MIGRATION OF THE EUROPEAN TRAIN CONTROL SYSTEM (ETCS) AND THE IMPACTS ON THE INTERNATIONAL TRANSPORT MARKET

Miroslav Obrenovic
Dr.-Ing. Bärbel Jäger
Prof. Dr.-Ing. Karsten Lemmer
German Aerospace Center (DLR) – Institute of Transportation Systems

1. INTRODUCTION

Currently approximately 20 different train control systems are in use in Europe. Taking the Thalys high-speed train connecting Paris, Brussels, Cologne and Amsterdam as an example, it has to be equipped with seven different CC-systems including antennae, sensors and control panels. To reduce this number and thus to realise a cost effective and seamless cross-border railway operation ETCS will be implemented in the next years. Therefore the legislative preconditions in the form of EU directives 96/48/EG and 2001/16/EG have been established. Besides the political demand the optimal migration of this new technology will be a crucial condition for its success. The migration on strategic level is described by a number of corridors for the high-speed and conventional rail. Now each country has to find the optimal way for the migration of ETCS on particular corridors concerning the national railway network as well as the rest of the related corridor and the entire future ETCS network. Optimal deployment on strategic level and the identification of the optimal approach for each corridor, track and track section will be crucial for the operational as well as micro and macro economical opportunities and threats.

2. ETCS – THE NEW EUROPEAN TRAIN CONTROL SYSTEM

The strategy of a standardised European railway operations control has been embarked on for ca. 20 years now. Various consortia of railway companies and signalling industry have tried to agree on a common action. Since 1998 UNISIG (Union Industry of Signalling) consisting of Alcatel, Alstom, Ansaldo Signal, Bombardier, Invensys Rail and Siemens has been working on the specification for ERTMS/ETCS. Thereby, different functional and technical levels have been defined in order to be able to serve high-speed tracks as well as slower rail freight lines and low density secondary tracks. On the one hand this scalability is necessary for reasons of highly unequal requirements in different countries and different line types and on the other hand due to constraints coming from the migration process.

To achieve *interoperability* – to ensure, that trains equipped with ETCS and GSM-R equipment made by one manufacturer are able to operate on a network equipped by another one – a common set of specifications has been elaborated. Currently the System Requirements Specification (SRS) 2.3.0 is stable and applicable. Specific technical issues – e. g. integration of level crossings – will be considered in the release version 3.0. Additionally in order to increase scalability and to accelerate the migration process, a low-cost access to ETCS – Limited Supervision is being discussed and will be specified in the SRS version 3.0 as well. Test specification for the certification

of conformity has been carried out by notified bodies based on SRS 2.2.2 and still is to be updated to the version 2.3.0.
Besides the *technical interoperability* a harmonisation of *operational rules* has to be carried out. First draft therefore has been elaborated by the ERTMS Users Group. It will first be applied only on regular operation. Fall back situations in case of failures are still based on national rules.

3. MOTIVATION FOR ETCS MIGRATION – OPPORTUNITIES AND THREATS

There are four basic types of motivation, which can be identified for the migration of railway operations control:

- Rationalisation – economic aspects;
- Improvement of track performance (e.g. interoperability, speed);
- Absent availability of currently used technical components or systems;
- Political decisions.

For ETCS deployment, legislative preconditions in terms of EU directives 96/48/EG and 2001/16/EG are given. They address European conventional rail respectively the high-speed lines. Thereby, corridors defining strategic system deployment have been carried out. ETCS aims on providing an interoperable railway operation. Migration of a new CC-system has impacts on operational as well as financial and global macro economic aspects. Among others, following *opportunities* are expected:

- Positive impacts on transport and railway technology markets

Barrier-free access to European railway infrastructure will conduct an increase of competition and thus higher cost efficiency. From the customer’s point of view, after a certain level of elasticity, increasing competition leads to falling prices. Especially in the area of cross-boarder traffic, an increase of transport volume and thus a modal shift toward railway can be expected. Precondition therefor is demand of service on defined corridors for passenger and especially freight traffic. Latest cost-benefit analyses for ETCS corridors show the expected positive impacts.
From the Train Operator Companies (TOC) and Infrastructure Managers (IM) point of view, asset cost for the new system should decrease as well. The procurement market of standardised system components offers cost reduction due to the competition on the one hand and economies-of-scale effects on the other hand. These effects, arising out of the extension of the delivery area for the signalling companies (partly as an export out of Europe, too) lead to cost reduction in the development and the production process as well and thus to a long-term win-win situation between railways and industries.

