements around Europe.

Extensive discussions took place with Traffic Wales management on this aimed at setting up a feedback/discussion session but unfortunately the internal approval processes proved problematic and due to time constraints meant that it was not possible in the end.

5.3 The Netherlands Pilot

5.3.1 Introduction

At the outset of the project discussion took place with Rijkswaterstaat, the Dutch national road administration on involvement in the research work and it was found that both VCNL (the national traffic control centre) as well as VCMN (the regional control centre for the centre region of the Netherlands) were interested in hosting a pilot to test the functionality of the STEP prediction tool in a TCC setting. These two control centres share a building in the city of Utrecht.

Initially, it was agreed that an attempt would be made to run a pilot scheme in both control centres simultaneously. Both the national and regional control centre perform different tasks and therefore feedback from both of these would present different views on how best to apply short term predictions to support daily tasks. At the same time work was initiated on setting up the prediction model including setting a server where the predictions were to be made, the collection of regional network data for the prediction software, calibration of the model for the region around Utrecht using automatic calibration routines and also the development of a web client.

5.3.2 The STEP Prediction Algorithm

The predictions used in the pilot are generated by a combination of algorithms and models. The core model used is the Lighthill-Whitham-Richards model [1,2]. Traffic is modelled as a fluid stream, where ‘bottlenecks’ form regions where the ‘fluid’ flows slowly, i.e. where traffic congestion occurs. The model was originally developed in the 1950s, but has proven to be powerful in predicting the global dynamics of traffic jams in many scientific studies. The difficult part however is to calibrate the model for a large-scale network such as the network included in the pilot study in Utrecht.

Despite the model’s simple form, there are many numerous parameters to determine including the demand at each on-ramp at each time of the day, the average route choice at each intersection or off ramp in the network, the capacity of each section of the road and the average distance between vehicles when flow is at capacity. To make matters even more complex, these parameters are stochastic and dynamic by nature (for example, the average distance that people keep to their predecessor determines the capacity of a road). The capacity therefore depends on human behaviour, introducing a stochastic component. Furthermore, the capacity changes over time as a function of the weather, lighting conditions, road works or incidents.

Since 2010 Fileradar in the Netherlands has been developing advanced routines to perform the entire calibration automatically. Some of the routines have proved themselves since then and provide excellent results, such as the algorithms used to predict demand and route choice. Others were, during the course of the pilot, still in the experimental phase, such as the capacity calibration algorithm to automatically determine the dynamic capacity at bottleneck locations. This algorithm detects queues and then tries to replicate the observed dynamics of each queue in the prediction model by changing the capacities of relevant segments. This way, after a short period of observation, predictions can be made of any queue, recurrent or non-recurrent, and the dynamic nature of the capacity is automatically taken into account. As the focus of the control personnel was especially on the management of non-recurrent situations, this is a highly desirable feature.

In order to have useful results for traffic controllers, both the length of the jam and the speed of vehicles in the jam need to be predicted more or less correctly by the model. The capacity calibration algorithm works really well on isolated cases, where a single queue occurs due to a single bottleneck. Unfortunately, the network of Utrecht is a network with very complex traffic congestion patterns: spillback over intersections, interaction between different bottlenecks and so-called moving jams that all occur on a regular basis. The capacity calibration algorithm was not able to cope sufficiently with these complex patterns and as a result, the predictions were not as good as hoped for when the pilot was planned.

5.3.3 User Interface Issues

Building on the outcomes of WP2 (as presented in Section 2) further dialogue with TCC staff helped to identify the preferred option for presenting the predictive traffic information that best supported operational requirements. A variety of options were considered including presenting the predictions in a split screen showing two maps (current and predicted situation), visualisation of the remaining capacity on corridors and alerts when and where ‘spillback’ are forecast to occur at particular locations.

