

Societal Embedding in High-Speed Train Technology Development: dominant perspective from a case study ¹⁰

Susana Martins Moretto (s.moretto@campus.fct.unl.pt), IET/CESNova, Faculty of Sciences and Technology, Universidade Nova de Lisboa

Abstract

The present article posits constructive technology assessment as the dominant perspective of societal embedding practices in the technical development process by the high-speed train manufacturing industry, resulting from a research study conducted in 2011 (Moretto 2011). The article covers the main elements of the study, being the high-speed train manufacturing industry's strategic intelligence, technology pattern, knowledge exchange, technology trajectories; and finally presents the arguments justifying constructive technology assessment as the dominant approach.

Key-words: constructive technology assessment, strategic intelligence, high-speed train manufacturing industry, railways

JEL codes: M16, R42

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Introduction

Today the high-speed train is commonly recognized as a symbol of modern Europe, reinforcing the competitive position of its cities and improving the quality of life for its inhabitants by providing fast and efficient transport between Member States' business and cultural centers. The high-speed train became the natural choice for journeys with distances between 250 km and 1000 km or with a door-to-door duration from 1 to 5 hours¹¹. Passenger services are frequent and reliable, trains are comfortable and safe, access is easy and high quality information is available.

Travelling by high-speed train today is seamless, flowing from guaranteed intermodality at stations and airports, providing an array of on-board services based on the same advanced technologies available at home or in the workplace, and providing passengers with a seamless connection to the world outside. Transportation by train has a limited impact on the environment and other external effects, with a considerable degree of user flexibility as a result of an effectively controlled transport chain and related services (intermodality, ticketing, information, etc.).

The picture described above, extracted from the ERRAC¹² strategic agenda 2020 (2007), is the result of a political and normative change in the sector introduced by the European Commission Transport White Paper (COM/2002) in 2001, and three consequent railway packages in 2001¹³, 2004¹⁴ and 2007¹⁵, accompanied by a positive growing demand for transport services. Determinants for this change were European foreign oil dependency, transport congestion, climate change and territorial integration. Europe has been successful in eradicating national technological barriers, modernizing service operations and equipment, increasing investments in new rail networks and opening the rail market regulatory framework (Seabra Pereira, 2011). In fact, looking at public data from the European Commission (EC) and the International Union of Railways (UIC), one can actually recognize the dimension that the sector revitalization took with the increase of rail transport market share, the network expansion and travelling time reduction (Moretto 2011).

Today over 40% of European transport traffic for medium-length distances is made by high-speed train. In one decade, Europe doubled its fleet from approximately 620 operating units in 2000, to 1.243 in 2010, becoming the largest fleet in the world; its dedicated network increased from less than 3.000km in 2000 to 6.214km in 2008 (EC 2010), with an additional 8.705 km

¹¹ The time between the two city centres of Paris and London is 30 percent shorter by high-speed train compared to airplane travel. Also, the time between the heart of Paris and Brussels is one hour shorter by high-speed train compared to automobile transport (ERRAC 2007).

¹² ERRAC stands for the European Rail Research Advisory Council, which is the European technology platform of the sector, responsible for establishing the technology vision, agenda, roadmaps and impact assessment for the rail sector. Link <http://www.errac.org>.

¹³ First railway package of 2001 http://ec.europa.eu/transport/rail/packages/2001_en.htm.

¹⁴ Second railway package of 2004 http://ec.europa.eu/transport/rail/packages/2004_en.htm.

¹⁵ Third railway package of 2007 http://ec.europa.eu/transport/rail/packages/2007_en.htm.

planned (UIC 2010). The number of passengers on all existing lines (Germany, Belgium, Spain, France, Holland, Italy and the United Kingdom) increased from 15.2 billion passenger per km in 1990 to 92.33 billion in 2008 (EC 2010), a figure that is expected to triplicate by 2025 (UIC 2010).

In a circuit of major European cities (Paris, London, Amsterdam, Koln, Frankfurt and Brussels) from 1989 to 2009, travelling time has reduced from 4 hours and 2 minutes to 2 hours and 24 minutes¹⁶ - a 38 percent decrease. Furthermore, the European railway sector reform also introduced reorganization of competition and management, price pressure, reduction in employment in train operator companies, and shifted design, maintenance and technology research to the manufacturing industry (Seabra Pereira 2011). All together, the reform pushed for greater coherence between expenditure, technologies, knowledge and policy needs (Cadet 2011). Technology actors become confronted with issues of competitiveness, environment, public acceptability and other aspects of "social quality", to use Rip's (1997) terminology.

