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Visions on high-speed trains: a methodological analysis

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Visions on high-speed trains: a methodological analysis ¹

Métodos de Análise Prospectiva [Foresight Analysis Methods]

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Visions on high-speed trains: a methodological analysis

Abstract

Future Oriented Technology Analysis (FTA) has been visible in railway planning since 2001. Over a dozen reports have been produced in the past thirteen years, the majority being descriptive endogenous technocentric visions. They have played a role in the revitalization of the sector, predominantly relating to collective alignments and interdependencies in choice and form of the technological path the various stakeholders' follow to achieve policy goals. A striking example is the case of ERRAC visions, where strategic agendas and roadmaps greatly impacted the high-speed train technology transition from the second to the third generation of vehicles. However, today's socio-economic events have revealed the limitations of previously applied FTA fall short for railways. In particular, there is an inability to bridge technocentric visions with the societal challenges that are becoming increasingly prominent on the policy agenda. To fill this FTA-need in railways it is here proposed a role for constructive technology assessment as bridging function towards achieving success in the transition to a next generation of high-speed trains. The findings here presented result from the analysis of reports and interviews with their commissioning institutions and drafters.

Keywords: future oriented technology analysis; constructive technology assessment; technology transitions; s-curve; multi-level alignments; high-speed trains

JEL codes: O31, O38, R42

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1. Introduction

The White Paper on Transport (COM(2001)370final) in 2001, liberalizing the railway market and announcing investments of EUR 269 billion between 1996 and 2020 for the construction of a pan-European high-speed train network linking the major cities in Europe, was widely seen as a wake-up call for the declining railways to embrace modernization (Preston, 2009).

To tackle the announced new market conditions imposing new sector alignments and technical requirements (of modularity, interoperability, sustainability and safety) stakeholders changed their business approach from a tactical approach to a more strategic one, introducing greater anticipation, influence and knowledge exchange, addressed by Future Technology Assessment (FTA).

Over a dozen of relevant reports have been produced since this wake up call. STOA scenarios (2005, 2013) and TRANSvisions (2009) commissioned by European institutions; the European Railway Technology Platform visions (2001 and update 2011), agendas (2002, 2007) and roadmaps (2012); UNIFE industrial association market outlooks (2006, 2008, 2010, 2012, 2014) and train manufacturers' internal forecasts and future reports such as those of Siemens (2006, 2009, 2010, 2011).

Particularly striking, as it will be demonstrated in this paper, are the reports from the European Technology Platform for railways (ERRAC). The platform's visions from 2001 were the result of unprecedented collective exercises towards a common envisaged future, which culminated in the articulation of a unified direction, with new collective technological path dynamics in stark contrast to the once nationalised and fragmented sector. This can be seen as a new "technological path" (Robinson and Propp 2008) because of the resulting realignment of stakeholders and newly established interdependencies.

The technology areas suggested by the articulated vision documents were reflected in the funding programmes of the European Commission's 6th Framework Programme (FP6). Collaborative research and development projects funded by FP6 significantly contributed to the high-speed train technology transition towards the third generation of vehicles. With the ICE350E and the AGV series launched in 2006 by Siemens and in 2008 by Alstom, integrating some of results from projects as MODTRAIN (modularity), EUDD (interoperability), RAIENERGY (sustainability) and Safeinteriors (safety).

The promise of the commercialization of the eagerly anticipated new generation of “champion-trains” was soon after frustrated by the successive financial crises occurring from 2008, putting on hold the planned investments with respect to rail tracks and orders for the new series of vehicles. Parallel ICT advancements challenged the railway system. In particular, the rapid rise and societal uptake of digital technologies, could contribute to include, for example, the “connected traveller” as an outcome of these advancements.

These supra-systemic and diffuse waves of events revealed a gap between technocentric FTA exercises of predicting technological trajectories futures (Dosi 1982) and the open-ended and diffuse societal challenges that have to be addressed. Also new types of societal stakeholders that were previously unknown to the railways have emerged as important. These include social networks or movements supporting specific causes, like “ride sharing services” or “carbon footprints”. They might not be directly concerned in the development of high-speed train technology but have the capability of impacting its technology system.

Railway operators are responding by extending their service to door-to-door transportation and looking to ICT to integrate services. Moreover DB and SNCF have been champions in providing bicycles and car sharing to users of their train services. In their turn, train manufacturers are now revising life cycle costs, as well manufacturing times and developing maintenance free vehicles; while pushing for market uptake of results from the past decade of collaborative research with planned SHIFT2RAIL joint undertaking.

In this process of reorientation in railways, FTA could potentially contribute by supplying the right additional instruments to bridge technocentric scenarios with the societal challenges. Constructive Technology Assessment (CTA) proposes a reflexive strategy, including a broader and deeper understanding of socio-technical dynamics and extended value chains (to include societal actors).

In this paper an analysis is made on FTA in the railway sector, narrowing it down to the most impacted technology systems with regards to high-speed trains, in order to finally speculate on the contribution CTA can give to the success of the next generation of vehicles.

2. Methodological approach

This paper presents the results from a qualitative study conducted by the author on FTA practices in the railways sector by referring to the case of the high-speed train technology

system. It characterizes the types and role of FTA in the European High-Speed Railway technology system by analysing and characterising found reports on high-speed railway and contrasting them with actual developments of the high-speed railway sociotechnical system. The analysis is drawn on a broad range of concepts models arising from different theoretical streams in the sociology of innovation, science and technology studies and constructive technology assessment.

