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Are railways ready for technologically capable societies?

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Abstract

There is an observed exponential technological capability of society resulting from digitalisation. BlablaCar-sharing in a short time impacted SNCF high-speed trains service. Are railways ready to embed new societal actors in their value chain? Our study reveals that despite this industry strategic intents it lacks formal practices allowing reciprocal knowledge exchanges to occur throughout the technology development process. Therefore, missing the opportunity to add value from society. This way, by recurring to constructive technology assessment theory, we propose a set of measures to be considered by the sector collectively under the scope of Shift2Rail. They center in ensuring that reciprocal knowledge exchanges occur. Initially in shared future visions and later within technological research projects. Through curated events, safeguarding a minimal risk for the industry, paying attention to tailoring knowledge exchanges to the respective technology readiness level and relying on a third-party orchestration provided by technology assessment practitioners.

Keywords: innovation management; technology assessment; knowledge exchanges; digital society; high-speed trains

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1. Society changing capabilities and demands

Society is gaining from digitalisation an unprecedented and exponential technological capability reflected in new mobility demands. Some of which proved capable of impacting large incumbent industries as high-speed trains. BlablaCar in France for example. The car-sharing application was developed in 2003 by a young traveller unable to arrive at its destination by TGV. A few years later the application was capturing a significant market share from the French high-speed train operator SNCF.

This event caught European railways under pressure to get returns from a decade of massive investments in collaborative research developing the AGV and ICE-350E (or Velaro), introduced in 2008 and 2006 respectively. These vehicles embedded technologies from industry alignments at an unprecedented scale. They responded to the foreseen European Union regulatory pressures (COM (2001) 370), of a liberalised trans-European railway market requiring the trains to be modular, interoperable, safe and environmentally friendly.

Societal innovations from digitalisation brought additional competitive pressures. They extended traditional technology selective environments from business and regulations to society and reinforced the relevance of society in rail networks and collaborative research.

Years have passed since and statistics continue indicating that the high-speed train industry is still addressing society as business as usual. Marketing and branding campaigns continue surpassing research and development. They miss reciprocal knowledge exchanges with the emergent actors.

In this paper, we present results from our study further enquiring on the actual readiness of the high-speed industry to embrace these new societal actors in their collaborative research and development process. We also list a set of recommendations and practical measures to be considered by the value chain within Shift2Rail.

2. Theoretical references

From the various strands found in Technology Assessment (TA), addressing technology and society, we mobilise Constructive Technology Assessment (CTA), with origins in the nineteen-eighties in the Netherlands regarding biotechnology and nanotechnology sciences. CTA functions as anticipation, reflection and intervention feeding back insights from a wider network of actors into the design of new technologies even before they emerge. It is suited for strategic management of rapidly evolving and uncertain value chains (Rip 2001, Parandian 2013, van den Ende et al. 1998).

The extended networks described in CTA have an actor element, including more stakeholders with a variety of roles to the process of technology emergence, and a chronological element, bringing together players from upstream, midstream and downstream in the value chain.

This approach can be said to temporarily remove the chronological bias regarding the power to shape technological development, including its directions and adaptations (van den Ende et al. 1998).

CTA often positions as a way to overcome the institutionalised division of labour between promotion and control of technology (Rip and Te Kulve 2008, Robinson, 2010), known as the Collingridge dilemma (Collingridge 1980). It deals with the inherent asymmetries between impactors (insiders, at the source of the technology) and impactees (outsiders, impacted by the technology). Each with different powers, timings, interests and expectations (Parandian 2012, Robinson 2010).

To overcome complexities and uncertainty that brings, CTA proposes bridging events between actors (Parandian 2012), orchestrated by a third party, to explore each assessment world (supply-chain plus in Robinson and Propp 2007), and ultimately arrive at socio-technological scenarios of aligned visions (Parandian 2012, Robinson 2010).

It applies to a particular technology in two steps (Schot and Rip, 1997). The first concerns the analysis, aiming at setting the scene through problem identification, the determination of technological development phase, actors involved and their expectations. The second is about practices of intervention guiding future technology formulations with society embedded.

