World Conference on Transport Research
Lisbon, July 11-15, 2010

Governance of innovation in the European railway sector

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Abstract

The European railway sector has undergone major transformations over the past two decades. Domestic reforms have been buttressed by European directives aimed at creating a single European railway market. In this new environment roles have been significantly redistributed, leading to new organizational models. A new and dynamic equilibrium is emerging, to which all railway stakeholders are trying to adapt.

The paper looks at the European Rail Traffic Management System (ERTMS) from the innovation perspective. It argues that the concurrent liberalization of the sector and the technical harmonization (via the introduction of a pan-European signaling technology) have fragmented the railway sector on different levels (e.g. technological and organizational). The difficulties in developing and deploying a pan-European standard attest to the necessity of re-thinking innovation processes in the railway sector, particularly when those relate simultaneously to infrastructure management and operations. Among others, a broad consensus/alignment of the stakeholders on the type of performances aimed for (e.g. social, technical, operational, environmental or financial) need to be explicitly integrated in railway market organization models and by extension in railway innovation models.

The article contributes to the analysis of innovation in large technical systems (LTS) by introducing a framework of performance objectives for the governance of innovation in LTS.

Keywords: railways, innovation models, Europe, governance, performance.

Introduction

For the past 20 years the European Union has been working towards reviving the railway sector and creating a "Single European Railway Market". To do so, it has launched into an ambitious liberalization process. A number of important Directives (grouped in packages) have been introduced (e.g. regarding licensing, capacity allocation, access charges, etc.).

In parallel to the liberalization process and in order to make the "Single Market" a reality, the railway sector has embarked on a European-wide project of harmonizing the networks from a technical perspective[1]. This is made possible in part through the introduction of a commonly-agreed upon standard (or set of standards) for signalling known as European Railway Train Management System (ERTMS)[2]. Once fully deployed throughout the European railway network or at least through a number of corridors, it will allow trains to run across Europe without having to change drivers or locomotives[3].

Heralded as one of the major railway innovations in recent times, the tribulations of ERTMS in its development and deployment phases (De Tilière and Laperrouza, 2009) provide a good illustration of the necessity to integrate the technical dimension into the dominant economic approach to liberalization. As noted by Künneke & Finger (2009) notwithstanding unbundling, in a technical sense the railway system remains a network with a strong degree of complementarities and consequently fundamental coordination needs. While achieving an integrated market rests on ensuring technical interoperability across the network (e.g. cross-acceptance of rolling stock, unified signalling, etc.), the unbundling of the infrastructure management from the operations of trains risks to create new issues of interoperability between the newly created/separated entities.

The paper argues that the paradigm shift taking place in the railway sector – of which we only start to see the contour – calls for a broad governance framework. It further argues that innovation processes need to be re-considered in light of the new environment by specifically taking into consideration coordination needs as well as performance criteria. The first section summarizes some of the major changes that took place in the European railway landscape in the last two decades. The second section identifies a number of challenges that have emerged from the liberalization process by illustrating them through the case study of ERTMS. The third section briefly reviews the major innovation models in the railway sector and how they apply to ERTMS. The next section introduces multi-dimensional performance objectives and argues that these criteria should be explicitly discussed and included in the innovation models and processes. The final section argues that coordination of the European railway sector remains a

[1] While limited to high-speed lines (HSL) and a number of freight corridors one can imagine that the harmonization effort will in due time be also extended to conventional lines.

[2] ERTMS is composed of ETCS (a standard for in-cab train control) and GSM-R (an extension of the GSM mobile communications standard for railway operations).

[3] The technical harmonization is accompanied by an operational harmonization (e.g. recognition of driver licenses across Europe) since it has been recognized that the latter can pose as much a barrier to the creation of a single market as technical harmonization.

central issue in the framework of the current integration process. It suggests that new mechanisms are required to deal with multiple performance objectives and the multi-level and decentralized environment in which railway innovations now take place.

I. Major changes in the European railway landscape

For much of the 20th century European railways suffered from financial losses (usually covered via public subsidies), management inefficiency and an insufficient commercial outlook. During the past two decades, European Member States have progressively reformed their railway sectors with the goals of reducing state support, enhancing productivity and increasing the sovereignty of the market (Nash, 2008)[4]. In practice reforms concentrated on the introduction of competition into the rail transport market via separation of infrastructure from operations (at least in an accounting sense), on the progressive opening up of the market for new operators and on rules regarding the allocation of slots and the pricing of infrastructure use. To ensure non-discrimination between the incumbent companies and new entrants various regulatory models were introduced, many of them resting on the creation of independent regulatory agencies.

