COSMOS - Results of the MOTION Demonstrator for Congestion and Incident Management Strategies in Piraeus

Günter Kruse
Siemens AG
ATD SV PSM
Hofmannstr. 51
D - 81359 München
Germany

Background

The EU funded COSMOS (Congestion Management Strategies and Methods in Urban Sites) research project has developed, validated and demonstrated new procedures for reducing and, where possible, preventing traffic congestion in urban areas. These procedures comprise special modules for Congestion and Incident Management on the basis of Automatic Congestion and Incident Detection.
They are integrated into intelligent urban traffic control systems for signal control and for route guidance in order to make the best use out of the capacity at intersections and in the links between them.
One of the demonstrators of the COSMOS project is the MOTION Demonstrator for Congestion and Incident Management. It has already been installed in Piraeus (Greece) in an area with 22 intersections and 4 Variable Message Signs (VMS). (Figure 1)

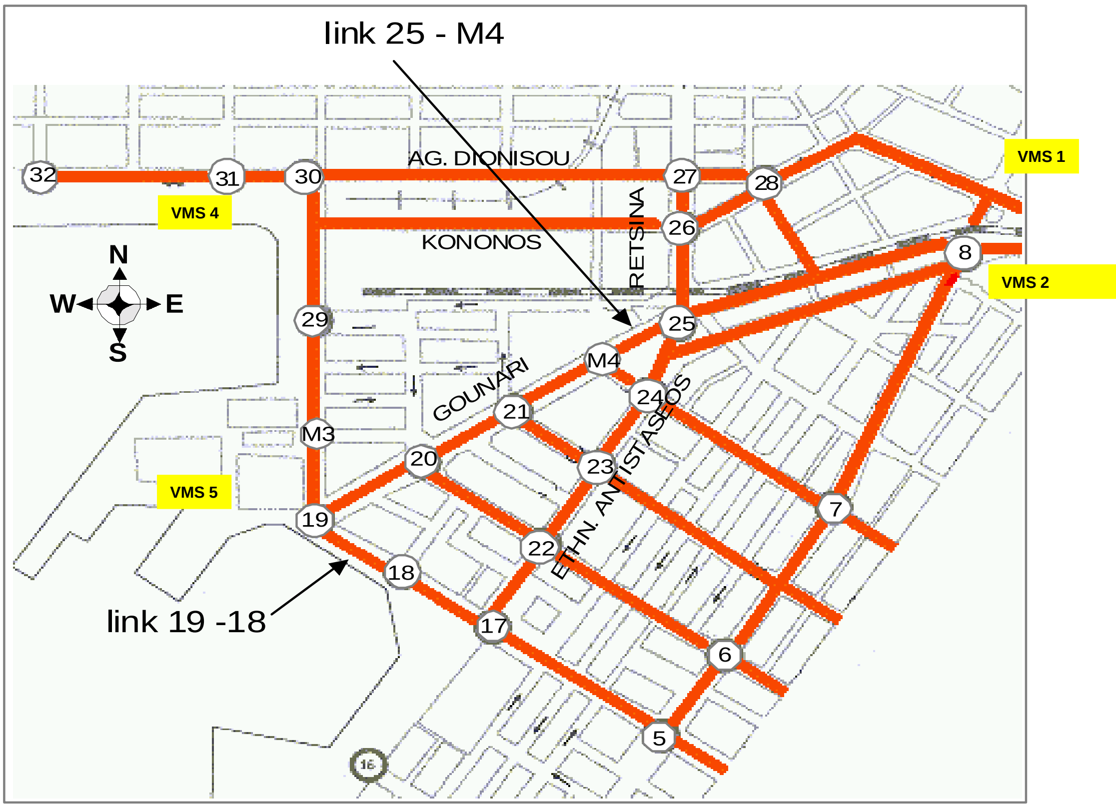

Figure 1: MOTION Area in the city centre of Piraeus near the port

The Urban Traffic Control (UTC) System MOTION

The basic idea of the UTC System MOTION which means "**M**ethod for the **O**ptimization of **T**raffic Signals **I**n **O**n-line Controlled **N**etworks", is to combine the advantages of well designed Green Waves for the current major traffic streams in a network with the flexibility of an immediate response of the local control methods to the current status of traffic. To realize this flexible control, traffic data are collected in the road network, they are processed and analyzed in order to optimize all components of the signal program (for all intersections in the network): cycle time, stage sequence, offset, and green time split. (Figure 2)

