Susana Cristina dos Santos Gomes Martins Moretto
Licenciatura em Relações Internacionais, Universidade Lusíada
Mestrado em Estudos Europeus, Collège d'Europe

Technology Assessment and High-Speed Trains: facing the challenge of emergent digital society

Dissertação para obtenção do Grau de Doutor em Avaliação de Tecnologia

Orientador: Doutor António Paulo Brandão Moniz de Jesus, Professor Associado com Agregação, Departamento de Ciências Sociais Aplicadas, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa

Co-orientador: Doutora M. Rosário M. R. Macário, Professora Associada, Departamento de Engenharia Civil, Arquitectura e Georrecursos, Instituto Superior Técnico, Universidade de Lisboa

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Abril 2017

Technology Assessment and High-Speed Trains:
facing the challenge of emergent digital society

In memory of my mother Luisa Martins

Acknowledgements

During this PhD journey I have sourced from inspiring people met along the way. Here, I leave my expression of gratitude to them by evoking their names and contributions.

The first person is my husband Luca Moretto. He is the most intelligent person I have ever met. He is the main supporter of this enterprise and my main anchor to the corporate world which I left at the early stage of my PhD. Also, my son Alessandro. He born and gown alongside this dissertation. My mother Luisa Martins. The most intelligent woman, entrepreneur and friend. She will eternally live in my heart.

This journey started because of Nuno Boavida. He was an *old* friend from the early times working in Brussels. We re-encountered years later at a conference in Lisbon. He introduced me to Technology Assessment (TA). The PhD was about to launch in Portugal by Professor Brandão Moníz. Soon after we become PhD colleagues and co-author of papers. I shall say that Nuno was a key element also for our research group with his TA Reading Labs. There he shared a series of reference publications and promoted regular discussions between colleagues.

In its turn Professor Brandão Moníz became my dissertation principal supervisor. He was active supporter of my research. His fulltime engagement was essential. His latter sabbatical period at the Institute of Technology Assessment at the Karlsruhe Institute of Technology (ITAS-KIT) in Germany, where significant research projects as PACITA, enlarged our research group. I benefitted from the multiple exchanges with researchers at ITAS, visits to the institute, joint participation in conferences and publications in journals and books. Today the PhD is dual with ITAS-KIT.

Moreover, Professor Manuel Seabra Pereira, pioneer and distinguish element of ERRAC European Railway Research Advisory Council, and Professor Rosário Macário, a woman I admire and leader in transport research, were kind to accept the co-supervision of this dissertation. It extended our long collaboration and friendship from early times in my career when I worked for UNIFE (the European Association for the Railway Industry). Both were a very important link to railway research.

Halfway through my PhD journey I was fortuned to meet Douglas K. R. Robinson, PhD, from the LISIS of Paris Est Marne-la Vallee University. He was a former student of Professor Aire Rip at Twente University. Douglas is a reference author in Technology Assessment and active developer of Rip's Constructive Technology Assessment (CTA) theory. Douglas became my main and most valuable source of TA insides. He was kind enough to accept to be co-author in various papers, opening doors for publication and presentations. He gave me unconditional support. Also, Jens Schippl, a researcher on Transport Scenarios at ITAS-KIT, became influential in my work and co-author. Both Douglas and Jens directed me to the relevant theoretical references and methods in TA.

My PhD was not only a theoretical journey crossing ways with people from TA and railways as mentioned. It was also a geographical journey encompassing learnings on the broad of strategic innovation management. Soon after I started my PhD in Portugal I moved for personal reasons to Santiago de Queretaro in Mexico. There I entered the academic carrier as researcher and lecturer at the Universidad Autónoma de Queretaro. This was only possible because Professor Alberto Pastrana and Professor Luis Rodrigo Valencia Perez at the Business and Administration School opened the door of their Innovation Lab. I am very much thankful to them for this unique opportunity. In Mexico, I also met a very interesting Professor in Philosophy of Innovation, Fernando Gonzales, PhD. Inspired by Mumford, Professor Fernando Gonzales developed charts from his interpretations to the understanding of technology as tool and process which were source of inspiration in my modeling on high-speed trains technical and commercial trajectories (figures 4.11 and 4.12).

When I later moved to Shanghai, I was very fortunate to meet Professor Chen Song, Vice-Dean of the School of Economics and Management of Tongji University. He was also Professor for Innovation Management. He gave me the opportunity to continue my research and lecture at Tongji. The writing of the final pages of this dissertation happened instead in Hong Kong, where I subsequently moved afterwards. There, Professor Naubahar Sharif from the Social Sciences Department of the Hong Kong University of Science and Technology challenged me to exploit my research results to the Hong Kong Express Rail Link.

I would like to extend my gratitude to the members of the thesis evaluation committee (CAT - Comité de Avaliação de Tese), in particular Professor José Nuno Varandas da Silva Ferreira and Professor Zuzana Dimitrovová, also Professor Prof. Doutor Virgílio António Cruz Machado, Professor Manuel Duarte Mendes Monteiro Laranja, Douglas Keith Raymond Robinson, Nuno Filipe França Gouveia Boavida.

And finally, express my appreciation to the various comments received from anonymous peer reviewers and responses to the survey from the various professionals in the railways and in the Technology Assessment community.

Abstract

The present PhD dissertation addresses the extension of selective environments of new technologies within the high-speed train technological system from business and regulations to the wider society. And, it argues the recognition of society as an actor in that system.

Motivating it is the observed ever increase exposure of high-speed trains to public acceptance, caused by empowered society from fast ICT advancements. They refer to digitalization - the rise of social media and big data, combined with the widespread use of mobile technology - changing if not revolutionizing our understanding of product and service selection.

Unprecedented societal demands, opening a new market segment, require new technologies to integrate with the emergent digital system. Moreover, societal actors became themselves innovators. Inevitable they have to become part of the value chain widening the collective of stakeholders. However, such raises the dilemma of promotion and control and adds complexity and uncertainty to the industry in deciding which technology to select.

Statistical evidence shows that businesses are figuring out ways to embed societal actors in their value creation. In this dissertation, I demonstrate to the high-speed train industry *how* is it falling short in addressing societal embedding in their product creation and argue *why* requires improvement.

Technology Assessment provides the approach for the orchestration of the necessary dialogue with societal actors for better anticipating potential development in the full system and for embedding the resulting technology options within.

By exploiting it to the high-speed train industry innovation strategic management, the aim of my dissertation is, borrowing the words of Douglas K. R. Robinson, to "arrive to a better informed designs of future working worlds, which are structured by theory while empirically well grounded, so they are usable by decision makers".

With this work, I expect to contribute to the new governance structure for research and development set buy the railway industry SHIFT2RAIL (Joint Undertaking for Rail Research and Innovation).

Key words: Strategic Innovation Management, Technology Assessment, Constructive Technology Assessment, High-speed trains

Sumário

Com a presente tese de doutoramento proponho uma nova abordagem na seleção de novas tecnologias integrantes do sistema da alta-velocidade-ferroviária, que efetive a extensão dos tradicionais enquadramentos de triagem (condições de mercado e regulamentares) aos sociais desde a fase inicial do desenvolvimento tecnológico.

O motivo encontra-se no observado fenómeno de crescente relevância social e seus revigorantes atores emergentes da sem precedente digitalização que muda, se não revoluciona, a forma como as novas tecnologias são selecionadas.

Por digitalização entende-se redes socias, "big data", "cloud", acompanhados pela utilização de comunicações moveis em rede, geradoras de comunidades de partilha e usuários inovadores.

Com as resultantes novas procuras e ofertas sociais, a indústria de alta-velocidade-ferroviária vê-se confrontada com o dilema da "promoção e controlo tecnológico" alargado, o que acresce complexidade e incerteza às existentes praticas de triagem das suas novas ofertas.

Estatísticas demonstram que apesar das medidas exploratórias para a integração social estas têm sido na sua maioria de imagem e marketing e menos no seu envolvimento na criação de valor através da investigação e desenvolvimento.

Da análise desta problemática no sistema de alta-velocidade-ferroviária Europeia, é minha ambição, (usando as palavras de Douglas K. R. Robinson) "chegar a designs mais informados de futuros [tecnológicos] que funcionem, que sejam estruturados pela teoria enquanto empiricamente bem fundados, utilizáveis pelos decisores".

Para tal pretendo demonstrar como será possível nesta indústria introduzir a Avaliação de Tecnologia, instrumento de apoio à decisão de politicas e estratégias tecnológicas socialmente integradas, para uma orquestração do necessário diálogo entre os promotores das tecnologias e os atores sociais, a implementar por antecipação e integração sistémica das soluções tecnológicas desde a fase inicial de desenvolvimento.

Desta forma espero contribuir para a nova governança da investigação e desenvolvimento da industria ferroviária na Europa recentemente lançada pela iniciativa SHIFT2RAIL (Joint Undertaking for Rail Research and Innovation).

