FINAL REPORT

TR1015 COSMOS

Congestion Management Strategies and Methods in Urban Sites

Project co-ordinator: The MVA Consultancy

TELEMATICS APPLICATIONS PROGRAMME (TRANSPORT)

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TR1015 COSMOS

Congestion Management Strategies and Methods in Urban Sites

Setting the Scene

It is recognised that urban congestion is a major traffic problem in Europe. The European Commission esti-mates, for example, that economic losses through traffic delays in Europe total 150 billion Euros per year. Congestion generally occurs when the demand for roadspace is greater than the supply, a situation that is worsened when incidents, such as accidents or vehicle break-downs, occur and reduce available roadspace. The extra costs of traffic congestion are borne directly by car drivers and their passengers. Conges-tion also affects buses and trams, reducing the attractive-ness of public transport, and leads to increased pollution, which affects all urban residents and contributes to global warming. In COSMOS the aim has been to develop, validate and demonstrate new procedures for reducing and preventing the traffic delays caused by congestion and incidents in urban networks.

Approach

Following an exploration of perceptions and requirements of users (highway and traffic authorities) and a definition of general strategies for congestion and incident management (CIM), demons-trators for SCOOT, MOTION and UTOPIA were developed, incorporating these new strategies; in addition, reroute-ing responses were integrated with the demonstrators. The resulting enhanced UTC systems were then validated in three test sites: London, Piraeus and Torino. In line with programme guidelines, project validation consisted of two stages: verification and demonstration. In the verification stage, focusing on the technical aspects of the demonstrators, the physical functioning of each system was tested under non-operational conditions. System demons-tration was conducted under operational conditions and concentrated on the acceptance of the application by end-users and on a comprehensive impact analysis in order to evaluate the benefits of the application. The three demons-trators were developed separately, according to their individual operating needs, but a common evaluation frame-work was adopted to enable a collaborative evaluation of system effects.

Results and Achievements

For the SCOOT demonstrator a new enhanced version of the INGRID incident detection module was developed and MONACO, an existing off-line program, was enhanced to operate on-line within the SCOOT system to monitor traffic and detect recurrent congestion and identify critical links. Existing SCOOT gating facilities were improved for greater flexibility and to allow more rapid response to detected incidents. Further-more, VAMPIRE, a new pro-gram for rerouteing has been developed and implemented.

The major MOTION system enhancement resulting from COSMOS was the inclusion of the CIM function, which uses strategic input to modify control parameters, thus realising strategic decisions in traffic management. In addition, several other MOTION functions were improved, including Network Incident Detection and Offset Determination. The PORT system has been implemented to control several VMS.

Enhancements to UTOPIA and the townsupervisor in Turin included the development of a new function - the Common Control Strategy Manager (CCSM) – and the improvement of automatic congestion and incident detection and rerouteing.

The technical assessment, or system verification, was performed in order to establish that the enhanced versions of SCOOT, MOTION and UTOPIA were operating in the correct way. The verification was successful, with some minor fine-tuning of the systems done in preparation for the demonstration of system effects.

The evaluation of the London system during the demon-stration phase included user acceptance tests to determine the effect of the VMS, which displayed messages generated by the UTC system. It was found that 12.6% of traffic was diverted by the VMS rerouteing advice. Impact analysis of the effect of SCOOT gating showed a 22% reduction in delay and a 43% reduction in congestion. Simulation tests indicated a network capacity improve-ment of up to 20%. The impact on emissions and fuel consumption was also favour-able with reductions in the emissions of three major pollutants and an 8.5% reduction in fuel consumption resulting from COSMOS enhancements.

Evaluation of MOTION looked at the traffic improvements achieved by the introduction of CIM measures and the introduction of rerouteing. User acceptance tests to determine the effect of VMS messages generated by the rerouteing software indicated that 19% of drivers who noted the VMS followed the rerouteing advice given. Impact assessment tests showed that journey times in the test network fell by up to 19.5% with the introduction of CIM and again by 13.6% with the introduction of rerouteing. The number of congested intervals recorded fell by 20% with the introduction of CIM and by a further 12% with rerouteing. Emission of three major pollutants fell with CIM and with rerouteing. Fuel consumption fell by 10% with the introduction of CIM and by a further 4% with rerouteing.

User acceptance tests in Torino indicated that up to 6% of vehicles were diverted by VMS giving rerouteing advice. Impact assessment indicated that with COSMOS enhancements traffic on the main path inward to the city centre experienced an 18% reduction in delay; this was achieved without increasing delays to traffic on other network paths. The duration of incident and congestion events was reduced by the enhanced system, most notably during the AM peak when the duration of these events was halved. The assessment of the impact of the Torino demonstrator on emissions and fuel consumption showed a reduction in emissions of three major pollutants; a reduction in fuel consumption of 4% was achieved.

Conclusions and Plans for the Future

The results of the COSMOS demonstration tests are extremely promising. The three enhanced UTC systems were based on commonly defined strategies for conges-tion and incident management and for rerouteing, but otherwise were developed separately and implemented and tested in three diverse test sites. All three systems showed positive results in terms of user acceptance and impact analysis. This outcome suggests that, regardless of the specific technical and operational characteristics of a UTC system, there are some basic principles and strategies for congestion and incident management and rerouteing that can be implemented in a range of UTC systems with substantial benefits: reduced delays for car drivers and public transport users, and reduced emissions for all urban residents.

To maintain the position of SCOOT as market leader in UTC systems regular updates of the system are essential. The commercialisation of the COSMOS developments forms part of this process. It is expected that MONACO, VAMPIRE and the upgraded version of INGRID developed in COSMOS will be available with the next release of SCOOT.

Economic exploitation of the enhanced MOTION system will take place as part of the exploitation strategies of Siemens, the owners of MOTION. As part of this strategy, MOTION will be integrated into the Siemens UTC system MIGRA Central before the end of 1999.

Exploitation activities for UTOPIA, a commercial system marketed worldwide even before the enhancements carried out in COSMOS, were already underway during the course of the project. The exploitation process will continue and the results of COSMOS tests will be disseminated to customers in the traffic industry worldwide.