To comply, manufacturers invest about 500 million euro a year in new materials, signaling, telecommunications and information systems, tilting trains, power trains, ERTMS and platforms development (Seabra Pereira, 2011). According to Seabra Pereira (2011), the industry searches for innovative solutions with two main objectives: performance and attractiveness. To solve performance problems, the industry targets technology developments, for example, those that which concern wheel/rail contact fatigue, design/simulation tools, system integration, materials (lightweight); structures (optimization and design for manufacture), aerodynamics (noise abatement), mechatronics (wheel/rail, steering and suspensions). On the other hand, to foster more specific research tailored to achieve defined outcomes to make the vehicle attractive, the industry targets technology developments in areas such as energy power, biomechanics, human/machine interface, environmental friendliness, safety and comfort.

It is mainly in this last referred group of technology developments that societal embedding occurs in the industry (see page 63). The industry uses technology assessment to align its technology developments at an early stage with future external constraints, so that risks of market failure are mitigated. As it will be seen further, constructive technology assessment (Rip, 1997) is the prevailed approach as the high-speed train industry involves societal actors in the technology construction process.

Looking forward, ERRAC (2007) foresees that in the next decades the challenges posed to this sector will shift from policy issues (pushing for a full interoperable and modern transport system) to end-users (rapidly changing mobility patterns).

¹⁶ The biggest reductions have been achieved in the routes London-Brussels (from 4 hours and 52 minutes to 1 hour and 55 minutes, -62%) and London-Paris (from 5 hours and 12 minutes to 2 hour and 15 minutes, -57%), in this case due to the Eurotunnel. Other significant reductions are Paris-Brussels (from 2 hours and 25 minutes to 1 hour and 22 minutes, -43%) and Koln-Frankfurt (from 2 hours and 10 minutes to 1 hour and 10 minutes, -46%) (EC 2010).

If that is the case, product attractiveness through societal embedding will become increasingly relevant for the success of the next generations of high-speed trains.

In the following sections, the present article aims, therefore, to proceed with the analysis in light of constructive technology assessment as advocated in Rip (1997). Section 1 covers social embedding in high-speed train product development; Section 2 contextualizes societal embedding in industry technology strategic intelligence; finally Section 3, demonstrates the industry's constructive technology assessment approach to technology and product systems and technological and commercial trajectories. The article concludes with the arguments of constructive technology assessment as the dominant perspective practiced by the high-speed train industry.

Societal embedding in product development

Developing high-speed train technology involves a significant amount of investment and high risks, characterized by a long innovation cycle¹⁷ against a rapidly changing complex system, adding a high socio-economic impact. To become competitive, the high-speed train manufacturing industry soon understood it could not manage technology development on a basis of trail-and-error, as had happened in the past with train operators. The industry today develops its products on a non-linear system of multi-level players, contrasting with the linear system at the time of train operators.

Societal embedding became the industry's top management "strategic intelligence" tool (Smits, 2008) to anticipate "integration" of new technology in train operations and markets; to assure "admissibility" according to regulations; and to foresee "acceptance" by customers and end-users (Rip 1997, 131). This way, top management expects to increase acceptance of their technology decisions by the public, clients and governments as a means to mitigate market failure and ensure a return on their investment.

As it will be put to evidence by this article, societal embedding in the form of technology assessment is practiced by the industry from the earliest stages of the technology development process through collaborative R&D projects, scientific papers, conferences, workshops, trade shows, training sessions and, most recently, consultations in social networks. One could argue the extension and effectiveness of such societal activities carried out by the industry, but that would have to be based on findings from a different study, yet to be conducted. Moreover, this could only be done properly if the industry were to have an institutionalized model for such practices, which is not the case.

¹⁷ Technology trajectory in the industry ranges between three to five years from technical development to final product; and four to five years from responding to a tender to its final commercialization (cf. UIC, 2010).