The analytical approach requires to be informed (Moretto 2017) by the study of the elements of technical change, tracing the evolution of the innovation journeys (van de Ven 1999, Rip 2012), actors multi-level perspective (Geels 2002) and its dynamics (Parandian 2012).

While its practices of intervention include socio-technical scenarios (Rip and te Kulve 2008, Parandian and Rip 2013), or expectations mapping (van Merkerk and Robinson 2006), it can also include open-ended roadmaps

(Robinson et al. 2013), multi-stakeholder workshops (Krabbenborg 2013), bridging events (as formulated by Robinson 2010, p. 13) and also backcasting (Schippl 2008).

In our study on the high-speed train technology development process and society, we mobilise CTA analytical framework (Schot and Rip 1997, Robinson 2010), leaving for a future research CTA practice-oriented exercises. To contextualise data, we recurred to technology transitions visualisation map (Geels 2002) and to modulate data we turned to innovation journeys (Deuten et al. 1997), value chain multi-level alignments (Geels and Schot 2007) and futures formulations methods (Propp and Robinson 2007). We have validated our findings with an online survey to the relevant stakeholders.

3. Findings

3.1. Society within technology transitions

Alstom AGV and Siemens ICE-350E represent the latest generations of commercialised high-speed trains. They were introduced in 2008 and 2006, respectively, resulting from incremental innovations to the previous two generation of trains. The application of Geels (2002) technology transitions mapping allows visualising the events that pushed for the technological transformations of those trains and locate possible societal pressures within.

The visualisation map was initially developed by Geels to contextualise technology transitions in the shipping industry, based on Rip and Kemp (1998) and Schot (1997) analysis of the levels of technology changes. The map sets three arenas where events leading to transitions may occur: the landscape (where policymakers, society and other actors from different sectors); the regime (where the technological value chain); and the niche (where new specialised providers of technology). Events attributes vary. They can be hyper-turbulence pressures, specific shocks, disruptions, regular changes or avalanches of events. They can be exogenous or endogenous to the technology regime and they can disrupt or produce incremental technology changes.

For the purpose of our study we completed Geels maps with historical data form authors as Constant (2006), Giuntini (2011), Meunier (2002) and Keseljevic (2015). The result is presented in figures 1(a) concerning the AGV and 1(b) the ICE-35E .

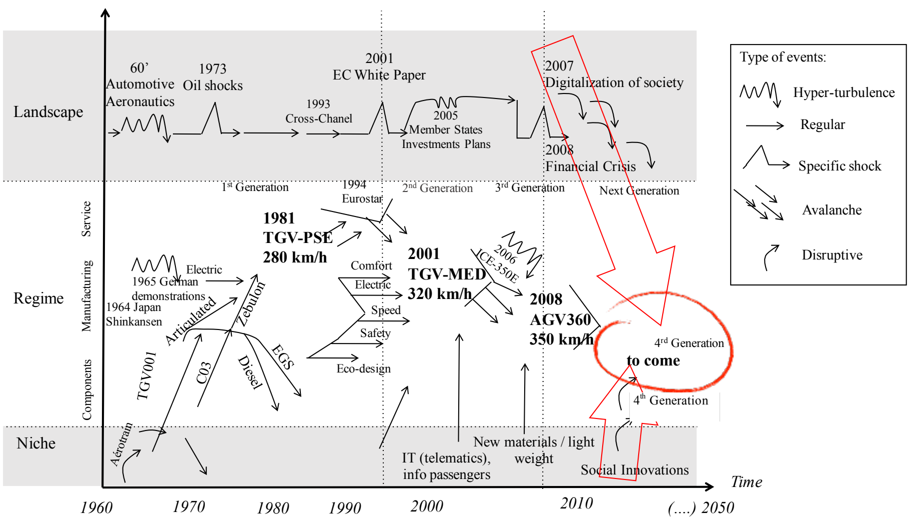


Fig. 1(a). Societal pressures during the TGV/AGV technology transitions (Moretto 2017).