Contact Details

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1 Setting the Scene

1.1 The Challenge

Urban congestion is a major traffic problem in Europe. The European Commission estimates, for example, that economic losses through traffic delays in Europe total 150 billion Euros per year. Congestion is generally most severe on the radial routes leading to city centres during peak commuting periods, and in central business districts throughout the day. The main cause of congestion is the oversaturation of road networks, which occurs when the demand for roadspace is greater than the supply. This situation is worsened when incidents, such as accidents or vehicle breakdowns, occur and reduce available roadspace. The extra costs of traffic congestion are borne directly by car drivers and their passengers. Congestion also affects buses and trams, reducing the attractiveness of public transport and leads to increased pollution, which affects all urban residents and contributes to global warming. Possible solutions to congestion include increasing road supply or decreasing traffic demand.

It is no longer accepted that building new roads can alleviate traffic congestion since suppressed traffic demand is released onto the new road network. In addition, road building is generally not an option in urban areas due to physical and environmental (and financial) constraints. Decreasing traffic demand through demand management may have a major impact on congestion reduction in the future. At present however, few demand management schemes have been implemented. Therefore, network signal control systems will have to cope effectively with increasing traffic congestion and traffic incidents for the foreseeable future.

Most of the congested routes and road networks in Europe’s urban areas are equipped with traffic signals for intersection control. Existing signal programs are generally not well prepared to deal adequately with problems in the network caused by congestion and incidents. The major programs in use for on-line network signal control were originally designed to optimise network efficiency - for example, to minimise delays or stops - in unsaturated traffic conditions. Some programs have adaptations that enable them to react, to some extent, to congestion and incidents. However, so far no program for traffic signal control contained general procedures for congestion and incident management (CIM).

1.2 The COSMOS Project and Consortium

Against this background COSMOS has developed, validated and demonstrated new procedures for reducing congestion in densely trafficked urban areas. These new procedures have been implemented in three traffic signal control programs, SCOOT, MOTION and UTOPIA, and validated in three test sites, London, Piraeus and Torino.

The new procedures comprise:

- special modules for Congestion and Incident Management (CIM) which can be included in on-line network signal control systems, and

- strategies for rerouteing traffic to make the best use out of the capacity at junctions and in the links between them.

The COSMOS consortium included Siemens, the Transport Research Laboratory (TRL) and MIZAR Automazione, the organisations responsible for the design and development of SCOOT, MOTION and UTOPIA, three of the most advanced UTC systems in the world. These system developers have been able to judge the appropriateness and applicability for each system of the common control strategies that have been developed for congestion and incident management. The four consultants in the consortium (The MVA Consultancy, Heusch/Boesefeldt, Centro Studi sui Sistemi di Trasporto and Eratosthenes) have long-standing experience in advising local authorities on the best solutions to their transport problems. These four consultants have also been involved in the development and/or application of SCOOT, MOTION and UTOPIA in the past.

In COSMOS, The MVA Consultancy was Project Co-ordinator, assisted in project management by TERU at Napier University. Heusch/Boesefeldt was overall System Engineering Manager, and led the verification and demonstration of the MOTION system in Piraeus. Centro Studi sui Sistemi di Trasporto (CSST) developed the Town Supervisor function of UTOPIA and led the system demonstration in Torino.

The Technical University of Hamburg-Harburg developed the portable rerouteing software, implemented in the London and Piraeus test sites. TORG at the University of Newcastle upon Tyne developed the Path-Flow Estimator, used for O-D estimation in Piraeus.

The Traffic Director for London (TDfL) and the Traffic Control Systems Unit (TCSU), the authorities responsible for traffic control in London, assisted in planning and executing the SCOOT demonstration in the Borough of Kingston. Furthermore, the TDfL chaired the COSMOS User Board. Eratosthenes provided local assistance and liaison with the authorities in the Piraeus test site.

The Technical University of Munich, as Evaluation Manager, planned and executed the collaborative evaluation of the demonstration of the three systems in the three test sites.

2 Approach

2.1 Project Objectives

The central objective of COSMOS was to build and verify demonstrators for congestion and incident management (CIM) in urban network signal control. The project aimed to:

- develop general strategic plans for integrated urban traffic control under congested traffic conditions, including in particular signal control, VMS and rerouteing;
- refine existing concepts for urban incident and congestion detection strategies;
- within the general framework given through the strategic plans above, develop detailed strategies and algorithms for congestion and incident management (CIM) through on-line network signal control;
- integrate these strategies and algorithms with strategies for urban rerouteing;
- implement the new signal control strategies and algorithms in the UTC systems SCOOT, MOTION and UTOPIA;
- verify the new combined procedures for signal control and rerouteing on-line in London, Piraeus, and Torino; and
- assess the impacts of the three enhanced systems according to a common evaluation framework.

2.2 Methodology

To achieve these objectives the work of the project was broken down into a number of workpackages, broadly following the 5–phase model of User Needs, System Design, System Development, System Verification and System Demonstration. The eight COSMOS workpackages are described below:

WP1	Project Management	covered internal project management and quality control and assurance on project level;
WP2	External Co-ordination	covered liaison with the European Commission and other projects of the 4th FP, and dissemination activities;
WP3	Strategy Development	covered the analysis of user requirements, the development of integration concepts, and the development of the common control strategies for CIM;
WP4	System Development	covered the building of demonstrators for CIM as part of SCOOT, MOTION and UTOPIA and for rerouteing;

WP5	System Verification	covered the implementation of the demonstrators in the sites in London, Piraeus and Torino; and the collection, processing and initial analysis of system performance;
WP6	System Demonstration	covered the implementation of amendments to the systems that were necessary following the verification phase, and the collection, processing and initial analysis of the data concerning system effects;
WP7	Evaluation	covered the development of an evaluation plan for the verification and demonstration phases and the collaborative analysis of system performance and system effects;
WP8	Exploitation Plan	covered the development of a plan for the exploitation of the project results

Under WP 3, COSMOS started with the definition of general and specific user requirements for congestion and incident management. Based on these requirements, the strategic interfaces between urban signal control and other UTC systems (in particular rerouteing either with VMS or through in-vehicle route guidance, but also public transport and parking management) in the specific context of CIM were defined. This integration concept comprised both data flows and the requirements for prediction and modelling tools and strategies for the development of control decisions.

In the next step, the common control strategies (CCS) for congestion and incident management with on-line network signal control were elaborated. These principles took account of:

- the information available from automatic congestion and incident detection (ACID) or from the system operator;
- the possibilities of on-line urban network signal control; and
- the restrictions set by the demands of other UTC systems.