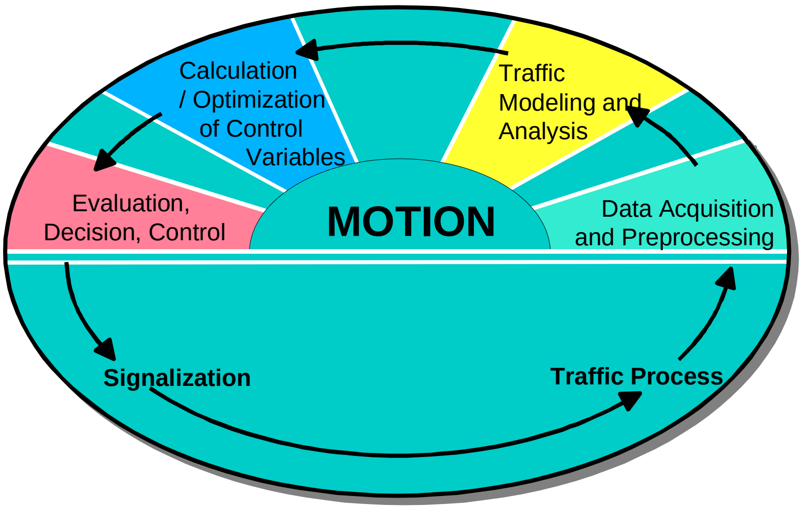

Figure 2: MOTION Traffic Control Loop

Traffic Modeling and Application for the on-line Operation of MOTION

The *first important step* for the MOTION system is the detection of traffic data. MOTION is designed for the use of existing and newly installed detection equipment. For network control with MOTION, measurement points are needed at least at the most important entry and exit points of the network.

The *second step* of the MOTION algorithm is the Automatic Incident and Congestion Detection. It uses different algorithms dependent on the location of the equipment to derive the traffic status and problem development at the measurement points. For these algorithms data like the traffic volumes, the degrees of saturation of the signal groups and the occupancy rates at the measurement points are needed.
With the data of the detection equipment another traffic analysis is realized: the estimation of the most important individual traffic streams using the "PATH FLOW ESTIMATOR" software developed by the Technical University of Newcastle (England).

The *third step* is the optimization of control parameters of the signal programs. The construction of the network of Green Waves is now based on the optimisation plan, using basic signal plans (with optimal green time split and cycle time) of each intersection as constructive elements.

In a *fourth step* the decision is made to change the signal programs at the intersections. Dependent on the infrastructure of the local controller and on the used local control method the signal programs are then prepared to be tranferred to the local controller where further adaptions and modifications of the signal program can be realized.

For the demonstration in the COSMOS project the MOTION system was enhanced and had to be adapted to the existing Piraeus system architecture so that different preparatory tasks had to be realized within the project.

MOTION Demonstrator in Piraeus

The COSMOS project started in 1996 and was organised in several workpackages.
The *Strategy Development* comprised the analysis and the development of general Congestion and Incident Management Strategies for urban traffic control (in 1997).
The *System Development* covered the building of the demonstrator and the enhancements of the control systems (for MOTION in 1998).
The *System Verification* comprised the implementation of the standard system and the demonstrator in the test sites with initial analysis of the system performance (for Piraeus in summer and autumn 1998).
The *System Demonstration* covered the implementation of amendments that were necessary following the verification phase and the collection, processing and the analysis of the data concerning the system (in winter 1998).
Finally the *Evaluation* comprised the analysis of the system performance and the system effects (in spring 1999).

