Standardized Data Interchange Between Railway Systems: an Integrated Railway Information System

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1. Introduction

1.1. Problems in current railway information management systems
The operation of very complex systems like railways require the availability of dependable and complete information in order to be able to maximise performances, optimise decisions and improve return-of-investment, that is in other words to keep and increase their competitiveness.

Every railway subsystem produces large quantities of data, which needs to be handled in order to properly manage operation of trains and infrastructure. Monitoring systems create data through sensors and elaboration, data are transferred where needed and eventually further elaborated to take decisions. Today, the problem is no longer to make data available, as they normally exist somewhere or can be easily produced: the problem is to have the right data in the right place at the right moment.

Existing information systems worked well in the past but now suffer from severe limitations, as they cannot really guarantee the main requirements in terms of:

a) quality of data (data have to be accurate, timely and reliable, in order to derive appropriate and useful decisions from them)

b) meaning of data (data have to be clearly identified within their context in order to have a correct, unambiguous meaning for all consumers; this transforms data into real information)

c) integrability of data (information need to be easily elaborated, transferred and merged in order to take complete advantage of it)

As a matter of fact, the current situation is that:
- A lot of information is available, but difficult to retrieve in an easy and complete way
- Extracted information is not ready for further elaboration, so it is difficult to achieve fully automated processes
- Maintenance of information systems is difficult and expensive (updating, check of consistency, expanding)
- Implicit information can be hardly uncovered (data mining)
- A clear point of view, with info restricted to a specific area and to a specific User Group, is not simply achieved

The problems are emphasised when considering highly distributed, weakly structured information systems, which is unfortunately the case of railways.

1.2. Why sharing data?
Railway information systems produce and consume data in proprietary formats, which makes it difficult to share it between different applications and systems. Specific interfaces have to be defined and developed to achieve integration. Traditionally, railways are not keen to open their information systems to external organisations and are reluctant to accept the idea of information exchange.
On the other hand, there is an increasing need to have a wide and easy data sharing capability across railway subsystems, systems, organisations and countries. A few examples can well depict where such needs come from and their importance in the railway organisation.

European Directives ask for clear separation between railway operators and infrastructure managers, in order to open the market allowing more operators to access the railway lines, offering competing services. Since June 2007, railway freight market has been liberalised and this will be extended to passenger service in 2010. While this can bring benefits to customers in terms of service quality and better fares, it can create barriers which can prevent optimisation and possibly hinder safety. Moreover, in the upcoming Trans European Railway System the split of responsibility and number of actors can further increase, as e.g. train ownership and maintenance companies can play separated roles.

In order to remove bottlenecks and barriers, a smooth and timely information flow is needed between all the actors.

Another example is represented by railway corridors, important international lines within Europe and neighbouring countries, for passenger high-speed traffic but also for freight, where different vehicle owners, train operators, infrastructure managers, traffic managers, maintainers and authorities are involved in order to facilitate the planned service. All the actors need to exchange information between themselves, which is necessary to really be able to run such kind of international services, having customers to deal with only one front-end interface.

In order to better identify an interoperability framework for all actors in the railway arena, the European Commission defined some Technical Specifications for Interoperability (TSI), the first of which, related to freight service, is already approved and under implementation, while many more are in progress or planned. TSI's specify the minimum requirements to be fulfilled in order to achieve the needed level of interoperability and are mandatory for all the involved actors. Basically, they require that specific information be made available to the other actors in a well defined format and through a common interface, so as to achieve the needed data exchange required by the service.

Finally, it is important to mention that railways need to continuously improve their performance level, in order to be more attractive and competitive. While this can often imply big investments and multi-year projects, it is possible to achieve substantial improvements optimising current processes and better deploying existing information systems in order to support decisions at all levels, operational and strategic, both within each individual organisation and involving different organisations.