Based on these general principles, strategies for CIM in urban networks were defined. These are rules that determine under which *circumstances* which *tactics* and *tools* are to be employed to respond to incidents and congestion situations as they are detected. The circumstances were defined as a number of scenarios, dependent on the location and severity of congestion and incidents in particular links in the network. The responses to these scenarios were defined as tactics (e.g., gate the entry to a link, open the exit from a link) and tools (e.g., increase cycle time, balance offsets); these are measures which can be taken within UTC systems to alleviate congestion.

Following this definition of general strategies for CIM, demonstrators for SCOOT, MOTION and UTOPIA were developed in WP 4, with new strategies and algorithms for the detection of congestion and incident scenarios and for signal plan responses. In addition, rerouteing responses were integrated with the demonstrators. In this way, the common development of user requirements, of integration concepts and of common control strategies for CIM in Workpackage 3 branched out, in subsequent workpackages and tasks, into the specification of algorithms and the building of three separate demonstrators for SCOOT, MOTION and UTOPIA. Following the development of these systems extensive verification tests were performed in three test sites (WP 5), to establish that the systems were performing correctly. Following the successful completion of these verification tests, system demonstration tests (WP 6) were performed in the three test sites to establish the impacts of the systems against previously defined evaluation objectives. A collaborative evaluation of CIM and rerouteing strategies in the three UTC systems was performed (in WP 7) according to a common evaluation framework which had been defined earlier in this WP. Finally, an exploitation plan was developed in WP 8.

2.3 Detailed Description of Evaluation And Validation

2.3.1 Evaluation/Validation Objectives

The purpose of the COSMOS validation process was to establish whether the enhanced UTC systems performed as intended and then to evaluate the impacts of the systems. Project validation in COSMOS, following programme guidelines, consisted of two stages:

- In the **verification** stage the physical functioning of the systems was tested under non-operational conditions. Verification concentrated on the technical aspects of the systems.

- System **demonstration** was conducted under operational conditions. Demonstration concentrated on the acceptance of the applications by end-users and on a comprehensive impact analysis in order to evaluate the benefits of the applications.

2.3.2 Evaluation Sites

London/SCOOT

The Royal London Borough of Kingston-upon-Thames was the test site for the on-street trials of the SCOOT demonstrator. The road network in Kingston is a modern high capacity gyratory system around a restricted access central shopping centre. SCOOT controls the traffic signal junctions on the gyratory system where the trial was held. A VMS outside the network diverted traffic from Kingston in times of congestion. The trials involved measurements of the traffic performance with and without the strategies developed in COSMOS. Incident response strategies were assessed using simulation where the effect of different strategies on the incident conditions could be studied in a reproducible manner.

The data gathered for the assessment of the enhanced SCOOT system in London were collected over a three-month period. The control strategies in operation were:

11 – 17 January 1999: No VMS and no gating

18 January – 11 February 1999: VMS without gating
12 February – 15 March 1999: VMS and gating
16 – 26 March 1999: Gating without VMS

Piraeus/MOTION

The city of Piraeus is the largest port in Greece. The passenger port is the main landmark of this area, as it services seven million passengers and one million vehicles annually. The operation of this large terminal, virtually in the centre of the city causes severe problems in terms of traffic conditions of the area, with subsequent negative impacts on the quality of the environment. The part of the city network selected as the COSMOS test site faces most of the traffic problems of the city in terms of stops, delays, congestion, lane closure etc., as it includes the core section of the Central Business District and the passenger port area. The network included in this area consists of a number of primary road sections used for traffic entering and exiting the city and the port, thus providing the basis for alternative route options. Rerouteing mechanisms were developed and implemented by making use of the existing infrastructure.

The evaluation of the Piraeus demonstrator was based on traffic data measured during the three phases described below. Data was subsequently gathered for Phase 0 (no MOTION).

1 – 11 December 1998: MOTION (Phase 1)
11 – 22 January 1999: MOTION + CIM (Phase 2)
25 January – 5 February 1999: MOTION + CIM + rerouteing (Phase 3)

Torino/UTOPIA

The 5T system network was used for demonstration tests of the enhanced UTOPIA UTC system. The test site for impact assessment covered two specific locations in the network. The first location comprises a part of a controlled arterial, Corso Einaudi, affected by serious recurrent congestion problems during the morning peak hour and occasional congestion problems, mainly due to priority actions at the downstream end of the arterial. The second test area covers a trunk of a radial road, Corso Unione Sovietica, including several intersections often affected by congestion in both the morning and evening peak hours. On this area, besides congestion management it is also possible to operate rerouteing actions through 2 VMS signs. The first VMS, located on Corso Unione Sovietica about 1.5 km upstream from the test area, can redirect traffic entering the city on Corso Unione Sovietica to go straight on or turn on a parallel controlled arterial (Corso Agnelli). The second VMS is located in a section of the test area on Corso Agnelli and can redirect traffic either on Corso Unione Sovietica, through the first junction of the test area, or on Corso Agnelli itself.

In the Torino test site the following scenarios, with the indication of the active COSMOS functions, were the basis for the assessment of the enhanced UTOPIA UTC system:

10 – 22 May 1999:	BASIC (5T system operational, without COSMOS enhancements),
23 May – 10 June 1999:	COSMOS (full application of COSMOS enhancement),
1 – 15 May 1999:	UTC (application of UTC COSMOS enhancement only).

2.3.3 Assessment Categories

In the COSMOS evaluation four different kinds of assessment categories were distinguished:

- The **technical** assessment addressed the question of whether an application has fulfilled the predefined technical objectives. This did not address the impacts of the system on its environment. Technical assessments were mainly part of the verification phase.

- The **user acceptance** assessment aimed to establish the attitudes and perceptions of users to the applications investigated. This kind of assessment was performed both in the verification and demonstration phase but with different target groups of users.

- The aim of the **impact** assessment was to consider the impacts or effects of an application on the target groups of users by determining the changes of assessment indicators. The main indicators used were delay and congestion, which were calculated on the basis of measurements made during the demonstration phase. Furthermore, exhaust emissions were estimated based on the differences in delay calculated for the systems with and without the COSMOS enhancements; emission factors used in the calculations were taken from the report *'Car Exhaust Emission Factors in the Federal Republic of Germany'* edited by the Federal Office of the Environment.