Strategies to alleviate the problems caused by congestion and incidents in urban traffic networks have been identified in the COSMOS project. On principle, all of the congestion and incident management (CIM) measures described there can be applied in MOTION. For the application in Piraeus, however, there was a number of constraints that reduced the CIM measures incorporated in the demonstrator. Four of the defined "CIM tactics" were implemented in the Piraeus network: "Entry Gating", "Open Exit", "Prevent Blocking of Crossing Traffic", and "Give Priority to a Particular Traffic Stream".

The new Network Incident Detection module (NID) in MOTION was used for the detection of incidents and congestion in the traffic process of the road network. Generally accepted algorithms, independent from other modules, are implemented into the system. The traffic situation was determined with the main focus on congestion detection. Algorithms were adapted to the locations of existing detectors in Piraeus.
In addition several other MOTION modules (especially the User Interface) have been enhanced in order to support the above mentioned functionalities and to guarantee their best possible use.

The rerouteing task in the MOTION Demonstrator was done with an external rerouteing tool based on the macroscopic dynamic traffic flow simulator MAKSIMOS developed by the Technical University of Hamburg-Harburg (Germany).

It simulates rerouteing alternatives on-line with the traffic data delivered by MOTION and recommends the optimal routes through the network. The two-component configuration needed a new interface for interaction between the signal control system and the route guidance system.

Implementation of Congestion and Incident Management (CIM) Measures in the Piraeus Network

In the Piraeus test site the MOTION Demonstrator focuses on CIM measures in specific locations of the network. (Figure 3) This demonstration of MOTION in Piraeus allows for an effective evaluation of the MOTION demonstrator itself, and also for an effective collaborative evaluation of the COSMOS CIM measures demonstrated in other networks.

- Tactic I : Entry Gating

The CIM tactic that is implemented most widely in the Piraeus network is Tactic I, "Entry Gating". Gating is implemented at the edges of the defined MOTION control area in Piraeus and is designed to prevent too much traffic entering the central control area by reducing the green time when congested or incident conditions have been detected. These conditions were defined during the verification phase.

Table Examples for Locations and Conditions for Tactic I in Piraeus

Junction	Conditions which prompt Entry Gating
8 e	(congestion or incident in 20-19) AND (incident in 21-20) AND (congestion in 25-M4)
18 s	(incident in 18-19)
27 n	(incident in 25-M4)

e = eastern approach, n = northern approach,
w = western approach, s = southern approach

