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Nicolas Crettenand

Ecole Polytechnique Fédérale de Lausanne
Marc Laperrouza

Ecole Polytechnique Fédérale de Lausanne

Matthias Finger

Ecole Polytechnique Fédérale de Lausanne

Christof Duthaler

Ecole Polytechnique Fédérale de Lausanne

Edited by

Matthias Finger

Management of Network Industries

Ecole Polytechnique Fédérale de Lausanne, Switzerland

Rolf Künneke

Economics of Infrastructures

Delft University of Technology, The Netherlands

Managed by

Marc Laperrouza

Management of Network Industries

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THIRD ANNUAL CONFERENCE ON
COMPETITION AND REGULATION IN NETWORK INDUSTRIES

19 NOVEMBER 2010

BRUSSELS, BELGIUM

Performance and Coherence in Network Industries

CRETTENAND Nicolas[1,2], LAPERROUZA Marc[1], FINGER Matthias[1], DUTHALER Christof[1]
Ecole Polytechnique Fédérale de Lausanne (EPFL)
[1]Chair, Management of Network Industries (MIR)
[2]Energy Center (CEN)
Station 5, 1015 Lausanne, Switzerland
Phone: +41 21 693 00 89
Fax: +41 21 693 00 00
nicolas.crettenand@epfl.ch

Abstract

Network industries, such as electricity, railways and air transport, are very complex technical, economic, and political systems in which the interplay of technology and institutions has a significant impact on performance. While the performance of the network industries has always been relevant in one way or another (e.g., affordability and reliability of the service), the definition of performance has changed with the process of liberalization and has become more and more focused on economic efficiency. This paper argues that the targeted performance objectives (e.g., technical, operational, social, economic and/or environmental) have to be defined beforehand; only then can technology and institutions be aligned so that a certain coherence between them leads to the targeted performance (based on the "coherence framework"). This paper aims to further define performance in the network industries as well as to further substantiate the coherence framework between institutions and technologies. The methodology is based on case studies in different network industries.

Keywords
performance, coherence, institutions, electricity, railways, air traffic

Introduction

Network industries such as electricity, railway, air transport, potable water and telecom provide essential services. They are very complex technical, economic and political systems, and have high asset specificity and few substitutes. Technical or institutional failures within the network have significant and large scale systemic consequences. Network industries exhibit interdependencies (Laperrouza, 2009) and support other technologies and the pace at which they are built determines the pace at which other technologies can be diffused (Saviotti, 2005: 17). The performance of network industries matters, mainly from a macroeconomic perspective, i.e. public welfare, which includes several dimensions such as economic (e.g. consumer welfare), social (e.g. social welfare), technical (e.g. accidents), operational (e.g. delays) and environmental (e.g. CO_2-emissions).

The network industries have undergone over the past 20 years significant reforms, i.e., de-and re-regulation within the liberalization process. These were mainly institutional changes. The aims of reforms differed between network industries. In certain cases, the objective was to increase consumer welfare by the introduction of competition. In other cases, like in railways, the aim was to reduce the losses incurred by the incumbent state-owned operator.

With the liberalization the considerations about performance have changed. Performance does not matter solely from a macroeconomic perspective, but with the appearance of multiple actors performance is a concern at the firm-level as well. Over the past two decades social and technical performance (e.g. accessibility and availability) have been trumped by economic performance.

Finger, Groenwegen and Künneke (2005) have postulated that the performance of the network industries is related to the degree of coherence between institutions and technology. Their claim stemmed from the observation that liberalization (as an institutional change) has introduced a certain incoherence between the new liberalized institutions on the one hand and the current state of the technology on the other hand. Therefore, performance – they claim – will be affected by liberalization. This has to be looked at from a sector-specific perspective, as in some sectors liberalization may well improve performance as a result of a better adequacy between technologies (which have evolved prior to liberalization, e.g., telecom) and the new institutions. In other sectors, however, performance will suffer, as the newly liberalized institutions are no longer in line with the technology (e.g., railways). Furthermore, the authors state that performance is not a unified concept, so that the coherence between technology and institutions affects differently the different types of performance (technical, operational, social, economic and environmental).

While this offers a convincing conceptual framework from which to analyze the performance of the liberalizing network industries, their theory remains weak on several accounts: first, performance in the network industries is not yet well defined and more conceptual work is needed here. Second, the concept of coherence (between technology and institutions) remains fuzzy: here also substantial work is needed to better conceptualize the concept of coherence. Finally, the links between such coherence and performance is not yet well established, which constitutes a third conceptual challenge.

The goal of this paper is to make a contribution to the conceptual framework of coherence between institutions and technologies in the network industries. In order to do that, we will proceed as follows:

- In a first section, we present and critically analyze the coherence framework. We mostly focus on the contributions by Finger, Groenewegen and Künneke (Finger, Groenewegen et al., 2005; Groenewegen, 2005; Künneke and Finger, 2007; Künneke, 2008; Künneke, Groenewegen et al., 2008), but also refer to other authors who have contributed to such theory building. In doing so, we identify and qualify the three main weaknesses of that framework.

- In a second section, we review the literature on performance in network industries showing that there is no clear definition of performance yet, and more importantly that the definition of performance depends on the level of analysis.

- In the third section, we present three cases – namely the liberalization in the electricity, the railways, and the air transport – from the perspective of the infrastructure manager using the broad conceptual framework. In particular, we highlight how performance is being looked at in these sectors. In section four, we analyze these cases so as to improve upon the existing conceptual framework. This section therefore contains the main results of our paper, namely in the form of an improved conceptual framework, focusing in particular on the first weaknesses identified in the framework (i.e., performance definition) and in the outline of future research requirements and perspectives.

- Finally, section five gives concluding remarks.

1. The coherence framework

Within the coherence framework, performance is a function of the coherence between institutions and technologies. The framework is based on the literature on the co-evolution between institutions and technology in network industries (Finger, Groenewegen et al., 2005; Groenewegen, 2005; Hodgson, 2006; Künneke, Groenewegen et al., 2008; Kunneke, 2008; Ménard, 2009). We start by reviewing a number of concepts used in the framework and in the literature. We begin with the broader concept, before narrowing down to coherence and performance.

North defines **institutions** as *"the rules of the game in a society or, more formally, the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic. Institutional change shapes the way societies evolve through time and hence is the key to understanding historical change."* (North, 1990: 3) Institutions therefore can be formal or informal, and are for example institutional arrangements (e.g., contracts, alliances), the formal institutional environment of socio-technical systems (e.g., laws and regulations) and the institutional environment (e.g., values, norms, traditions, and customs).

Saviotti (2005: 12) defines **technology** as *"the set of activities by means of which human beings modify their external environment."* These "activities" mostly refer to technical artifacts and do not include ideas. Within the case studies of this paper, the electricity, railways and air transport sectors represent the technologies.

Co-evolution is the reciprocal interactions between two populations, entities or systems. These interactions have a significant causal impact on each other and need to be strong and in localized proximity (Kallis, 2007). The literature of co-evolution between institutions and technologies describes the general process of changes within them and highlights the necessity to align these changes (Finger, Groenewegen et al., 2005; Künneke, Groenewegen et al., 2008; Kunneke, 2008). It does not provide a framework to measure and compare institutions and technologies nor to measure the impact of the changes. Neither does it explain how governments could facilitate such an alignment. The framework of coherence between institutions and technologies tries to overcome this problem in the case of network industries.