As a first step a classification is made of the public available FTA reports addressing the high-speed train technology system. Doing so it was used Robinson and Propp proposed classification method (2011, p.23, table 2, of levels of innovation chain+ analysis), to which has been added other elements as “function” and “approach”, “year of issue” and “stakeholders” involved. The element “function” and “approach” is supported on Grunwald (2011) attribution of “function” to “outputs”, while “approach” to “inputs” from stakeholders exogenous or endogenous to the supply chain.

The analysis proceeds by locating the different types of FTA activities within the high-speed train innovation trajectory (transitions) over time using the s-curve model. The high-speed train technology evolution here presented refers to speed (Zhou and Shen 2011) plotted against the rate of adoption (number of service providers operating high-speed trains).

Once this is done found FTA reports are contextualized in the multi-level framework referring to the transition to the third generation of high-speed trains. Here is used the multi-level framework of Geels (2002) in combination with technology transfer taxonomic model from Pavitt (1984 extended to services by Castellacci, 2008).

The deployment of FTA to the high-speed train technology system is further narrowed by finding evidences between the relevant report recommendations with the reference collaborative research project MODTRAIN.

Finally this paper concludes speculating on the possible role constructive technology assessment (CTA) could play in this matter as bridging function between technology and wider society (Schot and Rip 1997, Rip and Schot 2001). The data and facts presented here are based on secondary data retrieved from the indentified reports and inside views from the commissioning authors and drafters, collected at different occasions.

3. FTA in the European High Speed Railway system

3.1. Classification of FTA addressing high-speed trains

Publicly available FTA reports addressing high-speed trains were classified based on the table from Robinson and Propp (2011, p.23, table 2) referring to “methodology, objectives, outcomes and nature”, and to which it was added the year of issue, function, stakeholders and approach.

FTA report	Year	Function	Stakeholders	Methodologies		Objectives	Outcomes	Nature	Approach
STOA scenarios	2008 2012	Policy-making	European Parliament, third party assessment, group of external experts mostly from academia and policy	Social, science analysis	Back casting	Functions of expectations; relationships between emerging and incumbent technologies	Connections between technologies and grand challenges are mediated; they emerge from interactions between technically and socially enabling factors per future path	Prospective	Exogenous
TRANSvisions	2009		European Commission, third party assessment, group of external experts		Delphi				
ERRAC vision	2001 2011	Strategy-making	ERRAC Secretariat, ERRAC members: associations incl UNIFE, CER, EIM and individual value chain firms and national gov.	Rationales of expectations -mapping	Workshops (plenary)	Endogenous futures (techno centric) and enabling conditions	Ongoing interactions in areas of concern	Descriptive	Endogenous
ERRAC Strategic research agendas(*) Roadmaps (**)	2002* 2007* 2012**			Techno-organizational mapping	Working groups	Actors activities (and we should add competences)	Innovation Chain horizontal and vertical links and merging supply chains		
UNIFE market-outlooks	2006 2008 2010 2012 2014		External Consultant, UNIFE secretariat and members from industry	Forecasts					
Siemens futures	2006 2009 2010 2011		internal	vary from scenarios, Science fiction, forecast					

Table 1. Classification of publicly available FTA reports on high speed railway systems

From the classification of the reports in table 1 two types of reports were found: endogenous, the majority with 14 reports, and exogenous with only 3 reports. The endogenous reports, of industry inputs and initiatives, are about technocentric exercises, serving mainly as output strategic purposes (selecting promising technologies, engagements) and present these

strategic aims in a descriptive nature (communicating capabilities, expectations and values on certain issues).

The exogenous reports commissioned by the European Commission and the European Parliament present both a policy-making function as outputs (legitimizing options) and a prospective nature as input to improve understanding of possible cause-effect relations in a broad sense within high-degrees of uncertainty.

a) Endogenous reports:

The endogenous reports include ERRAC visions (2001, 2011) strategic agendas (2002, 2007) and roadmaps (2012), UNIFE market outlooks (2006, 2008, 2010, 2012, 2014), Siemens futures (2006, 2009, 2010, 2011). ERRAC visions are the only endogenous reports meeting a policy-making function, specifically oriented to target the European Commission. While ERRAC agendas and roadmaps, UNIFE market outlooks and Siemens futures are dominated by a strategic purpose of alignments within the supply chain.

Following on Robinson and Propp (2011) classification, ERRAC visions are rationales of expectations mapping; resulting from workshops in plenary prepared internally by the secretariat of the platform; which objectives are endogenous futures (technocentric) and enabling conditions; producing ongoing interactions in areas of shared concern. ERRAC strategic agendas and roadmaps as well as UNIFE market outlooks and Siemens futures, share the same techno-organizational mapping, based on a variety of methodologies; which objectives are actors activities and competencies. Only UNIFE market outlooks are actually commissioned to a third party, with all the other endogenous reports being drafted internally.

b) Exogenous reports:

Passing to the exogenous FTA exercises, and continuing with Robinson and Propp (2011) classification, they include STOA scenarios (2008, 2013) and TRANSvisions (2009). These reports present a clear policy function, of the initiative of the European Parliament and European Commission, contracted to a third party, involving external experts to railways with a broad knowledge on transport mainly coming from research centres. In particular STOA follows a social science analysis approach, using backcasting; objectives are functions of expectations; relationships between emerging and incumbent technologies; producing connections between technologies and grand challenges, which are mediated; outcomes

emerging from interactions between technically and socially enabling factors per future path; presenting a prospective nature.

3.2. FTA and the high-speed trains innovation trajectory

Since 2001, FTA is included in the high-speed train innovation trajectory (s-curve of performance and adoption).