The reforms were initiated by Directive 91/440 – granting access to railway undertakings[5]. A White Paper published by the Commission in 2001 (European Commission, 2001) outlined its ambition to revitalize the sector through the introduction of competition – freight was to be fully liberalized by 2007 and passenger service by 2012 – and through the reform of institutions[6]. The idea was to increase both the capacity and the safety of the sector. A first package of Directives was adopted in 2001 with the objective to achieve market opening of rail transport and create a single European railway market. It was designed around 3 axes: splitting the infrastructure from the activity of railway transport[7], opening to competition the access to the network and achieving a regionalization of passengers regional railway transport. The European Commission then adopted in January 2002 a second package of measures to revitalize the railways by rapidly building an integrated European railway area. In March 2004 the Commission proposed a third railway package containing measures to move the European railways forward. Adopted in October 2007, it introduced open access rights for international rail passenger services including cabotage by 2010.

While the European Commission has taken the driving seat in reforming the sector, Member States still battle hard to retain control on their national networks. In many European countries

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[4] Nash identifies four additional objectives: 1) improve rail's market share in international traffic, 2) clearly differentiate the role of government, train operator and infrastructure manager, 3) put intermodal competition on a level playing field and 4) introduce direct "on-the-track" competition.

[5] Some countries preceded the Commission's effort. In 1988 Sweden, the first European country to reform its railway market, demanded complete separation of infrastructure from operations and the empowerment of regional governments for planning and funding of regional services. The UK followed in 1993 with the passing of the Railways Act which led to the franchising of all passenger operations to private operators.

[6] The Commission should adopt a Communication on the Future on Transport in June 2009.

[7] Three different models for separation have emerged in Europe: 1) complete separation, 2) holding company and 3) separation of key powers (Nash, 2008).

there are important delays in transposing EU Directives into domestic laws and even more delays in implementing the new legal frameworks – Member States differ in terms of how they have interpreted requirements set by the legislation. In fact, the majority of the countries only implemented the EU's minimum requirements[8].

Notwithstanding the delays in implementing EU Directives reforms have meant changes in the regulatory, market and organizational structures with far-reaching consequences for all the stakeholders. In some instances, the former vertically integrated state monopolies were unbundled and privatized (e.g. in the UK). In other instances, (e.g. in Germany) concentration has been on regional competitions. Some countries (e.g. Italy) have granted licences to new entrants to operate high-speed lines. Whereas privatization remains the exception, unbundling of the infrastructure manager from the operator is by-and-large on the way in most Member States[9]. France which has resisted reforms has now separated infrastructure from operations and allowed competition in the freight sector. On the ground, there are large variations in the extent to which railway markets are open to potential new entrants. Whereas the freight market is open to competition since January 2007 the passenger market remains to be open. While the different Member States are all taking divergent paths of liberalization, one can nonetheless note a number of significant changed that took place in the European railway landscape since the 90s (see Table 1).

Table 1: European rail era

	Previous era (till 1990)	**Transition era (1990-2005)**	**Current era (after 2005)**
Organizational structure	Vertically integrated	Voluntary unbundling	Mandatory unbundling[10]
Regulatory policy and legislation	National	National with supra-national transport policy and directives	National with EU Directives (railway packages)
Drivers	Public service	Public service, productivity and financial sustainability	Public service, productivity, financial sustainability, environmental concerns
Market structure	Monopoly	Monopolistic (infrastructure) and market-oriented (services)	Monopolistic (infrastructure) and market-oriented (services)
Market opening	Closed with limited international traffic	Ad hoc opening of domestic markets	Freight open Mandated opening of passenger market
Ownership	Public ownership[11]	Mostly state-owned	State-owned (infrastructure) Some private rail companies
Regulatory arrangements	None (Ministry)	None (Ministry)	Independent railway authority
Scale of network	Regional and national	National to international	Increasingly international

Source: Authors

[8] Countries are routinely sanctioned by the Commission for failing to transpose or implement new laws pertaining to railways.

[9] Sometimes only in an accounting sense (e.g. Switzerland or Germany).

[10] Under the mandatory unbundling, European countries have opted for different options, e.g. Total vertical integration Competitive access Vertical separation

[11] Governments generally became system owners during the first half of the twentieth century.

To create and support this new form of market organization, new regulatory regimes were set up (Coen, Héritier et al., 2002). During the first decade one could find a wide diversity in the type of regulatory bodies adopted by Member States. They could be classified in 3 broad groups (IBM, 2007): many European countries had a Ministry in charge or no regulatory body with decision-making powers. A handful of countries had adopted either a "railway authority" model (dealing primarily with licences, safety and other railway-specific administrative tasks) or a special regulatory authority (Austria, Germany, Italy, UK, Latvia and the Netherlands). Only 3 countries (Germany, Austria and the UK) had specially trained staff dealing exclusively with regulatory matters and with far-reaching powers to enable them to enforce their decisions. Some of the new Member States, in comparison with many old ones, had already set up better organized regulatory bodies. It is interesting to note that almost all countries that had made relatively good progress in terms of opening up their rail transport services markets had a special regulatory authority but most of the regulatory bodies had not yet been required to make decisions on discrimination cases. More recently there has been a shift towards setting up independent regulatory authorities. In France such an authority – Autorité de Régulation des Affaires Ferroviaires (ARAF) – has been created at the end of 2009.