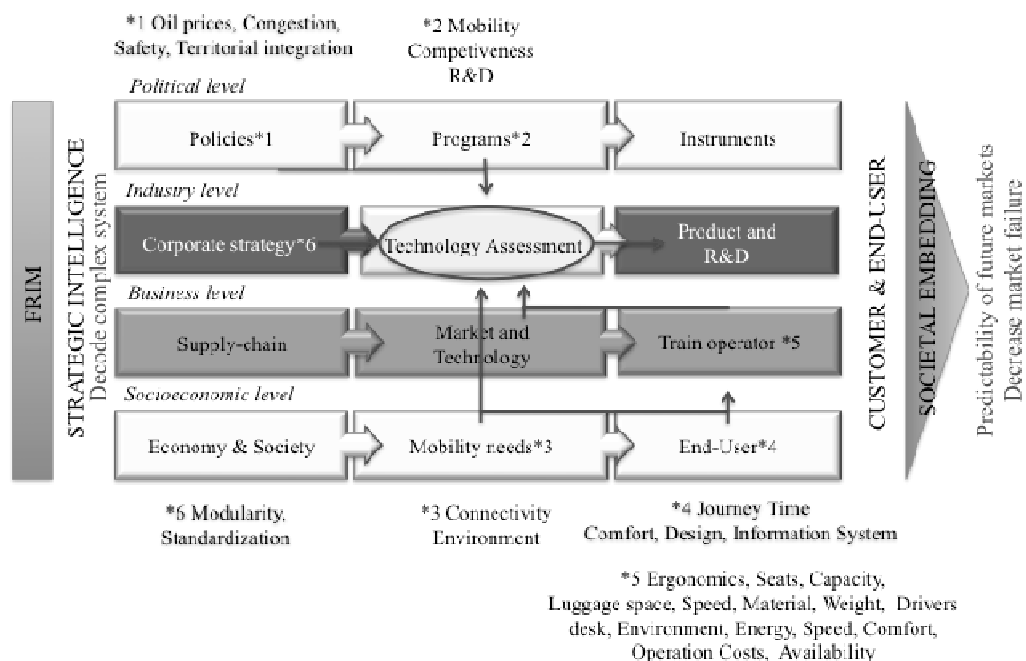
Contextualization

The contextualization of societal embedding as means of technology assessment of the innovation management system in the high-speed train manufacturing industry is part of their corporate strategic intelligence. Besides it, one has to consider technology forecasting, technology foresight, evaluation and road mapping. Such classification anchors on the theory presented by Smits *et al.* (2008) which also presents technology assessment functional elements, such as task focus to support decision-making, problem-orientation and intensive interaction with a wide variety of actors.

Strategy level

The figure below aims to showcase the function of technology assessment within the high-speed train manufacturing industry's strategic intelligence system.

Figure 1. Technology assessment within the high-speed train industry



As Figure 1 shows, technology assessment is found at the industry level, functioning as a filter for external constraints – at policy, socio-economic and business levels - to be then considered by top management in the technology development process.

This function is also described in Rip (1997) as the behaviour of firms towards the “external environment” in which a new product has to survive. Rip identifies three levels of constraints “business environment”, “regulation environment” and “wider society”, which correspond roughly to the terminology of Figure 1, as follows: business level constraints, policy level constraints and socio economic level constraints.

Continuing with the description of Figure 1, at the policy level (top of the matrix), technology assessment filters governments’ policy drivers, such as decreased oil dependency, climate change and territorial integration, as a means to anticipate programmatic and regulatory constraints, such as specific norms targeting noise reduction or increased safety of high-speed train vehicles and funding to develop technological solution. In Figure 1 at the socio-economic level (lower extreme of the matrix), technology assessment aims to decode future mobility trends, in terms of connectivity and environment for instance; and, end-users’ expectations, such as journey time, comfort, design, and information system.

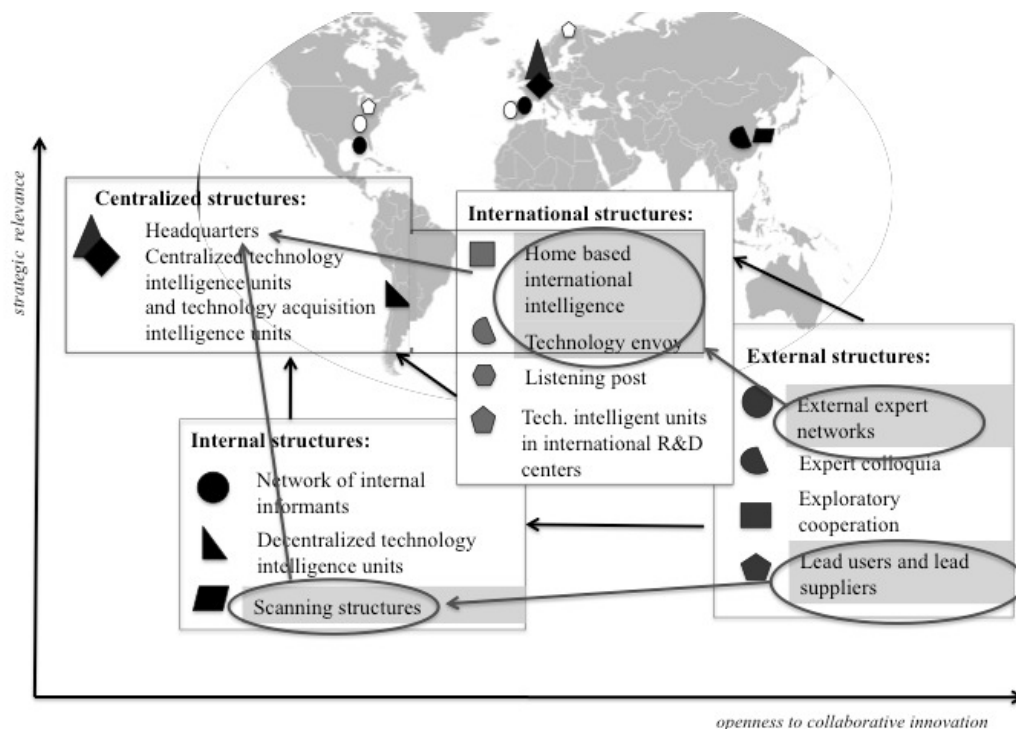
At the business level (lower middle part of the matrix), technology assessment filters market and technology constraints. At this stage, the industry aims to decode the market structure and anticipate clients’ technical specifications, such as train capacity and information systems. It is also used to detect new innovation trends within and outside the sector, from component suppliers and knowledge centers, for example.