- Decrease of life-cycle costs (LCC)

Additionally to the asset cost impacts above, due to the computer technology and radio communication on the one hand and the shifting of the equipment from track to the rolling stock ETCS components aim at causing lower maintenance cost compared with current national systems. Especially in

cases, where line side signals or cables can be removed, this effect seems to be evident. Infrastructure managers stand to benefit from that fact.
From operators' point of view, financial benefits can be identified as well. From the date, ETCS is implemented along the whole corridor, railway operation with locomotives including just *one* CC-system become possible. This implies among others:

- Increase of cost efficiency;
- Breaking cost and technology limits of deployable radius of locomotives;
- Lower access barriers for TOCs.

Once harmonisation of operational rules is done, a significant decrease of training cost for train drivers can be achieved as well.

- Positive impacts on operational performance and RAMS[1] criteria

This point is to be regarded dependent on a current situation in affected national railway networks. Taking the German railway network as example, capable national CC-systems LZB and PZB90 are currently in use. Here, an improvement regarding operational performance – speed, headways, etc. – is not to be expected. On the other hand, some other networks have over aged systems respectively an automatic train protection is not widely spread (Table 2 in Section 4). Nevertheless, standardisation in the technology domain will lead to harmonisation of RAMS figures on a high level in future ETCS network and thus to safety improvement within international railway transport.
On the other hand, some *threats* occurring within the scope of ETCS migration have to be exposed as well.

- Asset cost

Though expecting a decrease of LCC, high investments for ETCS components have to be made first. Especially due to high asset cost for the on-board equipment, railway operators have to face this challenge. Therefore, specific subsidies have to arrange for additional motivation for ETCS deployment.

- Certification process

In spite of aspired interoperability, certification process of ETCS components is still quite complicated and cost-intensive. Regarding operations control generally, cross-acceptance – homologated and certified systems in one country are accepted in another one – is still often not practicable. Various adaptations of certification documents are needed. Resultant cost will be added on the product prices and thus increase asset cost.

- Long life-cycle and depreciation period for current national systems

Two different types of ETCS migration can be identified. "Natural" migration would mean that national legacy systems will be replaced by ETCS according

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[1] Reliability, Availability, Maintainablity, Safety

to their particular end of lifetime step by step. This is highly different along defined corridors and implied unequal migration period and strategy for each track section. Thus interoperability can be achieved only in a long-term. Otherwise, “fast” migration implies removal of not completely depreciated national systems, which is a financial challenge. With parallel equipment of ETCS and national systems, this issue can be solved, interoperability is achieved. However, in this case maintenance cost will increase.
Hence it becomes evident, ETCS migration is a multi-dimensional optimisation problem, which only can be solved applying a methodical approach shown in section 7.

4. MARKET CONSIDERATION

There are two kinds of markets we have to address with respect to the migration of an interoperable train control system. On the one hand, international rail transport for passengers and freight – on the other hand the current state on train control systems in Europe.
A total of 72 % of land freight transport and 92 % of passenger transport within the EU are being provided by road, with just 17 % of freight transported by rail. The large difference between road and rail transport volumes constitutes a real danger for European competitiveness as it is estimated that road congestion costs represent approximately 1 % of the Gross Domestic Product (GDP) of the EU.The imbalance is further reflected in the areas of safety, the security of energy supply and environmental quality - road vehicles are responsible for 84.2 % of the CO_2 emissions attributed to land transport.
Due to the globalisation, European single market and the outsourcing effects in most industry branches, seamless and cost efficient cross-boarder traffic – passenger and especially freight – is one crucial criterion for the success of European railways. Interoperability as a target in the domain of railway transport in Europe is being affected by several technical and operational obstacles. Some of them are e. g.:

- Different track gauges
- Electrical power supply
- Height of station platforms
- Maximum track gradients
- Etc.

The lack of standardisation becomes evident especially in the number of more then 20 different train control systems currently used in Europe. These technical solutions have been specific issues of national railway networks, thus leading to a fragmentation of the European landscape (Fig. 1).