- The **socio-economic** evaluation aimed to determine the social results of the application, focusing on the final utility for the users affected. Due to shortcomings in available data for both the calculation of the benefits and of the costs of the systems it was not possible to carry out a comprehensive cost-benefit analysis for any of the demonstration sites. An attempt has been made, however, to quantify both benefits and costs as far as possible to establish that there was a clear economic benefit to the COSMOS developments in each of the three sites.

For verification and demonstration tests in each site a detailed evaluation framework was developed and was followed throughout the verification and demonstration testing phase.

2.3.4 Evaluation results

Following system development, verification tests allowed fine-tuning of the systems in preparation for demonstration tests. The demonstration tests were performed in each test site by taking measurements from the network for a base scenario, that is, with the UTC system operating but without any of the system enhancements made during COSMOS. These base scenario measurements and the network indicators calculated from them could then be compared with data measured from the network for the scenarios where the system was operating with the newly developed COSMOS enhancements. The results of the demonstration tests, described in detail in the next section, all indicate that substantial improvements in network operation were achieved by the enhanced COSMOS systems when compared against the base case.

2.3.5 Experience of User Groups and Peer Reviews

A User Board was established early in the project consisting of traffic system managers from European cities and representatives of motoring groups, thus representing the target users of COSMOS end products. The User Board was chaired by Derek Turner, Traffic Director for London. The role of the User Board was:

- to provide feedback on the user requirements of European cities in the light of current policies and problems and, thereby, guidance on the direction of the work to seek to assure its relevance for subsequent exploitation
- to review and provide advice on the technical documentation (deliverables) produced by the consortium

In fulfilling these two roles the User Board has been extremely successful in COSMOS.

The Peer Review process developed within COSMOS required an in-depth analysis of each project deliverable by reviewers not involved in producing that deliverable. Many peer reviews were internal to the consortium, but for key deliverables in Workpackage 3 and Workpackage 7 and for Final Project reports, the peer reviewers were drawn from the COSMOS User Board. For both internal and external peer reviews, the quality of deliverables has been improved by the peer review process.

2.3.6 Collaboration with other Projects

In London, the CLEOPATRA project (a DGXIII project, which ran roughly in parallel with COSMOS) has focused on the use of VMS to provide advice and information to motorists. The Kingston test site used in COSMOS did not fall within the CLEOPATRA study area, which focused on North London and so the collaboration, was mainly in terms of the exchange of simulation and survey results. The new INGRID system developed as part of COSMOS has been made available to the ROMANSE project and some early testing of the system was carried out in Southampton, prior to it being installed in London. The collaboration was effected by TRL who were partners in both projects.

The module for automated congestion and incident detection (ACID) of the control system MOTION, developed within COSMOS, was implemented in Cologne in the DGXIII project EUROSCOPE (TR1023) in parallel with the Piraeus application. This resulted in a mutual fertilisation of both applications, providing a wider base for experiences and a European view of the results.

The application of the Path Flow Estimator has benefited from the use of the program/algorithm in different European 4th Framework and "Engineering and Physical Science Research Council" projects during the scope of COSMOS. Among them, the link of COSMOS to the CLEOPATRA project has proved to be very effective, as improvements have been made in parallel to cope with the different requirements of the test sites (Lyon, Stockholm, Toulouse and Torino for CLEOPATRA, Piraeus for COSMOS).

In Torino, COSMOS collaborated mainly with two other research projects. CLEOPATRA, working on rerouteing, has shared with COSMOS results for the rerouteing strategy (developed within COSMOS and used in CLEOPATRA) and shared surveys on VMS. A second co-operation has been established with FLUIDS. The aim of FLUIDS was to develop an interface able to guide the operator in the understanding and solving of problems on the controlled network. The logic implemented in INDICA (the UTOPIA module for congestion and incident analysis) has been given as an input to the artificial intelligence model developed within FLUIDS. Additionally, a comparison between the detected events of the two systems has been carried out.

Furthermore. COSMOS contributed to Cross-Project Collaborative Study on ‘VMS In Urban Areas’ that has been carried out on programme level.

3 Results and Achievements

3.1 Introduction

As mentioned before, the objective of COSMOS was to build and verify demonstrators for CIM, and to evaluate their impacts following a standard project framework so that the evaluation focused on technical assessment, user acceptance, impact assessment and socio-economic evaluation. Technical assessment was performed as a necessary prerequisite to the demonstration, which covered user acceptance and impact assessment. This technical assessment, or system verification, was performed in order to establish that the enhanced versions of SCOOT, MOTION and UTOPIA were operating in the correct way. The verification was successful, with some minor fine-tuning of the systems done in preparation for the demonstration of system effects.

3.2 SCOOT

3.2.1 The Demonstrator

The SCOOT demonstrator is the set of components, enhanced versions of existing programs, that has been built into an operational system in London for the verification and demonstration phases of the COSMOS project. It is composed of several modules, but is best described in terms of four tasks that must be performed. One task is to detect incidents, the second is to detect and analyse recurrent congestion, the third is to modify the signal control to alleviate the effects of the congestion and the fourth is to determine when the VMS sign recommending when traffic should re-route is displayed. For incident detection, the INGRID algorithm was enhanced and complementary features added to SCOOT. The detection and analysis of regular congestion is the responsibility of the MONACO program and the existing congestion management features of SCOOT were extended with improvements to the gating logic and additional facilities to be used in response to incidents.

A VMS was installed on the main approach to Kingston from central London and used to advise through traffic to take the longer route round the A3 Kingston by-pass when there were large delays in Kingston. A new programme VAMPIRE was written to monitor the delays in the SCOOT network and recommend the setting of the VMS.

Evaluation of the London system is described below according to the assessment categories in the COSMOS evaluation plan, and has comprised:

- An on-street evaluation of the congestion and rerouteing strategies.
- An off-line evaluation of incident response strategies using the STEP simulation.

3.2.2 User Acceptance

The degree to which the VMS met the user needs was judged by the proportion of those vehicles that were believed to have a realistic choice of route that diverted when the sign was in operation. The measurement of the diversion was made by automatic traffic counters, which were positioned to measure the flow of vehicles approaching the VMS and downstream of the VMS along the A3 by-pass. The traffic leaving the A3 and travelling towards the centre of Kingston was found by subtraction. The proportion of vehicles travelling to Kingston when the sign was in operation was compared with that at the same time of day when no recommendation to divert was displayed.