In spite of the important market and regulatory changes carried out the integration of the European railway market is far from achieved. Part of the reason is that the European Union has been pushing two major but contradictory objectives at the same time: the liberalization of the national markets and the creation of an interoperable network. In fact the regulatory governance structure necessary to achieve these two objectives differs. In the first case, it requires regulation for economic and financial performance. In the second case, it requires regulation for technical and operational performance. In fact, as we will see with the case study of ERTMS, they are potentially conflicting. Achieving technical interoperability comes at a huge [immediate] cost to railway operators and infrastructure managers without really bringing major returns in the short-term. In other words, like in other network industries, the sequencing of reforms matters. Achieving technical harmonization of the European railway network matters would have probably eased the re-organization of markets and the introduction of competition[12].

II. Challenges that have emerged from the liberalization process and their illustration with ERTMS

While the initial aim to see railways play a central part in the European integration process has failed to materialize so far, a new wind seems to be blowing on the European railways (e.g., increase in traffic, favourable policies driven by environmental concerns, improvements in the opening of markets, etc.)[13]. But numerous challenges remain before railways can play a leading

[12] Within technical standardization it would have probably been more efficient to harmonize operational rules before technical rules.

[13] Some of the barriers to further integration lie in inadequate organizational structures to handle changes in task execution, inadequate mandates and lack of willingness of national regulators to implement and enforce administrative changes as well as lack of resources and willingness of rail undertakings and infrastructure managers to adjust to changed market structures.

role in EU integration, let alone before the creation of a single European railway market. Despite significant progress, a tension remains between Member States and the EU Commission when it comes to regulation and, more generally, governance of the railway sector. Recurrent delays of Member States in transposing and implementing European Directives pertaining to the rail sector attest to the reticence of countries to relinquish (regulatory) authority on their domestic operations[14,15]. It also shows the limits of the current institutional setting in which the EU drafts policies that remain at the "good will" of Member States.

In practice the multi-level of governance (regional, national and supra-national) has created a patchwork of stakeholders whose interests are seldom aligned. Moreover a limited number of strong national railway companies (e.g. DB and SNCF) seem to play a disproportionate role when it comes to defining (or not) technical choices/trajectories.

For the time the European railway sector remains fragmented on several levels:

- **Technical**; problems of interoperability remain due to the technical complexity of the sector as well as the size of the network; in order to move the process forward interoperability is only mandated on high-speed lines and along a number of (freight) corridors[16];
- **Financial**; despite a notable improvement in the economic situation of many railway operators, their financial standing is far from excellent; infrastructure manager are even in a worse situation since the charging mechanisms do not truly reflect costs – government subsidies make up for the losses;
- **Organizational**; the vertically integrated monopolies have been unbundled and are under competitive and performance pressure; railways are increasingly decentralized and run according to market rules; ownership too is being transformed from one/few actors to several actors; at times public ownership is replaced by private or public-private arrangements.;
- **Administrative/legal**; in virtue of the subsidiarity principle, national railway legislations are diverse both in terms of their design and implementation

[14] In the case of Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification, six issues with considerable leeway for interpretation can be identified, leading to a potential for 240 different policy combinations that have to be addressed one by one. Empirical findings suggest that problems in transposition processes occur in almost 66% of all national implementing measures: 47% of national implementing measures have been notified late to the European Commission, of which 70% recorded delays of more than six months, with a maximum delay of 4.8 years. The time length of missed deadlines varies significantly between Member States and between transport sub-sectors (Kaeding, 2008).

[15] This is not restricted to the railway sector. In the telecommunication sector, Member States are resisting the creation of a pan-European telecommunication regulator.

[16] Conventional rail and regional traffic will be addressed at a later stage.

In the electricity sector institutional fragmentation has led to several shifts with reliability consequences (De Bruijne, 2006)[17]. So far many countries have resorted mainly to a purely national approach to resolving these fragmentations. At the European level emphasis has been placed on the market to address these issues.

The case of the European Rail Traffic Management System (ERTMS)

One central characteristic of any networked systems is the need for technical interdependence or compatibility. This means, among others, that increasing the competitiveness within the European railway sector cannot rely solely on an economic approach. For instance technical measures need to be taken to guarantee an interoperable railway system across Europe[18].

Establishing a European-wide technically interoperable railway system rests in part on a common signalling system. The sector has spent the last 20 years developing a pan-European control and command system (ERTMS) that will, in time, enable convoys to run from Sweden to Sicily without changing the train set. The system-wide innovation serves three purposes: improved interoperability of the trans-European rail network, the creation of a single market for procurement and the optimization of rail operations on a European-wide scale. While the ultimate goal of ERTMS is to ensure cross-border interoperability, its "side-benefits" are numerous: better and safer working conditions for train drivers, savings for railway undertakings in the long-term – different signalling systems for various networks are no longer required in the cab – and increasing the capacity utilization of the existing rail network – up to 20% through higher speeds and reduced headways. As such, ERTMS plays a critical role in Europe's railway market liberalization and integration agenda.