Palavras Chave: Gestão Estratégica da Inovação, Avaliação da Tecnologia, Avaliação da Tecnologia Construtiva, Alta-Velocidade-Ferroviária.

Table of Contents

I. INTRODUCTION ---------- **1**
1.1. Changing demands: what is at stake for the high-speed train sector? ---------- **1**
1.2. The dissertation ---------- **6**
1.3. Structure ---------- **7**

II. THEORETICAL REFERENCES ---------- **9**
2.1. Technology Assessment ---------- **9**
2.1.1. Multiple strands ---------- 9
2.1.2. A problem of selection ---------- 11
2.2. Constructive Technology Assessment ---------- **14**
2.2.1. Selected strand and its implications ---------- 14
2.2.2. Distinctive theoretical elements ---------- 15
2.2.3. Origins and applications ---------- 17
2.2.4. Theoretical aspects of relevance for the high-speed train industry ---------- 19
2.2.5. Theoretical elements developed ---------- 21
2.2.6. Contribution ---------- 22

III. METHODOLOGY ---------- **23**
3.1. Research questions and propositions ---------- **23**
3.2. Research framework ---------- **25**

IV. THE CASES OF THE AGV AND ICE-350E DEVELOPMENT PROCESS ---------- **29**
4.1. Strategic intelligence ---------- **30**
4.1.1. Introduction ---------- 30
4.1.2. Strategic function of TA ---------- 33
4.1.3. Data collection ---------- 35
4.1.4. Organisational structure ---------- 36
4.1.5. Technology development ---------- 41
4.1.6. Findings ---------- 53
4.2. Technology transitions ---------- **56**
4.2.1. Introduction ---------- 56
4.2.2. Theoretical references ---------- 58
4.2.3. Technology transitions AGV and ICE-350E ---------- 61
4.2.4. Findings ---------- 71
4.3. Multi-level Perspectives ---------- **73**
4.3.1. Introduction ---------- 73
4.3.2. Analysis ---------- 73
4.3.3. Findings ---------- 80
4.4. Anticipation through future strategic formulations ---------- **82**
4.4.1. Introduction ---------- 82
4.4.2. Methodology ---------- 84
4.4.3. FTA and the European High Speed Railway system ---------- 85
4.4.4. Findings ---------- 96

V. SURVEY ---------- **99**
5.1. Introduction ---------- 99
5.2. Data collection ---------- 102
5.3. Unit of analysis (Q1, Q11, Q12) ---------- 105
Results (Q1, Q11, Q12) ---------- 111
5.4. Respondents preliminary view on the survey topic ---------- 112
Results (Q2, Q3) ---------- 118
5.5. Results ---------- 119
A. STRATEGIC INNOVATION MANAGEMENT ---------- 119

i) Technology development characterization ---- 119
Q13. R&D expenditure ---- 120
Q14. R&D strategy ---- 121
Q15. Technology surveillance ---- 123
Q16. Posts in technological surveillance ---- 125
Results (Q13-Q16) ---- 127
ii) Technological development multi-level dynamics ---- 128
Q17. The purpose for undertaking technology developments ---- 129
Q18. Existing technology development practices ---- 136
Q19. Openness to collaborative research ---- 138
Q20. Technological partnerships ---- 139
Q21. Relevant factors for conducting collaborative research ---- 141
Results (Q17 – Q21) ---- 143
B. SOCIETAL EMBEDDING ---- 144
iii) Drivers and alignments in technology change ---- 145
Q22. Drivers for technology change ---- 145
Q23. Requirements for technology change ---- 148
Q24. Sources of drivers and requirements ---- 158
Q25. Appraisal instruments ---- 161
Results (Q22 to Q25) ---- 162
iv) Societal elements in the strategic management approach ---- 164
Q26. What represents alignment with societal actors? ---- 165
Q27. Management for societal embedding ---- 167
Q28. Dealing with the anticipation dilemma ---- 170
Results (Q26-Q28) ---- 173
v) Futures ---- 173
Q29. Visioning the future ---- 174
Q30. Sources of future reports ---- 176
Q31. Methods to access futures ---- 178
Q32. Futures should consider ---- 180
Q33. Futures expected contribution ---- 181
Results (Q29-Q33) ---- 183
5.6. Survey main results ---- 184
A. Main Results – Strategic Innovation Management ---- 184
B. Main Results – Societal embedding innovation management ---- 185

VI. FINDINGS SUMMARY ---- 189

VII. CONCLUSIONS, RECOMMENDATIONS and IMPACTS ---- 195

BIBLIOGRAPHY ---- 201

ANNEXES ---- 215
Annex 1. Map of the high-speed train network in Europe ---- 215
Annex 2. Survey questions ---- 216
Annex 3. Dissertation summary chart ---- 233

Figures

Figure 1.1. Enterprise use of social networks, by purpose and sector, Europe 28, year 2013 5
Figure 2.2. Simplified taxonomy on the main TA strands 12
Figure 2.3. Enactment and Selection adapted by Robinson (2010) from Garud and Ahlstrom (1997) 17
Figure 3.4. Research plan 26
Figure 4.5. Extended Product Construction Process to society referred in Deuten et al. (1997) 34
Figure 4.6. Societal embedding within strategic intelligence 36
Figure 4.7. Societal embedding and the technology surveillance structure 39
Figure 4.8. High-speed train multi-actor system 42
Figure 4.9. Societal embedding within high-speed train multi-actor relations 44
Figure 4.10. Societal embedding within the product technological system 47
Figure 4.11. Societal embedding within the technical trajectory 49
Figure 4.12. Societal embedding within the commercial trajectory 51
Figure 4.13. Overview of societal embedding in the different dimensions of the high-speed train technology development 53
Figure 4.14. Technological transitions of the reference high-speed trains worldwide 57
Figure 4.15. Rip and Kemp micro-meso-macro approach to locate technology transformations 60
Figure 4.16. The French TGV/AGV technology transition 62
Figure 4.17. German ICE technology transitions 67
Figure 4.18. The AGV and ICE-35E multi-level perspective from 2001 to 2008 74
Figure 4.19. High-speed trains technology innovation over time (s-curve) 87
Figure 4.20. Future strategic reports and multi-level perspective since 2001 to our days 92
Figure 5.21. Product development process environments 100
Figure 5.22. High-speed train product development process environments in time 101

Tables

Table 4.1. Classification of reports on future oriented technology assessment (FTA) referring to the high-speed train system *85*

Graphs

Graph 5.1. Respondents categories (Q1) 106
Graph 5.2. Respondents categories resulting from their institutional affiliation (Q11) 107
Graph 5.3. Breakdown by respondents' institutional affiliation (Q11) 108
Graph 5.4. Country distribution (Q12) 110
Graph 5.5. Country distribution by institutional types (Q12) 111
Graph 5.6. Aspects valued when decision is made to take the high-speed train (Q2) 113
Graph 5.7. Aspects valued when decision is made to take the high-speed trai. Breakdown (Q2) 114
Graph 5.8. Aspects valued when decision is made to take the high-speed train. Breakdown (Q2) 114
Graph 5.9. Should users and wide society have a say in the technology development (Q3) 116
Graph 5.10. Should users and wide society have a say in the technology development. Breakdown (Q3) 117
Graph 5.11. High-speed train industry expenditure on R&D as a % of total turnover (Q13) 120
Graph 5.12. High-speed expenditure on R&D as a % of annual turnover. Breakdown (Q13) 121
Graph 5.13. Does your institution have an explicit R&D strategy? (Q14) 122
Graph 5.14. Does your institution have an explicit R&D strategy? Breakdown (Q14) 122
Graph 5.15. Does your institution have an explicit technology surveillance structure? (Q15) 124
Graph 5.16. Does your institution have an explicit technological surveillance structure? Breakdown (Q15) 124
Graph 5.17. You or a colleague take part in technological surveillance as follows… (Q16) 126
Graph 5.18. You or a colleague take part in technological surveillance as follows. Breakdown (Q16) 126
Graph 5.19. Purpose for undertaking technology development activities (Q17) 129
Graph 5.20. Purpose for undertaking technology development activities: Product development and design (Q17a) 130
Graph 5.21. Purpose for undertaking technology development activities: Manufacturing process (Q17b) 131
Graph 5.22. Purpose for undertaking technology development activities: Modelling and planning (Q17c) 131
Graph 5.23. Purpose for undertaking technology development activities: Certification and homologation (Q17d) 132
Graph 5.24. Purpose for undertaking technology development activities: Cost reduction (Q17e) 133
Graph 5.25. Purpose for undertaking technology development activities: Solve technical problems (Q17f) 134
Graph 5.26. Purpose for undertaking technology development activities: Make the final product attractive to users (Q17g) 134
Graph 5.27. Purpose for undertaking technology development activities: Enter new markets or gain market from competitors (Q17h) 135
Graph 5.28. Purpose for undertaking technology development activities: Anticipate new societal challenges, policies and market conditions (Q17i) 136
Graph 5.29. Existing technology development practices (Q18) 137
Graph 5.30. Existing technology development practices. Breakdown (Q18) 137
Graph 5.31. Openness to collaborative research (Q19) 138
Graph 5.32. Openness to collaborative research. Breakdown (Q19) 139
Graph 5.33. Technological partners (Q20) 140
Graph 5.34. Technological partners. Breakdown (Q20) 140
Graph 5.35. Relevant factors for conducting collaborative research (Q21) 142
Graph 5.36. Relevance of collaborative research. Breakdow. (Q21) 142
Graph 5.37. Rate in relevance the factors driving your research and development (Q22) 146
Graph 5.38. Drivers for technology change. Breakdown (Q22) 147
Graph 5.39. When developing a new technological solution (TRL) which requirement for alignment you consider? (Q23) 148
Graph 5.40. When developing a new technological solution for the high-speed train at which technological readiness levels (TRL) you consider identified requirements for alignment? (Q23) 149
Graph 5.41. Requirements relevance at TRL 1. Basic principles observed and reported (Q23) 150
Graph 5.42. Requirements relevance at TRL 2. Technology concept formulated (Q23) 151