It was found that the rerouteing strategy succeeded in diverting an average of 12.6% of the traffic turning towards Kingston when the VMS was used in the morning peak. This was regarded as surprisingly high, but the result was significant at the 1% level. Presumably as so many drivers diverted, the information provided by the VMS met a need of a large number of users.

3.2.3 Impact Analysis

SCOOT already contained many techniques for the efficient control of traffic in congested conditions. The main development under COSMOS was the new gating logic to enable action at a distance to reduce the inflow of traffic to a critical area that is suffering from congestion. As described below, the benefit of the gating logic has been proved and it has been demonstrated to be capable of providing major benefits.

Impact on Delay

The network delay was calculated as the sum over all links of the product of delay per vehicle and flow on each link for each quarter hour during a 2-hour period in the AM peak. These values were then summed over the survey period to give an overall figure. The reduction of delay when gating was operating in Kingston compared with SCOOT without the new gating was 22%, a result that is statistically significant at the 1% level.

Impact on Congestion

Congestion was defined as the proportion of the cycle time that a detector is continuously occupied. SCOOT congestion implies that the queue on the link is, or is about to, seriously reduce the outflow from the upstream junction. In addition congestion, in SCOOT terms, is much more likely on a short link than on a long link, and is network dependent. With these provisos, the reduction in congestion, as defined by SCOOT, achieved by the introduction of the new gating logic was 43%.

The conclusion is that gating very significantly reduced the incidence of congestion that was likely to block the exit from upstream junctions. This is a very satisfactory result as the gating strategy was designed to reduce the probability of queues building up in the gyratory system, blocking the exits from upstream junctions and leading to gridlock.

Impact on Network Capacity

It is likely that the gating strategy will have increased the overall network capacity by ensuring that the Kingston gyratory system does not lock up and that capacity is not lost through blocking back across junctions. It is, however, not possible to quantify the impact of the gating strategy on network capacity on site since there must be a continuous stationary queue of vehicles waiting to enter the network for valid measurements of capacity to be made. The simulation work on incident response strategies was deliberately set up to ensure that there was always a queue of vehicles waiting to enter the network in order to provide valid results on network capacity. Simulation results, using the STEP traffic simulation tool, indicated that increases of throughput in the range of 2 to 20% were obtained, if SCOOT implemented an optimum strategy. The best strategy and level of benefit was dependent on the location of the incident along the link. The greatest benefits were achieved when an incident occurred close to but not at a junction.

Impact on Emissions and Fuel Consumption

For each network link, the average speed and flow during the morning peak with and without gating were taken from the assessment of delay. The average emissions and fuel consumption with and without gating were then calculated according to the methodology described in paragraph 2.3.3. This analysis indicated that the introduction of gating led to a reduction in CO emissions of 11.5%, a reduction in $C0_2$ emissions of 9% and a reduction in hydrocarbon emissions of 10%. NOx emissions were calculated to have increased by 8% with the introduction of gating. A reduction in fuel consumption of 8.5% was achieved.

3.2.4 Socio-Economic Analysis

In the analysis of the Kingston data it was difficult to put a benefit on the effect of the VMS. Changes in flow towards Kingston were detected when the sign was operating, but because of the distance to the centre of the town it is difficult to isolate the effect of the VMS. Concerning the congestion results, many of the COSMOS tools and tactics were already available in the commercial version of SCOOT that was installed in London. Therefore many of the congestion tactics and tools were in operation in the 'before' situation as well as in the 'after' survey. The engineering work involved in setting up gating in a new network can be estimated at one day per gating cluster. Assuming 7.4 hours for a day and 74.75 ECU per hour the total cost for the COSMOS enhancement gating would be about 1100 ECU. If VMS are required there would be the cost of the VMS and about one day for setting it up.

The reduction in delay can be used as the basis of the estimated benefits. According to the EVA-Manual 16.40 ECU per hour can be taken for this calculation. Implementing gating at the Kingston test site produced a reduction of network delay of about 33 vehicle-hours per hour. This leads to benefit of about 541 ECU per hour and 714,120 ECU per year for the London test site.

3.3 MOTION

3.3.1 The Demonstrator

MOTION (Method for the Optimisation of Traffic Signals In On-line controlled Networks) is installed in Piraeus, controlling a network of 20 signalised intersections in the city. The MAKSIMOS software for calculation and visualisation of rerouteing decisions is installed on the MOTION View Computer. In COSMOS, strategic input facilities for MOTION have been improved by preparation of a new user interface. A major system enhancement resulting from COSMOS is that strategic input to MOTION is used by the CIM function as a tool to modify control parameters in order to realise strategic decisions. Furthermore, a number of existing MOTION functions have been improved and prepared for congestion and incident purposes, in particular network incident detection and offset determination.

The evaluation of the COSMOS Piraeus Demonstrator is based on impacts resulting from the comparison of the traffic situation characteristics (travel time, network capacity, fuel consumption etc.) during four phases:

Phase 0 Base situation (fixed-time control)
Phase 1 MOTION
Phase 2 MOTION+CIM (with CIM measures implemented)
Phase 3 MOTION+CIM+REROUTING (with CIM measures and VMS rerouteing messages)

The focus of the analysis was to show the improvements for the traffic situation within the network gained by the use of a combined system of CIM and MOTION (Phase 2) against MOTION alone (Phase 1) and of a system consisting of MOTION, CIM and the rerouteing program MAKSIMOS (Phase 3) compared with MOTION and CIM (Phase 2).

3.3.2 User Acceptance

Influence of VMS on rerouteing decision

Roadside interviews were conducted to establish whether drivers had seen and noted the VMS rerouteing recommendations displayed, and whether drivers had followed the recommendation. A total of 199 questionnaires were completed during surveys in the AM peak. 44% of the drivers who passed a VMS sign noted the sign, of these drivers 19% followed the recommendation given by the VMS. That is, 8% of the total number of drivers passing the VMS followed the recommendation. Drivers who did not follow the VMS recommendation were asked “Why not?” The most common answer given was that “I know a better route” (by 69% of respondents). The questionnaire surveys were performed in February and March when few tourists are in Piraeus. In the summer tourist months, it would be expected that a higher proportion of non-locals would be driving in Piraeus, and would be more likely to follow a VMS recommendation.