This **coherence framework** aims to link the degree of coherence between institutions and technologies and the performance of the network industry infrastructure. As developed by Künneke, Finger, Groenewegen and Menard, it contains a way to compare and match institutions to technologies (Finger, Groenewegen et al., 2005; Groenewegen, 2005; Künneke and Finger, 2007; Künneke, Groenewegen et al., 2008; Kunneke, 2008; Ménard, 2009). The framework is conditioned by the fact that it applies to network industries and not the individual products so often described in theories of co-evolution.

The **critical technical functions** are central to the functioning of network industries which are complex infrastructures. If these three functions are not properly assumed, then the functioning of the infrastructure system is diminished. These functions are always assumed by way of a combination between technology and institutions and can be described as follows: First, there is the function of interconnection, which deals with the physical linkage of different networks that perform similar of complementary tasks. Interconnecting networks is the prerequisite for operating them as a system or running a common market on them. Second, interoperability ensures that mutual interactions between network elements can take place. In an electricity network, this is achieved either by synchronizing the network elements to the same alternating current (AC) frequency (in Europe, 50 Hz), or by linking them through a direct current (DC) interconnector (first network function) and transform the electricity at both end of the interconnector. In the railway network, different historical track gauges are either harmonized or rolling-stock is fitted with flexible gauge axles. Third, system management pertains to the question of how the overall system is being managed, including capacity management dealing with the allocation of scare network capacity.

The critical technical functions exist because there are **network constraints** which they try to remedy. Duthaler and Finger (2010) define five constraints. The interconnection constraint is the ability to physically interconnect parts of the network. The interoperability constraint is the ability to interoperate between parts of the network. This may be limited, even if a physical interconnection is established. System management is affected by three constraints. The capacity constraint is given by the fact that any (physical) network has a limited transmission capacity. The controllability constraint deals with the limitation of the amount and direction of flows on a network and due to physical properties or other restrictions. The storability constraint is the ability of a network to store what it carries, which may be very limited such as in the case of electricity.

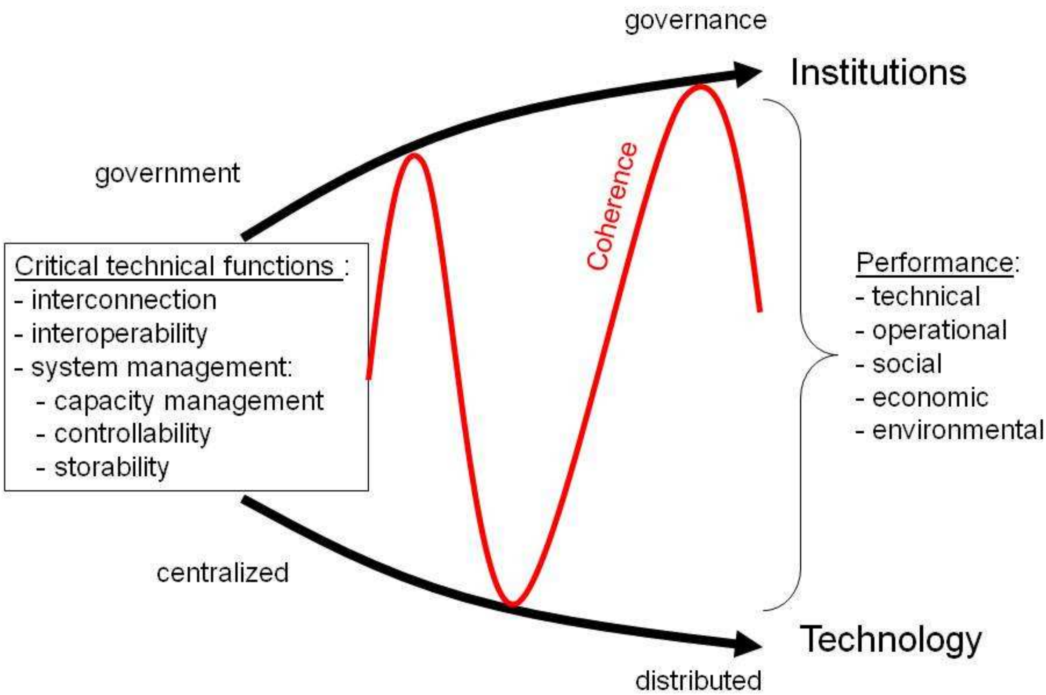
The **degree of coherence** between institutions and technologies was defined by the coherence in scope of control (i.e., geographical space), the coherence between coordination mechanisms (decentralized, centralized, peer-to-peer), the coherence in resolution (i.e., how detailed the geographical view is) and coherence between speed of adjustment (e.g., operational balancing, duration of contracts and lifetime of infrastructure). Using these four perspectives, the degree of coherence can be evaluated for each critical technical function and increases the better the institutions and technology are aligned. In Duthaler and Finger (2010) it is shown that the degree to which coherence is able to explain the performance of network industries depends on the sector-specific and time-dependent importance of network constraints. In other words, the contribution of coherence in explaining performance is sector-specific and time-dependent. Apart from coherence, other technological and institutional factors contribute to explaining performance.

More research is clearly required on this coherence aspect as it remains fuzzy. Especially the evaluation of the degree of coherence needs to be better elaborated. The relationships between the coherence and the network constraints and critical technical functions need to be better defined as well.

Performance in this framework is defined by way of three parameters: the economic performance, the public value and the integrity of the technical system (Finger, Groenewegen et al., 2005, Ch. 2.3). The economic performance concerns the static, dynamic and system efficiency. The public value is defined by the quality, accessibility, affordability and reliability of the service, as well as the environmental aspects. Performance criteria of the technical system integrity include resilience and robustness.

Figure 1 schematizes the framework and is an adaptation of the original figure of Finger, Groenewegen et al. (2005). Newly introduced was the dynamics observed in most network industries of institutions moving from government (nationally centralized institutions) to different modes of governance (e.g., local, supra-national). The technologies moved from centralized and vertically-integrated to more decentralized und unbundled technologies.

Figure 1: The framework of coherence between institutions and technologies



Source: Authors

The literature on the coherence framework highlights the need of alignment between institutions and technologies when institutional and/or technical changes are made to the infrastructure. Before recent development, it did not provide a roadmap of implementation.

In a recent paper (Finger, Laperrouza et al., 2010), the **dynamics** of the network industries are analyzed based on the coherence framework. Dynamics are introduced by the role of the actors influencing the institutions (i.e. rules of the game), the innovation and development of technologies and the definition of performance. The dynamics are also conditioned by different sets of configuration in which a network industry can operate (e.g. public monopoly, competition over network, competition of networks). That paper concludes on governing these dynamics within network industries. In summary, the technology needs to be supported by suitable institutions in order to reach the targeted performance. The coherence framework conceptualizes this finding, but remains very qualitative and general.

1.1 The weaknesses of the coherence framework

The first two weaknesses are related to the definitions of performance and coherence. As performance is the target to reach and institutions and technologies have to be aligned accordingly, it's the first weakness of the framework to deal with. It's the focus of this paper.

The coherence definition which allows evaluating the degree of coherence between institutions and technologies has to be further developed as described above. A possible avenue could be to introduce measurable indicators for the technologies and institutions for each of the four described types of coherence, and thus allowing a quantitative comparison of institutions and technologies.

Furthermore, the causality between coherence and performance has to be better developed and defined once the latter two are clearly defined. The research will show if more coherence always increases the performance or not, and if incoherence is required to trigger technological and/or institutional innovation.

Another issue to further investigate within the framework is the definition of the unit of analysis. The unit of analysis is currently defined by the technical system boundaries. Using the critical technical functions, the boundaries are determined for each function (e.g., in electricity the physical interconnection with synchronized AC (interoperability) and same voltage level for the system management). Interconnection and interoperability are key to define the system boundaries, more from an infrastructure perspective ("hardware"). System management is key from a management perspective ("software").

