An integrated information model for traffic planning, operation and management of railway lines

A. Fernández¹, A. P. Cucala¹ & J. I. Sanz²
¹Instituto de Investigación Tecnológica (IIT) Universidad Pontificia Comillas de Madrid (UPCo), Spain
²Indra Sistemas, Madrid, Spain

Abstract

This paper presents an integrated information model for traffic planning, operation and management of railway lines, that has been implemented in the new control centre of the Madrid-Lleida high speed line. The long- and medium-term planning information is created with an off-line Planner Tool, generating an Operational Plan in XML format. This Plan contains data needed for real-time control (as train technical scheduling and infrastructure restrictions), crew and vehicle scheduling, passengers management (as commercial scheduling, transfers), and infrastructure cost assignment to train operators. The off-line Plan is exported to the operational network, and is the unique base information of every real-time system in this network: signalling control system, passenger information system and train supervision and delay control system. In the short-term (operation), when it is necessary to modify the Plan with the on-line Planner Tool, real-time systems are immediately notified using a MOM bus and changes are updated, so coherence of information is guaranteed. In the same way, any event generated by a real-time system is notified to the rest, sharing real-time information. Da VINCI is the product that implements this design in the high speed rail control centre of Zaragoza.

Keywords: railway planning, traffic operation, information model, system integration.

1 Introduction

Nowadays, the European inversion in new railway lines is relevant, especially in Spain due to an ambitious expansion plan of high speed lines. At the same time,
new technologies are being applied, especially with the implementation of European ERTMS standard and the use of the GSM_r for ground train communications. As a consequence, complexity of traffic real-time operation and management systems is increasing. Also, the European liberalisation of railway market in process introduces new management and efficiency requirements in these systems (Friebel et al. [1]).

As a result, more and more complex real time data have to be managed by operation systems in traffic control centres, and frequently these systems need common information, such as train movement events, alarms and warnings, thus systems integration is essential in modern traffic control centres (Rumsey [2]). Typically, real time data are shared using ad-hoc system-to-system integrations among different systems suppliers (on-line event integration, Olsen [3]).

Each real time system needs its own planification data, as timetables, crews, vehicles, etc. (Dreier and Brockmann [4]) that are usually generated by an associated off-line data generation tool (planification tool). Some planification data, like trains timetables, is basically the same for several systems (e.g. Traffic Control System and Passenger Information System), thus this information has to be repeatedly stored and managed by several planification tools. This situation could lead to the following drawbacks:

- The same information has to be introduced in different planification tools, and this could cause information inconsistence during traffic operation.
- When planification data have to be modified during operation, its necessary to introduce several times the same changes for each real time system involved (on-line replanification).
- Furthermore, data could be stored and showed in different formats, (e.g. timetables space-time diagrams), and detailed in function of the particular aim of each system (e.g. passenger timetable and regulation timetable).

A partial ad-hoc solution to these drawbacks is on-line planification data translation and consistency checks among operation systems (on-line planification data integration).

Frequently the planification tool and the corresponding operation system are provided by different suppliers, so off-line/on-line data translation is also required (off-line/on-line planification data integration).

In conclusion, with growing complexity of traffic control centres, where planification and operation systems are provided by different suppliers, multiple ad-hoc data integrations are required. This approach leads to maintenance difficulties, especially with the incorporation or substitution of systems.

In recent high speed control centres in Spain, a new information model has been implemented to improve systems integration. This model tries to establish a common data standard for traffic planification and operation systems. The standard includes both on-line event and planification data, and has to be observed by any supplier of actual and future systems in control centre. DA VINCI is the commercial product that implements this information model in Zaragoza high speed control centre.
In the following, the main aspects of the information model are to be described (section 2), as well as relevant integration capacities and functionality of Da VINCI (section 3).

2 Integrated Information Model

The proposed information model standardises both on-line traffic operation events and planification data using XML schemes. This information is shared by traffic operation systems through a message oriented bus (MOM) using publish and subscribe method. This integration bus is the only connection among every actual and future operation system in the control centre, instead of multiple system-to-system connections.