User Acceptance of Signal Plan Changes

Red light violations were considered to be a potential problem in the Piraeus test site. A test was performed to assess whether drivers would comply with the longer red times created by MOTION during signal plan transitions. The result of the test was that no car or truck was observed to ignore the red lights during the test phase, at the intersections located within or outside the MOTION controlled network. The conclusion is that the MOTION program does not have any bad influence on the traffic behaviour regarding red lights.

3.3.3 Impact Analysis

Impact on Journey Time

The model calculating the travel times was calibrated utilising the travel times collected by floating cars. Journey times were analysed for the six routes in the network, which represented the principal thoroughfares, which carried the main loads of traffic and for which green waves have been sought both before and with MOTION. The comparison between phase 1 (MOTION) and phase 2 (MOTION plus CIM) showed a reduction in journey times on all six routes. Journey times fell by, on average, 19.5% in the morning analysis period (8:00 am to 11:00 am). The journey time reduction in the evening analysis period (5:00 pm to 8:00 pm) was smaller, between 2% and 5%. Traffic volumes are generally lower during the evening analysis period, since the evening peak is less pronounced than the morning peak hour from 8:00 am to 9:00 am. The occurrence of a major peak in the morning meant that the implementation of CIM procedures, prompted by congested conditions, was more frequent at this time.

Comparing Phase 2 (MOTION plus CIM) to Phase 3 (MOTION plus CIM plus Rerouteing) - during the morning analysis hours only (since the VMS did not operate after 3:00pm) journey times again fell on all six routes selected for the analysis. The journey times fell by on average, 13.6%. Thus, the utilisation of the rerouteing system provided a benefit to the network traffic situation, over and above the benefit achieved by CIM measures alone.

The comparison between Phase 1 and Phase 0 shows that through the implementation of MOTION, the travel times for the morning hours are increasing for route 2 in the morning and evening and for route 4 only in the morning; travel times decrease for all other routes. The problem with route 2 is that it was chosen because it is one of the main alternative routes for rerouteing; but a large part of it is not located within the MOTION controlled network, and therefore does not show any direct effects of MOTION control. The changes in travel times amount to a small increase for the morning hours of 7.1% and a significant decrease for the evening hours of 23.6%, if all six routes are taken into account. If route 2 is excluded, then the result is a 1.0% decrease of the travel times in the morning and a 39.1% decrease for the evening hours. This shows very clearly that even the of congestion.

The analysis was performed for the four MOTION phases for five of the selected routes (excluding route 2) for the AM and PM analysis period. For each phase, nine hours of data was analysed for AM and PM. Again the most pronounced results were obtained for the AM period. The number of congested intervals (of 5 minutes) recorded in the AM peak fell from 19 in Phase 1 (MOTION) to 13 in Phase 2 (MOTION plus CIM) and 10 in Phase 3 (MOTION plus CIM plus rerouteing).

Impact on Emissions and Fuel Consumption

Using the common COSMOS methodology, the average emission of four major pollutants was calculated. The average emission of CO fell by 14.5% with the introduction of CIM and by a further 3% with rerouteing. Emissions of CO_2 fell by 10% with the introduction of CIM and by a further 2% with rerouteing. Hydrocarbon emissions fell by 13% with the introduction of CIM and by a further 4% with rerouteing. There was no change in the emission of NOx with the introduction of CIM and rerouteing.

Fuel consumption fell by 10% with the introduction of CIM and by a further 4% with rerouteing.

3.3.4 Socio-Economic Analysis

The costs taken into account in the MOTION socio-economic analysis considered the efforts necessary for a standard implementation of CIM measures with MOTION and a VMS system. For the UTC system with the MOTION software, no additional costs for hardware or software have to be considered, but there are costs for planning, implementation and testing of the enhanced UTC system and rerouteing software. For the VMS system the MAKSIMOS software has to be considered, and there are costs for the planning, implementation and testing of MAKSIMOS and for new messages and for rerouteing. The total costs were estimated at 27,000 EUROS. When these costs were compared against the travel time savings achieved by the enhanced UTC system with rerouteing (over a standard MOTION system), the analysis showed that the benefits achieved can be quantified as approximately 237,600 Euros per year.

3.4 UTOPIA

3.4.1 The Demonstrator

UTOPIA (Urban Traffic Optimisation by Integrated Automation) is a specific concept designed to improve urban traffic conditions through the application of fully automated control schemes. UTOPIA control strategies aim to significantly reduce the total time lost by private vehicles during their trips within the controlled area, subject to the constraint that public vehicles requiring priority shall not be stopped at intersections with traffic lights.

UTOPIA operates at three levels for the monitoring and management of urban traffic. The Town Supervisor level uses the congestion information to decide rerouteing actions in order to protect the congested link. The expected effects of rerouteing on demand (flows and turning percentages) are calculated and sent to the Area level of UTOPIA and to all the other systems. The Area level uses the information given by the Supervisor on the expected traffic demand to calculate the area signal plan for each region of the network. Incident warnings are collected by a new function developed within COSMOS, the Common Control Strategy Manager (CCSM), in order to implement the appropriate response. CCSM influences both the calculation of the area plan by altering some traffic parameters such as the automatic calculation of the weighting factors to be used by the local optimisation. The local level calculates the control strategy for the intersection every three seconds considering the state of the intersection to be controlled and the adjacent intersections.

The main goal of the COSMOS demonstration phase was to check that new COSMOS functions were functioning correctly from an operational point of view inside the integrated system and that they provided benefits in terms of traffic indicators. Two scenarios were considered in the demonstration tests, the BASIC scenario of the 5T system without COSMOS enhancements and the COSMOS scenario with the full application of COSMOS enhancements.

3.4.2 User Acceptance: VMS Rerouteing Recommendation

The surveys performed on turning proportions for the two VMS showed good results. The turning flows were manually recorded at the VMS and the turning proportions compared with VMS messages on and off. For one of the two VMS the percentage of flow diverted was between 2% and 6% depending on the period within the day (with the greatest diversion achieved in the PM peak), while for the other VMS no significant changes were detected. The lower proportion of vehicles diverted by the second VMS is possibly attributable to a more confusing text layout.