When all these weaknesses are dealt with, the matching of institutions and technologies to increase the coherence and therefore the performance within a network industry will become more concrete. Recommendations on how decision-makers can facilitate the alignment between institutions and technologies will become available based on the framework.

2. Performance in network industries

The original framework looked at institutions and technologies first, followed by conclusions on the coherence and performance. In this paper, we take the opposite approach by first looking at performance, followed by aligning institutions and technologies in a coherent way. Once the infrastructure is in place and operated, the performance should be measurable and therefore comparable with the initially targeted performance.

There is no consensus on performance of network industries (Karlsson, 2007: 2). This is partly due to unresolved problems in how to define and measure performance of network industries. According to Karlsson et al. (2007: 2) "*an analysis of sector efficiency that considers the hierarchical characteristic of many systems, specifically the efficiency effects that a subsystem imposes overall, has not been adequately addressed.*" Each network industry has its specific technical features which need to be taken into account, but there are similarities across the network industries as well. The literature review tries to give an overview of the current performance definition and of some indicators.

2.1 Literature review on performance in network industries

In a broader sense, performance can be defined as the "*accomplishment of a given task measured against preset standards of accuracy, completeness, cost, and speed.*"[1]

[1] http://www.businessdictionary.com/definition/performance.html (Nov 2009)

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)[2].

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[3]). 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 as pointed out by (Cole and Cooper, 2005), 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.

In their broad literature review of performance measurements Micheli and Kennerley (2005) point to the differences between private and public sector (for instance in the public sector PIs are always subject to political and social choices). Policy makers and managers of rail organizations have different interests and require different information. Managers are typically interested in performance at an operational level, seeking to improve the technical efficiency of their operation(s). Policy makers are primarily interested in performance at an aggregate level, seeking to improve the performance of the industry as a whole (Productivity Commission, 1999).

2 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.

3 For instance track maintenance or crime levels.

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.

The question of measuring the performance of firms active in network industries goes beyond the traditional notion of firm performance. Indeed, many of these firms are part of a wider environment than most firms. The interconnectedness of network industries implies that their performance not only very often cascades on other sectors. At the same time, their performance also often depends directly on actors within and outside the sector. The high-level of interconnectedness means that the definition and, more importantly, the measurement of performance in network industries poses a number of problems such as being able to determine where the locus of responsibility lies. In the case of railways, the lack of infrastructure maintenance can, for instance, reduce the speed at which a passenger or freight train can circulate over the tracks.

The existing literature is primarily about economic/social performance and secondarily about technical/operational performance. Several authors develop different approaches to performance and establish performance indicators, which need to be further developed (Lawrence, Houghton et al., 1997; Commission for the European Communities, 2004; Estache and Goicoechea, 2005; Jamasb, Mota et al., 2005; Martin, Roma et al., 2005). Several authors deal with regulatory performance, governance and performance, and ownership and performance (Boardman and Vining, 1989; Stern and Holder, 1999; Knieps, 2004; Spiller and Tommasi, 2005; Andres, Guasch et al., 2008; Gasmi, Noumba Um et al., 2009). These papers look at the regulation, industry structure, governance, ownership and then analyze the performance. This paper takes the issue the other way round - first set the performance objective, then put in place the technology and institutions (e.g. regulation, governance, technological choices), and gives a more important focus on technologies

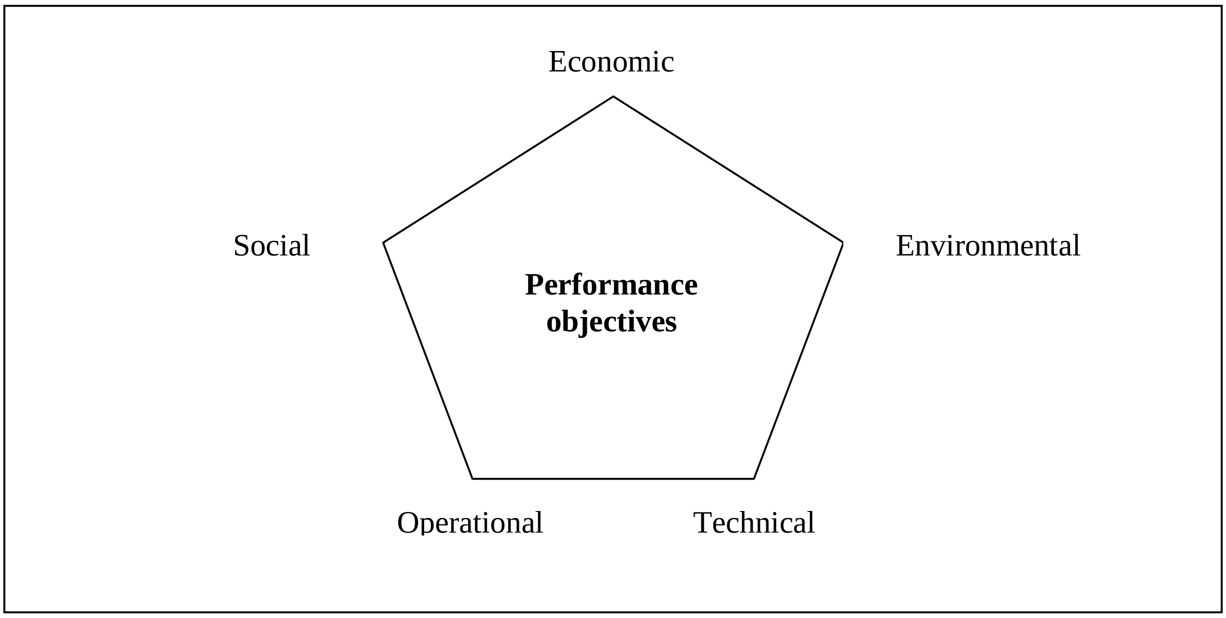
As intermediary conclusion it can be said that there are an infinite number of ways to look at performance and that there is no accepted definition. Based on earlier work on the coherence framework, five performance categories will be further developed in this paper using the case studies. They are introduced in the next section and the results are in Section 4.

2.2 Performance categories

The focus of many studies on a single category of performance fails to achieve comparative evaluation along several dimensions (Ménard and Ghertman, 2009: 170). Because the above mentioned institutional changes involve economic, social and environmental dimension, and because it is possible that there are trade-offs between these different dimension, studies need to use multiple categories.

Based on Finger et al. (2005), five performance categories are defined as represented in the following figure. The initial economic and technical performances are kept, the public value is divided in social and environmental performance, and the operational dimension is added. The categories have to be so large that they can be declined in every sector. Ultimately, the choice and weight of each category is a choice done by the stakeholders, in particular by the political actors.

Figure 2: Performance categories



Source: Authors

Examples of indicators per category are:

- **Economic**: price evolution in the sector, subsidies (e.g. subsidies per pass-km in railways), and production costs (e.g. costs per kWh in electricity)
- **Social**: consumer satisfaction, accessibility, affordability, quality of service
- **Operational**: reliability, use of the network (e.g. average load factor in railways), congestion
- **Technical**: availability, losses (e.g. kWh per km in electricity), delivered service per capita (e.g. kWh per capita in electricity)
- **Environmental**: GHG emissions per kWh in electricity and pass-km in railways

In this paper, performance indicators are allocated to the three critical technical functions (one indicator can be linked to several functions) within the five performance categories. This shall contribute to further refine the performance definition within the coherence framework and in a broader sense for network industries in general.

Finally, the way performance is defined also depends if one has a sector perspective or a more narrow perspective such as the one of the infrastructure manager. The unit/level of analysis has significant implications particularly in network industries where downstream activities are, by definition, dependent on upstream activities.

