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# THE SCENARIO COORDINATION MODULE FOR THE MUNICIPALITY OF AMSTERDAM AND TRAFFIC MANAGEMENT CENTER OF NORTH-HOLLAND

## Integration of urban and freeway network control by using a scenario coordination module

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# ABSTRACT

In the Netherlands, the common approach for road network traffic control is top-down control by applying so-called *scenarios*. However, when the number of scenarios is getting larger, operators are often confronted with a dazzling number of choices which can be troublesome to the point that their decisions may adversely affect throughput. It becomes more difficult when the road network involves both urban networks and freeway networks. In this paper, we will present a Decision Support System (DSS) called the *Scenario Coordination Module* (SCM). This approach has been applied in the control system for the Dutch city of Amsterdam and Traffic Management Center of North-Holland. It was developed at the Dutch traffic management company Trinité Automation B.V.

# KEYWORDS

Urban road traffic control, Freeway traffic control, Network management, Decision Support System

# INTRODUCTION

In many countries, road traffic is the most important but also the most problematic form of transportation. It includes problems like frequent congestion, high pollution and extremely high fatality rates in comparison with other transportation forms. In most countries, it is common to apply traffic management to improve capacity of the road infrastructures and reduce the negative effects of road traffic.

Traffic network control can be achieved by several approaches. The best known approach Rathi (1988) in traffic control is the one characterized by traffic management centers applying so-called scenarios in response to current and predicted traffic states of the road network. Scenarios are actually a set of measure combinations for a road network or a subset of the road network. Scenarios are developed off-line and correspond to recurring patterns in the traffic state, such as the morning rush hours or the weekend exodus. We will call this the top-down approach, in which the traffic management center is the only entity allowed to take decisions. The top-down approach has been used in the Netherlands for the last decade; it is a generic way of controlling the overall traffic performance in the network. However, operators are often confronted with a large number of measure combinations. It is a complex task to select the most appropriate measures. This requires specialist knowledge and a lot of experience, which often can only be obtained after extensive training. As a result, the approaches used by human operators in traffic control centers are in general not structured nor uniform.

In order to improve this, it is necessary to provide a decision support tool Hegyi et al. (2000) Chen et al. (2006) to assist operators of traffic control centers in their decisions. This system should help the operators to react in a uniform and structured way to unusual traffic situations.

In this paper, we will present the control principle of the SCM and an example how it supports operators to select the most appropriate scenario. The approach based on a hierarchal system architecture which introduces a set of agents called *buildingblocks*. A road network can be divided into many subnetworks and each subnetwork consists of several buildingblocks. A string of links builds up a buildingblock. The state of a buildingblock, such as free flow or congestion, is based on traffic data from its links. *Service* is a number of measures each agent can take in order to deliver a certain request like *reducing the inflow*. A set of coordinated traffic services in buildingblocks can represent a *scenario* for a subnetwork and a road network can have a number of subnetworks with coordinated scenarios.

This approach is currently being implemented in real life as part of the FILEPROOF project for traffic control on the A10 beltway and urban roads of Amsterdam. The system was developed by the Dutch traffic management system company Trinité Automation B.V.

# System architecture of the Scenario Coordination Module

In the project, the nature of the system is inherently distributed over space, as links, the principal elements of a road network, are distributed over the network. Also, the traffic measures are distributed with sensors and actuators spread over various locations. The distributed components have to communicate with each other, as they work in cooperation. They continuously measure the traffic state and communicate about it to other links in real-time. The same goes for buildingblocks. Buildingblocks have to communicate with other buildingblocks to resolve conflicting services. They continuously calculate the state and communicate about it to other buidingblocks in real-time. The high level system architecture of figure 1 shows the structure of the system, in which the software entities represent road network elements. These network elements are:

- **Network**: represents a road network and consists of several subnetworks.
- **Subnetwork**: represents a subset of a road network and consists of several buildingblocks.