During the delivery of the pilot several changes were made to client based on feedback that was received from TCC staff and based on this recent history was added to the animation so that a 40-minute history and 20 minute prediction were shown in one single animation. Similarly, requests from TCC staff led to a queue lengths plot being built into the application, showing total queue length as a function of the time and comparing it to the historic average queue length over the day. As a result in one quick view the traffic controllers were provided with information on whether current day traffic levels were busier or less busy than average.

One of the concerns that had been raised about practical implementation was the availability of relevant data and the cost of obtaining these. The trial proved that the amount and kind of data that is routinely collected from standard roadside detectors and through existing communication channels is of the kind needed for a short-term predictor to be developed and calibrated. Although the accuracy of the prediction was not good enough, the available data was considered sufficient both in availability and type of information.

With the Netherlands pilot local road network information was made available via the NWB (Nationaal Wegenbestand), a government maintained map of the entire Dutch road network and traffic data was obtained from the NDW (Nationale Databank Wegverkeersgegevens), a government maintained online real-time comprehensive database of traffic measurements. The NDW also formed the basis for the data used during the pilot period in terms of real-time speed and flow with the project team being able to enter this data into the predictor with as little as 3 minutes delay.

The Netherlands pilot predictions were all run on servers in the cloud using default http and https protocols which provided several advantages. The only requirement for the actual user is a connection to the internet. Using default protocols reduces problems such as the need to install and maintain software on TCC operators’ own machines as well as avoiding problematic firewall and security issues. Importantly, it also helped to maintain full control of the real-time data flows provided by the roadside detectors.

5.3.4 Assessment of the Netherlands STEP Pilot

In March this year an official evaluation of the pilot scheme was held at the Utrecht national control centre. Overall, the control centre personnel revealed a positive view of the pilot from the star given that they had wanted short-term traffic predictions for a long-time. Indeed, traffic controllers were very happy with the fact that they had a direct influence on the development and adaptation of the software itself compared to being presented by something that is ‘as is’. The resulting user interface was rated as of a good quality, especially the dual map feature which was considered as user friendly and provided a good overview. The queue length plot was also a long desired feature and was therefore received well by the users.

During the pilot the traffic controllers had to deal with more changes as a new system was deployed where live camera images became available to monitor the road network. Therefore, there was even more pressure then normal on the 9 screens that are available to a traffic controller. This caused in some cases for the Dante web client to be put behind other applications. Because the client was offline when the new version was developed, the pilot was pushed to the background.

the prediction quality was not sufficient, which together with the fact that other new tools appeared during the pilot caused the use of the client to degrade, until at the end of the pilot it became apparent that the tool wasn't used anymore. However, had the prediction quality been sufficient, the control centre managers indicated that it would be very likely that the client would still be used. This indicates that every step needed to successfully host predictions in a traffic control centre was indeed taken, and all that needs to improve is the prediction quality itself.

One thing that the managers of the traffic control centre indicated was that if they would do the pilot again, they would focus more on a few interested users that would work with the tool, rather than just leave the tool open for all users. Naturally some users are more interested in a new tool than others who are more sceptical by nature (or nurture). If a small group of users are more proactively involved into the pilot, then they are more prone to call in case of problems or new ideas because they feel more that the pilot is 'theirs' than in the current setup.

In terms of the situations where predictions would be used, TCC operators revealed that given the current economic crisis they see many potential applications, where amongst others the predictions support decisions regarding:

- Answering what-if questions to efficiently apply the right traffic management scenario; currently there is no good decision support system available to the control centre for answering 'what-if' questions and ex-ante evaluation of different traffic management scenarios;
- Replacing fixed hardware by mobile hardware that is deployed at locations where predictions indicate that congestion problems will arise; and
- Efficiently sending road inspector / traffic officers to the right locations where predictions indicate that problems will arise.