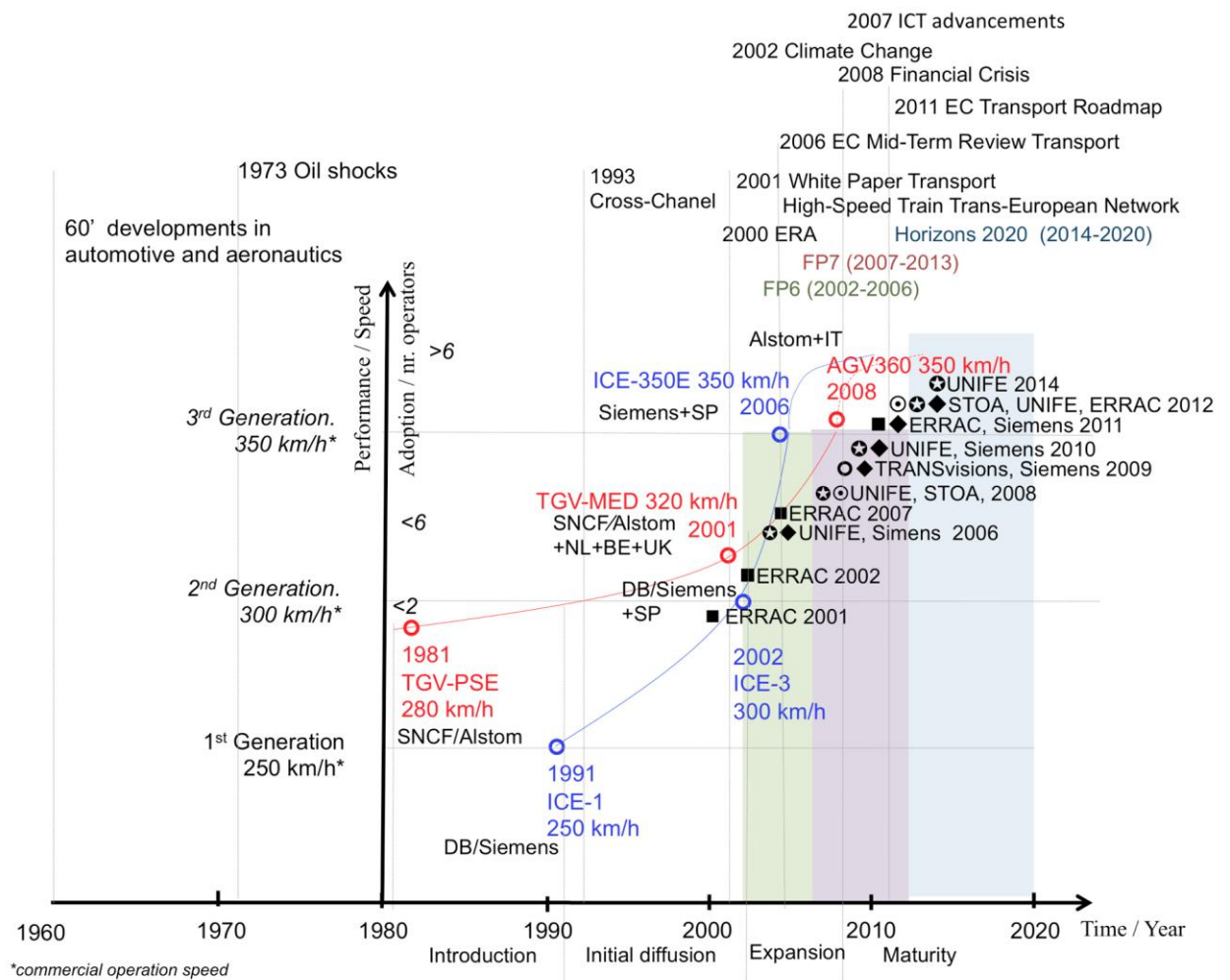


Figure 2. High-speed trains technology innovation over time (s-curve)

Source. Author's own rendition

As figure 1 illustrates were identified four main evolutionary stages in the high-speed train innovation trajectory (s-curve) measured in terms of performance of maximum speeds and

rate of adoption by train operators, overtime: a) introduction; b) initial diffusion; c) expansion; d) maturity.

FTA, as it can be seen in figure 1, emerges at the high-speed train technology transition from its initial diffusion stage to its expansion across Europe, and matures as its technology becomes widely adopted.

a) Introduction stage (late 50's-1991): technology driven (increase train speeds)

In Europe, two train operators the French SNCF and the German DB have been the pioneers in increase speeds of trains, lasting since the 1950's to our days. In Japan, this role can be attributed to JR with the *shinkansen* system.

They introduced the first generation of trains in 1981 with SNCF's TGV-PSE, followed in 1991 by DB's ICE-1, running at commercial speeds of 289 km/h and 250km/h respectively.

The technology development at that time was done on their own, in-house, in cooperation with flag manufacturers (SNCF / Alstom and DB / Siemens) requiring great efforts and progressing very slowly (the SNCF started evaluating running at very high speeds since it received the first CC 7100 electric locomotives of higher power already in 1954 but only in 1981 the first high-speed train was introduced to service).