### 1.3. An integrated solution

In this scenario, the IGRIS (Integrated Railway Information System) concept, developed by the InteGRail European research project [6], partially funded by the European Commission, can offer to:

- support steering decisions to improve performance
- enable standard semantic interfaces between applications
- allow reliable ubiquitous information interchange

This requires to define and adopt a set of open industry standards, which can enable and support the interoperability of new and existing information systems. InteGRail shall become the standard reference for interoperability of railway information systems.

A system which is InteGRail enabled or certified shall be able to smoothly join the railway information network and send/receive information according to its needs and contractual rights.
This favours interoperability, makes it cheaper to interface systems and allows new actors to enter the market with lower barriers.

One of the most important benefits will be to guarantee unambiguous data exchange, flexibility and scalability. This can be possible as all data have to match (be expressed by) a railway (Ontology based) data model, maintained by a suitable organisation. Such a data model is able to check its own consistency and to be easily expanded when needed (e.g. if new concepts or data are introduced). In this way, the InteGRail grid can grow gradually in a controlled way, avoiding it to crash or become too expensive to maintain.

As usual, a reference platform has the advantage to require only one well defined interface for each networked system, instead of n interfaces, if there is a need to connect it to n systems.

Taking advantage of new knowledge management technologies, IGRIS is able to:
- Organise knowledge in conceptual spaces, according to its meaning; avoid ambiguity through a standard data model
- Use standard languages to make queries and to represent information, which can be automatically processed
- Support information system maintenance by checking for inconsistencies with automated tools
- Allow easy automated extraction of new knowledge
- Define who may view certain parts of information

Through gradual deployment, IGRIS can help integrating current information systems, allowing easier data sharing when needed, avoiding early replacement and preserving investments already done in the past. On the other hand, IGRIS technology can be embedded in newly developed systems, which will have native interoperable interfaces, improving performance and exploiting the full power of the solution.
2. **The technological approach**

2.1. **Architecture**

The problem of information integration in a large scale is to virtualise the perception layer and augment it with enough semantic information so that integration can take place based on this semantic level. Therefore a transformation of raw data that we receive from sensors into information by use of ontology is the new approach that leads from a data-centric approach to a knowledge and information based one, while all knowledge about the actual state of Railway assets from Rolling-Stock parts to Infrastructure together with the relations of components and physical dependencies etc. are represented in a corresponding Ontology. InteGRail started from results of previous projects like EuRoMain [5] in which a domain specific XML-language was used as a first step to represent Railway taxonomies. As a following step, now the use of Ontology as an enabling technology that allows new information to be inferred from existing one [8] is important. On this level data is transformed and will embed the data into its proper formal relationships in a storage fusion that allows a very fine grained on-line analysis of monitoring information with automated reasoning which takes place in the next upper level. Based on the information sharing levels, software agents can collaborate using semantic annotated interfaces and combine so knowledge represented in the integrated Railway Information System and the Railway Ontology. With this architecture we will achieve a virtualisation of the spatial distributed information sets in the Railways.

This adaptation together with better self-description of the measured data and proper sensor information and relations allows to describe several views like mechanical dependencies or electrical properties or pneumatics and also spatial and topological relationships that will influence the system behaviour and maintenance process [7]. In this way, information is added and enriched with its relevant context, and the Ontology approach is used as enabling technology for better integration. As a result it is possible to make content meaningful to computers and this will enable the knowledge representation to be exploited by a description logic approach for inference of other information on higher levels such as maintenance and management aspects.

Furthermore it is possible to detect inconsistencies in the model and system behaviour by machine processable inference analysis that opens the door for a semantic driven
condition based monitoring and maintenance approach. The project aims to build a Railway Ontology as a basis for further standardisation work.

2.2. **Role of Ontology and an Ontology based data model**

According to InteGRail ontology mapping architecture, the InteGRail Railway Ontology creates something like a filamentary information structure to express the semantic relations that in total make up a structure that can be compared to something like a sponge.

All the Railway Ontology is distributed along a series of such very long filaments that can be spread over different InteGRail-Nodes in Europe and are linked with each other on the level of the distributed reasoning mechanism.