The study of ERTMS development and deployment across two decades illustrates the far-reaching changes brought by the European liberalization process. Three phases with a different emphasis characterize the project. Starting very much from an engineering perspective it shifted to politics – with the support of EU technocrats. The current phase sees the predominance of financiers (see table 2).

The case of ERTMS offers a good example of the necessity to deal with multiple aspects in the governance of the European railway system address the fragmentation issues – or else to run the risk of failing to achieve competition and integration[19]. The funding mechanisms for ERTMS remain divided between national countries and the EU; in addition, unbundling has modified investment cycles as well as the distribution of the burden. From an organizational perspective unbundling has created a "catch 22" situation where infrastructure managers and railway undertakings have an incentive to invest in ERTMS only if the other has done so. But the

[17] Shifts from long-term planning to real-time management, from design to improvisation, from anticipation to resilience, from detailed analysis to operator experience and from risk-control to reliability-seeking behavior.

[18] Mulley and Nelson (1999) decompose interoperability into technical, corporate, judicial and cultural dimensions.

[19] As noted the creation of an integrated and competitive railway market rests to a large extent on achieving network interoperability. ERTMS plays a central part in achieving such interoperability.

deployment of ERTMS is taking place in a different legislative framework than from the past, one that requires better coordination[20]. At the same time there is a need for an overall system integration: one is looking at the railway system in different ways with 27 "closed" railways systems that need to be harmonized. As a result, one important issue to be tackled is identifying all the relevant stakeholders and their respective incentives[21]. Given the important changes in the railway sector, many of the actors involved do not know how to proceed in the new environment where so many strategic options are available.

Despite substantial efforts in standardization, there are still important cross-country variations in the implementation of interoperability requirements[22]. Pellegrin (2008) argues that the failure to achieve unified specifications and thus an interoperable European network is linked to the absence of an industrial project manager. Instead, each equipment manufacturer, in cooperation with its historical network, has developed a complete system of specifications. Furthermore, the European Commission, nominally in charge of the project has so far shown limited capability in managing the large number of European rail stakeholders.

Table 2: Phases of ERTMS project

	Studies and specifications 1989-1997	**Final specifications 1998-2004**	**Roll-out 2004-till 2020**
Technical level		Class P to Class 1 SRS	SRS 2.2.2 and 2.3.0 Work on 3.0.0
Financial level	National	National	National and EU subventions
Organizational level	Integrated railways	Integrated railways	Unbundled railways
Legal level	Directive 96/48/EC	Directive 2001/16/EC	Directive 2004/50/EC Transposition delays
Administrative level	No regulation (Ministry)	No regulation (Ministry)	Independent railway authority
Stakeholders	EEIG, ERRI, EUROSIG	UNISIG, CENELEC, AEIF	ERA and associations
Emphasis	**Engineering**	**Politics**	**Financial**

Source: Adapted from UIC and Winter (2007) and personal interviews.

III. Evolution of the railway innovation models

The development of ERTMS actually coincided with a fundamental shift in railway innovation processes. In a nutshell, until the beginning of the 1990s, each country followed its own path: operators attempted to maintain their network inaccessible to foreign operators and favored their preferred national supplier/manufacturer for a sustainable co-operation. National industrial policies were always in the background, buttressed by very tight relations between operators, institutions and governments (Dobbin, 1994).

[20] For instance, there has been a separate handling of the two ERTMS components (i.e. GSM-R and ETCS) – for now, there is no integration responsibility between ETCS and GSM-R.

[21] It is important to keep in mind that many institutional players are not only linked to ERTMS.

[22] One should obviously differentiate the standardization of a technical component of the railway system (in this case signalling) from its regulation. The case study of ERTMS nonetheless shows that both are linked.

The needs of operators were driven by paradigms shared by institutions, manufacturers and governments at the national level. The resulting convergence in the decision-making process was intended to increase success rates in the development of systemic innovations. The strong involvement of national operators with the support of governments allowed the development of such innovations once a manufacturer was selected for a research program. Therefore more risk-taking and future-oriented strategies were possible for R&D, backed by a philosophy encouraging more long-term and co-operative strategies (De Tilière and Laperrouza, 2009). This innovation model increased the chances of reaching a critical mass of adoption in the national market. Subsequently the national supplier could compete for export sales using technical expertise and market knowledge acquired in the home market. But this model – driven by the paradigm of national industrial policies and "national champions" – brought so many obstacles and market barriers that in the early 1990s it was no longer compatible with the emerging European goals of creating a single European railway market (de Tilière, 2005).

The Directive 91/440 introduced a fundamental change in the organization of the railway sector at the beginning of the 1990s. The reforms led to higher financial risks for R&D investments (for instance study contracts funded by operators were replaced by open tenders leading to increased uncertainty). Technical risks were higher in first contracts, as the operator had a lesser role in the validation process as done in the past with the "lead-users". The operator was not involved anymore as early in the innovation process. At the same time there were no more extended tests projects for validation before commercial operation.