FTA was not actively pursued at that time, only cost and benefit analysis ex-ante on specific corridor projects to justify governmental decisions were conducted. The technology decisions here were tactical, based on the available resources (in France SNCF option to go for incremental innovation of full electric power high-speed train Zebulon, the TGV prototype, was precipitated by the oil shocks in 1973, putting aside contemporaneous developments as the disruptive Aérotrain or even the turbo train TGV001; in Germany the introduction to service of high-speed train was delayed during years because of disagreement between the government and DB in relation to the type of lines in which it should run, mixed vs. dedicated lines).

b) Initial diffusion (1981-2002): efficiency driven (adapting trains to different network conditions)

When developing the second generation of high-speed trains both SNCF and DB were looking for efficiency while further increasing speeds. The SNCF/Alstom TGV-MED was

introduced in France in 1991 and the DB/Siemens ICE-3E in Spain in 2002, running at commercial speeds of 320km/h and 300km/h respectively.

High-speed trains gained legitimacy, with Alstom and Siemens deeper understanding of the technology system from national operations and expansion to other countries (in 1994 the channel crossing link UK-France-Belgium, and in 2002 Spain).

Yet developments from the first to the second generation were slow (taking 20 years). They were about endogenous renewals with manufacturers adapting the existing vehicle technology platforms to specific orders requirements for cross-border operations or costumed to new clients (example improvements in aerodynamics, wheels, breaks, power cars and articulation cars configurations).

As in the first generation technological decisions were tactic, based on available resources, supported by exant cost-benefit analysis undertaken by governments. First step is however given towards FTA across railways in Europe when UK is pioneer introducing scenarios (Potter and Roy, 2000) to indentify innovation priorities in the liberalized railway market happening from 1993.

c) Expansion (2001-2008): interoperability driven (removing technical bottle-necks across-borders)

The transition to the third generation of high-speed trains culminates with the commercialization of the AGV in Italy in 2008 and ICE350E in Spain in 2006 running at speeds of 360 km/h and 350 km/h respectively.

Developments between 2001 to 2008 integrating fragmented technology systems in an interoperable one was a clear response from the two dominant manufacturer, Alstom and Siemens, to the liberalization of the railway market and announcements of massive investments for the completion of the trans-European high-sped rail, announced in the White Paper on Transport (COM(2001)370). The European Union's Railway Packages implementing the White Paper in its turn were ruling financial restrictions to state aid, requirements for technical interoperability, modularity and high safety standards, standard gauge and electric multiple units, etc.

Cost reduction became an important element for the manufacturers, aiming to increase their competitiveness in order to survive and expand business in the open market. Including

improved components technology interfaces; as well reduce time for assembly and reduction of life cycle cost.

For the first time Alstom and Siemens came in direct competition developing simultaneously the third generation of trains, the AGV and ICE350E. Siemens overpasses Alstom with the commercialization of the train to the Spanish RENFE. The AGV and the ICE350E, represented the reorientation of technology trajectories towards out of the shelf vehicles capable of meeting a greater number of operators, overcoming a legacy of costume-made vehicles.

The development of the third generation of trains accounted with many hours of strategic meetings at European level between Alstom or Siemens staff and supply-chain stakeholders, including direct competitors, ranging from component suppliers to service operators, including academia and end-users.

FTA surged here, opening the way for those interactions to happen. The first exercise was ERRAC vision (2001). It met a policy-making function to contribute to the European Commission drafting the successive calls of the six-framework programme for research (from 2002 to 2006), instrument implementing its research policy. The vision identified research areas reflecting the White Paper on Transport (COM(2001)370) set targets as modularization, standardization, improve environmental performance (noise and vibration, CO2 emissions from diesel engines, end-of life) and safety. ERRAC strategic research agenda, followed just after (2002) allowing for supply chain alignments.

Collaborative projects resulted such as MODTRAIN² and the EUDD Drivers Desk³ and other technical joint works as the former AIF⁴, which selected results were then integrated in the high-speed trains.

In 2006 the European Commission mid-term review (COM(2006)314) of the White Paper on Transport reaffirms the strategy's main guiding principles while directing the industry attention to new landscape developments (EU enlargement, the acceleration of globalisation, international commitments to fighting global warming and rising energy prices).

At this stage FTA significantly contributed to the acceleration of the technology developments (only 7 years separating the second from the third generation of trains). The industry saw in FTA a privileged instrument of anticipation, influence and knowledge exchange to cope with this new market and regulatory conditions.

² MODTRAIN stands for Innovative Modular Vehicle Concepts for an Integrated European Railway System. <http://www.modtrain.com>.

³ EUDD European Driver's Desk. http://ec.europa.eu/transport/projects/items/euddplus_en-htm.

⁴ Association Européenne pour l'interopérabilité Ferroviaire (no longer existing).

d) Maturity (from 2008): quality and capacity driven (attractiveness to passengers)

In our days the major issue for railways is quality, increase capacity and getting the core business right.

In 2010 the market for international rail passenger services in the European Union opened up to competition while emerging low-cost airlines.

The high-speed technology performance in terms of speed, reached its inherent limits (example increase speeds beyond 350 km/h are limited by safety and infrastructure, flattening the technology s-curve as shown in figure 1).

Alongside this technical limitation, railway market growth in Europe was inhibited by the financial crisis, with railways struggling to have returns on the previous years of investment in developing the third generation of trains and in the building of new corridors.

These uncertain conditions resulted in a proliferation of a second wave of FTA reports, which were targeted at managing this uncertainty through anticipatory coordination.

Train manufacturers and operators became aware of the strategic relevance of FTA in this industry to deal with the changing conditions (Siemens issuing since 2006 a series of reports focusing on its capacity and UNIFE also from 2006 is producing market outlooks every two years).

The breadth of the supply chain that participated in ERRAC also highlighted the importance of sector dynamics including bottom-up alignments (this was reflected in their strategic research agenda update in 2007 and introduction of a roadmap in 2011). Also policy institutions such as the European Commission and the European Parliament envisaged revising the setting of transport targets by contracting third parties to perform FTA (STOA 2008 and TRANSvisions 2012).