3. Case studies

The infrastructure manager perspective was chosen because of the similarities across the studied sectors which allow a common analysis. For one, the infrastructure manager shares the characteristics of natural monopoly. It ensures that only one firm provides the service. But additional research especially on the operators using the infrastructure (e.g. rolling stock operator) will be required to further refine the performance definition and its measurement in network industries, and the interaction between infrastructure managers and operators.

3.1 Railways

In the crudest way, a railway company can be considered as an aggregate production unit that operates in a given network and transforms labor, capital and energy inputs into units of transport services such as passenger-kilometers of public transport and ton-kilometers of freight (Farsi, Filippini et al., 2005: 72). For a large part of the 20th century the production of railway transport services tended to be integrated in a single entity[4]. The production of these services can nonetheless be divided into 3 elements:

- Infrastructure managers: the entity in charge of the physical railway network; in the vast majority, IMs are also in charge of the signalling systems and of the interface infrastructure (i.e. train stations). Given the economies of scale, IMs are usually granted monopolies.

- Railway undertakings: they are usually divided into firms transporting passengers and goods. In a number of countries, a single firm used to provide both services. With liberalization, competition has been introduced in both services. For instance, in Europe freight is open to competition. In passenger transport, competition on-the-tracks remains limited at the national level while competition-for-the-tracks is more prevalent at the regional and local levels.

- Slot/capacity allocators: the necessity of a slot/capacity allocator has emerged with the liberalization process. Its role is by-and-large is to ensure fair access to the network. Non-discriminatory access is particularly important since the unbundling of infrastructure from operations is in many cases still at the beginning creating an important asymmetry in the market.

Liberalization of railways and in particular of infrastructure

In most countries the infrastructure per se has not been liberalized. The liberalization effort has rather been focused on unbundling infrastructure management from train operations. There are a few countries in Europe where railway infrastructure is not fully in the hands of a single entity.

[4] In many countries the initial development of railways consisted in separated networks which at one point were grouped together (usually by nationalization) to form the integrated railway networks we are familiar with today. In fact, "as early as the mid-1830s it was generally agreed that the management of tracks and trains should be integrated. This did not rule out the subcontracting of train operations to independent companies, provided that these companies followed appropriate regulations, and worked to a centrally determined timetable, as on the railway system of today" (Casson, 2009: 251).

For instance, in Germany some minor players (dubbed *NE-Bahnen*) still own their old infrastructure and have often expanded their operations onto the network of Deutsche Bahn (Lalive and Schmutzler, 2008: 447). In Switzerland, Berne-Lötschberg-Simplon (BLS) operates more than 520KM of tracks (of which it owns 436KM)[5]. Management of infrastructure is limited to the network it "owns" in full[6]. In exchange for BLS operating the S-Bahn (suburban railway services) in Bern, CFF runs all the long-distance trains on the BLS network[7]. As to train operations, the system can be divided in two sectors: 1) international and inter-regional transports (operated by CFF) and 2) regional and local transport services operated by close to 50 regional railway companies. The latter operate under a regional monopoly license with the obligation to provide regular services at given tariffs (Farsi, Filippini et al., 2005).

Performance in railway infrastructure

Infrastructure performance systems are almost as diverse as the ways of organizing railway systems. That said some common railway performance indicators are found across Europe, e.g. the percentage of planned train-kilometers delivered per month, the percentage of services no more than 5 minutes late, the passenger-minutes late, the percentage of train cancellations, the train-minutes late (Hastings, 2010: 319-320).

In Switzerland a performance agreement negotiated between CFF and the Swiss Confederation defines the requirements and is updated every four years. At the same time the compensation rates per train and track kilometer are defined. A number of performance-related measures are expressed in the document that settles the mandate between the Confederation and CFF[8]. The mandate is worded in broad strategic orientations. Each business unit (e.g., infrastructure management, freight and passenger transport) is set goals related to transport policy, performance and finance. These are supplemented by social and environmental targets to be fulfilled by the company as a whole.

5 A convention between CFF and BLS calls for increased cooperation between the two companies – the former should acquire 34% of BLS AG's capital. BLS AG is owned by Canton of Berne (55.75%), Swiss Confederation (21.7%), legal entities and private individuals (14.4 %) and other cantons, municipalities (8.15 %).

6 Since January 2009, the Swiss Confederation is the majority shareholder of BLS Infrastructure (50.05%), followed by BLS AG (33.4%), Canton of Berne (16.5%) and CFF (0.05%).

7 This includes the following lines: Brig-Basel, Interlaken-Basel, Interlaken-Zurich.

8 Convention sur les prestations entre la Confédération suisse et la société anonyme Chemins de fer fédéraux (CFF), applicable aux années 2007 à 2010 (Feuille Fédérale, 2006).

In the case of passenger traffic, CFF is expected to absorb a majority of the traffic growth in the "grandes lignes" segment, to reach the agreed upon level of punctuality and to guarantee connections. At the same time, CFF is asked to increase its productivity in different domains (infrastructure, passenger traffic) by 3% every year. Some of the objectives are also financial: balanced cash flow over a five-year period, positive results in certain segments (e.g. "grandes lignes" and freight), neutral in others (e.g. infrastructure). Little is actually mentioned regarding the environment. The mandate asks that, "within the possibilities offered by the management of the firm, the strategy must follow ethical and sustainable principles"[9]. The infrastructure is not considered as an end in itself but must adjust optimally to the traffic on its network. The Confederation sets a number of strategic objectives: guarantee a high level of security, ensure network capacity[10] (optimal dimensioning and availability of the network), optimal usage of available capacities, improvement of interoperability, reduction of exploitation and maintenance costs (see table 2). The objectives given to the infrastructure manager vary little over time although emphasis seems to shift from time to time. For instance, one can expect that once it has been achieved interoperability will become a secondary goal while the environmental aspect (both noise and CO_2 emission reductions) may become increasingly important in the future.

Table 1: Objectives for rail infrastructure 2011-2012

Objectives	**Details**
Security	Reduce probability of occurrence and potential of high known risks
Network management	Optimal dimension and high availability of network
Capacity allocation	Guarantee independent attribution of capacity
Interoperability	Migration towards ETCS and GSM-R[11]
Productivity	Incentives for higher efficiency and purchasing synergies

Source: Authors, adapted from (Swiss Confederation, 2010)

The performance agreement between the Confederation and CFF serves as a management instrument in the traffic and infrastructure sectors, in which the strategic directives, objectives and offer of services to be followed, achieved and provided are set down for four years. The performance agreement includes an appropriation for payment, an instrument to govern

[9] Objectifs stratégiques assignés aux CFF par le Conseil fédéral de 2007 à 2010.

[10] Network capacity includes a stable schedule and maintaining delays in spite of an increase of the utilization rate.

[11] European Train Control System (ETCS) and GSM-R (a mobile telecommunication standard adapted for the railway sector) are two components of the new European railway signaling system.

expenditure in which the funds available for achievement of the required performance are stipulated.