Finally at the industry level (high middle part of the matrix), technology assessment addresses the industry’s own constraints, such as corporate strategy, product development and assembly. At this level, technology assessment aims to select all the internal elements that condition technology decision-making, such as cost-reduction, standardization and modularity. Figure 1 shows technology assessment as the central element at the industry level, which translates all the external societal constraints as part of a non-linear complex system, from the above mentioned levels, which, after consideration from top management are embedded in the product development process. It functions as an alert mechanism to new policy and normative initiatives, new customer specifications and changes in end-users’ mobility patterns. It also functions as an instrument to anticipate the socio-economic impacts of technology.

Organisational level

Technology assessment informally couples onto the existing strategic intelligence support structures and member staff, as well as to their links with external actors, from business industry, train operators, academia, governments and society (see Figure 2).

Figure 2. Technology intelligence organizational process



As highlighted in Figure 2, only some of those existing structures performed technology assessment activities, such as scanning structures, external expert networks, lead users and lead suppliers, home-based international technology intelligence and technology envoys.

Such structures have a common task focus: on support decision making (reporting to top management in the headquarters or subsidiary), problem-orientation and intensive interaction with a wide variety of actors, using formal and informal communication channels with internal or external information structures (Moretto 2011).

Scanning structures are part of the industry's internal organization, which integrates top management of the subsidiaries. They perform technology assessment activities at the local level, mainly as a means to anticipate the customer train operator specifications, but also to scan for the socio-economic and technological constraints, such as employment requirements, local policies, specific societal characteristics, norms, etc. The activities are performed by the high-speed train manufacturing industry with the national based suppliers, universities, train operators, certification bodies, associations and lead-users, on a project basis approach. They range from simple scanning on market conditions, as can be seen in the organization of a workshop, to the complexity of customizing the train to the local market, using R&D collaborative projects.

Home-based international technology intelligence and technology envoys are part of the industry's international structure. Despite their technology orientation as in the case of centralized technology units, their main focus is to support decision making based on a problem or project orientation in an intensive interaction with a wide variety of actors, at regional or national levels. These structural elements, at national levels, can overlap with scanning structures. Home-based international technology intelligence is located at the central intelligence unit, usually in the same country as the headquarters, responsible for scanning proactively for relevant information from all the other organizational structures, involving visiting those structures around the world and demanding information. Similarly, technology envoys are workers sent to a specific market to build up an external network with the local clients and institutions in cooperation with the scanning structure.

External expert networks are external to the high-speed train manufacturing industry, such as the European Rail Research Council (ERRAC)¹⁸, the Association of the Railway Manufacturing Industry (UNIFE)¹⁹ or the International Union for the Railways (UIC)²⁰. Such structures are useful to identify possible technology directions and future scenarios as they host discussion forums involving all the concerned actors. They periodically release technology or market outlooks, issue visions papers, elaborate strategic agendas and implementation road-maps and are coordinators of collaborative research projects addressing specific policy programs. At this level, information on trends is quite openly shared and has a long-term perspective. The instruments used are the ones found in other structures such as meetings, R&D projects, site tests, certifications and future exercises.