This FTA intelligence provided input for the generation of new research projects under the 7th framework programme such as TRIOTRAIN projects⁵ (towards common virtual certification) and contributed to the 2011 the European Commission roadmap on Transport (COM(2011)144), “Transport 2050”, aiming at increase mobility while reducing emissions, reaffirming rail central role for medium-distance transport.

⁵ TRIOTRAIN (2009-2013) <http://www.triotrain.eu/index.htm>

3.3. FTA and the high-speed train multi-level alignments

FTA exercises are the expression of multi-level alignments. They reflect, collective or individual, assumptions (on users, markets, regulation, technical progress), expectations, values and cultures, ultimately providing guidance to R&D activities, especially when translated into agendas and search. Furthermore FTA is a strategic instruments used to attract attention and resources from other actors.

Figure 2 is inspired on Geels (2002) multilevel alignments, in combination with technology transfer taxonomic model of Pavitt (1984) extended to services by Castellacci (2008) covering the period from the period FTA surge in railways in early 2000's.

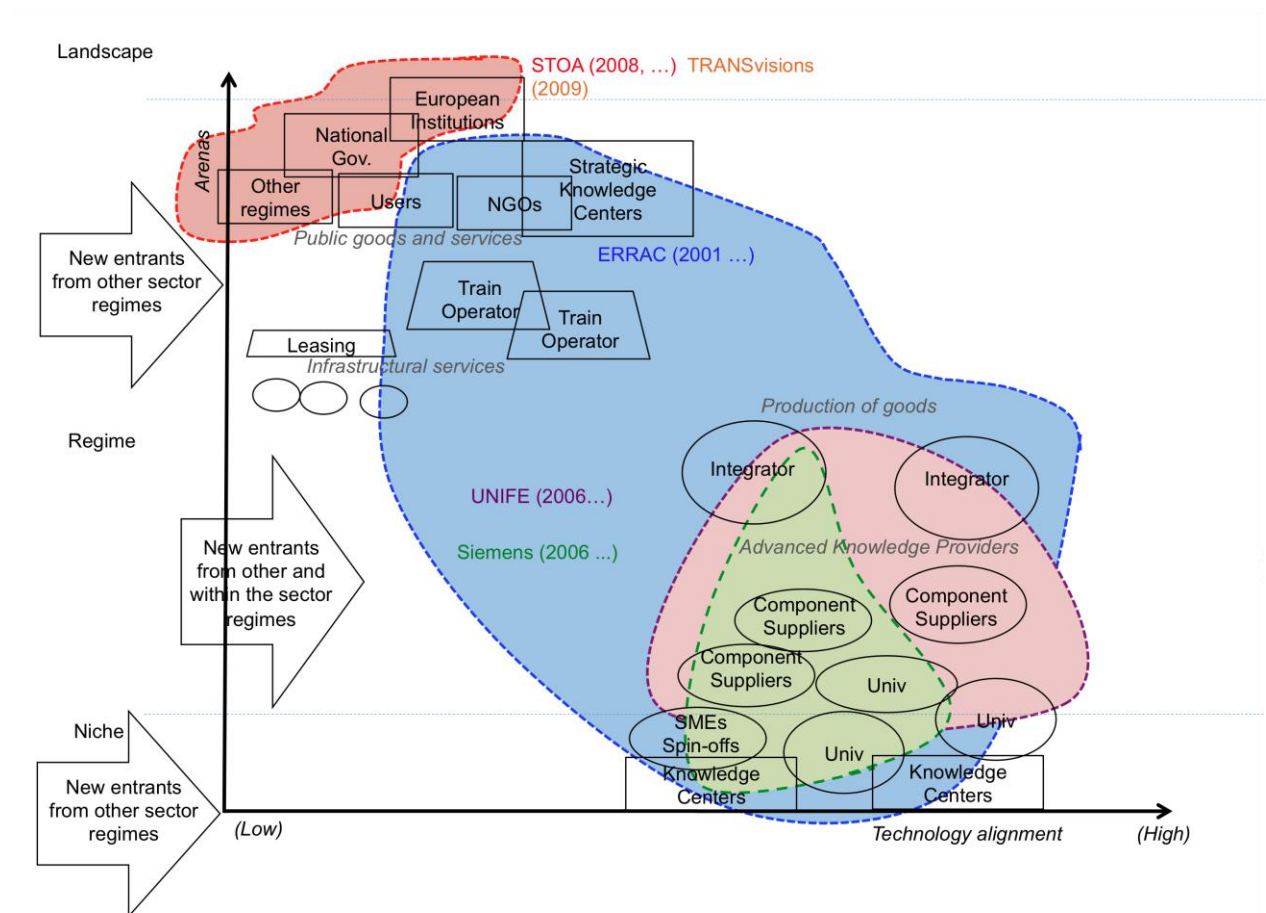


Figure 2. multi-level alignments since 2001

Source: authors

From figure 2 it can be observed that FTA analyses which address high-speed trains are, for the majority, industry initiatives, occurring at meso-level of the regime arena (following the multi-level framework of Geels, 2002), describing the overall interests and expectations from its participating stakeholders. Moreover we can see that the larger the collective of stakeholders involved is, the lower the technology alignment between them.

For example the ERRAC visions, strategic research agendas (SRAs) and roadmap, are alignments of the broad of interests of its members (ongoing interactions of common concerns). Interests vary according to each member's position in the supply chain. For example operating companies envisaged that to overcome technical operations problems, compliance with infrastructure and regulations (interoperability, safety, modularity, homologation, energy, weight, noise emissions, end-of-life, maintenance) as well as attractiveness to passengers (speed, comfort, availability, and ticketing prices) was necessary.