Data managed by the bus (real-time events and planification information) are stored as historical data, to be later used for control centre simulation, reports generation and costs assignment to train operators due to railway infrastructure use.

2.1 Real time-events

Two kinds of real-time events are managed in the traffic control centre: external events (as traffic interlocking events) and internal events (as alarms). Interlocking events are received in the traffic control centre by signalling control systems. Each event is standardised and published in XML format in the integration bus, and then, any system subscribed to this information will receive it. For example, the occupation of a track circuit can be interpreted as the arrival of a specific train to a station. This information (time, train identifier, station identifier, circulation sense, track circuit identifier) is used, for example, by the passenger information system to give the appropriated advices, by the train control system to regulate the train speed, by the automatic route setting system and by the traffic supervision system to calculate the delay and update the space-time diagram. Other real-time systems with field devices receive and publish in the bus external relevant events, like hot boxes or tunnel fire sensors.

Real time systems also generate internal events, as systems failures or HMI information introduced by the user, that are usually treated as warnings and alarms. These events are standardised and published in the bus, thus any system subscribed can manage warnings and alarms of other systems.

2.2 Planification data integration: Operational Plan

Planification data integration is obtained by two factors: using the standard scheme defined in XML, and storing all the planification information in a unique XML file called Operational Plan. The Operational Plan contains all the planification data required by every real time system at control centre, that is:

- Commercial train service: train number, type, platform, timetable, connections, etc.
- Technical train timetable at train control points
• Programmed routing information, including alternative routes between control points
• Vehicle scheduling information
• Crew scheduling information
• Infrastructure cost assignment information of each train
• Train supervision and delay control information: maximum and minimum speed, minimum commercial stop times, maximum delay to generate alarms, etc.
• Infrastructure restrictions: temporal speed limits, unavailable tracks and platforms, etc.
• Inter-service restrictions between trains that share vehicles, crew, passengers or any other resource.

This Operational Plan contains also applicability calendars associated to some data. For example, a specific train service may circulate only labours or have different stop stations depending on the day: it stops at an intermediate station only on Mondays.

2.3 Operational Plan life cycle

Traffic planification process can be divided in three steps: short-term, medium-term and long-term planification, depending on the temporal scope of the Plan:

• **Long-term planification.** Stable train services are planned in a long-term, with their commercial numbers, timetables, connections, etc. The Plan in this phase typically includes the framework agreement with train operators, with a temporal scope of approximately 6 months. Additionally, technical information can also be introduced in the Plan in this phase, such as predictable infrastructure restrictions (e.g. for programmed maintenance works), type of associated vehicles, train control parameters and technical train timetable and routing information.

• **Medium-term planification.** In this phase the plan is completed with all the programmable information, with a typical temporal scope of a week: crew and vehicle scheduling, train stop platforms, etc. Long-term train service information is updated with new train services programmed, cancellations and changes. In the same way infrastructure and inter-service restrictions are updated.

• **Short-term planification.** In real time operation, short-term re-planification allows the on-line modification of the Operational Plan, to include last-hour changes and incidents (for example cancellations, special trains, unexpected infrastructure restrictions, changes in vehicle and crew scheduling, etc).

Long term Plan is generated with the Off-line Planner Tool in the management network. During medium term phase the previous Plan is updated with the same tool, generating the medium-term Plan. This Plan is periodically
exported in standard XML format to the On-line Planner Tool in the operation network, through secure connections.

In real-time operation, the re-planification changes are introduced using the On-line Planner Tool, generating consecutive versions of the Plan. These versions of the short-term Plan are stored as historical data in the operation network, and a copy is sent to the management network to be processed for infrastructure cost assignment, inform generation, etc.

Modifications of the Operational Plan are introduced in the On-line Planner Tool, and the changes are added to the Plan in an incremental format, generating the new Plan version. The On-line Planner publishes an internal event in the integration bus informing of the changes in standard XML format. Any operation system subscribed to this information will receive and update automatically its planification data.