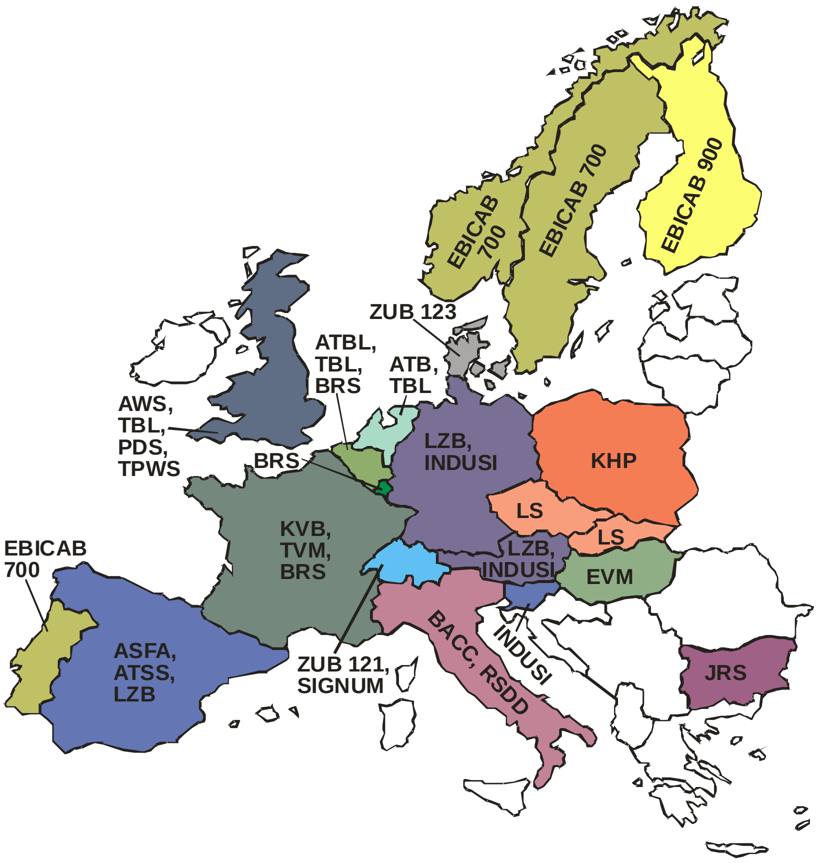

Figure 1: Fragmented European landscape of train control systems

The European Rail Traffic Management System (ERTMS) with its core ETCS and GSM-R aims to resolve this problem in the area of signalling as well as speed control and supervision.

Macro economic benefits for each country result from the volume of international transport made by rail. ETCS aims to make cross-boarder traffic more efficient. Thus the share of this kind of traffic in overall rail transport volume has to be considered first.

Country	Share of international transport in overall railway traffic volume	
	Freight Traffic [%]	Passenger Traffic [%]
Bulgaria	7	0,2
Poland	30	0,1
France	40	3
Germany	50	2
Luxemburg	73	93
Netherlands	78	4
Switzerland	28	5
Italy	23	2
Spain	20	4
UK	6	4

Table 1: Source: Union Internationale des Chemins de Fer, European Conference of Ministers of Transport, Eurostat and national statistics

Table 1 above shows the heterogeneous transport situation displayed on a sample of European countries.
On the other hand, the current state regarding national CC-systems has to be analysed. In order to understand the different types of migration drives and the decision to implement ETCS within the European railway landscape, besides the share of international traffic, the existence of automatic train protection is an important aspect as well (Table 2).

Country	Share of not equipped track km and vehicles with automatic train protection	
	Track km [%]	Vehicles [%]
Bulgaria	85	71
Poland	39	34
France	12	27
Germany	10	5
Luxemburg	5	12
Netherlands	4	0
Switzerland	0	0
Italy	63	5
Spain	11	20
UK	1	0

Table 2: Source: UIC Migration Strategy Group 2003

Hence, the necessity of ETCS implementation for safety and performance reasons in particular networks can be pointed out. This heterogeneous application field implies requirements for highly functionally scalable European solution covered by ETCS.

5. POSSIBILITIES FOR DEMAND MANAGEMENT AND MACRO-ECONOMIC BENEFITS

It is a political target to realise modal shift from road to rail especially in the field of freight traffic. Macro economic benefits can be generated in terms of safety, energy consumption and environmental pollution improvements.

- ETCS has to be seen as a driver for global optimisation

In order to improve performance of railway operation on international lines there are various measures to be taken. Thereby ERTMS/ETCS provides the framework for a successful course of action on the field of railway operator organisation, logistics, regulations as well as infrastructure investments, etc.