Also deemed necessary was that, while train manufacturers and their component suppliers aimed at production cost reductions, compliance with regulations, customers (operators) requirements and most recently attractiveness to end-users were thought of as a key driver.

Alongside the manufacturing and production part of the system, academic scholars also were part of the ERRAC vision, with scholars looking to further develop knowledge in this area field; where member states are considering territorial cohesion and GDP growth.

ERRAC reports are drafted internally by its secretariat. Their contents result from plenary workshops and focus groups where ERRAC members meet. In these workshops, participants identify future technological areas of common interest and enabling conditions. They are then further developed by ERRAC strategic research agendas (SRAs). They reflect the rational of expectations, capabilities, alignments and knowledge exchange.

ERRAC reports however vary in their function. ERRAC vision for instance have a policy function, targeting mainly the European Commission through the inclusion of its recommendations in the policy agendas and instruments (in 2001 was the six and seven frame-work programme for research, while in 2011 was Horizons 2020); while the SRAs and roadmaps have a strategy function, targeting the supply chain to indicate the technology path in the direction of the envisaged future.

Restricted UNIFE market outlooks or individual reports as from Siemens cover a specific level of interests within the supply chain (the ones of the manufacturers and their suppliers) naturally much more aligned in the technologic areas of shared interest. Their methodology is based on technolo-organizational mapping of actors and their activities and competences. In

UNIFE collective market outlooks for instance it is clear that their reports result from the integration of vertical and horizontal forecasts from its members.

These types of reports are inclusive of each other prospective exercises. Meaning that the UNIFE market outlook integrates data from its members internal forecasting exercises, combining them together at sub-regime level. In its turn the ERRAC visions integrate those forecasts by professional associations in the specific area of research and innovation at regime arena. Higher is the level in which prospective exercises are produced in the technology innovation-chain wither is the engagement from different stakeholders.

However the above seem to disregard exogenous prospective exercises such as STOA or TRANSvisions. Only Siemens clearly referred to other sector's Delphi results as from Energy. Moreover the methodology of endogenous reports' reflect commissioning stakeholders life cycle cost approach based on quantitative indicators, bypassing qualitative elements inherent to today's emergent societal challenge, such as sustainability and mobility.

Exogenous reports, such as STOA and TRANSvisions, are commissioned by policy actors to a third party with the purpose of political guidance of technology development to support responding to policy and societal grand challenges. They have a policy-making function and in particular STOA introduce social sciences in its methodology. A third party, accounting with the contributions from experts' which are outside of the railways supply chain, conducts these reports. Despite using recognised intelligence tools such as Backcasting or Delphi, both reports share common objectives of monitoring expectations and relationships between emerging and incumbent technologies. Of note is that in STOA (2005, 2012) the outcome results from the mediation on the connection between technologies and grand challenges and from the interactions between technical and societal enabling factors. The level of technological alignment in specific technology systems as the high-speed train is low. But again also those reports do not make any reference to industry ones and the involved stakeholders are not the same.

3.4. FTA and the high-speed train technology system

The technical innovations introduced by the third generation of high-speed trains system were driven from FTA.