Graph 5.43. Requirements relevance at TRL 3. Experimental proof of concept (Q23) *152*
Graph 5.44. Requirements relevance at TRL 4. Technology validation in laboratory (Q23) *153*
Graph 5.45. Requirements relevance at TRL 5. Technology validation in relevant environment (Q23) *154*
Graph 5.46. Requirements relevance at TRL 6. Technology demonstration in a relevant environment (Q23) *154*
Graph 5.47. Requirements relevance at TRL 7. System prototype demonstration in an operational environment (Q23) *155*
Graph 5.48. Requirements relevance at TRL 8. System completed and qualified through test and demonstration (Q23) *156*
Graph 5.49. Requirements relevance at TRL 9. Actual system proven through successful mission operations (Q23) *157*
Graph 5.50. Indicate your sources of information on technological drivers and requirements (Q24) *159*
Graph 5.51. Indicate your sources of information on technological drivers and requirements. Breakdown (Q24) *160*
Graph 5.52. In which type of instruments you base your technology decisions? (Q25) *161*
Graph 5.53. You base your technology decision on which type of instruments. Breakdown (Q25) *162*
Graph 5.54. What represents technology alignment with societal actors? (Q26) *165*
Graph 5.55. What represents technology alignment with societal actors? (Q26) *166*
Graph 5.56. Technology management includes the following elements? (Q27) *168*
Graph 5.57. Technology management includes the following elements? Breakdown (Q27a) *169*
Graph 5.58. Technology management includes the following elements? Breakdown (Q27b) *169*
Graph 5.59. Technology management included the following elements? Breakdown (Q27c) *169*
Graph 5.60. Technology management included the following elements? Breakdown (Q27b) *169*
Graph 5.61. Do stakeholders pay attention to societal embedding when setting their technology strategy? (Q28) *170*
Graph 5.62. Mapping and monitoring relevant environment including society? (Q28a) *171*
Graph 5.63. Articulation of scenarios for societal embedding? (Q28c) *172*
Graph 5.64. Stimulating continuous learning during societal inclusion process? (Q28d) *172*
Graph 5.65. Relevance in visioning the future (Q29) *174*
Graph 5.66. Relevance in visioning the future. Breakdown (Q29) *175*
Graph 5.67. Futures sources of information (Q30) *176*
Graph 5.68. Futures sources of information, breakdown internal reports (Q30) *177*
Graph 5.69. Futures sources of information. Breakdown by institutions (Q30) *178*
Graph 5.70. Methods used in futures (Q31) *179*
Graph 5.71. Methods used in futures. Breakdown (Q31) *179*
Graph 5.72. Aspects futures should consider (Q32) *180*
Graph 5.73. Aspects futures should consider. Breakdown (Q32) *181*
Graph 5.74. What futures should consider (Q33) *182*
Graph 5.75. What futures should consider. Breakdown (Q33) *182*

Acronyms

AGV - Automotrice à Grand Vitesse

CAM – Computer-Aided Manufacturing

CAD – Computer-Aided Design

CER – Community of European Railway and Infrastructure Companies

CTA – Constrictive Technology Assessment

DB - Deutsche Bahn AG

MLP – Multi-Level Perspective

MODTRAIN - Innovative Modular Vehicle Concepts for an Integrated European Railway System

EC – European Commission

EC FP – European Commission Framework Programme for Research

EIM – European Infrastructure Managers Association

ERA – European Railway Agency

EPTA – European Parliament Technology Assessment network

ERRAC – European Railway Research and Advisory Council

EUDD – European Modular Train Cabin Concepts

FTA – Future Oriented Technology Analysis

GDP – Gross Domestic Product

ICE - Inter City Express

ITA – Institute of Technology Assessment of the Austrian Academy of Sciences

ITAS - Institute for Technology Assessment and System Analysis, Karlsruhe Institute of Technology

NOTA - Netherlands Organization of Technology Assessment

NTV - Nouvo Transporto Viaggiatore

OTA - Office of Technology Assessment (United States of America)

PCP – Product Construction Process

R&D – Research & Development

RQ – Research Questions

SAFETRAIN - Safe Interiors

SERA - Single European Railway Area (COM(2011) 144 final)

SECP – Social Embedding Construction Process

SHIFT2RAIL – Joint Undertaking for Rail Research and Innovation (Council Regulation (EU) No. 642/2014 of 6 June 2014)

SNCF - Société Nationale des Chemins de Fer Français

STOA – Science and Technology Options Assessment panel of the European Parliament

SRQ – Sub-Research Questions

TA – Technology Assessment

TAB – Office Technology Assessment at the German Parliament

TA-SWISS – Swiss Center for Technology Assessment

TGV – Train à Grand Vitesse

TRL – Technology Readiness Levels

UNIFE – The Association of the European Rail Industry [Union Internationale des Industries Ferroviaire]

UIC –the International Union of Railways [Union Internationale des Chemins de Fer]

I. INTRODUCTION

1.1. Changing demands: what is at stake for the high-speed train sector?

In recent years, developments in high-speed trains are receiving greater exposure from non-technical factors external to the traditional product design and business steaming from rapid developments of digital society.

Society has become empowered through social media, big data and the cloud, which, combined with the exponential rate of adoption of mobile technologies, is producing widespread service and social innovations. Examples include connected travellers, car sharing, car-pooling, etc.

This pressure adds to other existent societal challenges such as the after-effects of the financial crisis and the drive for sustainable innovation systems, with climate change, congestion, security and the aging population in Western societies (COM (2011) 144 final[1]).

An example of empowered society by digitalization is BlaBlaCar 20 million users, overpassing SNCF-Voyage market share (Chen 2015 and Casprini et al, 2015). The French railway company operating the TGV, responded introducing mobility services beyond the high-speed train, reducing tariffs and improving online information to travellers (Picard 2015, Steinmann 2014).

In turn manufacturers, such as Alstom Transport and Siemens Mobility[2], have been responding in the way they know best, through engineering. These firms are integrating lightweight and recyclable materials into their trains as well as energy converter systems. They are also making the train interiors attractive and further developing ICT solutions for better interfaces with travellers (Brandes, 2015, Saint-Martin, 2015).

As it will be here demonstrated, in railways the need for innovating through digitalization is coming *strongly* from the demand side, the so-called societal environments of new products selection (Deuten, Rip & Jelsma 1997), and only to a less extent from business, regulation and product

---

[1] The White Paper on a Roadmap to a Single European Transport Area (COM(2011) 144 final) stresses the need to create a Single European Railway Area (SERA) to achieve a more competitive and resource-efficient transport system capable to address the existent societal issues as here listed.

[2] For simplification those manufactures will be here referred as Alstom and Siemens.

development. This societal demand is challenging incumbents in railways to include resulting new demands and requirements into the product development processes of high-speed trains.

This relatively recent societal pressure for digitalization, through the exponential growth and use of mobile technology, has coincided with other industrial factors that are driving the directions of transport innovation in the established European railway industry. These factors include high expectations concerning the almost "certain" expansion of high-speed train networks, an increase in international passenger traffic and, most relevant for this dissertation, the market uptake of new technologies coming out from a decade of EU and member states stimulus[3].

Notorious is the case of the latest generation of high-speed trains in Europe, the AGV[4] and ICE-350E, and their embedded sub-systems (train-control-command systems, coupling systems, interiors, telematics and advanced materials, sub-systems interfaces, only to refer to some of the examples)[5].