The infrastructure manager has also defined a number of strategic objectives "for himself" (see table 3). In 2004 these were to "achieve operational excellence in the areas of punctuality, safety, availability and productivity even as financial resources become increasingly scarce"[12]. In 2008, the strategic objective for infrastructure became more precise:

- to maintain an efficient and cost-effective network
- to promote interoperability as well as the technical development and innovation of the standard gauge network
- to make more efficient use of the subsidies received, thus facilitating a reduction in such subsidies or a lowering of train-path charges
- to seek the support of train-path users for train-path planning; to operate a non-discriminatory train-path allocation system. As both co-owner and customer of Trassen Schweiz AG (Swiss Train Paths Ltd), to make optimum use of the capacities available
- to achieve a reasonable annual increase in productivity

Table 2: Strategic performance objectives and measures from infrastructure manager (internal)

Security	Collisions, derailments, # dangerous crossings, personal accidents
Performance	Network availability, infrastructure delays, delays safety equipment
Network use	Route-kilometer sales, route revenues
Productivity	Operations, maintenance, renewal

Source: Personal communication

Performance in Europe

In Europe the notion of performance is explicitly dealt with by Article 11 of Directive 2001/14/CE. It stipulates that "*a Performance Regime should be implemented throughout the*

[12] Source: various annual reports from CFF.

network within each Member State". Whereas the EU directive applies to the traffic *within a network*, it was considered opportune to develop a performance regime for international trains *between networks* so that the international trains wouldn't be subject to several national performance regimes.

In fact, Article 11 of Directive 2001/14/EC states that "Infrastructure charging schemes shall through a performance scheme encourage railway undertakings and the infrastructure manager to minimize disruption and improve the performance of the railway network." The Performance scheme is therefore a definite part of the infrastructure charging scheme.

A broader initiative is taking place at the European level to deal with performance regimes. Launched by the UIC Infrastructure Forum, the European Performance Regime (EPR) aims at putting in place a system which monitors the performance of the European railway service and which provides penalization to bad performances[13]. One of the strategic issues of the EPR is to build a common system for all European railways that avoids the fragmentation of different domestic system with more costs for the infrastructure managers (IMs) and the railway undertakings (RUs)[14]. Performance indicators include the number of train paths, speed of train paths and punctuality of freight services[15].

Performance in selected countries

In the Netherlands a number of performance schemes have been devised, including the availability of the infrastructure, disruptions to train traffic, timely order acceptance, quality of railway yards, ordering /cancellations, delay experienced/caused by railway undertakings and quiet wagon kilometers (ProRail, 2010). Italy has devised a performance quality incentive plan

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[13] In 2008 an EPR MoU on the EPR development was signed by many UIC and RNE Members and in March 2009 UIC called for volunteering Companies along the Europtirails corridors to start the preparations for the EPR Pilot Application.

[14] The common features of the proposed models: corridor-based approach , applied on the whole train path, monitoring made per train, based on delays, including secondary delays, providing an incentive to recover delays, foresees financial penalties, limits penalties to a warning function. In the Rotterdam-Genoa corridor the monitoring of traffic and performance is already conducted by IMs.

[15] Ministries of Transport are nonetheless asked to cooperate on the development of EPR including corridor aspects on the basis of punctuality measurements and broader shared analysis of causes of delay.

(called Performance Regime) based on delays recorded at the end of the journey by the trains running on the national rail network (RFI, 2009)[16].

By far the most advanced and transparent infrastructure performance system is the one in the UK – something that reflects the "advanced" state of liberalization of the British railway sector. The regulator publishes on a yearly basis a report on the performance of the infrastructure manager (Network Rail). These indicators are then grouped into a general performance indicator including safety, performance (train delays, public performance measures), asset stewardship and value (cost efficiency measure)[17].

Finally, a number of infrastructure performance regimes have been devised in the framework of the public-private partnerships (PPP) for high-speed lines in Europe (e.g. HSL Zuid).

Table 3 Network rail performance criteria

Indicator	**Criteria**
Network availability	– Possession disruption index – Freight disruption index
Train performance	– Public performance measure (total, long-distance, regional) – Cancellations and significant lateness (total, long-distance, regional) – Delay minutes (passenger, freight)
Infrastructure	– Number of asset failures
Customer satisfaction	
Finance	– Network Rail (IM) efficiency index – Expenditure (operations, maintenance, renewals, enhancements)

Source: Office of Railway Regulation (ORR)

3.2 Electricity

Liberalization in the electricity sector

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[16] The IM or RU are accountable for the delays recorded by any train, even trains belonging to a different RU, for reasons within their control, and penalties shall be applied calculated in accordance with Schedule E to this section. As regards the calculation of the penalties, they consist of € 2.00 per minute of delay and are to be adjusted on an annual basis according to the same procedures utilized for updating the access charge. The penalty payable for each delayed train by the IM or, through the IM, by another RU, shall not exceed 20% of the access charge due for the train itself, not including the traction electricity charge. At the end of each financial year, the IM calculates the penalties due/payable to the RU itself or the IM and enters it for no more than 1.5% of the value of the overall charge recorded to each RU.

[17] These indicators are also used for the remuneration of Executive Directors.

Before liberalization, the electricity sector was typically managed by vertically integrated utilities (VIU). VIUs operated electricity generation, transmission and distribution as a geographically confined monopoly (e.g. for a city, a region or a country). As a prerequisite for liberalization and electricity markets, VIUs had to be unbundled: While the generation and distribution part were opened to competition, the transmission part was seen as a natural monopoly and hence had to be regulated. Independent Transmission System Operators (TSOs) were created to operate the transmission system in a non-discriminatory way. TSOs typically own and operate the transmission system above a certain voltage level (e.g. 220 kV).

Thus, there are the following elements in the liberalized electricity sector:

- Generation: Generators, both central and decentral units as well as renewable and non-renewable, that produce electricity.

- Transmission: The Transmission System Operator (TSO) runs the transmission system, including the connection of generators, large consumers and underlying distribution networks to the transmission network.

- Distribution: Distribution System Operators (DSOs) run the distribution system at lower voltage levels that delivers electricity to the end consumers.

- Suppliers: Different from generators and DSOs, supplying companies may contract with consumers to deliver electricity, regardless of their point of connection.

In the following, we look at the TSO as the infrastructure manager, his critical functions and his performance.

Critical technical functions and the role of the infrastructure manager

First, there is interconnection. The interconnected system encompasses all parts of the system that are physically connected through transmission lines, cables or transformers. There is a horizontal interconnection that links geographic areas (neighborhoods, cities, countries, continents) and a vertical interconnection that links different voltage levels (through voltage transformation), from the highest-voltage transmission network (220 kV and above) to the low-voltage residential distribution network (e.g. 230 V). The degree of interconnection is determined by the amount of interconnection capacity between parts of the network. In the case of the European electricity system, the interconnected system ranges from the Nordic countries to Africa and from the Iberian Peninsula to Russia, Turkey and beyond.

The infrastructure manager(s) are responsible for maintenance and extension of (investment in) the interconnected network.

Second, there is interoperation. Interoperation between parts of an electricity system means that electricity can be exchanged between these parts of the system. Interoperation requires either a connection by a direct-current (DC) transmission line or cable (examples being UK-France, Norway-Netherlands, Italy-Greece) or a synchronized alternating-current (AC) connection, i.e. the network parts have to use a common frequency (such as 50 Hz) that has to be synchronized (that is, it has the same timing of the frequency oscillation). In the case of the European electricity system, the interoperated system ranges from the Nordic countries and UK till Northern Africa and from the Iberian Peninsula till Eastern Europe (Poland, Western Ukraine, Romania, Bulgaria, Greece and Turkey since September 2010.

The infrastructure manager(s) are responsible for a continuous interoperability by ensuring a proper AC synchronization or AC-DC conversion.

Third, there is system management: The critical technical function of system management further limits the scope of the electricity system, both horizontally and vertically: Horizontally, the need to maintain a synchronized frequency in an AC network yields a strong interdependence of all parts of this network, leading to tight system management. Network parts linked by a DC line or cable can and usually do also share system management functions, though to a lesser degree, leading to a loose system management. In the European case, (interdependent) system management regions are formed by the Nordic countries, the UK, and continental Europe (including parts of Northern Africa and Turkey). In vertical terms, the system management in an electricity system is divided by the voltage levels. The system management on the highest voltage levels (the transmission network, starting from 220kV, sometimes less) is typically done by an entity called transmission system operator (TSO), while the system management on lower voltage levels (distribution network) is done by more local distribution system operators (DSOs).