The two innovation models described here, as well as the ERTMS innovation process, point out to the radical changes of the European railway framework. They also partially explain why more than a decade was necessary before the first commercial deployments. The changes resulted in a redefinition of the roles of each actor (operators, infrastructure owners, manufacturers and institutions).

While ERTMS brings increased performances for safety, capacity and allows interoperability – great achievements from the technological side – big challenges have emerged in the management of innovation processes as well as the institutional and organizational changes: only a suitable institutional framework has enabled the ERTMS innovation to become a standard in Europe. The creation of ERA was a cornerstone in the European policy and the adaptation of its institutions. But even more than defining a new standard, the key role of ERA is to manage its long-term sustainability. For this, a strong and neutral arbitration of interests in the multi-stakeholder environment is necessary, each actor having its own interest in terms of functions, timing etc.

If the institutional framework is sometime a prerequisite for the emergence of systemic innovations, additional leverage and means must be defined for the diffusion of standards. If things are clear when building new lines, the key issue for ERTMS remains the renewal of existing infrastructures to ensure interoperability. Railways don't always find a business case matching the planning of the European Commission – a problem for the deployment of

European corridors. New ways shall be developed to find better means to proceed for a better overall performance of the European rail networks[23].

Table 3: Innovation eras

National Pre-1990	International 1990-2010	Global Post-2010
Captive and operator-driven: operators attempted to maintain their network inaccessible to foreign operators and favored their preferred national supplier	**Competitive and supplier-driven**: operators not involved anymore as early in the innovation process and suppliers competing against each other	**Co-opetitive and stakeholder-driven:** operators involved again together with other stakeholders; policy-makers as "regulators" of performance objectives

Source: Authors

The last two decades have witnessed a shift of the definition of technical solutions on the manufacturer side, letting operators focusing on the definition of functional specifications. It also led to more challenges in the system integration in the case of systemic innovations, as well as a more opportunistic and risky types of markets. The new framework is aimed at avoiding expensive R&D programs (as done in the 1970s) with a higher selection rate of future standards, based on cost-effective solutions. However, it brings an increased complexity in the decision-making process[24].

Technological changes are happening faster than during the "national" era and are increasingly being dictated by user needs. Moreover the push for unbundling/functional separation may have not reached its final stage leaving the door open for other potential system-wide innovations.

Such an environment calls for renewed coordination of systemic innovations – probably leaning more towards co-opetition than competition. However, since the stakeholders are much more fragmented, there is also a need for aligning the performance objectives on projects-level innovations as well as for those concerning the entire European railway network.

ERTMS is the first important case of a systemic innovation in the new "liberalized" railway era. But one should not extrapolate too much from the ERTMS/signalling case. ERTMS represents a particular case in railway innovations as not all innovations in the sector exhibit such a systemic nature. Some technological niches will remain captive for still some time – something not too surprising since railway, like electricity are characterized by both strong path dependencies and high barriers for radical innovations (Markard and Truffer, 2006).

Some challenges of innovations in railway networks

[23] For instance, national bodies will be required to better include full consideration of cross-border impacts in their decisions.

[24] This is mainly due to the vertical and horizontal disintegration of the actors' organizations, in addition to the unbundling of operators and infrastructure owners.

A number of innovation challenges can be derived from the case study of ERTMS development and deployment (De Tilière and Laperrouza, 2009). First bringing new technologies in high performance and complex systems requires the mastering of product innovation risks and of system integration of subsystems. It also requires dealing with the conflicts between life-cycle of subsystems and components (5-10 years) and the overall system (25-30 years) and ensuring a business case for disruptive technologies (customer acceptance vs. proven technologies). Second, it requires to take into consideration the characteristics of rail market (e.g., big volumes to be done punctually for particular countries; limited number of customers and suppliers per country with high costs of certification & homologation). Third, it requires integrating the concept of networks and path dependency. Particular technological trajectories are often are to stray away from, something that is re-enforced by network size and effects.

IV. **Addressing the question of performance objectives**

One of the central characteristics of European railway sector's liberalization lies in its market-driven approach. As noted above, the governments' recurrent failure to run "profitable" railway operations couple with mounting budgetary pressures led to the introduction of competition in several segments (e.g. freight and passenger transport). To ensure fairness (e.g. non-discriminatory access), the unbundling of operations from infrastructure management was also mandated. This had led to a dominance of an "economic" approach to reforming the railway systems at the national level, focusing more often than exclusively on balancing the railway budget. Some countries (e.g. France) have vivid discussions on the question of public service and the necessity to maintain it – even when the lines are highly unprofitable. But few seem to be addressing the question of the overall performance of their railway network.

A number of countries also already explicitly apply multi-dimensional performance objectives on a *project-per-project* basis. For instance the Swiss Ministry of Transport has developed a method to evaluate new railway projects based on criteria including generic objectives such as environmental, financial and social considerations (see table 3).