The process which allows to build such a structure includes two main steps. First, the concepts which are needed to describe the railway world are defined in terms of their properties and relationships (T-Box) creating a structure in the information space. This is the Ontology, which at the moment is completely empty. Then, real data can find their place in the structure as instances (A-Box), evolving in the form of information in accord with the Railway Ontology, so that we can later extract this information in the well known language of our understanding of today.

Such a role of the Ontology is vital in two ways. Firstly, the amount of T-Box-structures holds the semantic universe of discussion together as at the same time it tries to be extensible for upcoming new concepts. By its own structure that is visible here as Ontology-Pattern that is intrinsic to the T-Box ontology, it keeps everything compact and logically consistent and in places where it can go on to form these concepts to come into existence.

As a second point, the Ontology is also vital because it has a crucial long term validity over the A-Box entries. From a smooth and disperse knowledge representation in the past, we can see now with the InteGRail Information System (IGRIS) as the representation into a more holistic view that also allows distribution of information across Europe, which at the same time offers conceptual structure where the information elements are more compactly represented in a clear semantic knowledge space.

Therefore the T-Box Concepts, which are the starting points for condensing the concepts and relations, form an underlying scaffold, which is absolutely vital for the semantically unstructured incoming data, which can then, at the transformation level, flow into this scaffolding. It's very much like scaffolding, as you would build a house. The T-Box concepts goes up first, around the outside, and then the data later flow into that scaffolding and are gradually, constructed into the knowledge of understood structures. So generally the distribution of the T-Box-Concepts with respect to the A-Box instances that are structured in consequence are very strongly correlated. In other words, where there are good concepts, in general, there is the chance that A-Box Instances flow into and can be traced along the relations and causalities for better maintenance automation. That's very much in line with the expectations that we have made to advance the structured and holistic view on our railway systems.

On such basis, there are several challenges in structuring such information as the distribution becomes spread over Europe and across company and country boundaries. Meta structure of ontology design patterns are used here. This mapping and transformation is needed as logical structuring techniques which are really pushing the bounds of what we are able to measure towards what we now are able also to understand;
moreover, computer based agents are able to understand such information as well and can combine knowledge using automatic orchestration on the basis of semantic annotated interface structures.

2.3. **Approach for implementation**

So the first question we have answered is about the architectural principles of a virtualisation of perception that is inline with the semantic and ontological representation of information as a basis for further analysis. This will provide some more insights by the ways that software services interact with each piece of information that is now represented in clear semantics.

In order to really implement such architecture, InteGRail started from the definition of a Core Ontology, where all the basic railway concepts and relations were included. The intrinsically modular nature of the Ontology allowed to take advantage, when describing general concepts outside the railway domain, of existing Ontology which can easily allow to include common concepts like space and time.

When the project was addressing more specific sub-domains, e.g. railway maintenance, additional concepts needed to be added and linked to the Core Ontology. This allowed the InteGRail Ontology to grow and fulfil the description needs of all InteGRail applications. Even if creating a complete Railway Ontology is beyond the scope of the project, the feasibility of the concept and the way to finalise the task have been clearly shown. Moreover, technologies are available which can well support the implementation of the architecture.

2.4. **Involved technologies**

To achieve this, formal modelling is used to represent information enriched with enough context and formalised in this ontology; the basic idea is to represent data together with its context directly in the ontology language, e.g. OWL (Ontology Web Language). This ontology captures what is commonly understood about a specific railway topic by domain experts, allowing to preserve it for the future (knowledge management).

The Web Ontology Language, uses XML-based encoding and is compatible with RDF-Schema, the Resource Description Framework of W3C standard conceptual modelling that enables us to capture relationships in more detail. The big advantage of OWL is that it has a well founded formal semantics on the basis of description logics that provides automatic reasoning support for the given ontology. OWL offers the possibility for execution semantics in the form of on-line distributed intelligent processing to answer specific management and maintenance queries as they arise, because it represents domain concepts, attributes, values and relations, while the actual values are mapped automatically via the perception layer.