6 Summary and Conclusions

6.1 Introduction

One of the surprising outcomes of the research was that how little use was made of short-term predictors in practice amongst TCCs. Academic research has developed algorithms that have been tested in models and in simulated environments with substantial benefits but few of these seem to have migrated into real life and there are certainly issues to overcome in terms of quality of predictions and cost of establishing new systems. Data costs should not be a limiting factor. Our test implementation required no additional data collection over and above what is already connected, and the internet-based delivery mechanism means no other outlay on hardware than an extra screen.

There are common themes in the concerns that each of the Traffic Control Centres expressed: for starters many of the managers felt that their staff were largely unaware of the possibilities that short term predictors might offer to make their job easier and better. Almost all of them stated that they expected that costs of setting up a short term predictor in their own centre would be a major problem

From the research undertaken it remains easier to predict congestion at recurrent bottlenecks than irregular incidents. Regarding the first, warning of an early onset or an extra severe situation at a known problem point is already of use, as the tests in Utrecht have shown. Being able to provide TCC staff with not just short term forecasts of congestion but also with advice on how to respond to traffic jams that have not even occurred yet, is still proving to be very challenging. Of paramount importance is the need to continue to work on the online calibration algorithms whilst keeping close contacts to the TCC professionals that know their road systems well and provide valuable feedback.

The STEP project has provided valuable lessons and showed that all necessities are available and it is possible to deploy an operational short-term predictor into real-life TCC operations. Critical however is the quality of the prediction. Once this is achieved interesting decision supporting tasks can be built on top of these predictions alleviating workload on TCC operators. To increase the quality, further research is being actively pursued by Fileradar and results are expected in the short term.

6.2 Establishing Short Term Prediction Tools Within TCC’s

The primary objective of the STEP project was to investigate how to successfully apply short-term predictions in a Traffic Control Centre setting, and the pilot phase of the project sought to gain a better understanding of several fundamental elements such as user acceptance and trust of the prediction tool, the development of an appropriate interface that meets user needs, as well as technical deployment and the quality of predictions.

6.3 User Acceptance and Trust

A lack of user acceptance is a significant impediment to the success of new information systems, and implementing short-term prediction tools in a TCC is no exception. Through engaging with a range of TCC staff is clear that personnel are sceptical about new tools, because they often have seen so many of them, often with varying degrees of success. However by involving TCC personnel (including managers *and* actual end users) into the entire process from start to finish (ie. design to rollout phase) a sense of ‘ownership‘ is created increasing level of acceptance and open views of the merits of this type of system. From a process point of view it is recommended that when implementing such tools it is wise to form a taskforce of only a few TCC personnel who are enthusiastic about the idea. This will reduce the aforementioned problems and increase feedback levels.

It is technically possible to build a decision support system based on predictions, such as automatic re-routing advice or that relating to optimal scenarios to deploy measures based on the traffic predictions. However, trust is an important factor in the development of such proactive support systems, with users first needing to trust the predictions themselves before they trust the system outputs. As a result of this it is beneficial to initially show the predictions 'as is' and to get the prediction quality up to a standard where the user fully trusts the predictions. Once that is achieved, more proactive decision support tools can be built based on these prediction outputs.

6.4 Quality of Prediction Outputs

Several valuable lessons were learnt. These included that reasonably accurate predictions on a horizon of at least 20 minutes are needed in order for the predictions to support decisions made by the controllers. Importantly, the prediction model needs to be able to predict the effect of non-recurrent situations such as incidents or road works, because it is especially around those situations where traffic controllers really can make a difference by taking action. Feedback from TCC operators indicated that predictions only based on historic averages are not very useful for them.

The accuracy of the system predictions needs to be expressed in terms of both the predicted length of the queues (determines whether spillback is correctly predicted) as well as the predicted speed of traffic (which determines whether delays are correctly predicted). If both of these are accurately predicted, then TCC operators are able to make good decisions on which dynamic traffic management measures to utilise (such as re-routing, ramp metering etc.) Timeliness is also a critical factor, as generally TCC operators need to respond swiftly to emerging traffic congestion issues, with predictions required to be available to end users within minutes.