Table 4: NIBA evaluation criteria

Economic	Social	Environmental
Maintain good ration between direct costs and utility	Ensure basic servicing	Reduce environmental pollution
Optimize indirect economics costs	Ensure acceptation, participation and coordination	Reduce atmospheric pollution
Reach self-financing	Encourage social solidarity	Manage resources

Source: Office fédéral des transports (2009)

The UK has probably the most sophisticated approach to rail performance. The Office of Rail Regulation (ORR) has devised multiple performance and market monitoring mechanisms. For instance the infrastructure manager undergoes regular and public performance reviews on criteria as diverse as customer satisfaction, operations (punctuality) or finance.

That said, the technical aspect of conceiving and running a railway network are generally left to engineers and often only remotely included in the system's overall governance. At the same time, engineers are too often left out of the creation of new institutions (e.g. liberalization of the railway market). This is not to say that engineers do not participate in technical discussions at the EU level once the institutions are created. For instance, the European Railway Agency (ERA) has numerous "technical" working groups[25].

A substantial body of literature on performance management has developed since the late 1970s. The first attempts at performance evaluation and review were associated with the failed attempts at large scale strategic planning in the 1970s (Boland and Fowler, 2000)[26].

Performance measures can be used for monitoring trends in performances or for comparative analysis of companies' performances on key performance indicators (KPIs). The measures can be used to evaluate the companies' performances and to learn about and improve corporate policies and optimize management processes. Through effective communication, performance measures can also be used as a marketing tool to enhance corporate reputation (Gelders, Galetzka et al., 2008).

Cole and Cooper (2005) argue that performance indicators (PIs) are fraught with problems. For instance, taking the case of railways they criticize the narrow scope of performance indicators (strongly centered on punctuality and reliability whilst focusing only slightly on one aspect of safety[27]). They argue that the use of PIs reflects a wider political agenda (the maintenance and support of capitalism). For them, the use of railway PIs is an example of "how there is an increasing tendency on the part of government to quantify what cannot be quantified or 'make the invisible visible'" (Cole and Cooper, 2005: 199). In the UK, the performance indicators used by government to render the railways accountable are narrow. In addition the question remains as to whether the information that these indicators transmit to the public gives a realistic impression of the quality of service provided to rail users. Di Francesco (1999) identifies various problems relating to performance measurement in the public sector (output specification, quality and effectiveness measurement, client identification) and suggests some possible ways of coping with them. Four main performance measurement criteria are identified: validity, reliability, functionality and legitimacy.

Building on the NIBA evaluation criteria as well as on previous work on performance in technical systems (Finger, Groenewegen et al., 2005; Laperrouza and Finger, 2009), we contend that, akin to the *project-per-project* approach[28], system-level innovation processes also need to explicitly take into consideration the various dimensions of performance – we propose a set of 5

[25] In fact representatives from the various constituencies (operators, infrastructure managers and equipment manufacturers) often have an engineering background.

[26] Boland and Fowler also point to the difference between public and private sector performance. The former has to account to several stakeholders while the latter has to respond solely, at least in theory, to its shareholders.

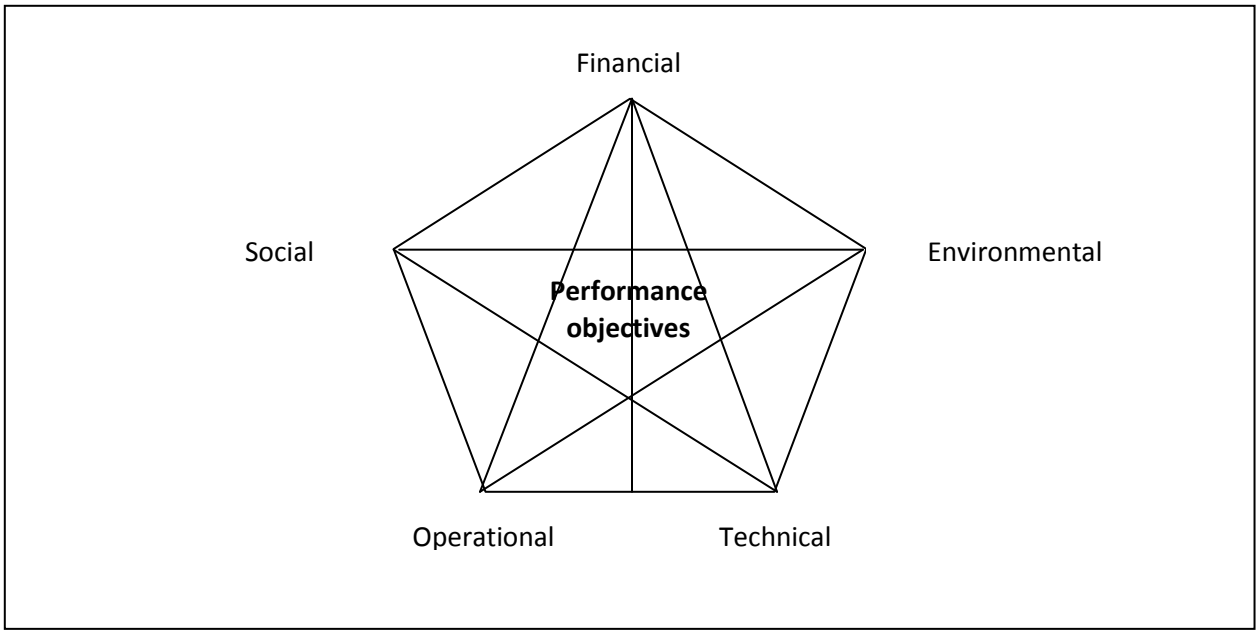
[27] For instance track maintenance or crime levels.