The AGV and ICE-350E were designed and developed in response to the changing regulatory and business environments from 2001 impacted by the European Commission initiative known as the White Paper for Transport (COM (2001) 370). However, these trains were still far from including digitalization in their design revealing a lack of exposure to and knowledge about the first signs of the digital pressures of today.

At the time of development of the AGV and ICE-350E, the business environment was favoring the emergence of economies of scale and entrance of new private train operators in competition with incumbents, to provide market liberalization, interoperable networks and opening of infrastructure access.

Also, the new regulatory requirements introduced in a sequence of *railway-packages* placed a heavy focus on the integration of the different national systems across Europe. The vehicles had to be

[3] EU and Member States investments since 2001 to 2014 added more than 6,000 km of high-speed track to the 1,000 km in 1990 on which trains travel at 250kph or above. Much more is under construction or planned (see UIC map in Annex 1). In December 2015 a new line from Leipzig to Erfurt was inaugurated (123km-long). A Milan-Brescia service is to begin during 2016 (39 km of high-speed track to be added). By 2017 four new French lines will come into service linking Bordeaux, Rennes, Strasbourg and Montpellier. The EU also plans to finance a €4.5 billion fast-rail link between Estonia, Latvia, Lithuania and Poland. Retrieved from http://www.economist.com/news/business/21638109-high-speed-networks-are-spreading-fast-face-rising-competition-problems-down-line see also https://en.wikipedia.org/wiki/High-speed_rail_in_Europe

[4] AGV, Automotrice à Grand Vitesse, manufactured by the French firm Alstom presented in 2008 the European high-speed train in its true sense since it incorporates the results of a number of flagship European projects and also it was the first train developed to meet not a specific order from a train operator but to meet a new regulatory environment. Retrieved from link http://en.wikipedia.org/wiki/Automotrice_%C3%A0_grande_vitesse#Customers, date 11.03.2015.

[5] This dissertation focus on vehicles only (rolling stock and its components). Excluded are other parts of the high-speed train system as infrastructure and signaling which have their own technologies and decision-making routines.

capable of running in a trans-European high-speed network that was set to become modular, interoperable, sustainable and safe.

In response the European high-speed train supply chain aligned in different collaborative research projects such as MODTRAIN (European Commission, 2006a, p.336-338), EUDD (European Commission, 2006a, p.330-332) and SAFEINTERIORS (European Commission, 2006a, p.414-416) with financial support via the European Commission Framework Programme for Research (EC FP). These and others projects represent a total budget of roughly 267 Million EUR[6] of funding by the European Commission allocated to railways between 2002 and 2013.

Manufacturers pushed for the technology development of their high-speed train platforms TGV and ICE into standardised ones, beyond individual customer orders. They aimed to result in off-the-shelf vehicles. A true novelty in this industry.

This way the AGV and the ICE-350E when introduced to the market, in 2008 and 2006 respectively, integrated many of the results from those and other collaborative projects.

The market-uptake of these trains was however much lower than initial expectations. Alstom had to wait approximately four years to deliver 25 units of the AGV to the private operator from Italy NTV[7], with no further orders since[8]. As for Siemens, it started suffering from increasing technology capability pressure from the Chinese competitor CSR Qingdao Sifang, which itself resulted from a previous decade worth of massive expansion of the Chinese high-speed network.

Manufacturers point the finger to the dominant conservative business culture of European railways. Incumbent train operators were resistant to the opening of the market and to regulatory integration (OECD, 2013). In addition, new emergent markets demonstrated a preference for lower cost trains

---

[6] The budget here referred correspond to the sum of the EC funding allocated to rail, being EUR 117 Million in FP6 2002-2006 plus EUR 150 Million in FP7 2006-2013 retrieved from the link http://ec.europa.eu/research/transport/rail/index_en.htm (14.03.2016).

[7] NTV (Nouvo Transporto Viaggiatore) is the Italian private high-speed train operator. Retrieved from link http://en.wikipedia.org/wiki/Automotrice_%C3%A0_grande_vitesse#Customers, date 11.03.2015.

[8] Retrieved from link http://www.globalrailnews.com/2014/04/08/ntv-gains-access-to-roma-termini/, date 26.09.2014.

from China. The most critical voices[9] said that new technological solutions resulting from European research projects did not manage more than a *disappointing* 30% of leverage effect [10,11].

To overcome these challenges, the railway industry, led by the train manufacturers, are now promoting a new governance structure for the various European research projects with the Joint Undertaking SHIFT2RAIL[12]. It focusses on technological demonstrators and is reviewing the mandate of ERRAC Technology Platform[13].

What seems to be left out from initiatives like SHIFT2RAIL and from developments such as AGV and ICE-350E is the recent surge of a digitally empowered society which has specific expectations, requirements and needs. Whilst the digital society is surging ahead, high-speed train industry is rapidly being left behind[14]. Following this train metaphor, will innovation in the high-speed trains take a different route and perhaps crash into these demands much further down the line? Or can anticipation and integration of these new design requirements be included in the innovation processes?

As it will be demonstrated, despite the industry's initial steps in making the necessary connections with the digital society and address their new emergent needs, they are still oriented towards promoting image and marketing of high-speed trains. Secondary appears to be their interest integrating this new phenomenon in the technology development process of the trains.

---

[9] ERRAC questions in one of its reports if the research projects funded by the European Commission in the past years, representing millions of Euros of investment, have been actually useful or relevant. Sourced from ERRAC report working group six WG06, 2010. Retrieved from link www.errac.org/spip.php?article25 date 5.03.2013.

[10] When enquired ERRAC WG06 by email (2 June 2014) the same figures were referred: "the percentage of successful projects in Europe (meaning EU part financed research) are around 30%; In Australia about 20%; In north America about 40%. All deals with collective partly governmental financed. The main reason for the poor figures are the complete lack of business perspective in creating ideas".

[11] European Commission, DG MOVE, Council Land Transport Working Party, Brussels 22 January 2014. Retrieved from link http://www.belspo.be/registration/shift2rail/SHIFT%C2%B2RAIL-O.%20Coppens-Brussels-021714.ppt date 26.09.2014.

[12] SHIFT2RAIL (also S2R JU) was launched by the Council Regulation (EU) No. 642/2014 of 6 June 2014 extending to research and development funding prototyping and large-scale demonstration activities. The European Commission in its impact assessment refers that SHIFT2RAIL is justified because of "(…) the market uptake and impact of EU rail research and development projects under previous framework programmes has often been low and slow (…)" (COM(2013)922 final) Links http://ec.europa.eu/transport/modes/rail/shift2rail_en.htm and http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0535&from=EN retrieved 11.03.2015.

[13] www.errac.org

[14] At the UIC 9th World Congress on High Speed Rail 2015 in Tokyo railways reflected the first signs of awareness on the disruptive power of digital society and ICT, in particular with the interventions of Rachel Picard, CEO, SNCF Voyages. According to Mrs Picard "digital society revolution" is triggering railways transition into a new technological era (…). In the last 15 years railways made a transition from the hardware into software era, entering today into the socialware, with the connected objects resulting in an exponential acceleration. She further states that this will open future fields of ICT application for railways as in vehicle/infrastructure interaction, maintenance and customer relations. But, as she continues, if for the automotive sector the response is already there with the automated vehicles, for railways one does not yet know what will happen (recorded round table 2, day 7/9/2015, time 10:35-12:45, ref. new record Picard 2/9/2015, from -2:13/00:11:58). Link www.uic-highspeed2015.com .

This lack of embedment of digital society in the research and development process is visible in a broad statistical study on the use of social media across different sectors (Giannakouris & Smihily, 2013). See figure 1.1, below, highlighting transport and manufacturing.