3. **InteGRail applicability**

3.1. **Holistic approach**

With the aim to favour the integration of railways, InteGRail does not consider only one specific subsystem, but spans over all parts of the railway system: rolling-stock, infrastructure, train operation and traffic management, reaching a holistic view. This is reflected in InteGRail applications, which address the main processes like monitoring and control, maintenance, strategic and operational decision support and communication, driven by the Ontology concept. As we have seen, InteGRail developed a Core Ontology, which can be expanded in order to include several domains.
For example, an extension of the Ontology in the direction of maintenance processes allows investigation of improvements to maintenance by better handling of information and associated concepts. This means to include concepts like faults and their consequences, such as operational prescriptions (e.g. speed limit) and needed actions (e.g. maintenance required, part to be re-placed, etc.), which can affect the train operation and the maintenance planning.

### 3.2. The three demo scenarios

To better show the holistic approach, covering the most important InteGRail applications, it was decided to define three demonstration scenarios:

- **DS1** - Set up and running of a new freight train service between two different European countries;
- **DS2** - Cooperation between Rolling Stock Undertaking and Infrastructure Manager by exchanging respectively infrastructure and rolling-stock related condition information;
- **DS3** - Support for optimal decision making when handling an incipient (or real) fault on a passenger train while it is in normal service.

The overall goals of the demonstrators are to:

- prove that architecture works;
- prove that functionality works, i.e. the information can be disclosed through the newly developed IGRIS functions and using the IGR Service Grid;
- the railway performance can be increased using these new IGRIS information systems functions

We will focus on demonstration scenario 3, which is more complete and closer to the holistic approach and so can better show the evolution from initial concept to real life implementation in a set of cooperating applications.

### 3.3. Demonstration Scenario 3

The main scope of the third Scenario is to show the improvement in efficiency of the overall railway system to manage an unexpected event (a critical fault that blocks the train) detected on a train in passenger service. This kind of event affects all railway domains (Operation, Traffic Management, RS Maintenance): Traffic Manager has to manage the whole traffic with the final objective to reduce the impact on the current services performed by the different trains and to ameliorate the situation in support of the expectation of the passenger on board the faulty train; detailed information has to be available to allow the operator to plan the best intervention, and to allow the rolling-stock maintainer to evaluate the impact of the fault on the train performance, in order to allow the Traffic Manager to find the most appropriate solution.

Consequently, this scenario involves cooperation between all InteGRail subprojects: SP3A is in charge to detect the fault by means of the On Board Train Control and Monitoring Systems (TCMS); SP3B is mainly involved to evaluate the fault and notify it to the Operational Decision Support System (ODSS – in charge of SP3C) together with the evaluation of its impact on the train performance. The ODSS can combine this and other information in order to evaluate the impact of available solutions on the overall performance of the affected part of the railway system, so as to suggest to the Traffic manager and Train Operator the more effective decision. For other faults, not blocking the train (called “Generic Fault”), the rolling-stock maintainer can identify preventive actions to avoid that an incipient fault (or a hidden fault) produces its effects with worse consequences.
In any case, suitable maintenance activities have to be planned, in a way that allows to minimise any disturbance, as well as costs.

The demonstration will be implemented in Italy and will be based on a Trenitalia Eurostar City (usually shorten as ES*City), train consist of two E414 locomotives (at the opposite ends) and ten intermediate coaches.

A similar concept, with some complementary objectives, will be demonstrated in a Czech demonstrator, based on data made available on ground by the commuter trainset EMJ471.

3.3.1. Storyline without InteGRail

A passenger train is running and a degradation phenomena affects a relevant equipment. As a consequence a fault having a blocking effect on the run is developing but no symptoms or diagnostic information are detected by on board staff. Incipient faults aren’t diagnosed.