In the European case and any other case of large geographic extension, the transmission network is the most relevant with regards to system management.

The infrastructure manager(s) are responsible for system management by maintaining frequency and voltage parameters within a certain range and by running a proper congestion management.

Performance criteria from an infrastructure manager perspective

There are several performance criteria that apply to the electricity sector and its infrastructure manager(s). For instance, the British electricity system operator, National Grid UK, defines its performance indicators based on the following criteria (Nationalgrid, 2010): Health and safety (injuries to employees and to the public as a direct result of TSO operation), shareholder value, reliability (electricity delivered as a proportion of electricity demanded), customer satisfaction, environment (greenhouse gas emissions, energy use, waste), employees (headcount, share of females and ethnic minorities, breaches of code of conduct), and society (community investments). Clearly, there are performance indicators relating both to the infrastructure management and to the infrastructure manager itself.

Based on the five performance categories introduced above, one can define performance in the following, generic way: Technical performance as the age and reliability of transmission assets (lines, transformers etc.), operational performance as system availability, system control quality (frequency, voltage), switching times and (n-1) system security, social performance as the degree of uninterrupted availability for end consumers, economic performance as congestion cost, redispatch cost, ancillary services cost, system operation cost, network cost (assets and maintenance), system losses and network investments, and environmental performance as the degree of integration of renewable energies and greenhouse gas emissions.

The extent to which these performance criteria are internal or external (i.e. externally communicated by the infrastructure manager, e.g. to a regulator), mainly depends on national legislation and regulation. Countries that apply an incentive regulation typically have a high degree of external performance indicators. Different from other sectors (such as air traffic), there is not yet a common set of performance indicators on the European level.

While performance indicators are similar for different TSOs, they do depend on the geographical scope taken into account. Some performance criteria apply at a regional or European level and there are inter-dependencies between the performance at the European level and the performance at the local/national levels. For instance, a reduction in congestion cost at the European level may require network investments at the national level, and therefore higher network costs (economic performance) at the national level.

3.3 Air transport

The air transport sector is a typical network industry in that it is characterized both by technology and institutions. Furthermore, both technology and institutions co-evolve so as to make the air transport sector particularly dynamic. The particular characteristic of the air transport sector as compared to the other network industries lies in the fact that it has never been vertically integrated. The sector is thus composed of three separate elements:

- Airlines: historically, airlines were national flag carriers, generally owned by the state (national government). In principle, every country had one national publicly owned flag carrier, which had a monopoly. The major exception here is the United States which never had a flag carrier. Since the 1980s (globalization), many of these flag carriers were privatized but nevertheless often enjoyed a privileged treatment vis-à-vis foreign competitors or new entrants.

- Air traffic control: air traffic control is of military origin as it its original purpose is to control and, with the help of the army, defend national air space. Over time, civil aviation activities became more important than military activities, leading to separate civil and military air traffic control, generally working in parallel. Still today, a substantial portion of national airspace is reserved for military purposes (up to 40% of the airspace). Over time Air traffic control has been autonomized from the public administration and transformed in public autonomous entities, however without being privatized. With the exception of Europe, air traffic control is still a national public and monopolistic endeavor.

- Airports: airports are local public monopolies, generally not competing against one another. They are owned by the local authorities and rarely by the national authorities. In some cases, one or several airports can be of national importance and as such owned by the national governments so as to support their national flag carriers. Two significant changes have occurred in matters of airports since the 1980s, namely (1) the fact that they are increasingly managed by way of public private partnerships (generally, the local authority remains the owner) and (2) the fact that smaller airports (often military airports) have been transformed to receive passenger traffic, parallel to the emergence of low cost airlines (see below 2).

All three elements, together, constitute the air transport system. From the above, we can see that there has been some organizational change (albeit quite limited) in the three elements (privatization, PPP, autonomization), but there has not been much technological change (bigger airplanes, better air traffic control). The challenge of the air transport sector is thus not so much in the different elements, than rather in its systemic nature of the sector, i.e., how can these three elements best be coordinated so as to perform optimally.

Liberalization of air transport

Air transport is generally considered to be a model of liberalization: it is said that markets have emerged and that they work because of the deregulation of the air transport sector. This is however not really true. To recall, liberalization in the air transport sector takes the form of so-called "freedoms", with the 9th freedom being the ultimate one. ""Freedoms" are the result not so much of markets but of negotiations between nation-states. As a matter of fact, even for airlines (let alone airports and air traffic control), liberalization is a very limited endeavor which can take three different forms:

- Countries negotiate among themselves to increase the amount of flights between themselves and to grant the rights to overfly their territory; they can also increase the respective freedoms (e.g., landing and taking passers in one country). Open sky agreements between countries are a further step in the liberalization in that not only pairs of flights are agreed to but baskets of flights.

- Countries, especially big countries, liberalize their air transport, something which first happened in the United States in the 1980s. This means that restrictions on the amount of flights, the fares, the conditions are eased so as to allow for more flights. Similar liberalizations have happened in China and in India.

- The third form is so far unique in that it concerns only the European Union with the idea to create a single European air transport market. This endeavor is similar to the previous one in what concerns the market for airlines but of course implies many countries and does not just happen within a country.

As a result of the above three forms of "liberalization", traffic volumes have increased exponentially since the 1980s especially, parallel to globalization: there are more airlines, more flights, and on certain routes more competition, leading to lower prices. This affects in particular Air traffic control and airports (i.e., infrastructure managers). A particular step in the increase of competition was made by the market entry of so-called low-cost airlines, and one can say that it is basically the low-cost airlines, and not so much the competition among the traditional network airlines, which has led to cheaper prices. Such market entry was made possible because of deregulation in the United States and the creation of a single air transport market in Europe. On the other hand, the network airlines have consolidated in so-called alliances – there are now only three global alliances, which has led to reduced competition among network airlines – and some of them have gone out of business, leading to concentration.

In short growing volumes will put pressure on the use of airspace and airport slots, both of which are limited. Pressure thus grows to improve Air traffic control and airport performance, in particular when it comes to capacity (airspace) and slot allocation (airports).

Performance in air transport

In terms of performance, one must mention the fact that there are no performance indicators for the air transport sector as a whole. Rather, performance is measured separately for airlines, airports and air traffic control. The only overall consideration and sometimes performance indicator pertains to safety, namely accident, serious incidents, and incidents).

As for air traffic control (ATC) or air traffic management (ATM), performance indicators pertain mainly to safety (incidents mainly), to ATC costs, as well as to CO_2 emissions. The following tables summarize the key performance indicators from the air traffic control and the airports perspectives.

Table 4: Performance indicators from the air transport perspective

Performance Indicators	**Definition**
Safety	The conformance of air transport to specified safety targets.
Delay	The time in excess of the optimum time that it takes a user to complete an operation.
Cost Effectiveness	The value for money that users receive from the supply of air traffic services.
Predictability	The ability of a user to predict variation and to build and maintain optimum flight schedules.
Access	The accessibility of airspace, ATC services and airport facilities under controllable conditions.
Flexibility	The ability of ATC to accommodate changing user needs in real time and without penalty.
Flight Efficiency	The ability of the ATC system to allow a user to adopt the preferred flight profile in terms of flight level and route.
Availability	The availability of critical ATC resources and of the ATC services provided to users.
Environment	The conformance of air transport to environmental regulations.
Equity	Equity of treatment of flights by all aircraft operators within and between specific classes of users.

