Architecture Development
for Traffic Control on the Dutch Motorway Network

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SUMMARY
The mainport area in the Netherlands is one of the top-five economic areas in the world, with the highest traffic and transport density in Europe. Growth in travel and transport demand over the past years has been higher than extensions in the road network infrastructure can compensate, resulting in frequent congestion, putting a threat to vital economic functions in the country. Consequently there is an acute need for more and better traffic control tools. The development and deployment of new tools is complex and requires contributions from many different parties in an open market environment. Architecture development at Rijkswaterstaat, part of the Dutch Ministry of Transport, Public Works and Water Management, is aimed at providing a common framework in which new (and current!) developments can be better focused and from which better choices can be made for a technical infrastructure and system building blocks. In this paper we briefly describe this architecture.

INTRODUCTION
Since the early eighties, Rijkswaterstaat has installed electronic systems to improve traffic flow and safety in the motorway network, including an extensive ‘Motorway Signalling System’ (for autonomous speed control and lane closure commands), ramp metering systems and Dynamic Route Information Panels (DRIPs). Information from these systems flows to a national Traffic Information Centre (TIC), providing traveller information to various Information Service Providers among which RDS/TMC and others. The increasing amount of control systems is causing a number of operational problems, comprising:
• the increasing number of operator tools, requiring better integration;
• control conflicts when different control tools are applied in the same area;
• control conflicts between traffic control centres in neighbouring regions;

Meanwhile different developments are being conducted through which future systems will:
• use floating car data from external service providers in addition to fixed point sensors;
• control traffic in a pro-active manner, rather than in a re-active manner;
• have a larger variety of traffic control tools, e.g. tools that can control carriageway configuration.

From the developments mentioned above it can be concluded that there is a need for a better coordination of both the traffic control measures and the supporting information processing facilities. This need can best be addressed by developing an architecture for traffic control. The most important effects of an architecture can be summarised as “understanding through overview”. An architecture consists of global models: models with a wide scope with respect to application domain as well as time. Its most important effects are:

- **To make complexity manageable.** Architecture provides structuring. Structuring is an important means to make complexity manageable. Through architecture it becomes possible for an organisation to handle problems with a higher degree of complexity.
- **To facilitate communication.** An architecture provides a common framework which enables the positioning of concepts and enhances communication.
- **To provide a wide basis for decision making.** Traditionally, architecture has an important role in the area of standardisation. Some effects can only be achieved when there is a broad consensus for some decision made, e.g. a communication protocol will only be useful if many people use it. An architecture defines the interfaces for which standards can be defined.
- **To increase the level of knowledge.** Knowledge is a key factor in our society. Because knowledge (usually enclosed within people) is expensive and because the development of knowledge is a lengthy process, choices with respect to which knowledge is gained and which knowledge is developed are always of strategic importance. Architecture provides a means to become aware of important knowledge areas.
- **Evolutionary systems development.** Evolutionary systems development is a way of systems development by which an ambitious goal is reduced to a series of small, reachable steps (increments). The evolutionary approach is commonly recognised as an essential tool to reach high levels of ambition. In evolutionary development, architecture provides the necessary framework which guides development.

The ITS Architecture [4] developed in the United States is the most well-known and most detailed architecture for ITS. This huge architecture is a rich source of information and is currently the most important example for any architecture development in ITS. Nevertheless, the methodology that was applied for its development has some drawbacks. The American architecture was developed by means of a system development method, a variant of the well-known SA/SD method (Structured Analysis/Structured Design) [2]. This method has a strong emphasis on functionality which results in a detailed functional description of ITS in the American architecture. In contrast, we favour a more infrastructure-oriented approach. The main problem with functionality oriented methods is that functionality, especially end-user functionality, is subject to frequent changes. Experience has shown that functionality-based systems show deficiencies in flexibility. Small changes in functionality tend to propagate through the whole system. In contrast infrastructural components have a far better stability. In our
opinion, this problem in system development is felt even stronger in architecture
development. More information on this difference in methodologies can be found in the
literature on object-oriented methods, e.g. [6].

In this paper we introduce the architecture for traffic control which is being developed as
part of the AVB (Architectuur voor VerkeersBeheersing, Dutch for: Architecture for
Traffic Control) project, a joint effort of the Transport Research Centre (AVV), the
Survey Department (Meetkundige Dienst) and TNO. A management’s perspective on
this architecture is sketched in [5]. The pro-active central coordination of traffic control
tools in the AVB-project is harmonised in the international DACCORD project [1],
sponsored by DG-XIII in the EU. The AVB-architecture is also harmonised in a wider
context, in the DG-XIII project KAREN [8], for the development of an overall European
ITS-architecture.