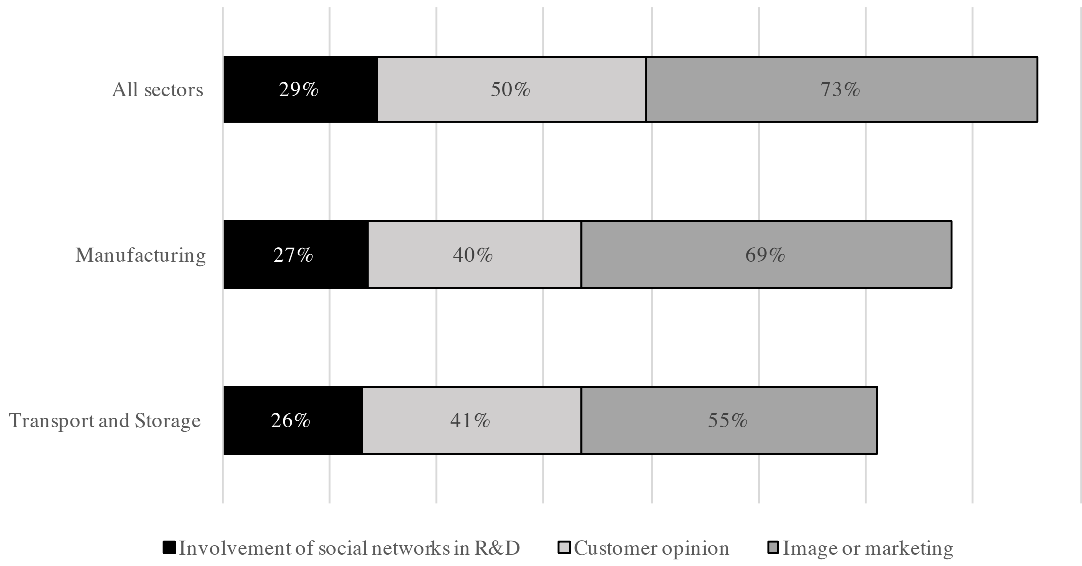


Figure 1.1. Enterprise use of social networks, by purpose and sector, Europe 28, year 2013
Source: extract from figure 4. in Giannakouris & Smihily (2013)

The involvement of social networks, via social media, in the technology development (in the figure referred in more restrictive terms as R&D) is no easy task for the high-speed industry, since such requirements fall outside their traditional "engineering" culture historically sheltered from strong market forces.

Engineers dominate these industry technology advancements, which despite their awareness and willingness have neither inclination nor training to address inherent social environments of selection in which research projects might fall[15].

Summarising the above, in the past decade we have seen a number of critical shifts affecting the high-speed rail industry: (a) liberalised markets and more competition (e.g. China and other players entering European markets), (b) the regulation environment stimulating modularity and standardisation across national rail innovation systems, and (c) most recently new demands stemming from the rapid rise of the digital society.

[15] They associate society to a high degree of heterogeneity and uncertainties tending this way to leave it out from their R&D collective action, which they compete to control (read Chapter V Survey).

1.2. The dissertation

With this dissertation I attempt to respond to two central questions: (i) *How the industry might be falling short in embedding society in their product creation?* and (ii) *Why there is potential for improvement?*

To accomplish it I shall mobilise an approach of Technology Assessment (TA) which includes at its heart design thinking. The approach called Constructive Technology Assessment (CTA) introduces the tools for anticipating the societal embedding of new technologies and integrating this knowledge into the design of products (Deuten et al 1997, Van Merkerk 2007, Robinson 2010), or, at a broader meso-level, the design of industries (Robinson and Boon 2014, Parandian 2012, Mazzucato and Robinson 2015). CTA often involves orchestrating collective anticipation and design (Robinson 2010, te Kulve 2011, Krabbenborg 2013) when elaborating strategies, visions and research projects.

Phrased in another way, in the words of Jens Schippl (interview protocol J. Schippl 20.5.2015) TA provides the methodology for better anticipating potential development in the full system and for embedding the resulting technology options within.

According to Douglas K. R. Robinson (interview protocol D. K. R. Robinson 20.5.2015) social dialogue requires tailored interactions to suite the technology readiness level in which the research project is (to optimise the value from such interaction) and move towards stabilizing design trajectories by reviewing societal requirements at early stages of the research projects (as means to reduce uncertainty and risk). This requires draw on a third party societal expertise to overcome referred dilemmas of promotion and control.

It is this *flavour* of CTA I will draw upon, what Schippl and Robinson have called the system (or meso) level of industries and railway systems[16] .

As Robinson (2010)[17], I shall locate my CTA at the meso-level of public-private consortia anticipating and coordinating an evolving industry. I thus focus on providing strategic intelligence for public-private consortia, such as SHIFT2RAIL (the Joint Undertaking for Rail Research and Innovation), with an eye to creating increased reflexivity about societal dimensions.

In this dissertation, I build my argument from a case-based analysis on how societal embedding "occurs" in the technology development process of two *reference* high-speed trains; the AGV and

---

[16] As opposed to CTA applied to individual projects or technologies fields (see lab-on-a-chip work by Rutger van Merkerk 2007, or supply chain analysis by Alireza Parandian 2012).

[17] Robinson (2010) located his work in nanotechnology R&D consortia to explore emerging and evolving value chains.

the ICE-350E. To do this, I investigate both train manufacturers[18] technological strategy formulation and implementation activity, the high-speed train technology transitions over time and at multiple scales of stakeholders' dynamics. I also study the way that industry formulates their visions of the future. To further ground and support these analyses, I have conducted a survey to corroborate my findings in the other elements of my study.

I conclude this dissertation with a reflection on what can be learned from analysing societal embedding in high-speed train development, and propose ways for supporting integrating ideas of societal embedding into the agenda setting process, in particular when railways elaborate their visions and undertake R&D projects in view of a next generation of high-speed trains.

1.3. Structure

This dissertation is the result of a journey. As I have already mentioned, my starting point was to find evidences of societal embedding in railway technology development processes (or product development processes) by doing case studies of the latest generation of high-speed trains, the AGV and the ICE-350E (chapter IV). The goal is to present at the end reflexive[19] guidelines for embedding societal factors in new technology development processes in railways.

Intermediate steps between the start and finish of this journey include the study of Alstom and Siemens strategic intelligence in the development process of the AGV and ICE-350E (section 4.1); the vehicles technology transitions (section 4.2) and their multi-level perspectives (section 4.3.); as well as industry future formulations on desirable futures (section 4.4).

Each of those steps intercepts and follows the footsteps of an emerging path of a constructivist perspective of technology assessment – starting with Arie Rip (Schot and Rip 1997, Deuten, Rip & Jelsma, 1997, and te Kulve & Rip, 2011), one of Rip's students, Douglas K.R. Robinson (Robinson & Propp, 2008, Robinson 2010, Robinson and Boon 2014), as well as Jens Schippl (Schippl and Fleischer, 2012). My dissertation reflects not only what I have absorbed from their various papers but also the multiple personal contacts and the privilege of joint works. I have also sourced from scholars in innovation studies and evolutionary theories of (socio-)technical change such as Nelson & Winter (1977), Dosi (1982), Pavitt (1984), Castellacci (2008), Lichtenthaler (2004) and Geels (2002).

[18] Alstom Transport and Siemens Mobility

[19] "Reflexive" here refers to CTA reflexivity, as explained in Rip and Robinson (2013), from interactions and mutual learnings occurring between the broaden of institutions and approaches in society and sectors in society during co-developments of technologies.

My preliminary findings were corroborated through a broad online-survey to the industry segments of the value chain (Chapter V), with 74 stakeholders replying to the survey covering rolling stock manufacturers, component suppliers, certification bodies, academia, governments and users.

Moreover, in parallel, the preliminary findings for each of the steps were presented at several conferences held between 2010 and 2016. The most significant ones were PACITA 2013[20] and 2015[21], the JRC Conference on Future-Oriented Technology Analysis (FTA) 2014[22], the UIC World Congress on High Speed Rail 2015[23], TRA 2016[24] and WCRR 2016[25]. Those were organised separately by the two different communities in which my research is anchored: the railway conferences where actors from the railways supply chain were present, and the technology assessment and foresight conferences where academia and R&D policy makers were present.

Those same preliminary finding have also been subject to scrutiny from anonymous peer reviewers when published in conferences proceedings, peer-reviewed journals and as chapters in books. The most relevant ones are the International Journal of Railway Technology[26] and PACITA 2012 book[27]. These discussions and reviews have provided valuable inputs into the writing of this dissertation as well as in my evolving research programme during this PhD.

Finally, findings are presented in Chapter VI. Conclusions, recommendations and impacts are found in Chapter VII. The bibliography is given at the end.

[20] Links http://pacita.strast.cz/en/conference/programme/ix-assessing-sustainable-mobility and http://pacita.strast.cz/files/prezentace/session_ix_moretto.pdf

[21] Link http://berlinconference.pacitaproject.eu/preso/

[22] Link https://ec.europa.eu/jrc/en/event/site/fta2014

[23] Link http://www.uic-highspeed2015.com/about/index.html

[24] Link http://www.traconference.eu/programme/overall-programme/

[25] Link http://www.wcrr2016.org/

[26] Link http://www.ctresources.info/aresults.html?q=S.+Martins+Moretto

[27] Link http://www.pacitaproject.eu/documentation/

II. THEORETICAL REFERENCES

2.1. Technology Assessment

2.1.1. Multiple strands

The dissertation both mobilises and contributes to Technology Assessment (TA). The rapid growth of ever complex technologies and the increased visibility of technology's role in shaping society place TA as an approach of a number of fields in social science and humanities, management and strategy.

Because of the ever increasing recognition on the importance of technological innovation on the economy and on society, TA is becoming more mainstream, more formalised and more embedded in institutions such as parliaments and firms[28].