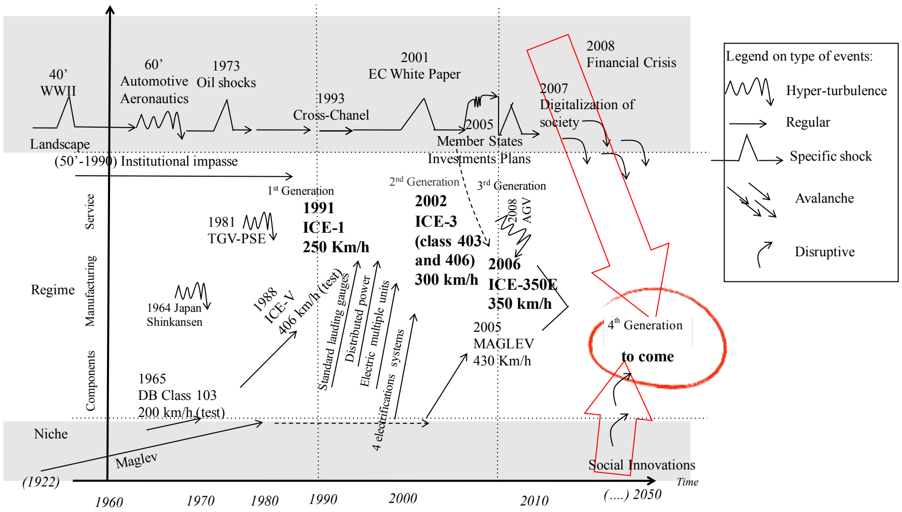


Fig. 1(b). Societal pressures during the ICE technology transitions (Moretto 2017).

Figures 1(a) and 1(b) reveal for both trains similar events driving technology transitions, with society emerging later in 2007 from digitalisation impacting the latest generation of high-speed trains, as described below.

The first generation of trains, TGV-PSE in 1981 and the ICE-1 in1991, were the result of a tactic response from France and Germany governments to occurred events at the landscape such as the Japanese Shinkansen, advancements in automotive and aeronautics, congested railway networks and the energy crisis. This last one was determinant in the selection of incremental technology options for the high-speed trains in detriment of radical solutions in development at that time.

The transition to the second generation of trains, the TGV-MED in 2001 and the ICE-3 in 2002, followed the same path of tactic responses to pressures, this time, emerging at regime level. The French and German operators, SNCF and DB, aligned with their flag manufacturers Alstom and Siemens to overcome technology failures and respond to different specifications to run the trains in the neighbouring networks. Technology transitions resulted in incremental hardware technological improvements to the previous generation of trains.

The technological transition to the third generation of vehicles, with the AGV in 2006 and ICE-350E in 2008, took a different direction. The industry shifted to anticipatory responses due to the regulatory pressures integrating and liberalising the trans-European railway market (COM (2001) 370 final). They lead to incremental improvements in soft aspects of technology, covering interoperability, modularity, sustainability and safety.

The fourth generation of trains is yet to come. Most likely it will result from digitalisation inherent societal pressures, which have been producing since 2007 a series of disruptive events at landscape and niche regimes, capable of impacting the existing generation of high-speed trains. They confer relevance to the social aspects of technology, creating a wave of unprecedented regime conditions and reinforcing the anticipatory nature of strategic decision-making in this industry.

3.2. Society within manufacturers technology strategy

The design, development and assembly of the third generation of high-speed trains, the AGV and the ICE-350E, disrupted by societal pressures were found in hands of the European manufacturers Alstom and Siemens as result of the European railway reforms set in 2001.

Like today, manufacturers were large incumbent multinationals developing the trains in collaborative networks, supported by strategic innovation management tools to decode the complex system in which they commercialised the trains. Their clients, train operators of high-speed train services, were preparing for the liberalisation of the market set to happen in 2010.