Lead users and lead suppliers are external to the industry. These are often invited to workshops, as external experts, informing openly on trends and benchmarking. The previous could be seen as a contribution to Rip (1997), as the

¹⁸ ERRAC is the European Technology Platform for rail. This technology platform thinks about the future technology and market trends for the rail sector, also involving competitor industries. Link: <http://www.errac.org/>

¹⁹ UNIFE is the Association of the European Rail Industry. It directly represents European companies responsible for the design, manufacture, maintenance and refurbishment of rail transport systems, subsystems and related equipment towards the European Institutions. Link: <http://www.unife.org/>

²⁰ UIC is the International Union for Railways. It represents the train operators and major infrastructure managers from all over the world. Its mission is to promote rail transport at world level and meet the challenges of mobility and sustainable development. <http://www.uic.org/>

author does not detail the organizational structure of technology assessment; rather, he limits to mention that the managers of industry are those who perform it.

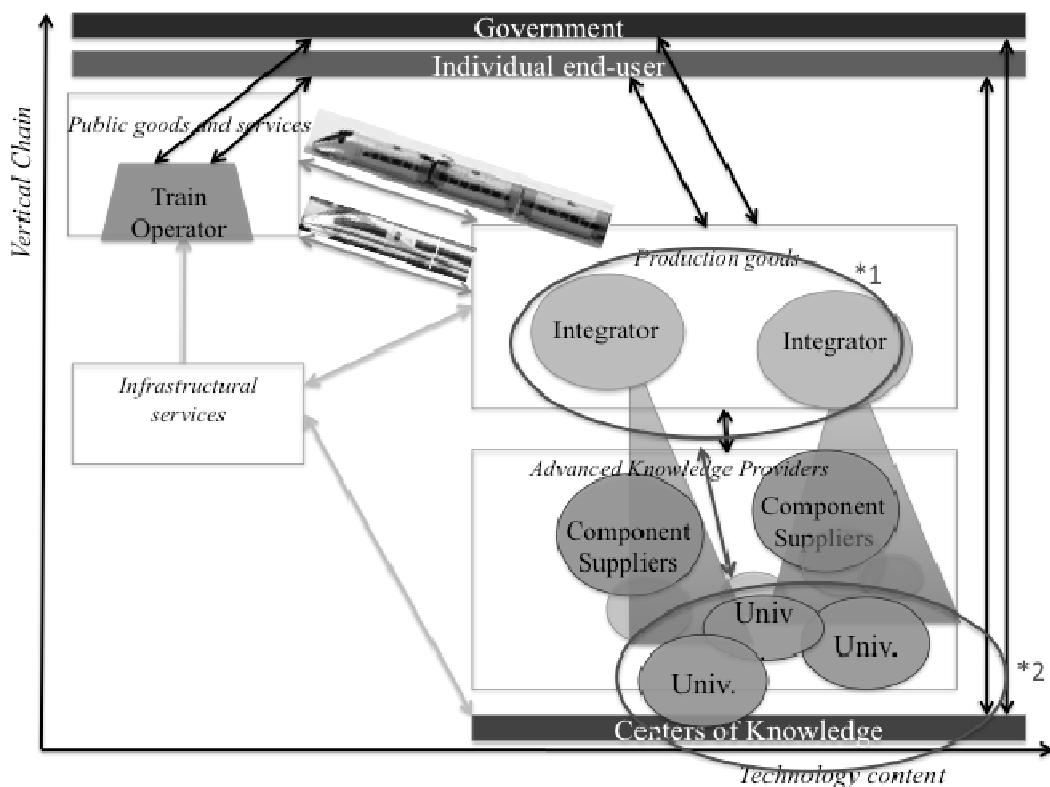
Approach

The main elements of constructive technology assessment (Rip, 1997), as described before in section 1, are found in the different technology development levels of the high-speed train manufacturing industry: system, product and technological and commercial trajectories.

Systemic level

The figure below helps to illustrate the evidences of societal embedding in the product development process at the systemic level, covering complex and multi-actor relations.

Figure 3. Multi-actor interaction pattern



At the systemic level, as shown in Figure 3, knowledge exchange, between the high-speed train manufacturing industry (Integrator*1) and other actors from different technology regimes, occurs vertically, assuming the form of pyramids (Moretto, 2011). Those pyramids are formed by the alignment of stakeholders, part of the supply chain, from the moment in which prospects of a business opportunity in a specific market arise (i.e. a order for trains). The pyramid formations can change from market to market; and component and sub-contracted knowledge suppliers (for example Tire 2 or Knowledge Centers) can appear in more than one pyramid formation.

It is up to the pyramid leader, usually the high-speed train manufacturing industry, to collect the customer's (i.e. Train Operator) requirements. Due to the technological complexity of the high-speed train and the number of actors involved, as well as the complexity of preparing an offer, it is common that the train manufacturer wishes to have access to the tender specifications as early as possible. But, as this is not always possible, the industry uses technology assessment to anticipate it.