Source: Authors

Table 5: Performance indicators from the airports' perspective

<table>
<tr><td rowspan="11">Operations</td><td rowspan="3">Traffic Activity</td><td>Total passengers</td></tr>
<tr><td>Total cargo</td></tr>
<tr><td>Total operations</td></tr>
<tr><td rowspan="4">Physical Facilities</td><td>Land area, runways, taxiways, apron</td></tr>
<tr><td>Terminals, concourses, gates</td></tr>
<tr><td>Ticket counter, security, baggage</td></tr>
<tr><td>Parking spaces</td></tr>
<tr><td rowspan="4">Airfield Aircraft, Terminal Passenger, and Landside Transportation</td><td>Runway, taxiway, airfield design, layout and aircraft processing efficiency</td></tr>
<tr><td>Airfield terminal area, aircraft processing efficiency</td></tr>
<tr><td>Terminal passenger flow and processing efficiency</td></tr>
<tr><td>Terminal curb and landside processing</td></tr>
</table>

		efficiency
Airline Fees & Charges	Aeronautical Charges-Airfield	Landing & take-off fees
		Aircraft apron, parking and gate fees
		Aircraft environmental fees
		Aircraft fuelling fees and other ground handling fees
	Aeronautical Related Charges-Terminal	Ticket counter space
		Boarding gates and loading bridges
		Administrative office space
		Flight kitchens and services
		Baggage processing/handling
		Passenger lounges
		FIS, BIDS and CUTE fees
Additional Passenger Services and Revenue Sources	Non-Aeronautical Concession Revenues-Terminal	Retail/specialty retail
		Food/beverage
		News/gifts
		Duty free/tax free
		Advertising
		Hotels
	Non-Aeronautical Concession Revenues-Landside	Parking
		Rental cars
		Taxis, buses, limos
		Rail and train stations
		Other commercial vehicles
		Hotels, conference centers, office buildings
		Shopping centers
Financial	Operating and Maintenance Costs	Personnel costs
		Soft costs/outsourcing
		Supplies and materials
		Repairs and maintenance
		Communications and utilities costs
		Law enforcement and firefighting costs
		Other operating costs
	Other Financial	Other non-operating revenues
		Cash flow and liquidity
		Debt (bonds and loans)
		Return on equity and assets
		EBITA and net profit
		Capital expenditures and costs
Passenger Service	Quality of Community Airline Service	Number of Airlines
		Airline routes and frequencies
		Aircraft types and fleet mix
		Airline competition and airfares
	Quality of Airport Facilities and Services	Quality of experience coming to airport
		Quality of passenger processing (check-in,

	(customer satisfaction)	gate, customs and immigration and security)
		Quality of airport commercial services
		Quality of airport physical facilities
Airport Council International-Airport Benchmarking to Maximize Efficiency		
	Environmental Impact	Air pollution
		Global emissions
		Aircraft Noise
		Incidents/accidents
		Congestions and delays
		Infrastructure Construction (erosion, impact on ecosystem)
		Water/soil pollution
		Waste management

Source: (Janic, 1999): Sources: Crayston (1992); Morrissette (1996)

Safety is the major indicator. Table 6 develops in further detail how the indicator is calculated. It contains not only safety as related to ATC, but also airports and airlines.

Table 6: Details of the safety indicator

	Accidents	**Serious incidents**	**Other incidents**
ATC Ratio	Number of accidents where ATC contributed, as direct or indirect causes	Number of serious incidents where ATC contributed, as direct or indirect causes	Number of other incidents where ATC contributed, as direct or indirect causes
Air-Air	Number of midair collisions	Number of critical near midair collisions	Number of other air-air incidents (e.g. loss of separations, deviations from clearance, airspace infringements)
Air-Ground	Number of collisions with the ground	Number of critical near collisions with the ground	Number of other air-ground incidents (e.g. CFIT incident, deviations from clearance)
Ground-Ground	Number of collisions on the ground	Number of critical near collisions on the ground	Number of other ground-ground incidents (e.g. RWY/TWY/AP RON incursions)
Others	Number of other types of accidents	Number of other types of serious incidents	Number of other types of other incidents
TOTAL	Total number of	Total number of	Total number of other

	accidents	serious incidents	incidents

Source: Authors

Critical technical functions

In terms of the critical technical functions, mainly interoperability and capacity management are an issue:

- Interoperability has mainly been an issue in the past and is mostly relevant for safety: the main issue here is the human and technical communication between the airline (airplanes) on the one hand and air traffic control (and airports) on the other. All commercial airlines are now interoperable (something furthered by the suppliers), but there remain problems of interoperability with general aviation and the military.

- Capacity management: with the increase of traffic, capacity management is becoming a growing issue, especially in North America, Europe and Asia now. Air traffic control is being constantly improved, in particular thanks to technological progress (satellite navigation, TCAS), but capacity problems remain and are actually becoming more severe.

4. Analysis

The case studies have been done from an infrastructure manager perspective, as is the analysis. First, each case is analyzed in itself, before a cross-sectorial analysis.

4.1 Sectorial analysis

Railways

Given the interdependencies between upstream and downstream providers in network industries, performance of railway infrastructure managers must be seen both from a firm-level and network-level perspective. In other words, some performances depend heavily on the interaction between train operators and track managers (e.g., noise generated by wheel-to-rail contact) while others are solely the resort of the infrastructure manager (e.g. asset failures). What complicates the matter is the economic characteristic of the infrastructure manager and its dependence on the government to fund its activities.

A number of comments can be made specifically to the performance measurement of the railway infrastructure manager in Switzerland. Overall performance and performance indicators remain rather general both at the government level and at the firm level. The strategic objectives of the Federal Council remain rather vague which plays both for and against the infrastructure manager. On one hand, it does not put excessive pressure to become more efficient. For instance, nothing seems to be planned in case the objectives are not met. On the other hand, the lack of precise performance objectives prevents the infrastructure manager from asking for the necessary resources to reach these objectives. Although performance and its indicators have been in use at the firm/division level for some time, publication of performance indicators in a transparent and regular manner remains, punctuality and safety aside, limited. To be fair the integrated nature of SBB and the lack of competition on the rails makes performance measurement less a requirement than in fully open access networks (e.g., in the UK). The absence of public-private partnerships in Switzerland also reduces the need to have a very precise understanding of performance. On the other hand, further liberalization of the passenger sector may require SBB or the regulator to define a transparent performance regime in which responsibilities are clearly defined and where the various actors are incentivized to perform.

Electricity

A key finding of the electricity sector case study is that in a highly interconnected and interoperable network (such as the European one), national and regional/European performance indicators are highly inter-dependent and potentially contradictory, in the sense that a performance increase on one level can entail a performance decrease on another level. Hence both the system boundaries and the organizational and institutional boundaries have to be taken into account when defining performance criteria.

In the European practice, performance criteria are defined both by national regulators and by European bodies, such as the European Commission or the newly created Association for the Cooperation of Energy Regulators (ACER). At the national level, the degree to which performance indicators are applied depends on the regulatory regime, which may vary from country to country: For instance, the UK and Nordic countries (as early movers in electricity liberalization) apply performance criteria far more extensively and transparently than other countries do. At the European level, harmonized performance indicators that apply for all of Europe have not yet been defined, the only exception relating to anti-trust indicators from DG Competition assessing the level of competition in national electricity markets.

Air transport

The infrastructure manager in the case of the air transport industry are the Air Traffic Control, and partly airports as well. The main problem here is capacity (airspace and airport slots), which obviously requires a supranational effort in terms of management but at the least in terms of regulation. However, no matter what is done in terms of capacity and corresponding performance, it will always also relate to safety and safety indicators.