To understand Alstom and Siemens strategic management alignments with society we recurred to Deuten et al. (1997) model on the elements of the extended technology development process. Authors argue that new technologies to succeed are required to align simultaneously with business, regulatory and social environments of selection from early stage in the technology development and they provide a list of required activities for alignments to happen. Based on that we elaborated a visualisation map, as shown in figure 2, completed with data collected from Alstom and Siemens annual reports and informal interviews to informers at the companies.

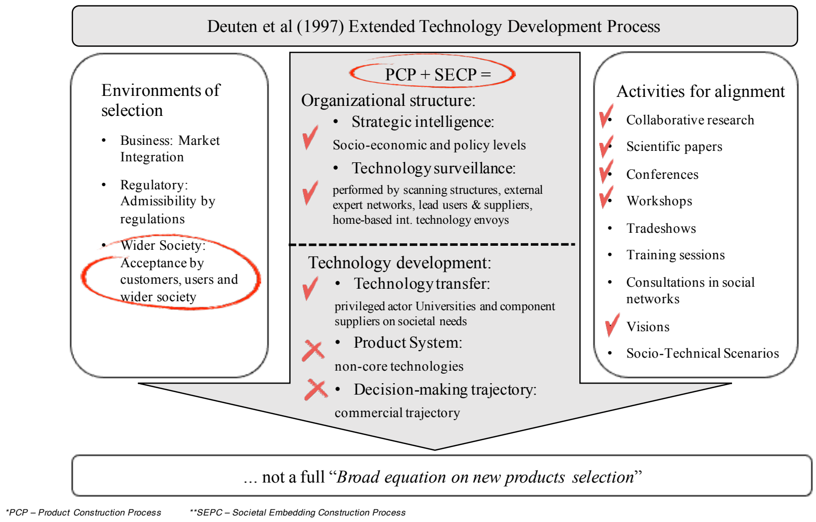


Fig. 2. Societal embedding in the strategic formulation of Alstom and Siemens during the development of the AGV and ICE-350E

Figure 2 reveals that found strategic alignments with society during the development of the AGV and the ICE-350E were limited to preparing the vehicles for commercialisation.

In the right column, on the environments of technology selection, it can be observed that Alstom and Siemens were pursuing society as means to cope with acceptance by customers, end-users and the wider public. They were concerned about the increasing professionalisation of social groups, such as environmentalists or consumer associations, influencing policy agendas and regulations.

In the central column, on strategic intelligence, Alstom and Siemens alignments with society occurred when preparing the trains to enter a market and related to non-core technologies, such as interiors and telematics. The subsidiary of each manufacturer interacted with local informers and promoted local participatory activities to collect customers and societal values and expectations that could add value to the trains and adapt the trains to the local needs.

In the same column, its seen that knowledge exchanges about society were held by the manufacturers' technology envoys and employees at the subsidiary with external experts mostly from academia and component suppliers. Alstom and Siemens promoted activities of social alignments ranging from workshops to support research projects.

3.3. Societal actors in the industry value chain multi-level perspectives

Alstom and Siemens developed the AGV and the ICE-350E in a different technology pattern of stakeholders' alignments from one of the previous generations of trains. Collaborative alignments dominated involving external actors. While for the previous generations they were bilateral with the costumer and vertically integrated.

To understand it in relation to societal actors we applied Pavitt taxonomy of innovation (as revised by Castellacci 2008) in combination with Geels and Schot (2007) levels of system innovation. Data was collected from the annual reports and position papers from the European Rail Research Advisory Council (ERRAC), the Association of the European Railway Manufactures (UNIFE) and the International Union of Railways (UIC).