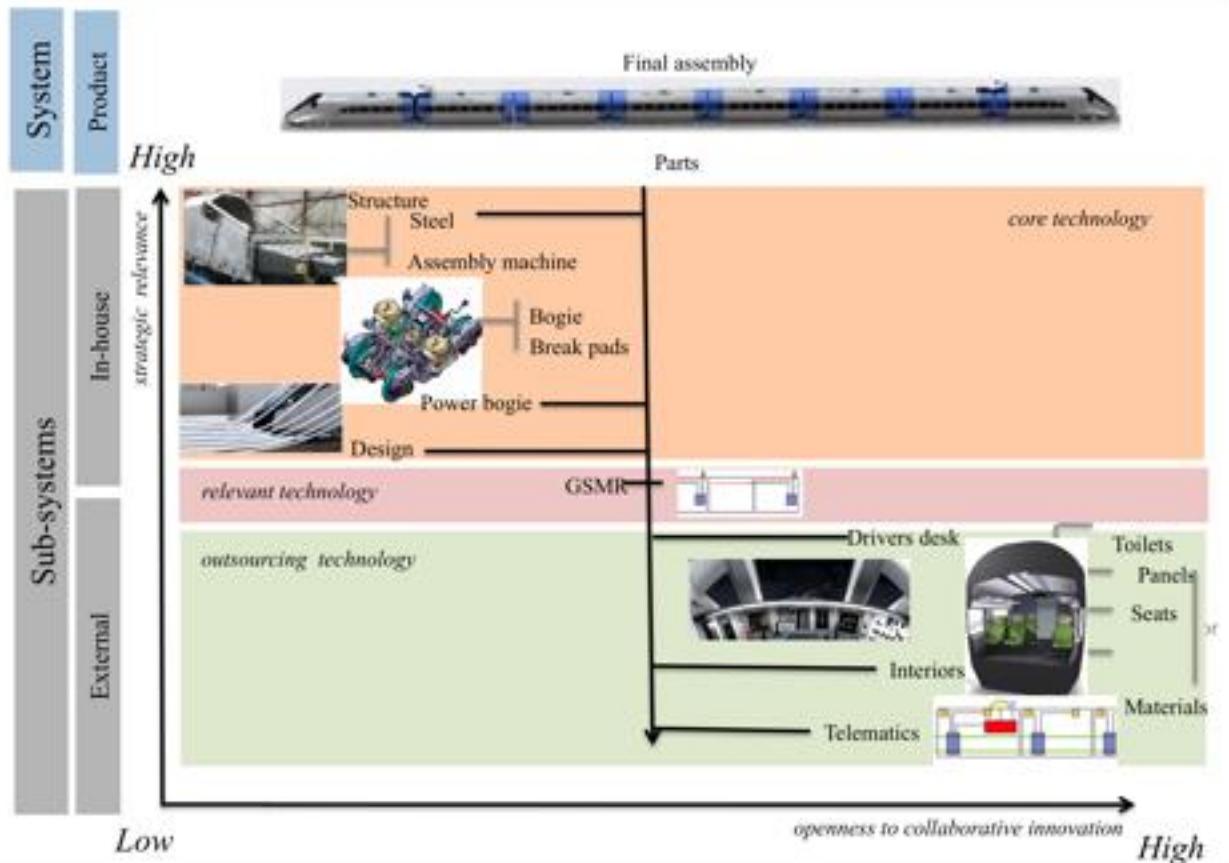


Figure 3. High-speed train vehicle technological system and sub-systems

Source: authors in Moretto et al (2012)

As figure 3 shows, the high-speed train vehicle is a very complex technology system⁶ in itself, integrating hierarchical⁷ subsystems until it reaches a point at which components are the minimal elements of the system, each of which manufactured by different stakeholders at differed levels in the supply chain integrated by the system manufacturer.

As it was referred, the introduction of FTA coincides with the liberalization of the railway market placing the technology development of high-speed train under the manufacturer's responsibility. In this situation, manufacturers become the sole actors who are knowledgeable of the overall architecture of the interoperable trains and their sub-systems interfaces. However, as outsourcing increases for costs-reduction, their knowledge decreases as the sub-

⁶ Simon (1962, p. 468) "Roughly, by a complex system I mean one made up of a large number of parts that interact in a non simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their inter- action, it is not a trivial matter to infer the properties of the whole".

⁷ Simon (1962, p. 469) "(...) parts within parts structure".

systems themselves sub-divide. Thus, this transformation means that they now lack supra systemic view on the transport system.

Manufacturers attribute different strategic relevance to sub-systems as shown in figure 3. Structural parts or bogie have high-strategic relevance, as they are in line with the manufacturers core competencies. They are developed in-house and co-developments take place under tight and restrictive confidentiality agreements. On the other hand, outsourced technologies such as interiors or materials provide a situation conducive to greater openness to collaborative innovation and broad consortiums exist which are ruled by cooperation agreements.

As it was mentioned ICE 350E and the AGV integrate collaborative research projects results meeting FTA orientations. The most referred to example is the MODTRAIN⁸ integrated collaborative project (FP6), conducted between 2004 and 2008, involving 36 partners, of a total budget of 30 million Euros (16 Million funded by the EU). This highly technical project addressed performance improvements (affordable and attractive interoperable rolling stock) identified in the business scenarios listed in the ERRAC Strategic Rail Research Agenda (2002) as overall transport growth (40% for passengers to 7500 billion passenger/km is expected in 2020) and transport demand increase (passenger market share will almost double and market volume will triple in comparison to 2000).

At the time of its preparation (2002-2003), a new legal framework was being introduced with the two first Railway Packages (High Speed and Conventional Rail Directives) supported by the Technical Standards for Interoperability (TSIs) and voluntary norms.

Train manufacturers were particular concerned on the risk new trains being subject of independent interpretations of the requirements set by the legal framework as well as on unproven prototype sub-assemblies falling outside system integrators tight certification procedures.

This way, main European railway systems manufacturers (Ansaldo Breda, Alstom, Siemens and Bombardier), sub-systems suppliers (Knorr-Bremse, Deuta Werke, Lucchini, and others) railway operators (SNCF, DB, FS) and professional associations (UNIFE, UIC, VBD, FIF, ANIE and RIA) joined efforts to collectively identify the interoperable constituents, validate and promote them at industry level⁹.

⁸ www.modtrain.org. MODTRAIN was concentrate on fixed formation passenger trains and universal locomotives capable running at 200 km/h and more.

⁹ Retrieved from www.transport-research.info/web/projects/project_details.cfm?id=36249

The project breaks down into four architectural parts (work packages) where possible standardization could emerge: bogie and running gear (MODBOGIE), train control and architecture (MODCONTROL), onboard power systems (MODPOWER), man-machine and train to train interfaces (MODLINK), dissemination (MODUSER), driver's interface (EUROCAB), passenger interfaces (EUPAX) and train interfaces (EUCOUPLER).

As technical implications MODTRAIN provided the high speed train market with a set of agreed specifications that allowed for better inter-changeability of key components for maintenance, as well as for a higher level of standardisation at the interfaces of the main train subsystems¹⁰. At the operational level, some of MODTRAIN's technical results (module and interface specifications) were introduced to the European Standardisation Organisations (CEN / CENELEC) and have become European norms¹¹.

The policy ramifications in which MODTRAIN builds on adds to the EC's previous legislative packages supporting the rail sector integration and increases its competitiveness. In these legislative packages, the Commission developed the Interoperability Directives introducing the essential requirements to ensure safe and uninterrupted rail traffic on the Trans-European network¹².

Moreover MODTRAIN also paved the way for a new type of cooperation between the different actors in railways and proves possible in this industry voluntary harmonisation beyond the mandatory requirements set in the European regulations¹³.