[28] We use the distinction between "projects" and "operational system" made by Geyer and Davies (2000).

performance objectives (see Figure 1 below) to inform the organization of railway markets and by extension railway innovation processes.

In many cases, there is normally more than one objective, and these objectives are often formulated in such a way that they are difficult to measure – not to mention making it impossible to aggregate them into an overall index (Bruzelius, 2010). It is also important to note that the various performance objectives are to some extent incompatible and often require an arbitrage between them.

Figure 1: Railway performance objectives



For instance, ensuring an optimal public service (e.g. providing transport to the whole population at an accessible cost) will most likely diminish the financial profitability of the railway undertakings. Similarly, improving the environmental performance of railways (e.g., by reducing noise pollution) may force train operators to reduce speed in certain areas and therefore reduce operational performance. One could imagine installing noise-reduction walls along the tracks but this solution would have an economic impact. In this latest example, it is also particularly interesting that the noise pollution is created by the contact of the train's wheel with the track. In a liberalized/unbundled environment, infrastructure management and train operations is more and more conducted by two different entities whose performance objectives may not be identical.

The arbitrage between the various performance objectives of the different stakeholders requires an appropriate/complex institutional setting, i.e. a governance mode which takes into account the liberalization of the sector. To make things even harder, one of the central transformation taking place is the transition from national governance to supra-national governance (Coen and Thatcher, 2008; Rodrigo, Allio et al., 2009). As a result, any discussion on

the performance of the railway system needs not only to be conducted between different domestic stakeholders but also at several levels (e.g. national and supra-national and even regional in some cases).

V. Applying governance mechanisms to railway innovation processes

Early on Puffert (1995) noted that 1) the new distributive functions in rail transport infrastructure planning and non-discriminatory track allocation control would require the creation of a new regulatory mechanism at the European level and that 2) the separation of infrastructure and operations would lead to important changes in the logic of international interest representation.

As noted, the management of railway systems was relatively homogeneous across Europe until the 1990s. The economic characteristics of the railways sector (e.g., theory of natural monopoly) meant that a national monopolistic operator was under price and service regulation to protect the general interest. In practice, demand was often to be met at any cost and for an accessible price. Limited competition was held at bay since "the preservation of the national character of the industry was considered the key factor governing the overall regulation".

Over time governments have increasingly become consumers rather than builders of large-scale systems but nonetheless retain a number of prerogatives like setting policy objectives such as efficiency, coherence, flexibility or fairness (Abbate, 1999)[29] . For historical reasons governance of the railway sector has so far been primarily addressed at the national level rather than at the European level. In fact, railway has notably lagged behind other network industries (e.g., electricity or telecommunication) . For instance the creation of domestic regulatory agencies has usually lagged behind other network industries since rail came rather late in the liberalization process (or had to face major opposition)[30]. When it comes to legislation at the EU level – the Commission disposed of only limited legal and institutional powers in order to overcome the resistance of the Member States[31]. This mostly comes from the fact that for most of its history, railways were conceived and managed almost exclusively at the national level. In addition, given the limited cross-border traffic, there was no real need to coordinate otherwise than through bilateral relations[32]. The study of ERTMS leads to a similar conclusion: while ERA is not a regulatory agency *per se*, it plays, together with the other railway stakeholders (industry associations and their members), a strong regulatory role but only to a certain point. It therefore finds itself in a weak position with a limited set of powers and strong oversight.

[29] Abbate identified a number of network characteristics which pose particular governance problems, including the interconnection of independent systems and geographic spread.

[30] Most formal governance structures and safeguards were exogenously drafted by political decision makers.

[31] The resistance to Brussel's intervention into domestic railway policies is diminishing but still strong.

[32] Such a bilateral approach is still used in cross-acceptance of rolling stock, although there are signs that coordination is done at the corridor-level and even at the multinational level – in part because of the work from ERA.

At the same time, the governance of the European railway networks is made ever more complex by the addition of a supra-national authority (EC) which passes Directives that need to be transposed and implemented into national legislation. The real difficulty lies in the fact that Member-States are often reluctant to give up control of their domestic railway sector. As noted by Steenhuisen & van Eeten (2008) "realizing multiple public values in a large scale technological system (such as railways) requires a myriad of trade-offs because realizing one value can directly affect, postpone or thwart the realization of other values". At the same time, it is important to recognize that the governance framework will need some flexibility in order to cater for the on-going transformation of the sector – for instance by adapting the governance framework to a given technology (and not the reverse). It is also important to keep in mind that incremental policies at the national level may be more effective than grand designs.