6.5 User Interface

The user interface developed for the Dutch pilot was received well by the end users and based on the discussions that took place during the preparatory phase. Displaying the predictions on an interactive map provides an efficient way for TCC staff to view the traffic predictions. Using a dual screen, where the actual situation is shown beside (an animation of) the predictions allows the traffic controllers to compare the predictions with the current situation, so that they can quickly estimate whether action needs to be undertaken. The user interface needs to update frequently, because timeliness is such an important factor.

6.6 Technical Deployment Issues

One of the major issues was the deployment of the pilot software within the TCC, which proved to be a real challenge due to strict IT policies that are standard across TCCs as a whole. In this case, the tool was successfully deployed because a rich web client was used which proved beneficial because it ensures that the client is always able to run the latest version of the software and updates can be made quickly, and can be run on any platform and network. The following conclusions can be drawn:

- A Rich Web Client works well in a traffic control centre because:
    - It is a good way of preventing a strict IT-policy to be an obstacle for deployment;
    - It ensures that the client always runs the latest version of the software;
    - Updates can therefore quickly be made, and an agile response to requests and bug reports keeps users engaged; and
    - It ensures that it can be run on any platform and network
- By having all communication go over port 80 and HTTP, the protocol that is used for web browsers, firewall issues are prevented; and

- Having good and fast technical support available is very important, not only because this keeps users engaged, but also because the software usually runs on critical systems with multiple applications that are vital to the functioning of the traffic control centre (and thus the functioning of the traffic system itself).

6.7 Essential Specification Aspects for Short Term Predictions

Throughout the pilot phase regular communication was established with the TCC operators who were using the system, which helped to establish a rapid response approach to dealing with specific issues that arose ensuring support engagement from both front-line staff and management. In addition, interactive sessions with TCC personnel were also hosted to detail the predictor's visualisation. This close co-operation with the TCC management and users helped to provide a clear indication of the essential aspects of short-term prediction that affect its use and acceptability. These include the following:

- It is important that the actual traffic flow prediction is of a very high quality, as TCC staff considered only the first 15 minutes to be of adequate quality to serve their needs. (The deterioration after longer lapse times were found to prevent the predictions being used for longer term forecasts);
- The preferred option for the presentation of prediction results selected by TCC staff was found to be through use of a split screen with actual traffic levels and animated predicted situation shown side-by-side;
- Data transfer latency is critical when implementing short-term prediction tools, with TCC staff often comparing predictions with existing real-life data that they are used to seeing on their screen. The data volumes are significant when compared with real-time traffic data because each updated prediction contains not just a single snapshot in time but a series in time from now into the future. Considerable time was spent on streamlining communications elements of the system so that staff felt comfortable with the outputs.
- Non recurrent traffic congestion and quantitative descriptions of that (in terms of minutes delay, length etc) were the most interesting, but also the hardest to achieve; and
- The provision of an aggregated graph showing the average and current total km network queue.

6.8 Future Deployment of Short-term Prediction

A lack of user acceptance is seen to be a significant impediment to the success of new information systems. Applying short-term predictions in a traffic management centre is no exception to this rule given the following:

- Traffic management personnel can be sceptical about new tools. Involving the personnel, managers and actual end users into the entire process from design to rollout can increase the chance of success.
- While it is technically possible to build a decision support system based on predictions, users first need to trust the predictions themselves before they trust proactive advice of the system. It is therefore advisable to first show only predictions until the user fully trusts these; once that is achieved, decision support tools can be built upon those predictions.
- The activities required also include: collect network data; prepare model, calibrate model, validate model, train users, deploy predictors, provide operational support to predictors, assess benefits realised.
- Authorities have limited resources and cannot accommodate complex configuration and maintenance activities.
- Prompt and effective technical support should be available.