We start by describing the framework for the architecture in which the various
components of the AVB-architecture are positioned. We then describe the current state
of affairs of the three principal components of our architecture (the Logical Architecture,
the Application Architecture and the Architecture of the Technical Infrastructure) in
somewhat more detail. Finally, we present some conclusions with respect to our work
and our plans for the (near) future.

THE ARCHITECTURE FRAMEWORK
The first step in the construction of an architecture for traffic control is the definition of a
framework in which the notion of architecture becomes meaningful. We distinguish a
number of layers that enable us to separately address the various issues that are relevant
for traffic control, together forming this framework. Each of these layers give a ‘view’
on the overall architecture by focusing on a particular aspect of the traffic control
system. Initially, we distinguish three layers (depicted as horizontal bars in Figure 1):
1. A layer which defines the Logical Architecture. This architecture describes the logical
behaviour of the traffic control concepts and developments mentioned in the
introduction. The Logical Architecture is described in more detail in a subsequent
section.
2. A layer which defines the Application Architecture. This architecture describes the
conglomerate of IT-components and applications needed for the implementation of
the logical behaviour described in the Logical Architecture in a usable and
maintainable manner. The Application Architecture is described in more detail in a
subsequent section.
3. A layer which describes the Architecture of the Technical Infrastructure. This
architecture describes the technical infrastructure (hardware platforms,
communication facilities, middleware, systems software, etc.) needed by traffic
control applications defined in the Application Architecture. The Architecture of the
Technical Infrastructure is described in more detail in a subsequent section.
Each layer provides a number of services to the layer ‘above’ it. Thus, the layer which
defines the architecture of the Technical Infrastructure provides infrastructural support to
the layer which defines the Application Architecture, and the Application Architecture, in
its turn, provides IT-support for the implementation and effectuation of the services provided by the Logical Architecture to the outside world. For the description of the layers themselves we use the **Unified Modeling Language** [9].

In addition to the three principal layers we also distinguish:

1. An **Information Architecture** which describes the (structure of the) information needed by the Logical Architecture, the Application Architecture, and the Architecture of the Technical Infrastructure (and in fact: by other ITS areas as well).
2. An **Institutional Architecture** which describes the organisation, i.e. the organisational units and individuals responsible for the execution of traffic control, and the relationships that exists between them.
3. A **Context Model** which describes the relationships that exist between the Traffic Control System and other ITS areas (such as incident management, public transport, freight transport, intelligent vehicles, travel information, etc.) to promote interoperability between surrounding ITS areas and the Traffic Control System.

An implementation of the architecture forms a traffic control system for the Motorway network. The Information Architecture, the Institutional Architecture, the Context model and the traffic control system itself are beyond the scope of this paper and will, therefore, not be further addressed.

The AVB architecture framework is sketched in Figure 1.

![Figure 1: The AVB architecture framework](image)

In the following sections we will describe the three principal layers in somewhat more detail.

**THE LOGICAL ARCHITECTURE**

The Logical Architecture describes the logical behaviour of the Traffic Control System. A number of components are distinguished within the Logical Architecture:
• a domain model which describes the traffic in its environment without the application of traffic control: vehicles, traffic flows, traffic rules, disturbances, shock waves, etc. The domain model is based on work previously done in the GERDIEN and SATIN projects [3, 7];
• a layered model which describes the approach taken to traffic control (see below);
• process descriptions for maintenance tasks with respect to traffic control;
• traffic control functions describing the operational tasks with respect to traffic control and
• a description of the information needs for traffic control.

The same motivation as for applying a ‘layered approach’ towards the overall design of the architecture framework also holds for the design of the logic behind the traffic control principles applied: by separating traffic control aspects in such a way that layers are formed with clear relations between lower and higher layers, the overview of traffic control is increased. The layers distinguished are given in Figure 2.