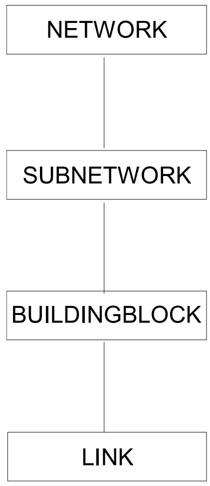



**Figure 1: System architecture**

- **Buildingblock**: consists of a string of connected links. It is a stretch of road in one driving direction that may contain crossings or other merge or choice points.
- **Link**: a segment of road in one direction without crossings or other choice or merge points except the begin and end point. There are two types, mainlinks and accessorlinks. The mainlink is the link from the merge point to the choice point and the accessorlink is the link from the choice point to the merge point Wang et al. (2008).

# Mechanisms of the Scenario Coordination Module

Let $C$ be the set of possible traffic control measures, such as lane closures, ramp metering, dynamic route information messages, etc. In general we can combine several traffic control measures. However, not all combinations of control measures are possible or allowed. Therefore, we define a set $\varsigma \subset 2^C$ of allowed combinations of traffic control measures. The number of the allowed combinations is still very large.
A road network is divided into a number of subnetworks. Let $M$ be the number of subnetworks. Each subnetwork consists of $j_n$ buildingblocks $Sub_j = \{B_{j_1}^{m_1}, B_{j_2}^{m_2}, ..., B_{j_n}^{m_n}\}$. $B_{j_1}^{m_1}$ is the first buildingblock in the jth subnetwork. The buildingblocks for both the urban and freeway networks are defined by $n_i$ links $B_{j_i}^{m_i} = \{L_{j_i}^1, L_{j_i}^2, ..., L_{j_i}^{n_i}\}$. $L_{j_i}^1$ is the first link in the ith buildingblock of jth subnetwork. The indicator of buildingblock ($I(B_{j_i}^{m_i})$) is determined by the critical links (such as the link with the lowest average velocity) $I(B_{j_i}^{m_i}) = \min\{V(L_{j_1}^1), V(L_{j_2}^2), ..., V(L_{j_i}^i)\}$. $V(L_{j_1}^1)$ is the properties (such as velocity and flow) of link $L_{j_1}^1$. According to the indicator value of buildingblocks, the different states of buildingblocks such as free flow (green) , congestion (red) and in between (yellow) can be determined $S(B_{j_i}^{m_i}) \in \{Green, Yellow, Red\}$. The state of buildingblocks are determined by the following equations:

If $I(B_{j_i}^{m_i}) <$ Red boundary, $S(B_{j_i}^{m_i}) =$ Red

If $I(B_{j_i}^{m_i}) >$ yellow boundary, $S(B_{j_i}^{m_i})$ = Green

Else $S(B_{j_i}^{m_i}) =$ Yellow

In this project, the yellow and red boundary in freeways are set to 50 km/h and 70 km/h, respectively. The services are defined for $S(B_{j_i}^{m_i})$. Let $S$ be the number of the states. A set of traffic services are pre-defined for each state. Let $Services(S(B_{j_i}^{m_i}))$ be the services. A scenario is actually a combination of traffic control measures in a subnetwork. In another words, a scenario $= \bigcap_{j_i=1,2,\ldots} Services(S(B_{j_i}^{m_i}))$. Thus, for a subnetwork, the number of combinations of traffic control measures is $L = j_n \times S$. For a network, the number of combinations of traffic control measures is $K = L \times M$. The number of combinations of traffic control measures is dramatically decreased and the combinations are spread over different layers.
As we can see from figure 2, there are three different layers in the SCM system: the monitoring layer, the control layer and the supervisor layer. In the monitoring layer, links receive the traffic data from sensors and filter the data using data filtering technologies Treiber & Helbing (2002). In the control layer, buildingblocks determine their states based on the traffic data of links and control different kinds of actuators(traffic control measures). In the supervisor layer, operators can monitor the state of subnetworks and apply a scenario selected by the SCM system.
However, there might exist conflicts on the boundary of two adjacent subnetwork. For example, one subnetwork wants to *reduce the inflow* to prevent congestion on the subnetwork, but an adjacent subnetwork wants to *enlarge the outflow* to prevent congestion on the subnetwork. In this case, *reduce the inflow* and *enlarge the outflow* are conflicting services. Buildingblocks can communicate with its neighboring buildingblocks and resolve the conflicting service using a priority ordering of buildingblocks. The one with higher priority can use its service to control traffic. And the one with lower priority has to disable his service.