Summary

The following table summarizes the performance indicators (at a strategic level) for all three sectors. The internal indicators were obtained through interviews and are the infrastructure manager's own measurement of their performance. The external indicators are the one published publicly. Both are considered in order to include all existing indicators.

Table 7: Performance indicators from the infrastructure manager perspective

Network Industry	Performance	
	Internal	**External**
Electricity [18]	**Technical**: Age and reliability of transmission assets (lines, transformers etc.) **Operational**: System availability, system control quality (frequency, voltage), switching times, (n-1) system security **Social**: Degree of uninterrupted availability for end consumers, electricity price. **Economic**: Costs of congestion, redispatch, ancillary services, system operation, network (assets and maintenance), system losses and network investments, **Environmental**: Degree of integration of renewable energies and	

[18] Nationalgrid (2010) and other TSO reports.

	greenhouse gas emissions.	
Railways	**Technical**: network availability **Operational**: punctuality, quality **Social**: quality **Economic**: productivity **Environmental** : noise and CO_2 reduction	**Technical**: interoperability **Operational**: punctuality, network management, capacity allocation **Social**: affordability **Economic**: productivity **Environmental**: noise (reduction),
Air transport	**Technical**: flight efficiency **Operational**: Safety, delays **Social**: accessibility and affordability **Economic**: ATC fees, airport fees, cost effectiveness **Environmental** : CO_2 emissions, noise	

Sources: Authors

4.2 Cross-sectorial performance indicators

Performance indicators are sector-specific. Nevertheless, common indicators can be found across network industries. Based on Table 7, the following outcomes can be derived. Firstly, the economic indicators are well defined and mainly concern costs and productivity. With the liberalization and privatization, the importance of the economic dimension of performance in the sectors is increasing. This is not surprising since state-owned firms tend to be increasingly treated as private firms. Secondly, the weight of the safety/security indicator as part of the operational category is gaining in importance as well. This indicator is linked with the delivery on time of electricity and the safety and punctuality in railways and air transport. In addition, acceptance of risk is falling. On the other hand, the importance of the technical indicators is decreasing. These indicators are well defined as well due to their historical importance, but are mainly reduced to the measurement of breakdowns today. The social indicators are not well defined anymore which shows their decreasing weight in defining performance. The question really is whether this is the problem of the infrastructure manager or the operator. The social indicators are mainly linked to affordability and accessibility, but with the stronger focus on economics, the quality notion is becoming less important. Finally, the environmental indicators are coming up and are currently almost solely linked to GHG emissions[19].

[19] More renewable energy within the electricity network is also a way to reduce GHG emissions.

4.3 Performance indicators allocated to the critical technical functions

In order to be more precise in evaluating the impact of the performance definition on the network industry, the performance indicators are allocated to the three critical technical functions described in Section 1 (see Table 8). As the degree of coherence is evaluated for each critical technical function, the indicators can contribute to make the evaluation more concrete and less conceptual. Therefore it could lead in a further research to better define coherence and its link to performance, as well as align institutions and technologies.

Table 8: Performance indicators allocated to the critical technical functions

Performance categories	**Critical technical functions**		
	Interconnection	Interoperability	System Management
Technical			
Breakdowns (availability)	X	X	X
Operational			
Security/Safety		X	X
Punctuality			X
System control			X
Social			
Affordability	X	X	X
Accessibility	X	X	
Economic			
Costs	X	X	X[20]
Productivity	X	X	X
Environmental			
GHG emissions	X	X	X

Source: Authors

Most indicators concern all three technical critical functions. Only the operational indicators relate mainly to the system management. Therefore, each performance category influences the degree of coherence in a broad sense and thus the alignment of institutions and technologies.

[20] Certain costs concern only one or two critical technical functions, such as congestion costs which relate only to the system management or ancillary service cost which relate to the system management and interoperability.

4.4 Improvement to the existing coherence framework

The main result is a better understanding of performance. The different actors (infrastructure manager, operators, regulators, customers, government) all define performance differently. Based on the five performance categories, each actor will weigh each indicator differently. Therefore, the alignment between institutions and technologies should vary with each actor's perspective, and thus the coherence represented in Figure 1 will follow each time a different curve.

Ultimately, the key question is who is setting the performance definition within the sector. For network industries, the consumers still perceive it as an essential service which is provided, which is less true for air transport. Thus, they will influence through their voting power (especially in Switzerland with the direct democracy) the government and its public policy objectives. Therefore, the key actor defining the performance in a network industry is the government. A further paper could elaborate on this point.

Even if there are performance indicators communicated to the public, it does not mean that they are the actual indicators used internally. As in certain cases, when the government does not give a clear definition of the required performance of the infrastructure, the infrastructure manager has the freedom to define himself internally his performance and the appropriate indicators. He will therefore measure internally.

Certain indicators important to the public such as affordability and accessibility are not part of the main measured indicators within the sector. This shows that the customers can't (anymore) influence as much as maybe wished certain aspects of performance of the network industries.

It had been suggested in Section 1.1 to introduce indicators for the four different perspectives (scope of control, coordination mechanisms, resolution and speed of adjustment) of the evaluation of the degree of coherence. As these four perspectives are applied to each critical technical function, and as the performance indicators have now be allocated to these functions, a link could be established between performance, through its indicators, and coherence, through its indicators related the four perspectives. This offers an approach to make the causality between coherence and performance measurable and more quantitative. Further research could develop on this.

5. Conclusion

The coherence framework aims to evaluate the degree of coherence between the institutions and the technology in the case of network industries. This evaluation should lead to assess the performance of the sector. Unfortunately, the causality between coherence and performance, as well as between coherence and the alignment between institutions and technologies remain fuzzy and very conceptual. This paper changed the approach to look first at the performance and then at the coherence.

In any case, both performance and coherence have to be better defined. This paper tackles the performance definition which constitutes the first weakness of the coherence framework. The methodology has been to review the coherence framework and performance literature, followed by cases studies of three sectors from the perspective of the infrastructure manager.

The analysis shows that performance is still loosely defined. However, there are common performance indicators across the three studied sectors (railways, electricity, air transport). The importance of the economic indicators, as well as security/safety as indicator, is steadily increasing as a consequence of the institutional changes such as liberalization and privatization. The environmental indicators gain in importance as well, whereas the social and technical indicators decrease in weight. As the economic indicators become the major performance measurement, the question in the end is how much the customers are ready to pay for which type of performance.

Most of the performance indicators concern the three critical technical functions. Thus the degree of coherence of each function is determined by all performance categories. No conclusion on the causality between performance and coherence can be derived yet. However, the clearer performance is defined, the easier it will become to study the causality based on the critical technical functions. Further research is therefore needed not only on the causality, but on the definition of coherence itself.

The problem of how the alignment between institutions and technology has to be established depends on which performance is targeted at. In other words, the questions are how to develop the right institutions given the state of the technology, or how to innovate and develop the technology within given institutions in order to get a certain performance. To be able to monitor the alignment, indicators should not change with every annual report. Continuity in measuring performance according to well established indicators must be given.

As developed in the analysis, it is ultimately the government who defines the targeted performance for the infrastructure manager within a sector as he operates in regulated monopoly situation. Performance indicators can consequently lead to decide on subsidies, fines and even bonus/malus for the managers.

Performance indicators to define performance, and thus further develop the coherence framework quantitatively, are nice to have, but if they are not linked to some decisions making, they are useless. It will therefore become more and more important that the governments and regulators use such indicators to monitor the actors in the network industries who provide essential services for the public welfare of its citizens.

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