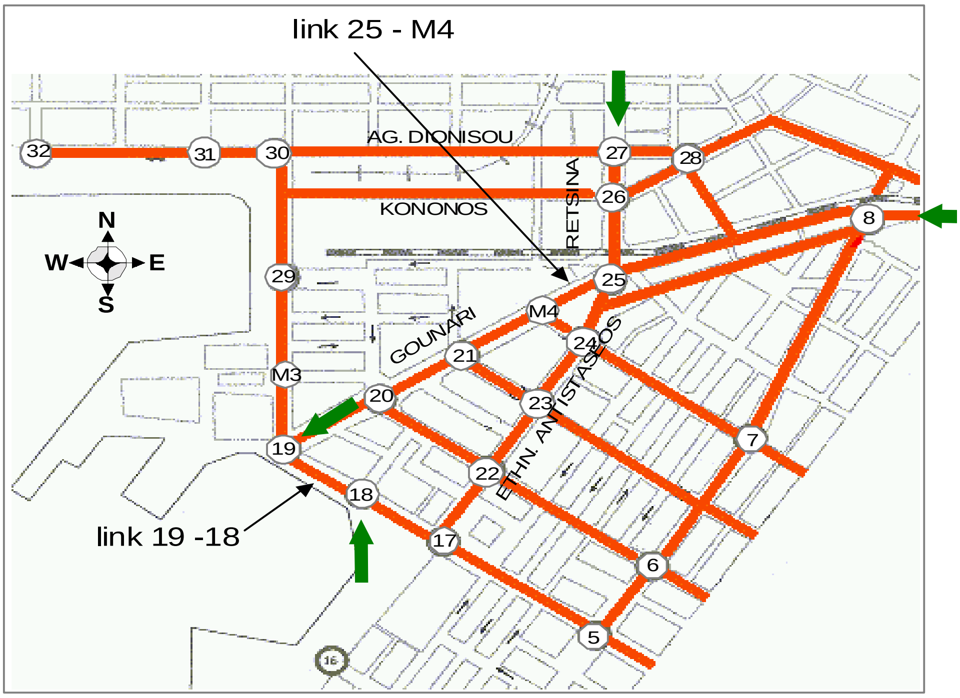

Figure 3: Examples for locations of CIM Measures in the MOTION Area

- Tactic II : Open Exit

MOTION as an adaptive control system already incorporates the actions that comprise "Open Exit" but it has to be added to those places where several problems occur and one direction has to get the priority. So "Open Exit" is implemented inside the MOTION control area in Piraeus and is increasing the green time to improve the outflow from those links which are congested or where incident conditions have been detected.

Table Locations and Conditions for Tactic II in Piraeus

Junction	Conditions which prompt Open Exit
18 w	(incident in 19-18)
19 e	(incident in 25-M4)

e = eastern approach, n = northern approach,
w = western approach, s = southern approach

- Tactic III : Prevent Blocking of Crossing Traffic

Tactic III is implemented in the MOTION Piraeus network in two specific locations. In order to prevent traffic in a congested link queuing back all the way to the upstream intersection and thus blocking crossing traffic at that intersection, it will be necessary to balance the green end offset at the neighbouring intersection according to the storage capacity of the affected link. In this way there is only inflowing traffic to the link as long as there is storage space available in the link.

Table Locations and Conditions for Tactic III in Piraeus

Location	Conditions which prompt Prevent Blocking of Crossing Traffic
26-25	congestion in 26-25
19-18	congestion in 19-18

- Tactic IV : Give Priority to a Particular Traffic Stream

Tactic IV is implemented in the MOTION Piraeus network in two specific locations, using two different tools. For balancing the green start offset between two intersections, it is necessary to determine the ideal offset so that the favoured traffic stream enters the congested link at precisely that time when the end of the queue of traffic in that link begins to move and storage space in the link becomes available.
In the Piraeus control area the decrease of green time, which is used for entry gating, is also used to achieve the aims of Tactic IV.

Table Locations and Conditions for Tactic IV in Piraeus

Location	Conditions which prompt Priority to a Particular Traffic Stream
19-18	congestion in 19-18
25	congestion in 25-M4 first priority for traffic at south stop line, second priority for traffic at north stop line

Practical Experiences and Results of the Field Trial

The System Demonstration was mainly done in winter 1998 with 4 different measurement phases between December 1998 and March 1999.

- MOTION -reference case- (without CIM) (Phase 1: December 1998)
- MOTION with CIM (Phase 2: January 1999)
- MOTION with CIM and Rerouteing (Phase 3: February 1999)
- Fixed Time Control (Phase 0: March 1999)

A phase 0 was integrated in addition to compare various effects of the new MOTION system with the existing Fixed Time Control system. But the main task was the investigation of the CIM and Rerouteing measures of the control system. During the measurement phases different aspects of user acceptance (Influence of Variable Message Signs on Rerouteing Decisions) and impact analysis were investigated. The main focus was on the impact analysis of the control systems.