![Figure 2: The layered model in the Logical Architecture](image)

These layers describe the following:
1. Policy objectives layer: the ultimate goals (in political terms) that have to be achieved by applying traffic control;
2. Control strategies layer: common guidelines for applying traffic control in general, priorities for and relationships between the recognised policies;
3. Traffic management tactics layer: guidelines for applying traffic control measures in given situations and under given circumstances by describing traffic control services. Currently the following traffic control services are recognised: decrease input of traffic to the network, decrease output, stimulate throughput of traffic in the network, stimulate output and stimulate input: all of these have a defined effect on traffic processes that may cause congestion at some segment of the network.
4. Traffic management scenarios layer: operational aspects of combinations of applicable traffic control measurements under (current or expected) circumstances;
5. *Traffic management measures layer:* the means through which traffic control can be applied;
6. *Coordinated signs and messages layer:* coordination of signals being presented to the traffic and
7. *Individual signs and messages layer:* individual signals being presented to the traffic.

Thus, the layered model as a whole describes how, at the top level, defined policies are translated into individual signals, at the bottom, being presented to the traffic in a given situation under given circumstances.

**THE APPLICATION ARCHITECTURE**

The Application Architecture describes the structure of the implementation needed for traffic control measures, control strategies, scenarios and operator support tools, in terms of a collection of software components that form applications (Figure 3).

Software components are groupings of functions that form single entities. Examples are software components needed to control a sensor, an algorithm for making calculations or a database. The decisions which software components are needed in the application architecture is primarily taken from the required traffic control measures (and in fact: even by the tactics, scenarios and strategies!) described in the Logical Architecture (these may or may not need automated support). Other choices for components are made from a number of quality requirements that introduce a need for extra components, e.g. for operation, monitoring and maintenance of traffic measure components.

Components required for the direct effectuation (of course, many auxiliary components are needed as well) of traffic control measures, are divided into three groups:

- *monitoring components:* responsible for the collection of data needed to carry out a given traffic control measure;
- *control components:* responsible for deciding which signals need to be shown to traffic in order to carry out a given traffic control measure and
• **signal components**: responsible for actually showing the (individual or coordinated) signals to the traffic.

By aiming at a collection of generic components (where possible) for each group, possibly subdivided into the region of the network they effect, it will become possible to build traffic control applications more easily, with less effort.

**THE ARCHITECTURE OF THE TECHNICAL INFRASTRUCTURE**

Where the Logical Architecture is concerned with the functionality of traffic control systems, the Architecture of the Technical Infrastructure (and also the Application Architecture) deals with the implementation of these systems. The infrastructure contains the most expensive components. Decisions about infrastructure are among the most important decisions in ITS.

We mention some important considerations concerning the architecture of the technical infrastructure:

• The information processing infrastructure aims at supporting the development of new information processing systems in traffic and transportation but it plays a vital role as well in the way legacy systems are treated. Traffic control has become dependent on these legacy systems, they cannot be simply discarded. New systems will have to be combined with legacy systems in a smooth migration path from old to new system concepts.

• The architecture of the technical infrastructure will try to follow mainstream technology. Mainstream technology has the best price/performance ratio and the best prospects that the next generation of technology will be upwards compatible.

• The role of government in the development of new traffic control systems will be different from what it used to be. In the past, Rijkswaterstaat was the main initiator, designer and implementor of traffic control systems. However the high complexity of traffic and transportation and the many connections that this area has with other areas in society, requires the creative force of the private sector. The role of government will shift therefore to the role of information infrastructure builder and systems integrator. Once a comprehensive information processing infrastructure is realised, the private sector will have the ability to build and offer applications for many areas in traffic control.

**CONCLUSIONS**

In this paper we have sketched an architecture, including its rationale, to be used for traffic control on the Dutch Motorway Network and we have outlined the basic principles of its major components.

In the second half of the AVB project (mid 1998 - end of 1999) we plan to:

• further develop the layers of the AVB architecture framework as sketched in previous sections. Currently each of these layers is in a different stage of development: some architectures are already described at a reasonable level of detail, others still exist in
an ‘outline’ form only. At the end of the project we aim to have each of them described at suitable levels of detail.

- further ensure that the work done in the AVB project can count on firm support by those involved in practical work in the field of traffic engineering, whether it be systems development or operational traffic control. We are convinced that no architecture will be successful without sufficient feedback from practical situations.
- building a *demonstrator* to show the practical feasibility of the architecture.

At present, we witness the first results of the first applications of the AVB architecture in the treatment of legacy systems and in the education programme for systems development within Rijkswaterstaat. The results so far are a promising indication that the intended benefits of the AVB architecture will be realised and that this architecture will play a important role in the system development for traffic control in the next decade.

**REFERENCES**