Including innovation processes in the governance framework

There is a vast literature on regulatory governance, including one that deals explicitly with network industries like railways (Coen and Windhoff-Héritier, 2005; Correa, 2006) or with multi-level settings like Europe (Majone, 1996; Doern and Johnson, 2006; Rodrigo, Allio et al., 2009)[33]. Finger, Groenewegen et al. (2005) argue that for ensuring satisfactory functioning of any infrastructure requires coherence between the technical and institutional governance while Merkert (2007) notes that it may be efficient to have different governance structures for different rail tasks as well as for different types of train operation and infrastructure provision. Most existing governance frameworks address questions of ownership, organizational form, methods of regulator or market design but they tend to leave out consideration regarding the technical aspect of railways[34].

Mayntz (2009: 15) argues that "liberalization has created industries with highly complex structures and intricate interdependencies between actors, processes, and system properties. In light of such complexity, regulation would have posed a big challenge even if it were not also beset by multiple and partly conflicting, goals. In this situation it may well be that governmental R&D policy receives new importance. The development of LTS has always been affected by governmental R&D policy aiming to stimulate technological innovation – not to aid liberalization, but to improve international competitiveness [...]. Where state control over LTS has diminished, R&D policy, i.e. indirect guidance through financial incentives, may become more important."

It has been argue elsewhere that liberalization has massively increased coordination needs. LTS have been turned into complex systems of spatially distributed, interdependent parts fulfilling different functions, owned and directed by market actors who compete, but also cooperate

[33] The heterogeneous technical nature of the current European railway network makes the comparison with other network industries/large-scale systems very hard/irrelevant. The aviation sector has a history of more than 50 years of international/global cooperation to standardize operations. In the telecommunication sector, which has a long history of standardization at the international level (e.g. via ITU), the hopes to create a pan-European regulator have been dashed.

[34] Bauer & Schneider (2008) make a distinction between the social and the technical subsystem and include 4 layers of design issues: embeddedness, institutional environment, governance and resource allocation.

with each other, and who have entered into a multiplicity of contractual relations (Mayntz, 2009: 18). Several authors have shown the impact of liberalization processes on innovation in LTS such as electricity or telecommunications (Godoe, 2000; Markard and Truffer, 2006). The growing complexity of the industrial structures has not seen a parallel evolution on the governance side (Peirone, 2007). Even at the government level, there has often been a failure to take into account the changing landscape. For instance, operations and financing of rail infrastructure are delinked – the former resting with the Ministry of Transport and the latter in the Ministry of Finance (Bruzelius, 2010).

To make things even harder different policy arenas follow distinct time cycles. In a recent analysis on innovation in transport ITF (2010) finds that "there is insufficient co-ordination of transport policy on the one hand, and transport innovation and promotion policy on the other. The long-term orientation of innovation policy following the innovation cycle is difficult to bring in line with short- and medium term-oriented transport policy aims and measures. Moreover, there is an insufficient level of awareness about the importance of innovation among both public and private transport stakeholders. There is poor synergy between transport policy and industrial policy – numerous stakeholders and competing priorities from different sectors of the economy make convergence on innovation initiatives difficult". A good place to start resolving those challenges could be the innovation scenarios of Kuhlman and Edler (2003), i.e. 1) concentration and integration of European innovation policies in transnational arenas, 2) decentralization and regionalization of innovation policy arenas and 3) centrally "mediated" mixture of competition and co-operation in integrated multi-level innovation policy arenas. Such a paradigm shift would require a dramatic departure from the Member States driven approach to organizing markets.

VI. **Conclusion**

The paper has argues that the Commission's objective to have a single railway market requires a paradigm shift as to how the overall European sector is organized. While a number of harmonization measures have been (or are on the way to be) achieved at the EU level (e.g. signalling) Member States retain a large discretion on how their railway networks are operated, financed and developed. The sector is thus in a "transition" phase where some prerogatives have been moved to the supra-national level while others remain at the domestic level.

The delay in deploying ERTMS as well as the problems linked to pursuing the development of the standard's next version attest to the necessity of having a global approach to the governance of the railway sector as well as to some of the innovations which are systemic by nature. For sure, systemic innovations (such as ERTMS) are more the exception than the rule. However, by showing the need to align the incentives of the major stakeholders, it highlights the importance to go beyond the simple rhetoric of markets.

The current European-wide governance deficit in the European railway sector is harmful for a number of reasons: it stymies innovation in the sector or at least greatly delays deployment of technologies. It also runs the risk of postponing the creation of a single European railway

market. The challenge will lie in finding a right balance between stimulating innovations in the sector (i.e. providing incentives for competing firms to invest) while avoiding to fall back in the era of captive innovation. Any governance framework put in place at the EU level will need to ensure that the European railway sector remains conducive to innovation and that the objective of a single European market for rail is achieved.

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