In a short time, we say one hour, a failure happens so the train is stopped between two stations, where the logistic conditions for any rescue and maintenance intervention are the worst. Moreover transferring passengers to another train is very complicated and a long queue of trains behind the faulted one is increasing.

In the meantime, the Traffic Manager (TM) is waiting for information from the pertinent Operation Maintenance Department (OMD) in order to start the rescheduling process. As soon as possible, OMD will communicate (by phone) times and possible constraints (i.e. the other binary is blocked too for transferring passengers on a rescue train) to TM. Issuing a contingency traffic plan is a task for TM but it needs fundamental information from some involved actors: OP (Operator) will provide suitable resources and IM (Infrastructure Manager) will identify new paths. This decision making process is often complicate since information systems used by the actors are not integrated, so the information exchange will be carried out several times to find a common feasible solution. Several phone conversations and a lot of time are required and the identified solution is often not the best.

This storyline is quite unsatisfying, so some new features have to be introduced:
- incipient faults diagnosis
- incipient faults promptly notified to all pertinent actors
- all involved partners contribution to rescheduling decision making process

Therefore we can come to an improved storyline, thanks to InteGRail issues that will integrate all actors in a shared process.
3.3.2. **Storyline with InteGRail**

A passenger train is running and a degradation phenomena affects a relevant equipment. As a consequence a fault having a blocking effect on the run is developing and a Fault Alert is simultaneously notified to on board staff, to OMD (on ground) and to TM, which will manage it through an Operational Decision Support System.

The OMD diagnoses an incipient faults and estimates an occurrence time. The risk is that in, we say one hour, a failure happens so the train will be stopped between two stations, where the logistic conditions for any rescue and maintenance intervention are the worst. Moreover transferring passengers to another train is very complicated and long queue of trains behind the faulted one will be created. OMD will consider those risks and decides to stop the train in a specified station. The train block is prevented but a new train must be arranged. Thanks to InteGRail data interfaces, as soon as information are received by OMD, TM will decide a new traffic schedule and some actors will be enquired: OP will provide suitable resources and IM will identify new paths.

Using InteGRail, this decision making process becomes easier and faster since information systems used by the actors are integrated: a OP resources manager will inform about available staff and rolling stock, IM path manager will inform about available path and a TM traffic re-scheduler will prepare a new traffic plan. An ODSS (Operational Decision Support System) will support the TM for:

1. identifying the current event on the basis of information coming from board monitoring system and from OMD;
2. identifying a procedure to arrive a solution;
3. collecting contributions from OP and IM;
4. activating and collecting results from a train re-scheduler application.

This storyline is improved because:

1. we avoid that a train is stopped in a critical place;
2. in a short time an optimised solution is issued because all actors jointly work by means of their information systems.

### 3.4. Some InteGRail applications

The work done during the previous years of project life allowed to define a number of applications in order to achieve the project objectives, driven by the demonstration scenarios and implemented in accord to the common general architecture.

As it is not possible to go through all InteGRail applications, we focus on the Intelligent Maintenance part, which includes a number of applications such as:

1. **Condition Analyser**: extended fault detection
2. **Unplanned Event Manager**: actions for critical conditions recovery
3. **Predictive Maintenance Server**: fault inference and diagnostic rules
4. **Lean Maintenance Optimiser**: performance boosting and scheduler
5. **Intelligent Depot Tool**: door for maintenance system Users

#### 3.4.1. **Symptom Agent**

Using the reasoner and the InteGRail ontology, together with other predefined ontology’s (e.g. Regional Connection Calculus – for location/ time based analysis), the SA analyses symptoms in order to detect meaningful diagnostic events and notifies them. Data can be a combination of historic recorded data and actual or computed condition/status data (snapshot).
3.4.2. RS Condition Analyser

The CA considers all symptoms and environmental data in order to identify real or incipient faults and it is responsible for the unplanned event manager. The CA can be hosted on the vehicle and on ground, or both. The physical disposition depends on the type and amount of data and the types of communication links available.