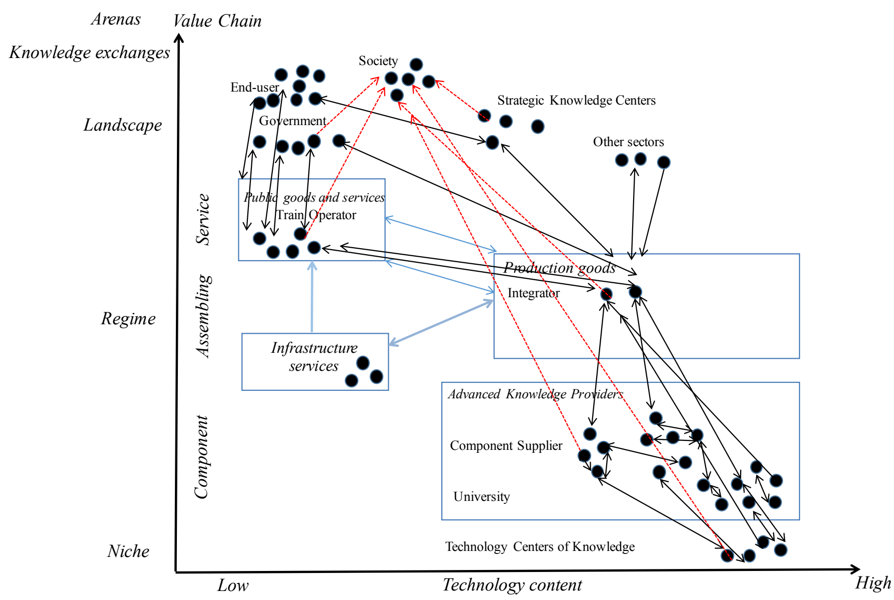


Fig. 3. Societal embedding railways knowledge exchanges during the development of the AGV and ICE-350E

In figure 3 it can be found that societal actors at landscape, mainly non-governmental groups and specific interest groups not technological oriented, were marginal to the dominant technology exchanges occurring at the regime arena between manufacturers, component suppliers, train operators and academia. When developing the AGV and ICE-350E stakeholders were aligning in response to the 2001 White Paper on Transport. At pre-competitive stage knowledge exchanges were dynamic, reflecting vague dependencies and exploratory interactions. Technology transfer was directed at anticipating major technology opportunities in the medium future.

Through alignments actors envisaged to anticipate others technology capacity and interests. For that they recurred to collaborative research projects, market analysis and survey their competitors. Information was flowing quite openly, but its disclosure was selective. Competitors could in the same research project, as for example in non-core technologies or relevant technologies to the setting of share standards. At the competitive stage, when preparing to enter a market, multi-stakeholders alignments and knowledge exchange revealed the form of a pyramid, reflecting tight dependencies and established interactions. At the top of each pyramid was the consortium leader, e.g. Alstom or Siemens as technology integrators for the specific case of the AGV and ICE0-350E.

It was observed that Alstom and Siemens, to overcome the complex multi-actor relations as described, practiced strategic intelligence in the terms already seen. They aimed at identifying actors' interactions and potential dependencies as well as unveil technology interests and capabilities; even in the anticipation of end-users' expectations, while addressing political and market conditions (including to a certain extend tender specifications and certification processes); or even to scan specific technology solutions being developed locally in the medium and long term.

With the advent of digitalization of society, from 2007, new technological actors are emerged from landscape and niche arenas external to railways regime where referred alignments were occurring. That imposed extending railways knowledge to the arenas of action where society is found and align with the new actors' own interests and expectations.

3.4. Societal actors within future agendas

As mentioned, railways shifted to a strategic management of technology in response to the 2001 White Paper on Transport, pushing for a trans-European high-speed train. Stakeholders aligned their visions and roadmaps in a surge of reports.

The European institutions commissioned STOA scenarios (2005, 2013) and TRANSvisions (2009). The railway value chain clustered in the European Railway Technology Platform ERRAC also produced a series of visions (2001, update 2011), agendas (2002, 2007) and roadmaps (2012). The industry association of manufacturers and suppliers UNIFE presented market outlook (2006, 2008, 2010, 2012 and 2014). Also, train manufacturers as

Siemens made public their images of the future (2006, 2009, 2010 and 2011). To assess societal actors' involvement within we recurred to Robinson and Propp (2011) classification table. We studied such reports methodology, objectives, outcomes, nature, purpose, type of stakeholders involved and their approach, if endogenous or exogenous to the railways.