- **Impact Analysis: Journey times**

The journey times on 6 significant routes through the network were calculated off-line with the MAKSIMOS simulation tool using the measured traffic data (detector values for volume) and signal programs in the following 3 Phases:

-	MOTION -reference case-	Phase 1
-	MOTION with CIM	Phase 2
-	MOTION with CIM and Rerouteing	Phase 3

During each phase, the data recording and the MAKSIMOS simulations were done for 3 days. During Phase 1, Floating Car Measurements were done additionally in order to compare simulated travel times with real ones for the calibration of the MAKSIMOS simulation tool. The average values for the journey times are shown in Figure 4.

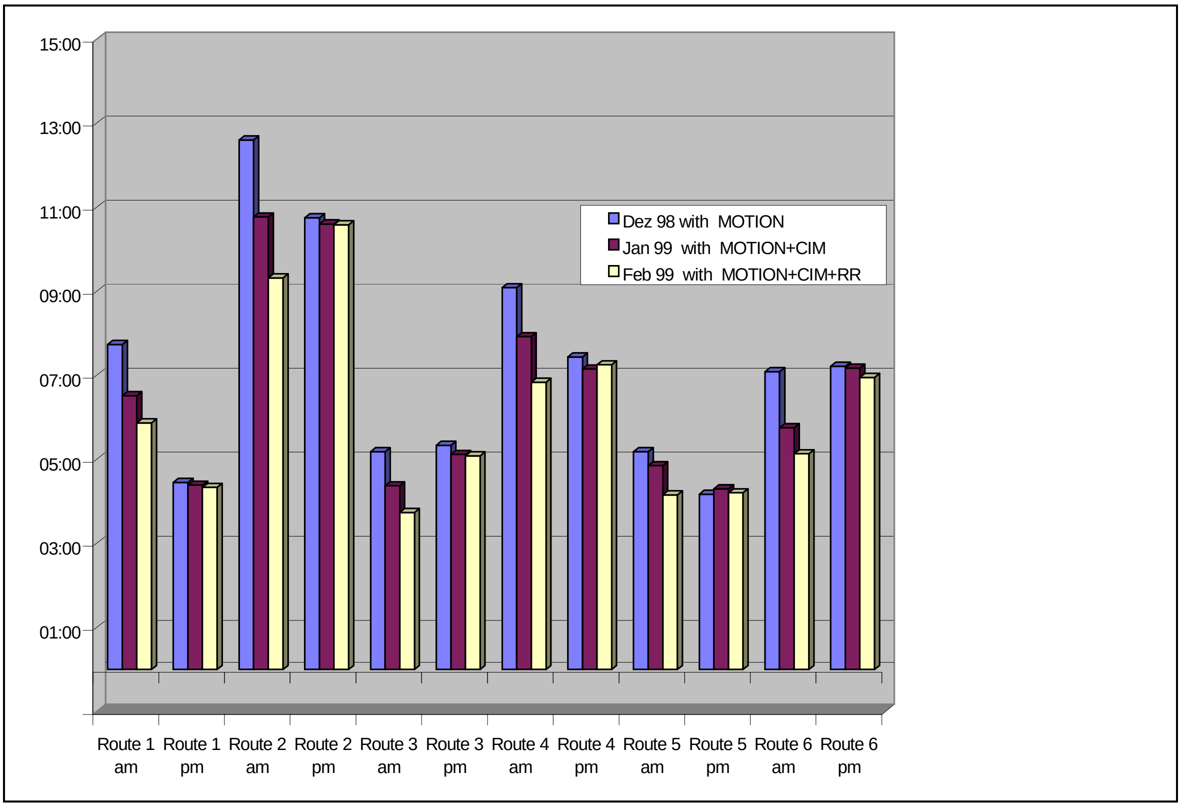

Figure 4: Average Travel Times (in minutes) for the 6 main routes in Piraeus for the Morning peak (am) and for the Evening peak (pm)

Results:
By comparing Phase 2 (MOTION with CIM) and Phase 1 (MOTION – without CIM) the average travel times on the 6 important routes through the Piraeus network were improved by about 8 percent.