A symptom is a piece of data, coming from a sensor or device, which has been evaluated as anomalous and needing further investigation. E.g.: a process variable with a value out of the range of normal behaviour. However, a symptom is not a fault and often is not directly linked to a fault, as this can require taking into consideration many symptoms, to compare the behaviour of different devices and so on.

A simple implementation of the Condition Analyzer can just hold cumulative data, so only being able to show an instantaneous state. A more advanced version could also hold some historic data, in order to calculate a trend or perform other time-based analysis.

The Ground Condition Analyser evaluates the fault as “Critical” or “General”. If the fault is Critical, it has an impact on train journey, and it has to be notified to the ODSS. The evaluation of the performance reduction is done by the Unplanned Event Manager.

3.4.3. Unplanned Event Manager

The UEM tries to allocate actions within the current planning of a depot and estimates the TTR (Time To Repair). It interfaces with a maintenance management application (MMS), directly or by means of an optimiser (see below).

It is responsible to coordinate communication between IMAIN applications and with external modules.

Fig. 4 - Overview of DS3 applications
3.4.4. Predictive Maintenance Server
The PMS analyses historical data in the fleet DB on ground in order to identify patterns which can bring to possible faults. The Ontology based repository, populated with real data, can be used by IMAIN applications in order to extract the needed information. This can be done with a combination of reasoning and Business Logic. The intelligent approach can so be able to identify information which is hidden in the available data, e.g. to detect the possibility of a fault in a certain time. The incipient fault can then be processed as a normal fault, to avoid heavier consequences. Identified faults shall be notified to the Unplanned Event Manager.

3.4.5. Lean Maintenance Optimizer
It is anticipated that moving from a scheduled approach to maintenance, to a condition and predictive based approach could cause an increase in waste of resources, material, process time, etc. To manage the change a Lean Maintenance Optimiser is proposed. The concept is that considering the situation of the fleet and of available depots, the LMO can apply lean concepts in order to suggest the best decisions for optimised maintenance. As an example, a maintenance activity can be split into two steps, to be carried out at different locations and time, in order to minimise train and depots unavailability.

3.4.6. Intelligent Depot Tool
The IDT offers a Graphical User interface to the Maintenance Operator, combines information coming from different sources, and provides a process interface between the Maintenance Operator and previously described applications.

Fig. 5 - An ES* City train as that envisaged in the DS3 demonstrator

3.5. Benefits
The benefits are accrued from a number of areas. Enabling the use of information that was previously either discarded as too hard to use, or laboriously transcribed from its raw form to some other system is a small step, with some benefit. Enabling unified, intelligent access to information and adding automated reasoning, allows previously impossible scenarios to be considered. This is a larger step, but by reducing the reliance on manual intervention can lead to better control of asset maintenance and therefore less variability. The extent to which existing systems can be adapted and interface will reach limits of cost and technology before all benefits are realised which means waiting for the introduction of replacement systems. When new systems are being considered, it should be possible to include the concepts from InteGRail to a greater extent, and gain additional benefits.
4. **Vision for the future**

4.1. **InteGRail Service Grid**

Deployment of IGRIS architecture will eventually bring to a wide number of networked services, cooperating to fulfill the requests coming from users or other applications, establishing a service grid. Discovery mechanisms can allow to easily include new services, which will be immediately available to other interested parties having the right to access them. The grid will span all areas of the railway system, implementing a holistic coherent information system, able to be accessed by many different applications according to their needs and viewpoint.

Joining the grid will be as easy as plug-and-play; together with the distributed architecture, this brings to a high level of scalability, allowing evolution for future needs and keeping network complexity under control, so reducing its maintenance costs.

4.2. **Possible standards**

Interoperability needs to be based on standards [4] and interoperability of information systems is no exception. Since the beginning, InteGRail had in mind to prepare some proposals for new standards, to be submitted to suitable standardisation bodies.