Table 1. Classification of future reports covering the high-speed train system

Report	Year	Function	Stakeholders	Method		Objective	Outcome	Nature	Approach
STOA Scenarios	2008, 2012	Policy-making	European Parliament; Third Party assessment; External Experts from academia and policy	Social Science analysis	Backcasting	Functions of expectations, relations between emerging and incumbent technologies	Connections between technologies and grand challenges are mediated; They emerge from interactions between technical and society factors; resulting in shared future paths	Prospective	Exogenous
TRANS visions	2009		European Commission; Third Party assessment; External Experts		Delphi				
ERRAC Visions	2001, 2011		ERRAC Secretariat; ERRAC Members (UNIFE, CER, EIM, Industry, EU Member Sates)	Rational of expectations mapping	Workshops (Plenary)	Endogenous futures (techno-centric) and enabling conditions	Ongoing interactions in areas of concern	Descriptive	Endogenous
ERRAC Strategic Agendas[1] Roadmaps[2]	2000[1], 2007[1], 2012[3]	Strategy-making		Techno-organisational mapping	Working Groups	Actors activities and capabilities	Innovation Chain, horizontal and vertical links and emerging supply chains		
UNIFE Market Outlooks	2006, 2008, 2010, 2012, 2014		External consultant, UNIFE secretariat, Members from the Industry		Forecasts				
Siemens Futures	2006, 2009, 2010, 2011		Internal		Vary from scenarios, science fiction, forecasts				

In table 1 societal actors are found marginal across the various reports. The dominant endogenous reports, from ERRAC and UNIFE, aligned the value chain techno-centric futures at regime level. They served stakeholders' strategic purposes of technology promotion and control in future policies, regulations, standards and market acceptance.

With manufacturers in their lead, they aimed the selection of promising technologies, guarantee engagements and ensure envisaged technological directions. They presented a narrative format, communicating the industry capabilities, expectations and values and areas for mutual knowledge exchange.

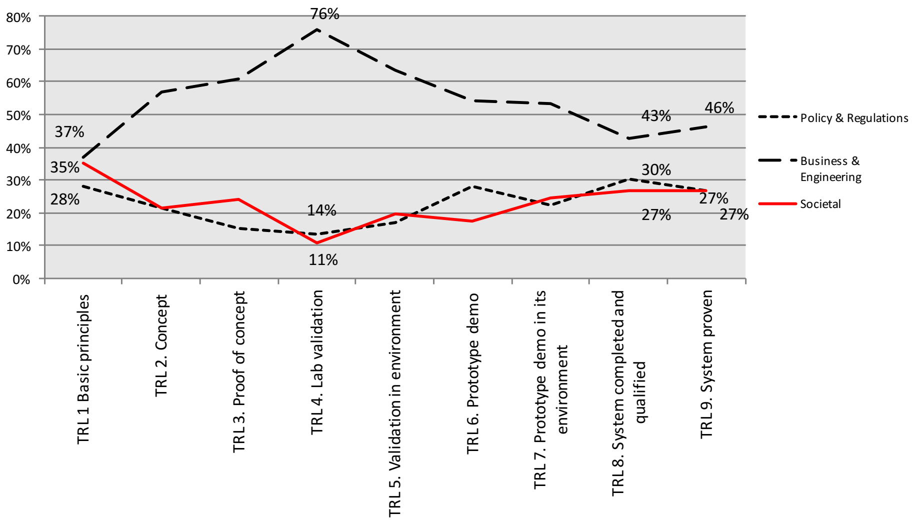
A striking example is ERRAC vision (issued in 2001 and updated in 2011). It was influential in the selection of technologies funded by the European Commission 6th Framework Programme for Research (FP6). The AGV and the ICE-350E embedded resulting collaborative research projects as MODTRAIN (modularity), EUDD (interoperability), RAILENERGY (sustainability) and Safeinteriors (safety).