Moreover, the industry also uses technology assessment to anticipate end-users' expectations, political and market conditions (including certification processes), or even to scan specific technology solutions being developed locally.

Universities (Uni.*2) and knowledge centers are industry privileged partners for such technology assessment activities at the systemic level, as they are direct sources of local constraints. Often Universities have direct relations with governments and local technology providers and are sources of specific advanced knowledge.

Product level

The figure helps to illustrate the evidences of societal embedding in product development process at the product system level.

Figure 4. Product system

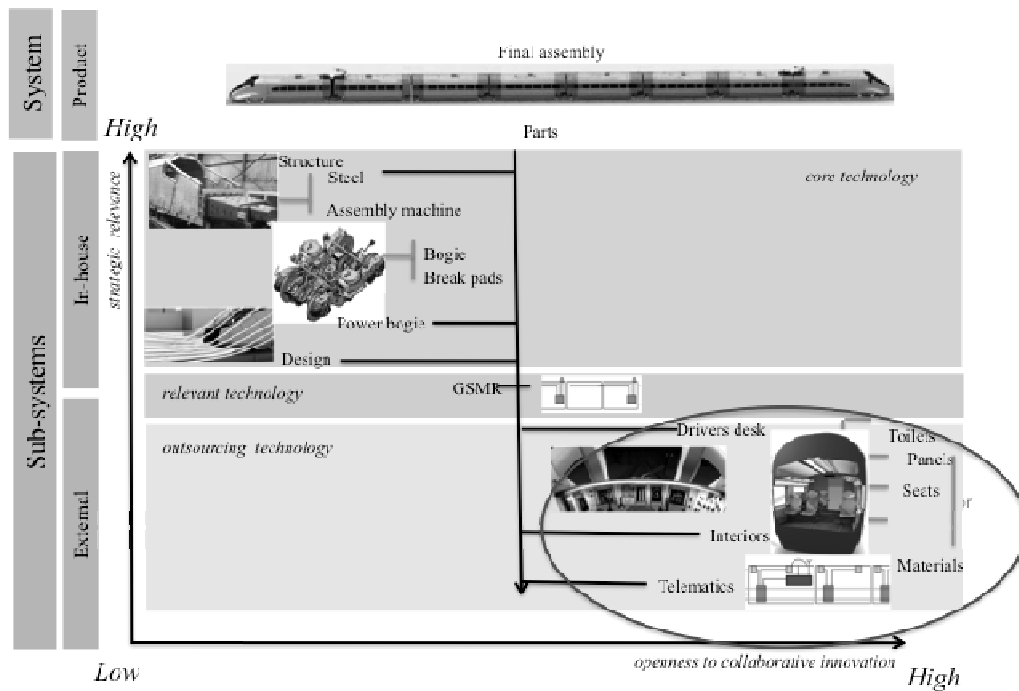


Figure 4 shows the high-speed train as a technology system, integrating sub-technology systems and components at different levels of technology intensity and openness of innovation (core technology, relevant technology, outsourcing technology).

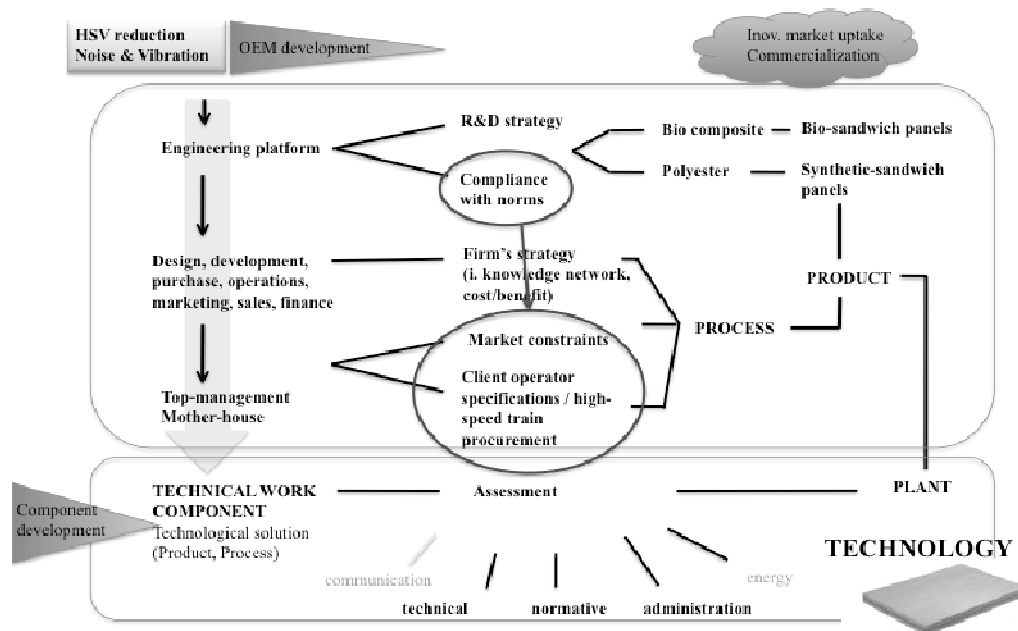
The high-speed train manufacturing industry assumes a top position in the product tree, meaning it has the task of assembling all the technology solutions in the train, and has the final decision on the technologies to integrate based on the customer expected specifications.