3.4.3 Impact Assessment

Impact on Journey Time

The impact of the enhanced UTOPIA system on journey times was surveyed at the network and at the detailed level. At the network level, from data collected by the UTOPIA system, travel times were derived, using the so-called BPR model, for the BASIC and COSMOS scenarios for different levels of traffic flow. Under the COSMOS scenario this analysis indicated travel time reductions of 2% at traffic flows of 1200 vehicles per hour and 10% at 1500 vehicles per hour.

At the detailed level, an analysis was made of the total delay with and without COSMOS enhancements, on individual links in the network, which form specific paths, inward and outward relative to the centre of the city. As expected, the integration of COSMOS enhancements strongly improved the performance of the system on the management of the main inward path (18% reduction in delay) during the morning peak without disrupting the opposite traffic (the outward path showed 4.5% reduction in delay) and the side roads (2% reduction in delay). Positive results measured during the off-peak period prove the capability of the system to adapt to different traffic patterns.

Impact on Network Capacity

The only data available in Torino stems from the BPR model. Analysis using the BPR model showed that COSMOS enhancements not only decreased travel times, but, while doing this, also increased network capacity in line with the reduction of journey times.

Impact on Congestion

INDICA (the module developed within COSMOS for incident and congestion monitoring) was used as a tool to validate and to assess the benefits provided by the introduction of new control strategies. The benefit of the COSMOS enhancements, in terms of system reaction to unusual traffic situations, was quantified in terms of the average duration of recorded incident/congestion events.

The result of UTC-level analysis showed that COSMOS has been able to reduce significantly the average duration of these events. Greater improvements have been measured during peak hours where the duration of recorded congestion events was reduced from 127 to 51 minutes during the morning peak, from 64 to 58 minutes during the evening peak and from 58 to 39 minutes during a “traffic day” (7:00 am to 10:00 pm).

Impact on Emissions and Fuel Consumption

The data for the emission analysis were taken from the test phase with and without CCSM strategies operating. The average values for the emission pollutants and the fuel consumption decreased as expected. The analysis indicated that with CCSM operating CO emissions fell by 5%, $C0_2$ emissions fell by 4% and hydrocarbon emissions fell by 4.5%. NOx emissions showed negligible change. Fuel consumption fell by 4%.

3.4.4 Socio-Economic Analysis

A cost benefit analysis was performed for the implementation of a full UTOPIA UTC system. This analysis considered the costs and benefits of the total improved system, and did not single out the particular costs and benefits of the COSMOS improvements. The analysis took into account installation, tuning, maintenance and communication costs for the system. Benefits considered were journey time savings for private travellers and public transport users. The analysis considered an estimate of costs and benefits arising from the equipment of a system of 150 intersections in a medium size city. The analysis quantified the benefit of installing a UTOPIA UTC system as 8,600 Euros per day.

3.5 Collaborative Evaluation of Three UTC Systems

The evaluation of user acceptance and impact assessment of three UTC systems in three test sites has involved the collaboration of different European cities and developers within the COSMOS research project. Due to the differing conditions in the test sites and the different UTC systems involved in COSMOS, a direct comparison of results cannot be made. It is not possible to identify one overall result, for example on the impact of CIM and rerouteing on journey times. The results of three different demonstrations do however offer many valuable insights, which enables a collaborative evaluation.

3.5.1 Collaborative Evaluation: User Acceptance

The tests in all three sites showed satisfactory results. The value of 12.6% diverted drivers during the weekday morning peak in London shows that the information provided met the need of a large number of users. In Piraeus 19% of the drivers who noted the VMS and were able to read it followed the recommendation. This effect could probably be higher in the summer period when the number of tourists visiting the Piraeus ferry port is higher than in the demonstration phase. In Torino one VMS showed satisfactory results with 6% of all drivers influenced and diverting their route, while the second VMS showed no diversion. The explanation for this could be the layout of the VMS, which was not easy to understand.

The COSMOS evaluation of user acceptance indicates that routeing decisions can be influenced by VMS, but that it is very important that the layout of the signs is understandable and the letters can be read by all drivers. Furthermore, it is clearly very important for those drivers who are familiar with the network that the recommendation of the VMS appears reasonable and reliable.

3.5.2 Collaborative Evaluation: Impact Assessment

The reduction in delay in the London test site when gating was operating compared with SCOOT without the new gating was 22%. The effect of the new gating logic was therefore quite marked, but this technique is particularly suited to road networks like that in Kingston and it will not provide the same benefits in every congested situation. In Piraeus comparison of travel times in the three phases showed a reduction of travel time over all routes in the range of 23% to 34% achieved by implementation of CIM and rerouteing. Due to the specific situation in Piraeus these results just give an indication that CIM and rerouteing provide positive results, but travel time savings cannot be seen as absolute values. In Torino the reduction in journey time on the inward path was 18% in the morning peak and 20% during the morning off-peak period.

On the basis of the definition of congestion, which is used by the SCOOT system, a reduction in congestion of about 43% was obtained through the use of the new gating logic. A significant part of this benefit was achieved through reduction of the incidence of congestion blocking the exit of upstream junctions. The analysis for the MOTION system in Piraeus showed that the total number of time intervals with congestion occurring could be reduced by approximately 30% within the three phases, with the greatest reduction in the AM peak. In Torino the total number of congested links was chosen as a measure. Also in this case, the calculations were based on the frequency of congestion. The COSMOS enhancements had a significant impact at network level, with an average reduction in congestion of 10%. Furthermore the average daily duration of congestion was reduced by 8%. The fact that journey times and congestion have been reduced in three such different cities under three such different systems allows the suggestion that the toolbox of CIM measures developed in COSMOS would provide the instruments to reduce congestion and journey times largely irrespective of the network and the UTC system in operation.

Judging the effects of congestion management on the overall network capacity was difficult. Simulation results from SCOOT in London indicated an increase of throughput between 2% and 20%, with the level of benefit being dependent on the location of the incident. In Piraeus no reasonable results were obtained, and from Torino only a general correlation between a reduction in travel time and increase in capacity was derived.

The exhaust emission factors and fuel consumption were calculated on the basis of average speed and delay. The emission of all the major pollutants measured, with the exception of NOx, fell in all three test sites with the introduction of COSMOS enhancements. Fuel consumption also fell in all three test sites. Due to the differing test sites and measurement periods, networks and available data the values cannot be compared directly, but the analysis showed that the effects of each system help to decrease emissions and fuel consumption.