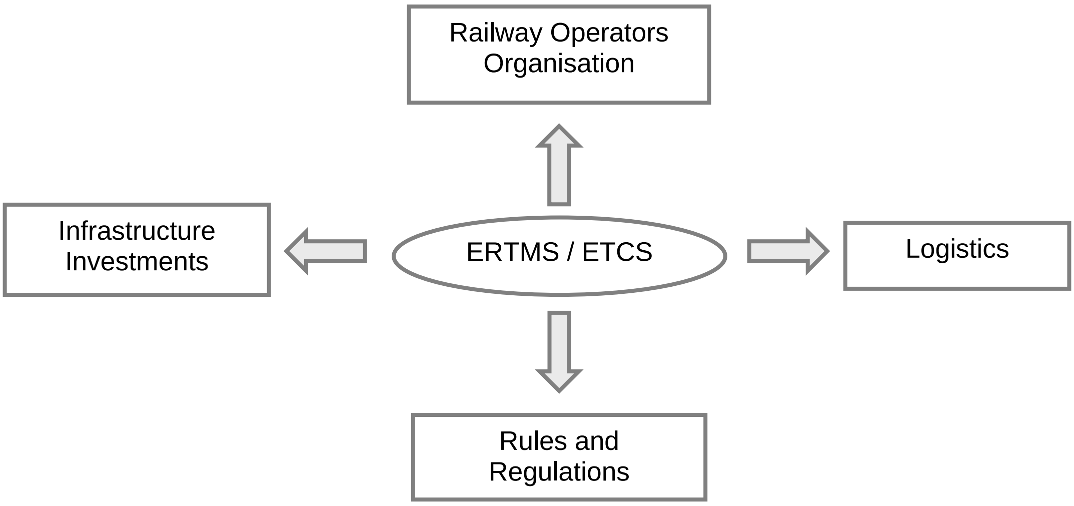

Figure 2: ETCS as a driver for global optimisation [ERTMS on the Corridor Rotterdam – Genoa]

ETCS as train control system has to be regarded as a driver within a scope of a number of measures providing a more efficient rail transport supply. In most cases ETCS itself will not be able to improve the performance significantly. However, combined with other measures, operational as well as the organisational structure can be optimised.
Thus an increase of demand for international lines – "yield management" by implementing a new technology can be carried out. Taking the rail freight corridor from Rotterdam to Genoa as an example, decrease in transport time from 22 hours to 18 hours in average as well as increase of punctuality from 70% to 85%, lead to a significant improvement of service. This new conditions are expected to increase the market share of rail freight traffic from 22% to 28%.

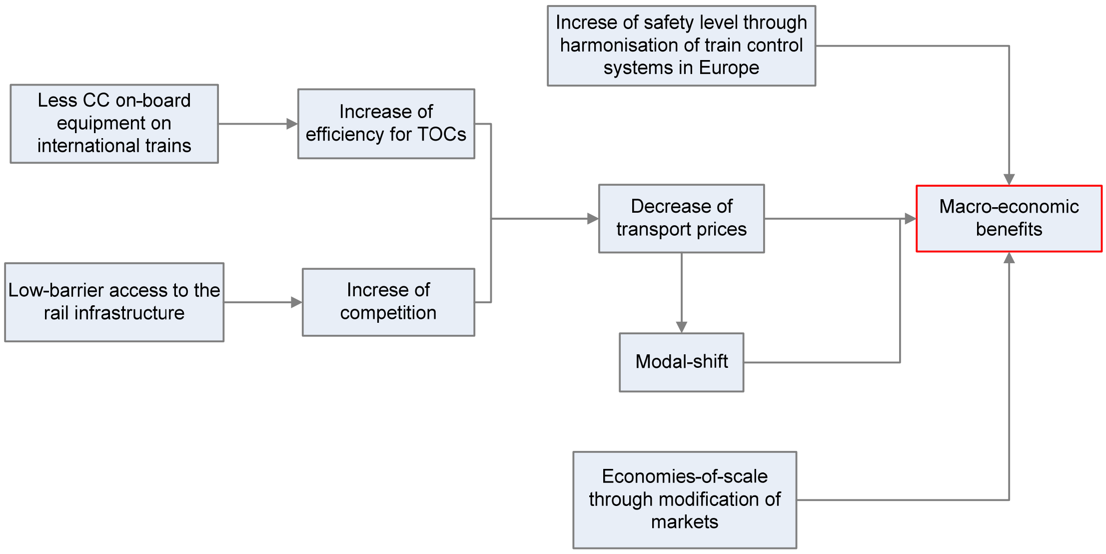

Figure 3: ETCS and macro economic benefits

Figure 3 shows possible cause-and-effect paths, describing the way ETCS is able to generate macro economic benefits.