Common to all TA strands, it is the wish to reduce the potential negative consequences of new and emerging technologies and to optimise the uptake and socio-economic impacts of new technologies (Schot and Rip 1997, Rip 2001).

Rip (2001, p.15512:15515, based on Schot & Rip 1997) points to another important role of TA, not entirely shared across all stands, that they contribute to the "(...) early identification and assessment of eventual impacts of technology change and applications in order to reduce the human and social costs of handling a technology in society compared when this happens by trial-and-error".

TA does have a history and one can describe it in terms of generations of TA.

- *First generation of TA strands*

The first generation of TA strands was policy-oriented emerging in the 1960's in the U.S. with the advent of the Office of Technology Assessment (OTA). At the time U.S. Congress saw the need to have advanced warnings on the potential societal, economic, ethical and political effects of new technologies in the U.S. and elsewhere. Thus, TA has its origins in providing useful intelligence for public policy.

[28] For the history of TA refer to Smits and Leyten (1991), van den Ende et al. (1998), Smits et al. (2008).

Around that period of time, TA was defined as “the name for a class of policy studies which attempt to look at the widest possible scope of impacts in society of the introduction of a new technology. Its goal was to inform the policy process by putting before the decision maker an analysed set of options, alternatives and consequences” (Coates 1976, p139).

However, as Tran et al. (2008) pointed out, at the end of the 1970s, American industry picked up the term of TA quite independently of the OTA definition, more in line with notions of technology readiness assessment. This industry stand used TA as a means of anticipating what was going on outside of their firm to see how it affected their own activities (as opposed to anticipating the effect of their technology developments on markets and society).

Moreover, whilst in the U.S. the Congress dissolved OTA in 1995, policy oriented TA was heterogeneously spreading across a number of public agencies in European countries with participatory traditions such as in Germany, Denmark, Switzerland and the Netherlands (Van den Ende et al. 1998, Rip 2001).

A branch of such activities can be defined as parliamentary TA. TAMI report (2004) and most recently PACITA project (2011-2015)[29] have been important European projects focusing efforts on sharing best practices and harmonising parliamentary technology assessment, in spite of the vast heterogeneity.

- *Second generation of TA strands*

The second generation of TA strands, emerging in the mid-1980s and early 1990’s, shows an uptake of TA by non-governmental institutions. In this wave, firms begun applying TA along the same lines as the original OTA thrust, as opposed to TA as technology readiness assessment (see earlier).

Here, TA acts as a tool in supporting strategies up to and including agenda building (Rip 2001, Van Eijnshoven 1997). During this time, TA became process oriented developing tools and methodologies targeted at shaping new technology developments in line with emerging demands.

The variety of methods applied ranged from trend exploration and Delphi, through to interventions in innovation networks and consensus meetings (Van den Ende et al. 1998).

It is no coincidence that this 2nd generation of TA coincided with the emergence of biotechnology, which began to raise societal concerns in the mid-80s well into the 90s and

[29] Link http://www.pacitaproject.eu/

2000s, especially with regards to genetically modified organisms. A pressure to anticipate on societal impacts became a pressing issue, which shaped motivations and approaches to TA.

Shedding light on the blurry borders between the different TA strands, Rip (2001) offers a typology of TA including: "Public Service TA", "TA for public arena", "TA to specific sectors", "TA in firms and technological institutes" and "Constructive Technology Assessment".

Böhle & Moniz (2015), building on such a typology, characterise TA in terms of the different spheres in which those strands might fall: the "Policy sphere", dealing with the "political system"; the "Public sphere" referring to "civil society" and the "Science & Technology sphere" dealing with the research and innovation system.

2.1.2. A problem of selection

Rip, Böhle and Moniz suggest that the applicable sphere to the cases or problems under analysis depends to whom TA addresses. It can be either decision-makers part of the policy system, civil society from the public sphere or firms and non-governmental bodies from the innovation system (Böhle & Moniz, 2015).

The authors contribute to overcome TA strands tenue boundaries. TA have multiplied in strands often overlapping, making it no small task for those who wish selecting the appropriate one[30].

To capture, and further develop, these authors efforts, I have created a simplified taxonomy on the main TA strands, shown below in figure 2.2, which can help locate them.

[30] In my research for literature on types of TA strands I also found Van den Ende et al. (1998) presenting a classification and methods. However I rather followed Rip (2001). This because Van den Ende et al. (1998) refers as types of approaches "Strategy Making" aside to CTA which is itself part of strategy making (in "supporting specific actors or groups of actors in formulating their (…) strategy" as said in van den Ende et al.1998, p.8:5-21). Van den Ende et al. (1998) also indicate backcasting as a type of TA, where in fact it seems to me rather a methodology. CTA in transport uses backcasting as in Schippl (STOA 2008). Moreover, Rip (2001) does not refer to this paper (van den Ende et al., 1998) following a classification based on the TA addressee. Nevertheless, Van den Ende et al. (1998) provide a useful explanation on the origins of TA and present a very comprehensive structure of TA methods.

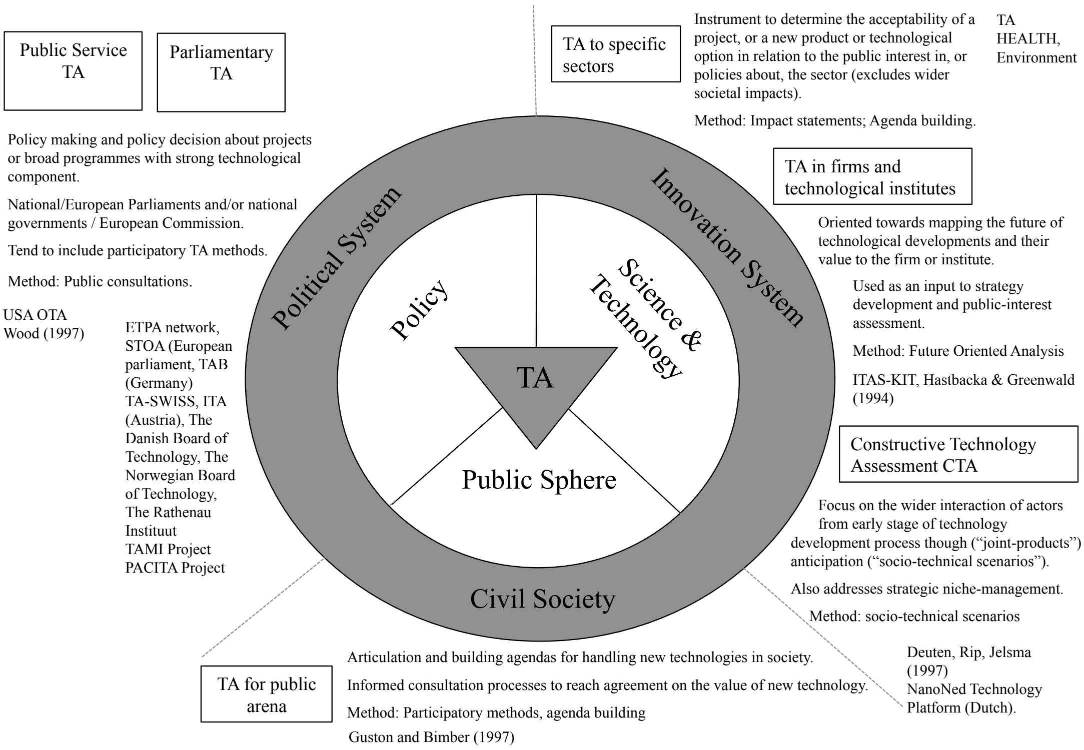


Figure 2.2. Simplified taxonomy on the main TA strands
Source: Böhle & Moniz (2015) chart combined with Rip (2001)

Figure 2.2 shows, for each approach, their relevant aspects in terms of scope, the dominant methods, key authors and, where possible, reference practitioners similar to those referred to in Rip (2001); matched with the spheres concerned (from Böhle & Moniz, 2015) [31].

The spheres in figure 2.2 can be broadly describe as follows:

a) Policy

In *Policy* predominate *Public Service TA* (Rip, 2001) and *Parliamentary TA* (Böhle & Moniz, 2015). These strands support decision making about projects or programmes that have a strong technological component (Rip, 2001). The main addressees are National or European Parliaments or governments including the European Commission. The main instruments used are public consultations and sometimes involve TA participatory methods. Theoretical references in the U.S. are Wood (1997) drawing on methods used by the now defunct OTA, while in Europe are the TAMI reports and PACITA project, where methods, including consensus conferences, guide TA applications by organisations such as the ETPA network,

[31] In figure 2.2, for simplification reasons, I only refer to the main strands and intentionally exclude sub-strands that exist or are emerging (such as real-time TA).