Technology assessment is therefore used by the industry, mainly at the level of non-core technologies (such as interiors and telematics), usually tailored to achieve defined outcomes or to make the train more attractive. The industry promotes collaborative research at strategic level, which includes a user group formed by end-users, customers, certification bodies and other relevant entities. It mainly occurs in the world region of the client, promoted by the technology envoy or subsidiary scanning structure.

Technology trajectory levels

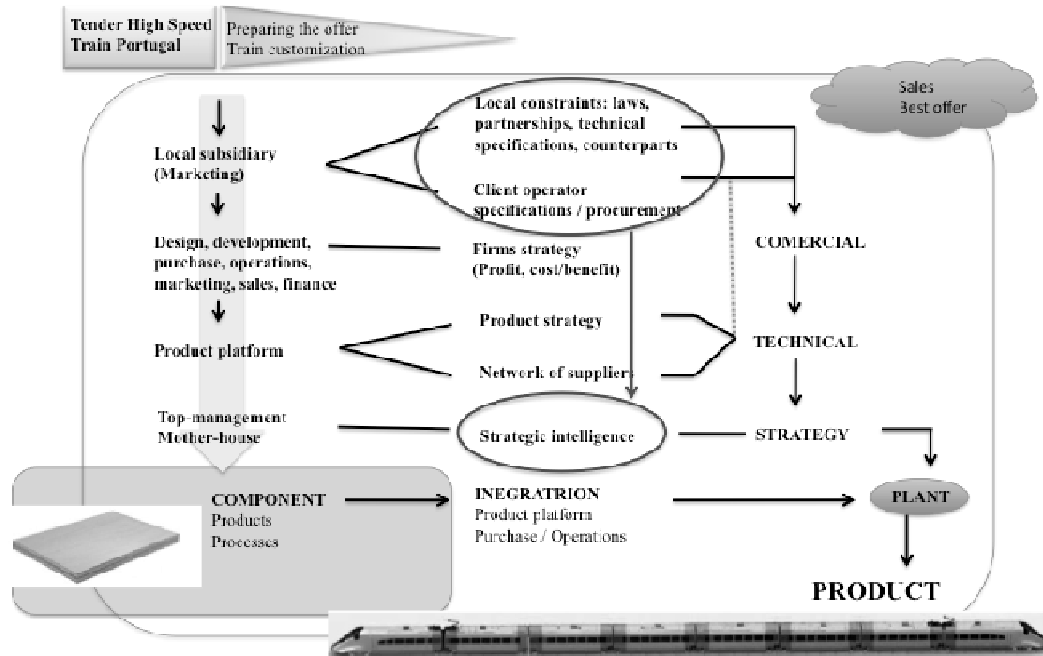
We can identify two technology trajectories of product development: technological and commercial. Technology assessment activities are mostly performed when the two trajectories meet, supporting top management's final decisions on the technology development options for the high-speed train, by adding societal information, collected at strategic intelligence level, to the technical and commercial ones. However, both trajectories also have in their process societal embedding, performed at some stage technology assessment activities, as now shown in the two figures below.

Figure 5. Technological trajectory



At the technological trajectory level, technology assessment might be performed by the engineering team, with exploratory contacts with local universities and component suppliers, to solve a technical problem, especially if they are from a lead market or are a lead supplier. However, technology assessment activities of this trajectory mainly occur at top management level when confronted with the final decision whether to integrate or not the technology solution in the train. Top management generally uses information from home based international intelligent units to confront the technology solution developed by its team of engineers with technology mega-trends. Top management can also use information from technology envoys, scanning structures and external structures, in targeted markets (lead markets or potential markets), to check whether the technology developed in-house meets specific market constraints and the expected procurement specifications.

Figure 6. Commercial trajectory



At the commercial trajectory level, technology assessment is performed with the high-speed train manufacturing industry promoting local actors' participatory and constructive activities as means to collect end-users and clients' information on the technical and socio-economic elements of procurement. Then, the results of this exercise are embedded in the technology development of the high-speed train vehicle to be offered to the concerned train operator.