Society was also marginal to the two reports exogenous to the railways commissioned by the European Parliament and the European Commission at the landscape. STOA and TRANSvisions served policy-making, legitimising technology options. Their prospective nature was aiming at improving the understanding of possible cause-effect relations in a broad sense within high-degrees of uncertainty. Stakeholders involved were mainly from academia and policy.

Technologically capable societal actors, from the 2007 digitalisation, convert such findings into a pressing issue for the railway industry and policymakers. They need to revise their reports methodologies to encompass and speak to these new actors.

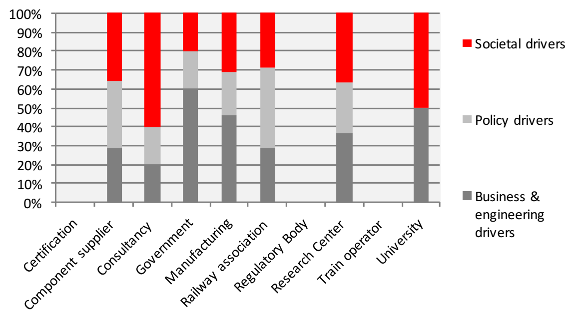
3.5. Survey validating results

Based on the previous findings we conducted an online survey (Moretto, 2017) accounting with the participation of seventy-four stakeholders from the high-speed train supply chain (e.g. train operators, manufacturers, component suppliers, infrastructure suppliers and managers, users, policymakers, regulatory and certification bodies, railway associations, consultancies, academia and research centers). They were selected from European projects database, members of railway associations and ERRAC working groups. The survey confirmed our preliminary findings on the industry alignments with society mostly occurring during strategy making then during the technology development process.

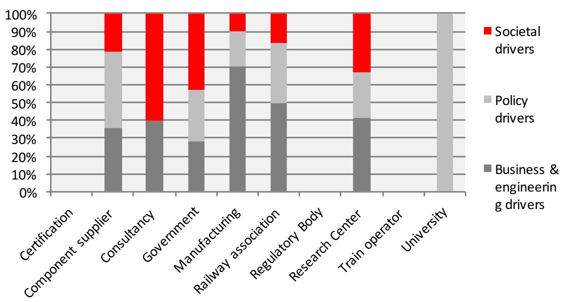


Graph 1. Technology drivers at each technology readiness levels (TRL)

As graph 1 demonstrates, societal drivers for technology change are at its high during TRL1 when basic principles and constraints are collected, corresponding to the strategic planning. Then they lose relevance as requirements for alignment during the actual development process is in place. In particular, in TRL4, when the technology is validated in laboratory. They regain relevance later in TRLs 8 and TRL 9 when the technology is being prepared to enter the market.



Graph 2(a). Technology drivers at TRL1 by stakeholder



Graph 2(b). Technology requirements at TRL8 by stakeholder

In figure 2(a), braking down technology drivers by stakeholder at strategic level TRL1, we found consultancies and universities the most engaged in scanning for society. While in figure 2(b), at implementation level TRL8, we found governments the most engaged, which indicates a concerned about the societal impacts of technologies. In its turn consultancies and research centers revealed the same level of consideration found at strategic level.

When asked to railway stakeholders if they had an employee responsible for societal alignments, only railway centers and consultancies responded positively. Another relevant element confirmed by the survey is the one referring to endogenous practices in the formulation of future visions. The majority of stakeholders were referring to the reports released by railways and ERRAC visions.

4. Recommendations

Our study reveals that despite the high-speed train industry strategic intents to embed the emergent technology capable societal actors in their value chain it lacks formal practices allowing reciprocal knowledge exchanges to occur throughout the technology development process.

To overcome such shortcoming the industry needs to revise its current research and development management practices. Move towards stabilising design trajectories and reduce uncertainty and risk, by reviewing societal requirements and capabilities from early stages of their research until market uptake. Increase attractiveness to passengers and wider society, by constructive pre-engagements from societal actors and early identification of unknowns.