Real time events published in the integration bus are also stored as historical data, and a copy is sent to the management network. These data, as well as historical Plans, are available in the management network for the inform generation tools, the infrastructure cost assignment tool and historical data simulation tool. In this way, the management tools get integrated historical data from different operation systems. For example, the historical data simulation tool can reproduce automatically a sequence of different operation system alarms.

3 Da VINCI: system architecture

The Da VINCI architecture is based on two main elements: an off-line planning tool and an Integration Platform.

The off-line planning tool is a powerful application that allows the issue of the operational plan, for which a metamodel of the planning has been defined and implemented by means of the XML standard.

As depicted into next figure the off-line tool deal with the market forecast the capacity of the infrastructure and the operators slot demand. A rational template menu drives the operator requesting the necessary information for a whole planning. The system guides the operator and provides him several kinds of help to facilitate the issue of plan checking the consistency of the parameter introduced and detecting the inconsistencies with the services planed.

In order to standardize and for providing an open vehicle of interchange among the different users of the operational plan, the XML standard has been selected. The plan provided by the offline tool is the master plan, that represents the theoretical planification. During operation the plan is dynamically adapted to the real time operation, producing a plan as operated, which includes all the modifications produced during the operation. The plan contains a historical record of the implemented modifications. All applications that use the plan are feed with the real time status of the operation plan.
According to the next figure, the Da VINCI Integration Middleware and rail services platform is divided in following different subsystems:

**Middleware Oriented Message**

**Basic Platform Services**
- Integration Sensors System
- Passengers Information System
- Regulation Support System

**Generic Rail way applications & services**
- Operation Supervision & Management
- Integrated Alarms Manager
- Record Replay & Simulation Monitoring

**Specific Rail way applications & services**
- Operation & Management Terminal
- Communication Network
- Demand & Capacity
- Video Surveillance

**Integration Services**
- IGW
- OMS: NTP, SNMP, Secu, DNS, FTP, NFS

**OSS:**
- GDBS
- HDB
- RTDB
- LDAP
- CUM
• Basic Platform Services
• Generic Railway Applications and Services.
• Specific Railway Applications and Services
• Communication Specific Platform Services

The Basic Platform Services is composed by an integration bus (Message Oriented Middleware MOM) through which are connected all the system applications including external and legacy ones. The bus is defined at three different critical time levels: Real Time Bus, Near Real Time Bus and Corporative Bus. All this three level buses are interconnected by means off unidirectional data gateways, avoiding external intrusions over the real time bus and allowing the information data flow to the near real-time and corporative bus, in order to provide the real time monitoring capabilities to other different user than the traffic and related operators.

The coupling between the applications and the MOM is performed via an application customized generic connector. This connector includes the data format conversion to the global data system model. The integrated Global Data Model allows a common global system status variables real time view, the integrity of the global data model is provided by the Real Time Data Base (RTDB), supported by an Objects Data Base, the historical persistency is provided via the HDB relational database. Besides the two mentioned DB, the platform provides DB services whatever external application need and includes persistency services to the electronic directory (LDAP), included as part of the command and user profiles management (CUM).

Data integration is managed by the integration service, that includes a specific integrated MMI denominated Integrated Geography Window (IGW). The IGW is based in a specific railway GIS developed for the Da VINCI, with a coherent perspective for rail way application. For all the integration services, the MMI are provided through a generic integrated terminal, specifically designed for rail way application (Operation and Management Terminal OMT). The terminal provides access to the Global Universe of resources and information of the integrated system. The specific subset of the global universe is user profile dependent, the specific user profiles are managed by the CUM. The Basic platform services includes the connectivity with other business services and all the operational support services as security, SNMP, DNS, NTP, NFS, etc.

The previous and the next figures show the connectivity between the BPS and external applications, including the relation between the applications and external field information.

The integration platform includes the Generic Railway Applications and Services (GAS) composed by:

• Operation Supervision & Management
• Integrated Alarms Manager
• Record Replay and Simulation
• Monitoring

The operation supervision & management services provides to the traffic operator and integrated vision of the services status providing information in
typical space time graphics merging the theoretical schedules with the real ones including information over delays and warnings relatives to the incompatibles status.