7 Dissemination Plan and Activities

7.1 Introduction

Dissemination forms an important part of the project in terms of sharing the results and findings of the research work undertaken. Whilst the results will be most directly applicable to inter-urban roads networks, opportunities to improve the traffic management within regional UTMC systems are also possible as a result of the research findings. Therefore the project results will also help inform urban traffic management contexts, where local traffic managers have expressed a requirement for effective short term predictions.

A programme of dissemination has already been initiated including the following:-

(i) Mott MacDonald presented on STEP at the UK UTMC Conference, Reading held between 11-12 December 2012, which covered the background to the research project and outcomes to date.

(ii) Mott MacDonald presented and discussed STEP short-term prediction with Osprey users in our Osprey user group in January 2013.

(ii) The 9th European ITS Congress 4-7 June 2013 in Dublin: Using Short Term Traffic Predictors in Traffic Management Centres:

This conference is sponsored by the EC and is one of the premier European events that showcases the latest advances in Intelligent Transport Systems and innovative transport solutions. The theme of this year's conference was "ITS: Real Solutions for Real Needs" with a primary focus on ITS solutions that are driven by policy as opposed to being technology-led. The emphasis was on proven deployed solutions and innovative R&D that is focused on solving real problems and delivering value for money in today's challenging economic environment.

A paper on the STEP project and research findings was included in the programme of the conference, which generated a significant amount of positive feedback from a range of organisations from Australia, Finland and Belgium who are actively considering implementing short term prediction capabilities.

(ii) UK UTMC Development Group (UDG) Guidance

A UTMC Technical Guide from the EraNetRoad Mobility Project STEP has been produced for dissemination of the key outputs from the reearch work aimed at offering advice and guidance for UDG members on specifying, designing and implementing short-term traffic predictors for traffic management system.

UTMC is a UK-led initiative which provides and maintains a technical framework for traffic management and related systems. It produces open specifications geared to the needs of real world projects, delivered through an efficient and innovative supply market. UTMC specifications are managed by the UTMC Development Group (UDG), endorsed by the UK Department for Transport, and published on the UTMC website at: http://www.utmc.uk.com. To help users get the best out of the UTMC Technical Specification, UDG provides a set of guidance documents addressing some of the associated issues, ranging from non technical aspects such as procurement policy and operations, to technical aspects such as database design and communications network configuration.

The guidance document has been based on the outcomes of the STEP project and submitted to the UDG as a contribution to the UTMC library of guidance documents.

(iii) Publication of Article in UK SmartHighways Magazine (Vol1,No 1):

The article discussed the common themes and concerns that Traffic Control Centres have on the topic of short-term (in the context means of betrveen lO minutes and an hour) prediction and provided an overview of the experience and lessons learnt with the implementation of a pilot project at the Utrecht TCC, revealing that it is possible to implement an operational short-term predictor into real-life Traffìc Control Centre operations.

Other events being targeted for dissemination of the findings include:

- The 11th European Transport Congress which will be held in Prague on 19-20 September 2013. This event is being organized by the Czech Technical University in Prague, Faculty of Transportation Sciences in cooperation with the European Platform of Transport Sciences. The Congress will be part of the celebration of 20 years anniversary of the Faculty of Transportation Sciences.

It is intended to present the findings of the STEP project at the European Transport Congress scheduled to take place in Prague where a variety of topics are being considered including transport research and education as well as intelligent transport systems. It is organized by the Czech Technical University in Prague, Faculty of Transportation Sciences in cooperation with the European Platform of Transport Sciences. The Congress itself will be part of the celebration of 20 years anniversary of the Faculty of Transportation Sciences.Additional opportunities to showcase the findings will be pursued as appropriate over the coming months.

In addition to the above, the outcomes of the STEP project will continue to be disseminated with Urban Traffic Management and Motorway TCCs during meetings that are held to share the findings and understand more about their aspirations in developing short-term prediction systems.

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