By comparing Phase 3 (MOTION with CIM and Rerouteing) and Phase 1 (MOTION) the average travel times on the 6 important routes through the Piraeus network were improved by about 14 percent.

- **Impact Analysis: Congestion**

The number of time intervals with congestion on the significant routes were calculated off-line using the measured traffic data (detector values for volume) and the signal programs in the 4 Phases:

-	Fixed Time Control	Phase 0
-	MOTION (without CIM)	Phase 1
-	MOTION with CIM	Phase 2
-	MOTION with CIM and Rerouteing	Phase 3

During each phase, the data recordings and the simulations were done for 3 days. The average number of time intervals with congestion are shown in Figure 5.

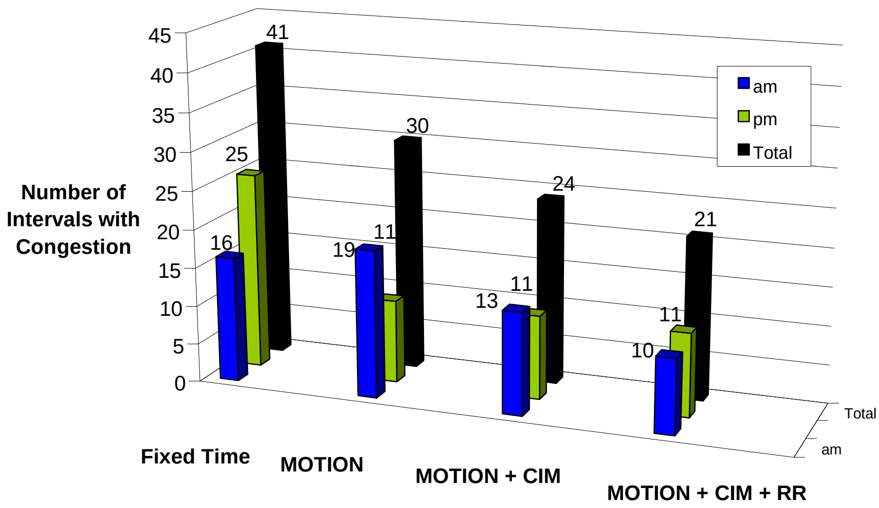

Figure 5: Average Number of Time Intervals with Congestion in Piraeus during the Morning peak (am), the Evening Peak (pm) and Total

Results:
By comparing Phase 2 (MOTION with CIM) and Phase 1 (MOTION) the average number of intervals with congestion in the Piraeus network was reduced
by about <u>20 percent</u>.

By comparing Phase 3 (MOTION with CIM and Rerouteing) and Phase 1 (MOTION) the average number of intervals with congestion in the Piraeus network was reduced
by about <u>30 percent</u>.

- **Impact Analysis: Emissions and Fuel Consumption**

The volumes of exhaust gas components emitted and fuel consumption in the entire network were calculated off-line with another simulation model of the Technical University of Munich (Germany) using the measured traffic data (detector values for volume) and signal programs in the 3 Phases:

-	MOTION -reference case-	Phase 1
-	MOTION with CIM	Phase 2
-	MOTION with CIM and Rerouteing	Phase 3

During each phase, the data recordings and the simulations were done for 3 days. The average emissions are shown in Figure 6.