6. VALUE BENEFIT ANALYSIS AND LCC

Besides defined tracks and corridors, other network sections e.g. feeder lines might also be a target area for ETCS. On lines, ETCS migration is not mandatory coupled with a renewal of signalling systems, a selection process regarding the appropriate target systems has to be carried out.

For the identification of the criteria suitable for the selection of the target system, the specific migration drive has to be regarded. Due to the high complexity of the decision model (section 3), including figures and indicators from the economical, technical, operational or political point of view, Value Benefit Analysis (VBA) is a suitable method to be applied. It is an approach for the systematic operations research, used at selection issues in case of different project options. The VBA originates from the engineering sciences and allows, contrary to the Cost-Benefit Analysis, the view on non-monetary assessment criteria as well, and aims not only at the economic efficiency. Nevertheless, the economical aspects and especially the LCC of the regarded systems will be crucial criteria in the decision process, receiving the appropriate weight within the scope of the VBA.

The LCC-Analysis takes into account the overall costs appearing during the entire life cycle, considering all purchasing, owning and the disposal of the system. It additionally identifies cost drivers by analysing the “cause-and-effect chains” between relevant figures and processes. Therefore, LCC-Model is to be elaborated for the regarded operations control system. Furthermore, there is a process analysis to be done in order to identify and optimise areas of cost-drivers, e. g. the development or the maintenance process. The Standard DIN EN 60300-3-3 gives a guideline including the elaboration of the system breakdown structure plan as well as the cost breakdown structure plan, needed for the analysis.

LCC-Model (Fig. 4) is a simplified image of the reality, which abstracts the main characteristics and attributes of the regarded system transferring them into the cost factors. Especially due to a long life-cycle of railway operations control, these costs have to be estimated partially. The long life-cycle requires the consideration of product modification costs during the operation phase, too. In order to determine the overall LCC, the single cost positions occurring during the life time have to be accumulated.

$$LCC = A_0 + \sum_{j=1}^{n} (O_j \times \frac{1}{(1+d)^j}) + D_n$$

LCC Life Cycle Costs (User-Oriented)
A_0 Positions of Asset Cost to the Date 0
O_j Positions of Cost of Operation and Maintenance during the Life-Cycle
D_n Positions of Disposal Cost to the Date n
j…n Life-Time of the System
d Discount Rate

To consider the net-present-value, the costs have to be discounted with a defined rate. Using this approach, an efficient method for the assessment of economical aspects in the selection process can be applied.