Despite the great accomplishment by MODTRAIN here referred as well as from other projects (EUROPAC¹⁴, EUDD¹⁵, etc) the industry is still disappointed with the rate of adoption of EU funded collaborative research results (about 30% against 40% in the North America)¹⁶. In response to this, ERRAC introduced in their roadmap (2012) a new bottom-up governance structure for research and development in the form of a joint undertaking, called SHIFT2RAIL.

¹⁰ Retrieved from www.transport-research.info/web/projects/project_details.cfm?id=36249

¹¹ Retrieved from www.transport-research.info/web/projects/project_details.cfm?id=36249

¹² Retrieved from www.transport-research.info/web/projects/project_details.cfm?id=36249

¹³ Retrieved from www.transport-research.info/web/projects/project_details.cfm?id=36249

¹⁴ EUROPAC on pantograph (2005-2007) http://www.transport-research.info/Upload/Documents/201203/20120315_103841_53919_Publishable%20Final%20Activity%20Report.pdf

¹⁵ http://ec.europa.eu/research/transport/projects/items/euddplus_en.ht

¹⁶ Source ERRAC informer.

4. Conclusion

Since the revitalization of railways in Europe FTA is playing an increasing role in the high-speed railway system as facilitator of a new industrial dynamics and integration of policies mainly on Transport and Research, unprecedented in this industry. That is evident in the enhancement of the high-speed train innovation system transition to the third generation of vehicles (2001-2008).

Also FTA has played a significant role in recent years, particularly as certain technical and infrastructural elements began reaching their limits in early 2000s, providing a need for more anticipatory coordination and targeted strategic intelligence to minimise risk, and to stimulate the evolution of a high-speed railway system.

However, amidst this rise in FTA for anticipatory coordination, it was found that there is a dominance of endogenous FTA approaches, where exogenous approaches would rather provide intelligence that speak to broader policy challenges and grand societal challenges.

Currently, the railway technology platform (ERRAC) provides pre-competitive forum (inclusive and dynamic), aiming and allowing for multi-level alignments in the liberalized innovation chain. The visions, strategic agendas and roadmaps of ERRAC have been enablers of technology dependencies by anticipating, influencing directions of the development trajectory of high-speed rail (see the White Paper on Transport (COM(2001)370) which has since been periodically revised and updated). The share of common interests in this industry is triggering and stimulating collaborative research projects, of which the first wave has been to a certain extent embedded in AGV and ICE350E trains becoming part of the dominant designs.

However, there is still a long way to go. The need for forums such as ERRAC to move beyond the dominance of endogenous FTA (highlighted in this paper) to a mix of endogenous and exogenous FTA (such as the STOA type activities) is becoming an increasing issue. This need for more exogenous FTA is further compounded by other shifts in the socio-technical system of high-speed railways. For example, as it has been shown in this paper, first railway operator and then their manufacturers once held a strategically important position of being knowledgeable of the whole supply chain, but today they are no longer knowledgeable about the whole supply chain due to the move from total in-house production by the major manufacturers towards outsourcing for costs-reduction, their knowledge decreases as the sub-

systems themselves sub-divide. This means there is no longer an individual actor with a supra-systemic view on the transport system.

Constructive Technology Assessment (CTA) approaches are a possibility here, and it is a recommendation of this paper that such approaches to FTA be supported in programmes such as Horizon2020 and European Technology Platform activities relating to railways and transportation. CTA, with its aim of more system level insights from actors across the supply chains and from users and third parties can be combined with approaches such as the multi-level approaches (Geels 2002) and would ideally be located at the meso-level of consortia such as European Technology Platforms (Robinson 2010). Being more specific, CTA could certainly be part of the ERRAC roadmapping process.

Constructive Technology Assessment (CTA) places an emphasis on contributing to the actual construction of new technologies and the way these become more or less embedded in society. The approach shifts the focus of future oriented technology assessment away from the reliance on processes of prediction in its strictest sense (and that which has been visible in the endogenous FTA in high-speed railway, see earlier) towards a process of reflexive anticipation through controlled speculation based on exploring the co-evolution of socio-technical systems. CTA (Schot and Rip 1997, Rip and Schot 2001) was developed with an emphasis on anticipation, articulation and feedback into ongoing processes that seems appropriate for including in the activities of European Technology Platforms. While actors will always take enabling and constraining factors in the situation into account, CTA adds to this because of a broader & deeper understanding of socio-technical dynamics, thus, increase speed of technology developments and mitigation of market failures.¹⁷

However, the inclusion of CTA for high speed-railway systems also brings with it challenges: key elements of the railway system show a high level of competition between actors, and thus coordination in such a setting is very difficult. It is a sensitive sector where technology is a competitive factor. However there are certain elements that are more conducive to collaboration. Europe plays an important role where the fact of existing several different national railway companies should not be an obstacle to common policy positions. It has been a very difficult exercise, but that can provide robust intelligence for the anticipatory coordination of European high-speed rail systems. Japan, Korea, China, US and Canada have their own policies for the high-speed railway systems, but do not have to cooperate with each other to improve their model. That is not the case in Europe. Each EU policy decision needs

¹⁷ To date, there have been a number of CTA activities in terms of lab-on-a-chip technology (Van Merkerk and Robinson 2006, van Merkerk 2007), nano drug delivery (Robinson 2010 p303 - 348) tele-health systems for chronic diseases (Elwyn et al 2012). Body Area Networks (Parandian 2013), Deep brain stimulation devices (Robinson et al 2013) and the many more applications.

coordination with the national ones and ability to bridge technocentric visions with the societal challenges that are becoming increasingly prominent on the policy agenda.

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