STOA (European parliament, TAB (Germany), TA-SWISS, ITA (Austria), the Danish Board of Technology[32], the Norwegian Board of Technology and the Rathenau Instituut.

b) Public

In *Public,* concerning civil society*,* is dominant *TA for public arenas* (Rip, 2001). It refers to the articulation and building of agendas for handling new technologies in society; it also includes informed consensus processes to reach agreement on the value of a new technology (Joss and Durant 1995), Kilver 1995). Here it is mainly used for participatory methods and agenda building. Illustrative references include Guston and Bimber 1997, Guston 1999, Russell et al. 2010.

c) Science & Technology

In *Science & Technology,* concerning the innovation system*,* are included *TA to specific sectors, TA in firms and technology institutes* and *Constructive Technology Assessment*.

TA to specific sectors, refers to instruments designed to determine the acceptability of a project, new product or technological option, in relation to the public interest in, or policies about, the sector, excluding wider societal impacts (Rip 2001). The most used methods include impact statements and agenda building. These concern the formal strands of Health TA or Environment TA.

TA in firms and technology institutes is oriented towards mapping the future of technological developments and assessing (prospectively) their value to the firm or institute. Used as an input into strategy development and public interest assessment. Recurrent method is Future Oriented Analysis. Reference authors include Hastbacka & Greenwald (1994).

Constructive Technology Assessment (CTA) focuses on the wider interaction of the broad range of actors (including society) that have a "stake" in the development, deployment and use of new technology fields (Robinson 2010). CTA has often focused on technology fields in their early stage of emergence, where uncertainty reigns and there is a need to both characterize potential future developments and also to construct assessment approaches collectively to assess these new developments (Robinson 2010). Originally developed in the Netherlands, early 1980s, particularly through a dedicated programme organized by the national nanotechnology initiative NanoNed (Rip and van Lente 2013), CTA has experienced periods

[32] The Danish Board of Technology, after resources were withdrawn, has now become a foundation. Link http://www.tekno.dk/?lang=en

of intense development and application, interspersed with periods of dormancy. In the past three or so years, CTA has been less visible.

2.2. Constructive Technology Assessment

2.2.1. Selected strand and its implications

For this dissertation, the subject of the technology assessment is the high-speed train value chain, and thus, a TA exercise falling within the innovation system part of the science & technology sphere of railways.

The *research problem* presented in the introduction, concerns the strategic management of the extended high speed rail value chain to include the broad of society at the early stage of development of high speed vehicles. Thus, a TA to direct and shape ongoing developments of emerging technologies.

From the families of TA that I have covered, the most relevant strand turns out to be CTA, which emphasises anticipation and the feeding back of insights from TA activities into the design of new technologies themselves by broaden of networks of actors. CTA is not done after technologies have emerged, but is based on anticipation, reflection and intervention – highly suited for strategic management of rapidly evolving (and uncertain) value chains.

The case of high speed trains looks both at the *product level* (the high-speed train vehicle) and at the *system level* (the high-speed train value chain and infrastructures that support it).

CTA applies several methods which serve two main purposes (Schot and Rip 1997) the one of analysis making (e.g. aiming at setting the scene through problem identification, phase in which is the technological development is, actors involved and their expectations) and practice-oriented (e.g. interventions allowing for future technology formulations embedding society).

CTA is informed by analysis of the dynamics of technical change, tracing the evolution of the innovation journeys of new product developments (Van de Ven 1999, Rip 2012) or multi-level perspective (Geels 2002, Robinson 2009) and multi-actor dynamics (Parandian 2012).

Common methods and approaches applied in CTA include socio-technical scenarios developed by Robinson and Rip (see Rip and te Kulve 2008, Robinson 2009, Parandian and Rip 2013), expectations mapping (van Merkerk and Robinson 2006), open-ended roadmapping (Robinson et al. 2013), multi-stakeholder workshops (Krabbenborg 2013), bridging events (as formulated by Robinson 2010, p13) and backcasting (Schippl 2008).

For the case of high speed trains, the process of product creation (in the words of Deuten, Rip & Jelsma 1997) is about strategic management of research projects through alignment (Schot & Rip 1997) of all the stakeholders in the supply chain (or network), including their visions on what the product should be. This requires a special attention to collective agenda building.

Therefore, in this dissertation, a CTA approach should be taken as to analyse the emergence of the digital society in railways, the process of embedding society in the collective agenda building and understand the anticipation of the technology areas most propitious for societal embedding.

CTA will be mobilised in different ways in this dissertation. For example, in chapters IV and V I apply CTA methodologies for the analyses of high speed trains and supply chain, whereas in chapter VII I shift to CTA practice oriented to formulate my recommendations. Such in ways that can be of use to strategic future-oriented formulations by the collective of stakeholders in SHIFT2RAIL[33].

2.2.2. Distinctive theoretical elements

The CTA strand[34] extends the application of TA to a broader audience than public agencies, such as firms, consultancies, non-governmental organizations, research centers and others. The methods may change, but the motivation remains the same: to "assess the promise, and the profit, of new technological options, and/or carry out a broad version of cost-benefit analysis, sometimes also including risks" (Rip 2001, p.15512:15515).

CTA places an emphasis on the impact of the new technology as a joint product of interactions between the broad range of actors involved; their connections beyond traditional stakeholders in the supply chain towards a broader more extended mix of public and private actors.

In this multi-actor and multi-dimensional space, CTA aims can be located at supporting agenda building through reflexive anticipation and assessment of new emerging technologies and the innovation pathways that may emerge.

---

[33] I chose to investigate the innovation system of high speed trains with a view to improving the design, development and embedding of high speed trains into society. However, another useful activity may have been in the other spheres shown in figure 2.2. For example, if the target audience would have been national or European governments or public agencies falling within the policy sphere, Parliamentary TA would have been a worthwhile strand. Parliamentary TA would have required an analysis on the formulation of policies for transport and research, including policy visions for a high-speed rail network, in Europe or in a specific country corridor. That would have required the analysis of the strategic intelligence of governments and public agencies in the process of regulatory forcing towards technology solutions (see Schot & Rip 1996, p.258:268).

[34] In a skype interview I made to A. Rip by Skype he stated that CTA is not a theory nor a discipline but a perspective of TA.

In this way, CTA can be used as a strategy support system, identifying key issues and elements that may be important for decision making during early stages in the technology development process (Rip 2001, p.15512:15515, Parandian 2013, van den Ende et al. 1998).

The extended network described in CTA has an *actor role* element (including more actors with a variety of roles the process of technology emergence) and a *chronological* element, bringing together actors from upstream, midstream and downstream in the value chain. Thus CTA can be said to, temporarily, remove the chronological bias in terms of the power to shape technological development, including its directions and adaptations (Van den Ende et al. 1998, p.11:20).

In this way CTA has often been positioned as a way to "(…) overcome the institutionalised division of labour between promotion and control of technology" (Rip & Te Kulve 2013), known as Collingridge dilemma[35].

It addresses with the inherent asymmetries between "impactors" (insiders, at the source of the technology) and "impactees" (outsiders, impacted by the technology) with heterogeneous powers, timings and interests and expectations (Parandian 2012[36], Robinson 2010, p. 114:1-523).

CTA proposes doing it by bridging events between impactors and impactees (Parandian 2012), orchestrated by a third party, to probe each other's assessment worlds[37] (supply-chain plus[38]), and ultimately arrive to socio-technological scenarios of aligned visions (see figure 2.3 below).

---

[35] Collingridge (1980) refers to: Information problem - at early stage of technology development is difficult to see their impacts and; Control power - control or change is difficult when the technology become widely disseminated and adopted.

[36] Impactors detain the technological knowhow from design as they introduce it. They are insiders, focus on technological development, and know little about the outside. While Impactees acknowledge the technology only when it matures, so they are followers. They are outsiders, but relevant in the technology adoption and diffusion. They have different knowledge, expectations and interests.

[37] Robinson (2010, p.114:1-523).

[38] To which Robinson's doctoral work have greatly contributed (Robinson 2012). See also paper Robinson (2009).