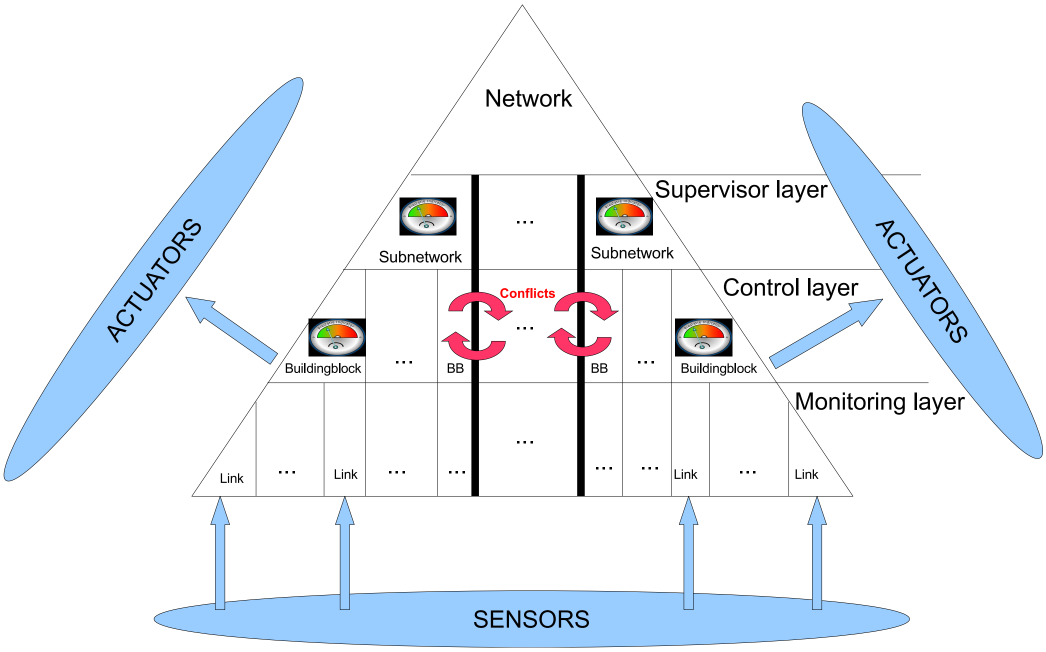



**Figure 2: Working mechanisms**

# Case Study: the FILEPROOF project

Before the FILEPROOF project started, traffic in Amsterdam urban networks and freeway networks are controlled separately by the municipality of Amsterdam and the highway agency.

Both of them try to get rid of congestions and optimize traffic flows from their own regions points of view. As a result, there are lots of conflicts between urban networks and freeway networks control. Moreover, all roadside equipments are controlled independently, for example, deferent systems are used to control traffic lights, ramp metering, etc. So traffic operators have to switch between different systems in order to control traffic. It is huge amount of work for operators and it also gives more chances for operators to make mistakes in their daily work.
After subnetworks and buildingblock are defined off-line, the state of buildingblocks can be calculated based on the traffic states of links every minute. And the corresponding traffic services can be used. We can see from figure 2 that the combination of the traffic services in buildingblocks can represent a scenario of a subnetwork. If the combination of buildingblocks states is changed for a subnetwork after a minimal life time of a scenario (for example 15 minutes), a new scenario will be proposed by the SCM system. Operators can accept or decline the scenario. If the scenario is declined, the scenario of the subnetwork remains the latest activated scenario. Operators can also manually change the scenarios for buildingblocks in subnetworks as they want. Moreover, the performance of the subnetwork can be evaluated by the states of buildingblocks. More buildingblocks with green indicator values in the subnetwork means a better performance of the subnetwork. Each subnetwork is independent and can have its own scenarios. Thus the combination of subnetworks can represent a scenario of a network.