3.5.3 Collaborative Evaluation: Socio-Economic Analysis

Although the costs and benefits of the three different systems cannot be directly compared, it can be stated that each of the analysed UTC systems has positive impacts which accrue to society at large, and not just drivers and passengers on the road network. The implication of this result is that with the introduction of CIM measures and rerouteing substantial society benefits can be achieved through the reduced travel times, reduced consumption of fuel resources and reduced emissions of pollutants. The marginal benefit over the cost of introduction of COSMOS enhancements to an existing UTC system would appear to be very significant indeed.

3.5.4 Collaborative Evaluation: Conclusions

The enhancements to three different UTC systems – SCOOT, MOTION and UTOPIA – were based on commonly defined strategies for congestion and incident management and for rerouteing, but otherwise were developed separately, based on the specific technical and operational needs of three diverse systems. Furthermore, the three systems were implemented and tested in three different test sites, with different physical characteristics and driving cultures. The evaluation of the three systems in the three test sites then followed a common methodological framework and all three systems showed positive results in terms of User Acceptance and Impact Analysis in the comparison of the UTC system with COSMOS enhancements against a system without COSMOS enhancements.

The assessment of User Acceptance in all three systems showed positive results with significant traffic diversions achieved by the display of VMS rerouteing messages. The Impact Analysis assessments, that is the comparison of journey times and congestion in the three test sites with existing UTC systems and with the UTC system plus COSMOS enhancements, indicated in all three sites that the COSMOS enhancements led to major network improvements.

These findings are extremely promising. They suggest that regardless of the specific technical and operational characteristics of a UTC system there are the basic principles and strategies for congestion and incident management and rerouteing, which form part of the toolbox developed in COSMOS, that could be implemented in a wide range of UTC systems in a wide range of traffic networks with positive results.

4 Conclusions and Future Plans

In COSMOS, the development of common control strategies for congestion and incident management (CIM) formed the basis of further work to build demonstrators for CIM by making enhancements to three existing urban traffic control systems – SCOOT, MOTION and UTOPIA. In addition, three further exploitable results were developed in COSMOS: the Town Supervisor, the top-level co-ordinating subsystem of the Torino 5T system architecture, the Path Flow Estimator (PFE) for establishing individual link flows and the Portable Rerouteing Tool (PORT), based on the MAKSIMOS traffic model, were all enhanced under COSMOS. The PFE and PORT, which were both implemented and tested alongside the MOTION demonstrator in the Piraeus test site, are free-standing programs and can be implemented alongside any UTC system, not exclusively MOTION. The results of the demonstration phase described in this report indicate that all the systems developed in COSMOS can contribute positively to the UTC market in the field of managing congestion and incidents and reducing delay and congestion in urban traffic networks. Improved management of congestion and incidents benefits car drivers and public transport users through reduced delays, and benefits all urban residents through reduced emissions.

In COSMOS, the kernel software of SCOOT was enhanced to provide additional facilities for CIM. For example, a gating facility was developed, which is used to limit the flow of traffic into a sensitive area. Three sub-products, which can be used in conjunction with SCOOT, were improved or developed. These are MONACO, a system for the monitoring and analysis of congestion, the incident detection program INGRID and VAMPIRE for rerouteing recommendations. It is expected that MONACO and VAMPIRE will be available with the next release of SCOOT. The upgraded version of INGRID that has been developed in COSMOS is also expected to be available commercially at this time. To maintain the position of SCOOT as market leader in UTC systems regular updates of the system are essential. The commercialisation of the COSMOS developments forms part of this process within the allocated research and development budgets of its owners (TRL, PEEK and Siemens).

The MOTION UTC system was enhanced for incident and congestion detection and management. Currently the enhanced system is deployed in the city centre of Piraeus, Greece. A cost-benefit analysis of the installation of MOTION indicates that savings in travel time outweigh the purchase and installation costs of the system. In the next few years economic exploitation of the enhanced MOTION system will take place through the traffic control system exploitation strategies of Siemens, the owners of MOTION. As part of this strategy, MOTION, including the COSMOS enhancements, will be integrated into the Siemens UTC system MIGRA Central before the end of 1999.

COSMOS field trials showed that the enhanced UTOPIA system and Town Supervisor developed in COSMOS have achieved a significant reduction in delays in the Torino network. UTOPIA has been developed by MIZAR Automazione S.p.A., who own the intellectual property rights. The product is commercialised through software license agreements with distributors or end customers. Research and development activities on the UTOPIA system are ongoing to improve and increase the functionalities of the system and the integration of emerging technologies in the system is a key objective in the development policy. Exploitation activities for UTOPIA were already underway during the course of the project. This process will continue now with COSMOS enhancements available and the results of COSMOS tests will be disseminated to customers in the traffic industry.

The Path Flow Estimator (PFE) is a network observation tool, which estimates path flows and travel times based on traffic count and historic origin-destination information and, therefore, provides a more complete picture of traffic volumes and flows in the network than the direct information from detectors would allow. The PFE has been further developed and tested in COSMOS, and, in field trials in Piraeus, showed extremely promising results. The key feature of the PFE is that it is portable and transferable to any UTC system and therefore forms a stand-alone product. The future exploitation of the PFE will focus on further research and development and/or information exchange with research establishments and implementation of the PFE as part of transport management projects. Several European cities have expressed interest in the PFE.

The Portable Rerouteing Tool (PORT) is a portable software module that can be implemented alongside any UTC system to enhance that system with an automatic rerouteing option. The PORT is based on the traffic model MAKSIMOS, developed in a previous EC project. The COSMOS demonstration indicates that network travel times can be reduced by an average of 10% by following the rerouteing recommendations of the PORT. It is expected that exploitation of the PORT, developed in COSMOS, will be achieved in further research work, agreements with other R&D institutes and UTC system developers and operators.

All of the above means that the work carried out in COSMOS has led to new and enhanced products, which have already proven their benefits to urban traffic management, and which are therefore expected to be introduced over the next years in many cities both in Europe and world-wide.

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5.2 Project Website

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There are links from this site to the sites of many COSMOS partners, with material relating to the work of the COSMOS project.

5.3 Project Cost, Commission Contribution and Timescale

Overall Cost:	4,107,779 ECU
Commission Contribution:	2,199,845 ECU
Timescale:	01.05.96 - 30.06.99

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