Work is in progress in several directions; possible standardisation proposals include:
- "A standard Railway KPI structure"
- "Ontology based standard Railway Data Model"
- "Standard Railway Communication Framework"

A first opportunity emerged as Technical Committee 9 (TC9) of IEC (International Electrotechnical Commission) approved in Bordeaux on November 2007 a NWIP (New Working Item Proposal) dealing with standardisation (functional blocks and components, interfaces, protocols, services provided) of several subsystems, including “Train Operator and Maintainer oriented services”. Such activities are now under the responsibility of WG 43.

Another good opportunity is within CENELEC. Technical Committee TC9X, WG B14 of this European standardisation body defined a general framework for communication within the railway system, identifying all needed network segments and interfaces, both on board trains and on the ground.

As standardisation procedures are normally rather slow and will take several years to be finalised, InteGRail, which is planned for conclusion at the end of 2008, will not be able to follow them up to their final step.

A deployment plan is under definition, so as to also identify an organisation or future project which can support the standardisation process and ensure that it will reach a positive final result. It will take care of InteGRail evolution and will be in charge of keeping contacts with the envisaged standardisation bodies and provide the needed inputs and cooperation.

4.3. **An InteGRail based organisation**

Following InteGRail dissemination efforts (e.g. Business Group activities, Web User Group, public workshops and events, etc.), a suitable User Group will be organised and maintained in the future, after the project will come to an end, in order to give information and assistance to organisations wishing to adopt the InteGRail approach. This could eventually result in a certification process, which can enable Information Systems and their interfaces to be “InteGRail approved”, so ensuring their mutual interoperability and conformance to emerging regulations and standards. The process will need to identify conformance testing procedures and one or more neutral service providers which will be able to apply them, so avoiding monopolistic threats and security issues.
In such direction, further cooperation with organisations like ERA (European Railway Agency) and RNE (Rail Net Europe) is envisaged. Other tasks refer to the need to regulate the evolution of the Railway Ontology, core of the InteGRail system, and to ensure an effective security policy related to shared information.

### 4.4. Deployment

As InteGRail follows an holistic approach, having a deep impact on railways organisation, it can only be deployed gradually and incrementally, so as to avoid problems due to fast changes not easily assimilated, while at the same time offering some first benefits since the beginning.

A deployment plan with therefore necessarily go through several phases:

- **Phase 1:** short term (1-5 years) - the key element in this phase is the integration of existing systems and the establishment of a robust architecture from which to launch the medium and long term strategies;
- **Phase 2:** medium term (5-15 years) – as some existing information systems will be life expired in this time frame, consideration to removal and replacement with alternative or improved systems will be required. First IGRIS natively conformant systems appear.
- **Phase 3:** long term (15-30 years) – IGRIS widely adopted as most new railway subsystems are borne with incorporated IGRIS interface, so delivering the vision in full.

### 4.5. Other research directions

One of the most important results of a good research project is to open new subjects and define new ideas, in order to pave the way for further research. InteGRail innovation relies mainly on the identification of an interoperability platform, which can be a common basis for many applications, in order to have them easily exchange the data needed to perform their tasks.

Such holistic approach has been proofed against some basic demonstration scenarios, using simple prototypes. However, full development of the platform and investigation of all possible applications is an issue for future research. Performance aspects in terms of response time and robustness will be addressed during the test phase, but will need further research in order to be improved up to the higher level allowed by available technology.

The same is for cost-benefit analysis, which InteGRail is starting, but will need to be better addressed in the future as long as benefits are better understood and costs are optimised.

### 4.6. Conclusions

Turning current organisation of railways into a knowledge-based Intelligent Railway Transportation System will be a tough task. Opposition is expected from the traditionalists railway stakeholders, especially incumbent railway operators, who see a risk for their information to be used against them by competitors.

However, railways have shown that they can face even quick evolution, when the benefits and the market requests are clear. Therefore a main task of InteGRail is to show a new direction that railways have to follow in order to improve their overall performance level, demonstrating clearly its feasibility and benefits.

### 5. References