Different formats of services view are provides including helps for the resolution of incompatibles status. This subsystem provides information to the regulation support system and to the passengers information system. This subsystem may be operated in a advanced CTC mode, including train tracking, automatic train numbering, interlocking command, automatic routing including prerouting among other functionalities.

The integrated alarms manager provides a homogeneous alarm display avoiding the diversity representation originated by the different sensors providers, the system represent the information coming from the sensor integration platform.

The record replay and simulation service allow the continuous recording of the railway system status and commands, so then any event of the system can be reproduced for their posterior analysis. This service includes the simulation by means of a synthetic environment of any of the elements parts of the rail way infrastructure and trains. The global status of the rail way system can be simulated as “what if” tool or for training purposes. The simulation capabilities can be used to analysis and debugging the Master Global Plan. The GAS provides the services for the status monitoring to the near real time and corporative networks.

Besides the services described into the precedent paragraphs the Da VINCI rail way integration and services platform, provides the following specific services as depicted into the next figure: Sensors Integration Services, Passenger Information Services, Regulation Support services.
Furthermore the specific sensors relatives to the interlocking system, the rail way infrastructure includes a broad set of specific sensors (e.g. meteorological sensors, derailment, hot boxes, pantograph checking, wheel plans checking, tunnels fire sensors, etc.) coming from different manufacturers, even for the same kind of sensor. This variety of providers and devices represent an operational problem that obliges to the operator interaction with different interfaces and functional applications.

When the quantity of sensor and suppliers increase the system becomes inoperative. In order to deal with this problem the integration platform includes a framework for the mitigation of the problem (Integration Sensors System and JINI Communication Platform). The philosophy of the framework consists to provide one homogeneous operational interface independent from the manufacturer. In order to reach this performance the system uses a virtualisation of the sensors via a JINI communication platform, that adds to the system the especial characteristics of the JINI technology, like self network configuration, plug and play capabilities and a high degree of fault tolerance.

The Integration platform includes Passenger Information Services, the system is implemented as multimedia web philosophy. It is a centralized multimedia distribution system including voice and music, admit three different sources for data ingestion: XML plans, real time video and recorded video. Audio is MP3 format. The system distribute the information up to the station displaying point (SDP), on which admits all the existing different display types. All the information for the whole line is under control and managed by the Passenger Information Centre. The data distribution deal with XML, http, RTP, RTSP.

A specific distribution platform for sending the regulation command to the trains is also implemented like specific service provided by the integration platform. This Regulation Support System distribute to the trains drivers the regulation commands, as calculated by the Operation Supervision and Management generic service, according the real time situation and future predictions.

The whole Da VINCI Integration Platform is implemented using the modern technologies of EAI like J2EE, Application Servers, Objects Data Base, etc. The intensive use of standards and the Java technology has demonstrate that the system is a open product solution on Unix, that actually has been implemented...
over different HW platforms. This solution introduce a high degree of isolation between the System and the HW and base SW, over which it is mounted, allowing that the life cycle of the product would be only dependent of the railway traffic control and management business model, being this one of the more important factors to the operational effectiveness and to reduce the cost of the system whole life cycle.

4 Conclusions

A new traffic information model, and its commercial implementation in high speed railway control centre of Zaragoza, have been described in this paper. This approach is based on data standardisation (both real time and planification data) and a message-oriented integration bus to interconnect operation systems. The main advantages of the proposed solution are the following:

- Data standardisation and publish and subscribe integration procedure allows operation systems to share information. This solution avoids ad-hoc system-to-system connexions and data translations.
- Future operation system, or substitution of the existing ones, can be easily integrated in the traffic control centre according to the established standard.
- The same data standard is also applied to off-line data planification tools. So, the same data model can be used in off-line planification, on-line re-planification, on-line operation and train operators data exchange without data translations.
- Operational Plan includes in XML format all the planification information required by every traffic operation system. This unique XML file improves and simplifies global data consistency through all the Plan life cycle, especially during re-planification process.
- The integration bus stores historical on-line events from all operation systems, and Operational Plans, in a unique and standard base data. This global and homogeneous information is used by infrastructure cost assignment tool, record replay system, and reports generation tools.

References