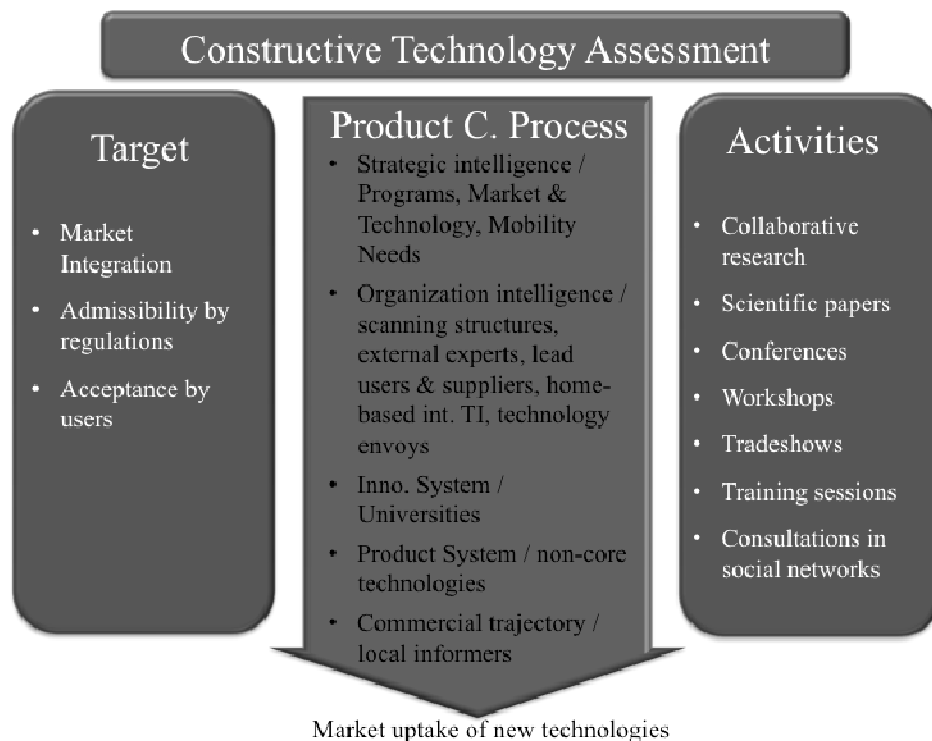
The local subsidiary, as a scanning structure, in interaction with local informers and universities, promotes participatory and constructive activities to anticipate customer's technical and socio-economic elements of procurement and end-users' expectations.

Top management, in turn, uses technology assessment to match technical developments of the high-speed train with commercial specifications given by the subsidiary.

Conclusions

From what was described before, if even we do not identify the dominant technology assessment perspective within the high-speed train manufacturing industry, it is easy to conclude that, from all the different technology assessment approaches found in literature²¹, it matches with the elements of constructive technology assessment as defined in Rip (1997), represented in Figure 7.

Figure 7. Constructive Technology Assessment and high-speed train industry societal embedding practices in product development (construction) process



According to Rip (1996, p. 251), constructive technology assessment attempts to address societal issues from an early stage of “product construction process” (PCP) by influencing its design, development and implementation practices, through dialogue and early interaction among actors (other than governments). According to the author, such activities target “integration in relevant industries and markets” (i.e. Market integration in Figure 7), “admissibility according to regulations” (i.e.: Admissibility by regulations in Figure 7) and “acceptance by the public” (i.e: Acceptance by users in Figure 7). As Rip (1997, p. 255) further

²¹ Rip (1996, p. 251), presents a summary of technology assessment approaches and concerned authors. Wikipedia (http://en.wikipedia.org/wiki/Technology_assessment) also presents a summary list of technology assessment functions and approaches.

continues, constructive technology assessment allows the translation of broader societal scenarios and agendas into actual design criteria for technology development with the ultimate objective of market uptake of new products.

In our research we try to add to Rip's work the application of constructive technology assessment to the high-speed train manufacturing industry. As it was covered in this article and shown in Figure 7. (central column) this practice is held at the strategic intelligence level, informally anchored in its existing organizational structures and networks of external experts, performed at different levels of product development process (PCP according to Rip, 1997), such as innovation and product systems, at the technical and commercial trajectory.

Technology assessment is not an institutionalized practice in the high-speed train manufacturing industry; rather it is practiced on an informal basis by the existing strategic intelligence's organizational structures and depends on personal engagement, mainly from top management to be performed. Moreover, the study does not cover technology assessment practices by other stakeholders and their interrelation with the manufacturing industry.

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