### User interface of the SCM system

Operators can monitor the state of the network and change the scenarios of each subnetwork by using the user interface of the SCM system ( see figure 3). The SCM window and the subnetwork window can be seen from figure 4. There are 8 different subnetworks showing on the SCM window in this project. Once a new scenario is proposed for one of the subnetworks, the status of the subnetwork is changed to ”Need to activate”. In the mean time, the subnetwork starts to blink. It reminds operators to take action on this subnetwork. Operators can click the ”activate” or ”decline” button on top of the SCM window to activate or decline the proposed scenario. Or operators can look into the subnetwork by clicking the ”Details” button. Then the subnetwork window is opened, the states of each buildingblock and the corresponding traffic services can be seen by operators. Operators can manually change the traffic services of each buildingblock.

### Results

By using the SCM system, more than 700 scenarios become manageable for operators. Furthermore, operators have structured and uniform procedures to select a most appropriate scenario from a large number of scenarios and they can also easily and smoothly change the scenarios when a special event or an accident happens.

## CONCLUSION

In this paper, we present a DSS called SCM to manage scenario-based top-down traffic control from a bottom-up approach. Especially, when the number of scenarios is getting larger, operators are often confronted with a dazzling number of choices which can be troublesome. The bottom-up approach by using the buildingblock agents is helpful with this problem. By using this approach, operators in traffic control centers have structured and uniform procedures

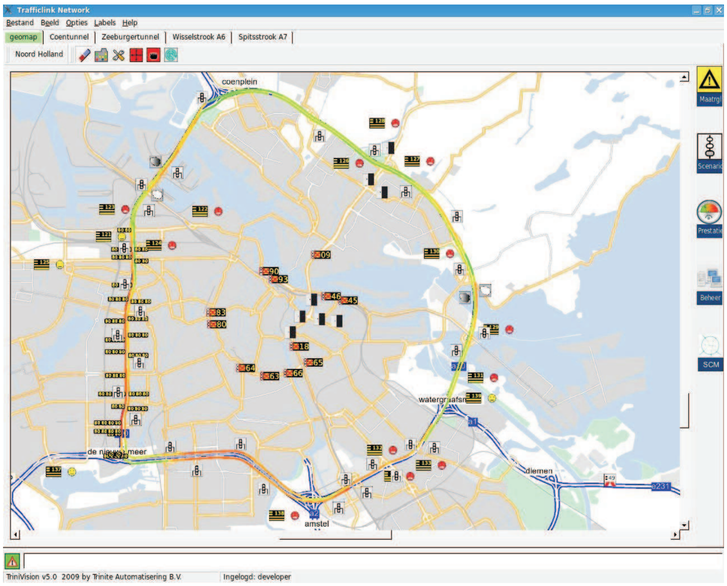
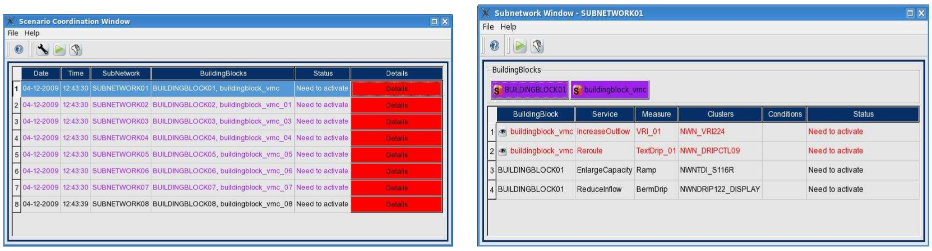



**Figure 3: Desktop**




(a) SCM window (b) Subnetwork window

**Figure 4: User interface of the SCM system**

to select a most appropriate scenario from a large number of scenarios. During the summer of 2010, the system will be activated and become fully functional.

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