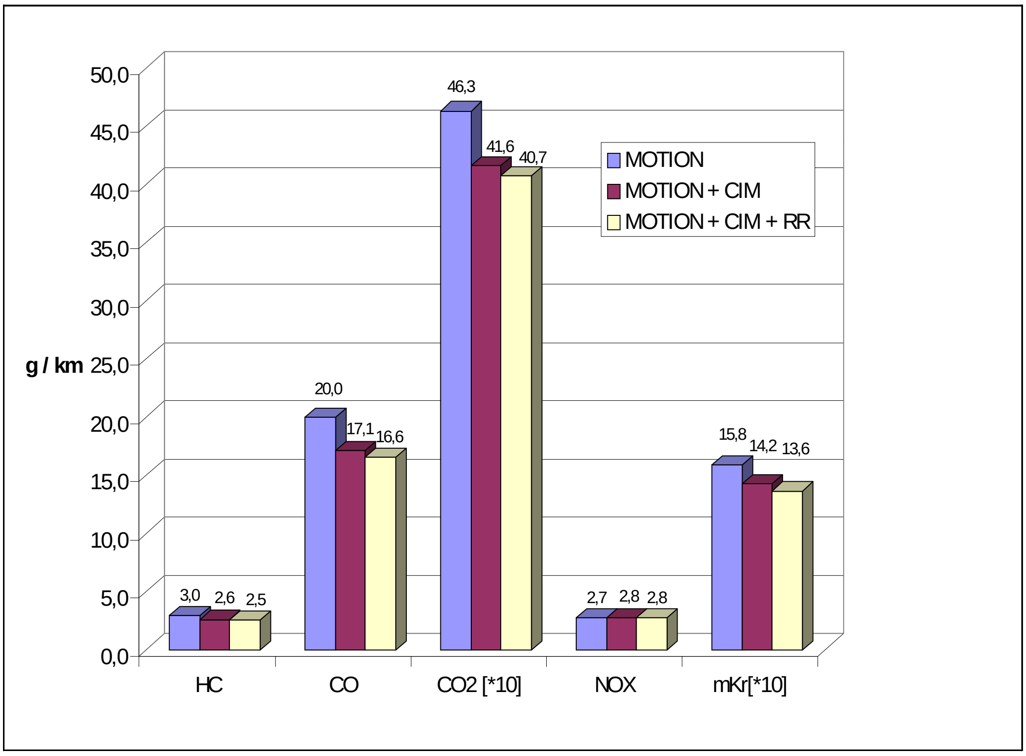

Figure 6: Average Emissions (Hydrocarbons HC in g/km , Carbon monoxide CO in g/km, Carbon dioxide CO2 in 10*g/km, Nitrogen oxides NOX in g/km) and Fuel Consumption (mKr in 10*g/km) in Piraeus

Results:
By comparing Phase 2 (MOTION with CIM) and Phase 1 (MOTION)
the emissions of CO in the Piraeus network were reduced by about 14 percent,
the emissions of CO2 in the Piraeus network were reduced by about 10 percent,
the fuel consumption in the Piraeus network was reduced by about 10 percent.

By comparing Phase 3 (MOTION with CIM and Rerouteing) and Phase 1 (MOTION)
the emissions of CO in the Piraeus network were reduced by about 17 percent,
the emissions of CO2 in the Piraeus network were reduced by about 12 percent,
the fuel consumption in the Piraeus network was reduced by about 14 percent.

Conclusions

The COSMOS project has developed and demonstrated new procedures for reducing and preventing traffic congestion in urban areas.
As an example the MOTION Demonstrator in Piraeus and results of the field trials are presented.
The implemented systems for intelligent urban traffic control and for route guidance do provide a significant benefit to the improvement of traffic conditions in the demonstration site of Piraeus. The results can be transfered to other cities all over the world.
It was found out that with the use of the on-line control method MOTION some traffic problems could already be solved by a dynamic and adaptive signal control.
In the case of high traffic load in the network new features for Congestion and Incident Management help to reduce traffic problems in addition:

- they improve travel times for the road users and reduce congestion,
- as an effect of the optimal urban traffic control the traffic related emissions and fuel consumption are decreasing.

If there is a route guidance system available with a connection to the MOTION UTC system it is possible to inform the road users about the traffic situation and divert them on appropriate routes to their destinations. And this is another additional positive effect on the traffic situation in the controlled network.

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