Overall it requires industry openness to consider society as a technological impactor capable of introducing innovations that may not relate at first with railways. Events for that to happen need to be curated to overcome the uncertainty and ambiguity societal involvement brings to an already complex development process. They should be tailored to suit the technology development level in which the research project is. They should be orchestrated by an experienced third-party, providing targeted and informed conditions to guaranteed impartiality, reduction of inherent complexities, reflexivity of actors' roles, mutual interactions and learnings.

Various types of third-party orchestration exist but it must be chosen with care as events should overpass marketing campaigns or public consultations. The industry should refer to technology assessment practitioners in academia, with acquired experience linking societal engagement to technology design and development processes. They bring their experience in other sectors overcoming techno-centric agendas and research projects.

Collaborative research and development projects, strategic platforms and operational organisations as Shift2Rail for their coverage of the value chain appear to offer adequate grounds to embed societal actors in the collaborative technology development process of high-speed trains. That can also happen on an individual level, by railway technological initiators as manufacturers, component suppliers and railway operators.

5. Application

Extending railway research to society is framed by the EU research policy objectives as stated in HORIZONS 2020, requiring the prioritization of research that responds to fast emergent societal demands. It is a guiding principle followed by Shift2Rail, ERRAC and rule for EU funded collaborative research projects.

Shift2Rail mandate sets the first collective strategic step bringing railway research closer to the market and therefore society, opening grounds for formalising practices of societal embedding during the technology development process. The regulation establishing Shift2Rail enhances ERRAC semantics by adding the adjective "radical" to the need of "enhance the attractiveness and competitiveness of the European railway system to ensure a modal shift towards rail". Also Shift2Rail Multiannual Annual Action Plan is featuring "extended stakeholders network". And the Annual Action Plan 2015 open call had a cross-cutting activity (CCA) on the "long-term needs of different actors in the railway sector" (S2R-OC-CCA-01-2015).

However, the mentioned Multiannual Annual Action Plan omits the necessary activities linking CCAs to the technology innovation programs (IP), as it could be with the IP4 on "IT Solutions for Attractive Railway Services" introducing the "semantic web for transportation", or with IP1 on the "Cost-Effective and Reliable Trains (including high capacity trains and high-speed trains)". These IPs are fostering solutions on digitalisation, big data and prospective market studies, related to the digitalisation of society. To overcome it, as a first step, Shift2Rail could call for a third-party study on the extension of the railway network to societal actors. It should identify them and map their technology visions, expectations and capabilities in respect to mobility and rail in particular.

Shift2Rail Annual Work Plan could then use the study results to prepare a CCA for the construction of socio-technical scenarios and roadmaps on technological areas experimenting societal innovations in railways. That should be leverage to technological large-scale demonstrator projects in the Shift2Rail Annual Work Plan. One way to do it could be for example with a work-package or a task where railway actors and relevant societal actors could be called to experiment and contribute to each other innovations. The technology readiness level (TRL) of the technology demonstrated would set the adequate approach for such interaction to occur.

ERRAC also offers an opportunity for the extension of railway research network to societal actors in ways that produce mutual interchanges. However, due to its mandate, it is limited to strategic agendas and roadmaps. The actual development and testing would have to be covered by the calls in HORIZONS 2020, in the same terms as suggested for Shit2Rail. The added value of ERRAC is the possibility to interlink with other transport modes technological platforms, as with aeronautics, waterborne and road. It is a fertile ground for societal embedding in new technologies targeting mobility. It would also allow for societal embedding on the science side of developments as Shift2Rail is mainly focusing on the one of technology.

Regarding societal embedding by individual railway stakeholders, as governments, manufacturers, component suppliers and train operators, it could be implemented by their strategic intelligence in ways that it would leave room for mutual learnings relations to happen. That means strategic consultations with the external societal actors that would open the way for common technology paths and engagements, not only promotion or legitimacy on the technology options. Governments could establish an observatory for technology assessment for example. Manufacturers and component suppliers could include in their organisational structure an employee responsible for societal alignments, also create cross-functional research teams, considers societal evaluation gates at the various stages of development and implement it the best way it meets its business needs.

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