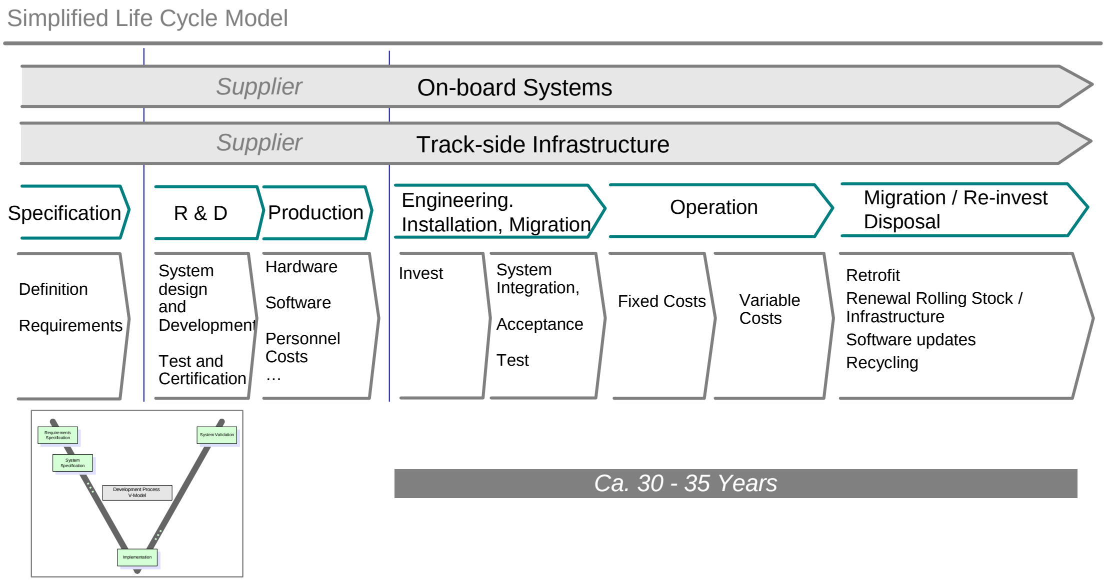

Figure 4: Simplified LCC model for railway operations control

7. STRATEGIC ETCS DEPLOYMENT VS. MIGRATION ON OPERATIVE LEVEL

The rapid development of new technologies raises the challenge to introduce new systems in existing environments. Especially in the domain of railway operations control – where life cycles are extremely long - a carefully designed migration process is necessary to update existing infrastructure and rolling stock with their long-term depreciation to state of the art technologies with their typically shorter life cycles. Thereby, selection of the appropriate target system (section 6) as well as the optimal migration strategy is highly responsible for the resulting economical and operational benefits or possible constraints.

In the railway and signalling sector, one main boundary condition is to keep up operation, safety and availability during the complete migration process. Together with the requirement to minimise the overall migration costs as well as to consider technical, political and other boundary conditions, the development of a suitable migration strategy becomes a complex multi-dimensional optimisation problem (section 3).

7.1. European Master Plan

Concerning national migration plans, a fragmented approach is definitely to be avoided. To be able to generate maximum benefits mentioned above, consistent corridors and in the next step a coherent ETCS network composed of them has to be created. Therefore, a conciliated migration approach on the strategic level has to be defined by means of a European Master Plan for ERTMS/ETCS.

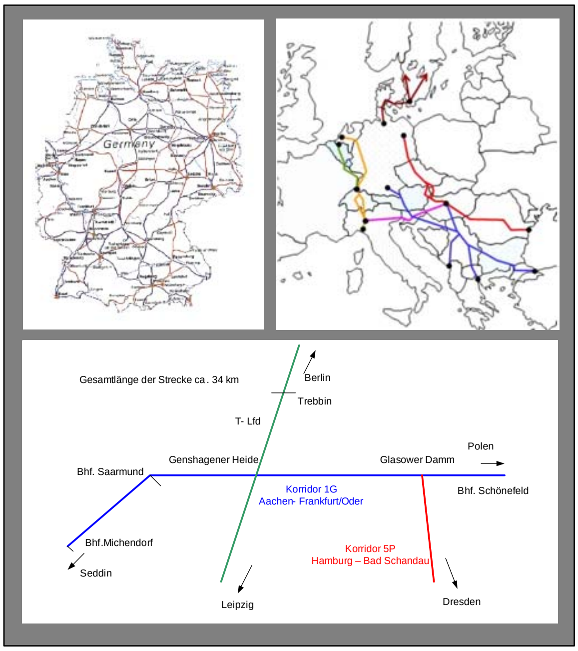

Figure 5: Different levels of migration issue

ETCS deployment including migration on European corridors has to be coordinated with national railway networks and the implementation on certain track sections – migration on operative level (Fig. 5).
Thus the arising ETCS Network is an interoperable rail backbone enabling the realisation of micro and macro economical benefits through an “end-to-end” business and service perspective (Fig. 6). With such an approach the new system moves toward the condition of “critical mass" generating additional motivation and thus accelerating the deployment.
To minimise financial impact for railway companies, coordinated funding plans will play another crucial role in terms of being a migration driver.

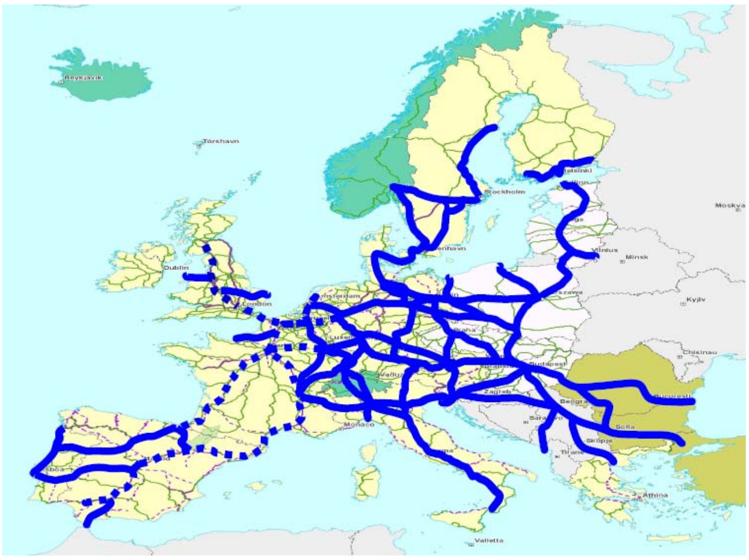

Figure 6: Strategic plan of an ETCS network [tsi-ccs]

7.2. Development and Evaluation of Migration Strategies

Not only defined corridors, building the ETCS network have to be considered. Feeder lines connected to the corridors as well as the entire train circulation plan must be involved into the identification of the suitable migrations strategy. Besides the required interoperability, the mixed traffic respectively the so called “*intra*operability” within each national network has to be ensured as well.

During the migration phase, a parallel equipment train- and / or track-side will be necessary. There are already some examples for similar approaches. Train-side parallel equipment with multiple CC-systems is quite common. So far, cross-boarder traffic can be realised without changing the locomotive. Examples therefore are e. g. type series 185, Thalys or ICE 3.

Track-side parallel equipment is being applied on several tracks, too. Reason therefore is mostly the increase of availability in case of system failure of the primary train control system. Parallel to the LZB, German high speed lines are equipped with the spot supervision system PZB. Increasing the amount of track kilometres equipped with ETCS the motivation for operators to equip their trains with the new system will raise as well.

Dependent on the stakeholder, different key figures are to be focussed on. To provide a neutral and global assessment of migration strategies as well as of cost-benefit-ratio, particular interests as well as macro economical benefits are to be considered.

The final target of the ETCS migration is not to have one more train control system overlaid to the national systems. Rather, ETCS has to be established as a substitution of national CC-Systems, at least on defined corridors. This should be a requirement on the migration process, while having in mind the higher operational and maintenance costs (as parts of LCC) in case of the parallel equipment track- or train-side.

ETCS migration raises problems on different levels. On the one hand, we have a strategic question of ETCS deployment using the corridor strategy. On the other hand, the characteristics of certain tracks and sections have to be considered on the operative level. Assessment of different migration strategies, e. g.:

- Parallel equipment with ETCS and the national CC-System track-side;
- Parallel equipment on-board;
- Parallel equipment on both system sides;
- STM-Strategy;

includes analysis and optimisation of two crucial figures – cost and time.

Since isolated migration cost is needed, basic approach of the Net Present Value Method is modified due to the determination of cash flows by comparing the payment stream of the regarded migration scenario with the continuation scenario of the current CC-system. Thus the costs the national system would cause without the migration toward ETCS are subtracted.

The other key figure – migration time – can be determined by regarding the specific strategy including the action sequence considering capabilities of installation, retrofitting, commissioning, etc.

$$C_0 = \sum_{t=0}^{n} (E_t - A_t) \times \frac{1}{(1+i)^t}$$

C_0 Overall Migration Cost
E_t Cost of the ETCS deployment (asset cost, maintenance cost, disposal cost of the legacy system)
A_t Cost of the reference scenario (maintenance cost of the national CC-system)
0…n Duration of the migration process
i Discount Rate

For railway companies, both - infrastructure managers and railway operators – migration cost as well as the overall LCC can be decreased receiving subsidies on national or European level. Thereby, reducing asset cost und thus the investments needed for the ETCS installation line and train side, a barrier of financing the new system can be faced.

8. CONCLUSIONS

This contribution gives an overview on opportunities and threats of ETCS rollout in Europe especially related to migration and economic issues. Thereby, different points of view und thus the idea on high complexity in this topic area is given. In spite of expected macro economical benefits, optimal migration strategy and transparent funding conditions will be crucial for minimisation of cost and operational constraints for European railway companies. Applying a methodical approach for development and evaluation of migration scenarios helps accelerating the ETCS deployment, reaching a "critical mass" and thus realising expected operational and long-term economical benefits.

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