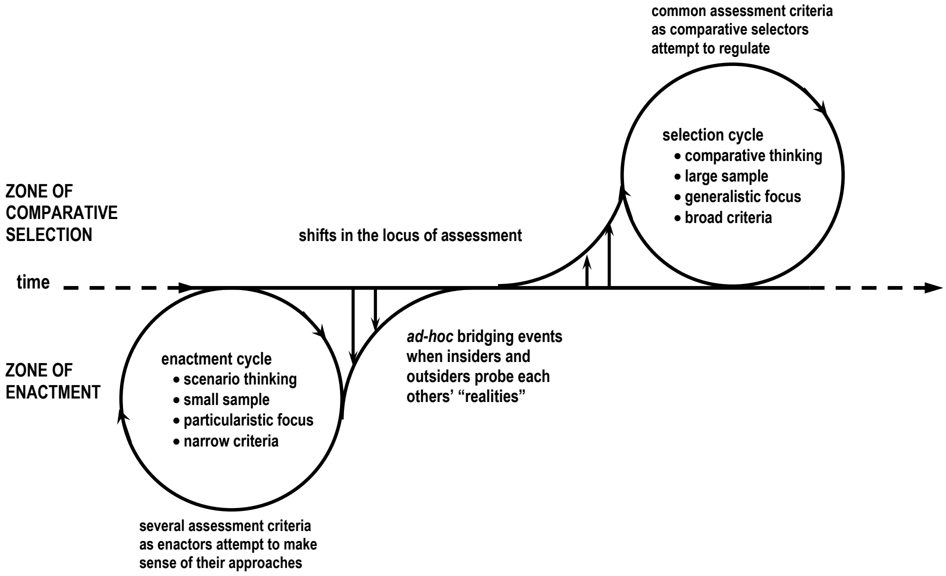


Figure 2.3. Enactment and Selection adapted by Robinson (2010) from Garud and Ahlstrom (1997)
Source: Robinson (2010, p.13)

Those scenarios not only take actors initiatives and interactions into account but also their surroundings. They are not used to extrapolate particular developments into future (control function) but rather to enhance the flexibility of stakeholders regarding their strategic decisions (mutual-learnings), which in its turn modulate technology developments (Robinson 2010, p. 114:1-523).

As referred in Parandian (2012) overall "it is not the aim of CTA to push societal learning process as a remedy for all evils, but to draw attention to the dimension of learning in interaction, in particular in heterogeneous interactions". This is done, in the words of Robinson (2010), through CTA methodology tailored for supporting "better informed designs of "future working worlds" which are learned by theory, but are empirically well grounded so they are usable by decision makers".

I take Robinson perspective on the goals of CTA as a core part of my dissertation.

2.2.3. Origins and applications

To understand the theory it is important to know its origins and applications. The main reference I could find was in Schot and Rip (1997) work, making the argument for CTA in the broader world of TA.

In retrospect CTA has its origins in the modern TA strands in the field of science and technology studies. It was introduced by the initiative of the Dutch government in the mid of the 1980's[39], to broaden decision-making about science and technology in society, with societal aspects becoming an additional design criteria.

At that time Netherlands Organization of Technology Assessment (NOTA), and now called the Rathenau Institute, was established to implement CTA. According to Schot and Rip (1996, p.253:268) two branches evolved. One oriented to public opinion (in Parliament) through public debate, and yet very attached to the first wave of TA; The other, which I have been referring to, on the "social learning how to handle technology" through devoting 1% of the funding in every technological innovation simulation program to TA studies[40].

The first branch of CTA was even subject to a policy document in the Organization for the Economic Cooperation and Development (OECD) during 1988 related to the externalities of technological changes (Schot & Rip 1996, p.254).

It is however the last referred CTA branch that is of the most relevance for my dissertation, which initially appeared during the 1990's as a component of the Dutch national programme for biotechnology and in 2005 in the Dutch national nanotechnology consortium, NanoNed[41] (te Kulve & Rip 2011). CTA methods have contributed to the agenda setting of future technologies and mapping the value chain capabilities to bring the technologies to the market.

Schot and Rip (1997, p.253:268) refer also to the project PRISMA[42], held at the end of the 1990's, focusing on CTA deployment in "demonstration projects" in the field of environmental friendly technologies in firms and other organizations. In this project developers simulate the introduction of environmentally friendly technologies in firms and other organizations.

Also, during the early 1990's, the authors refer to the Dutch institute for consumers (SWOKA) project called "Future Images for Consumers" aiming at incorporating consumers and their wishes into design processes. "The procedure consisted of a process of interactive meetings in which room is created for discussions and negotiations on design criteria and visions of both producers and consumers" (Schot and Rip 1996, p.253-254:268).

---

[39] That emerged three decades after the first generation of TA was introduced in the U.S.A. in the 1950's and 1960's.

[40] This could well be case for the new governance of research and development being set by SHIFT2RAIL.

[41] NanoNed is a consortium of Dutch research institutes working in nanoscience and nanotechnology. Rip (2005) explains how constructive technology assessment was implemented in drug delivery and molecular machines.

[42] For more information Schot and Rip (1997) and Dleieman and De Hoo (1993)

The method was also extended in 1996 to the Dutch programme on sustainable technologies (DTO) on the introduction of novel protein food replacing meat in the diet. CTA contributed to identify consumer requirements and identification of new market opportunities.

CTA is not restricted to the Netherlands. Also in Denmark CTA emerged quite early, during 1980's, reflecting this country tradition on public involvement. Monitoring it has been since the Danish TA organization. CTA is also found, but not labelled as such, in other countries such as Norway and Germany. CTA was introduced initially in the fields of telecoms and waste disposals respectively (see references in Schot and Rip, 1997, p.254:268). In Germany CTA has been mainly focusing on future technology assessment aiming at early awareness on the risks and implications of future technologies and less on the technology development process (most recent work Grin & Grunwald 2000, Grunwald 2011).

Since early 2000's CTA is in the process of building its own identity across Europe, addressing specific sectors or emerging niche technologies. There is an emancipation effort from the new generation of authors applying the theory from the first authors at the origin of its concepts and models.

Contributing to it is the new generation of "academics at the micro-level addressing better designs for technologies through bringing more people and more dynamics" (source Robinson, 2015.05.15). They have been mainly applying CTA on open-ended technologies such as lab-on-a-chip technology (van Merkerk and Robinson 2006, van Merkerk 2007), nano-drug delivery (Robinson 2010, p. 303-348:1-523), tele-health systems for chronic diseases (Elwyn et al. 2012), body area networks (Parandian 2012), deep brain stimulation devices (Robinson et al. 2013) along with many other applications. But also matured technologies such as micro-grid on energy distribution (see Manuel Baumman forthcoming dissertation with a view to the German market) and railways (with this dissertation focusing on high-speed trains in Europe).

CTA has been as well part of research and development projects (Weil et al. 2014). Relevant projects are TRANSFORUM[43] (Schippl 2008) dealing with strategic formulation in transports and the previously referred PACITA project[44].

2.2.4. Theoretical aspects of relevance for the high-speed train industry

A central article is the one of Deuten, Rip & Jelsma (1997) on the "Societal Embedding and Product Creation Management" where the authors advocate that, for new technologies to

[43] http://www.transforum-project.eu/.

[44] Link http://www.pacitaproject.eu/.

succeed, there is a requirement to go beyond market uptake through the inclusion of societal embedding processes as part of the product development process.

The authors in this paper address exactly the challenges currently faced by the high-speed train industry as described in the introduction: the one of reorienting the promotion and control of new technologies (dealing with business and regulatory environments) to the one of mutual-learning and orchestration (dealing with the wider society).

Deuten, Rip & Jelsma (1997), inspired by actor-network theory (Callon 1986, 1992), state that new technologies have to pass through different environments of selection, such as business, regulation and wider society. Each scenario addresses different elements accordingly the one of “integration” (business), “admissibility” (regulations) and “acceptance” (wider society).

These authors continue by saying that firms mostly tend to follow a sequential approach to those environments and; once their technology developments reach the wider society it might be too late to accommodate interests and values[45].

The authors suggest that to succeed, firms approach to the different environments of selection must be simultaneous and integrated in its product chain process from early stages of technological development. There is also the need to know at which stage the development of new technological products is. They call this the “extended innovation journey” (Deuten, Rip & Jelsma 1997, p. 136:148). It includes the traditional “Product Construction Process” (PCP) plus “Societal Embedding in Product Construction” (SEPC).

These authors recognise the “dilemma” it creates as it increases uncertainty in the product development project through adding more factors (and more actors) and thus revealing much of the previously unattended gaps[46] between the technology developers and the wider world of technology adopters.

Deuten, Rip and Jelsma (1997) suggest that firms should not fear market failure of new technologies as this leads them to take anticipatory actions for promotion and for control of acceptance of their new technology that are uncontrollable anyway. The authors rather suggest that firms should adopt an approach of mutual learning through actions of anticipation mapping what each actor can bring to the development.

In view, “orchestration” events, mediated by a CTA practitioner, should promote the necessary pre-engagements which in its turn result in “scenarios of embedding”. Also referred as “socio-technical scenarios” (Robinson 2009) they articulate how the new product can be embedded in

[45] Deuten, Rip & Jelsma (1997) refer as wider society actor’s consumer organisations, environmental groups, animal protection organisations and also public opinion leaders, media, independent scientists. It should also include social networks connected by mobile telecommunications, not existing at the time the authors wrote the paper.

[46] This gap refers to differences in knowledge, interests and culture.

its environment; they “bridge” actors’ gaps in strategies & interests and they promote necessary alignments (Paradian 2012).

The authors state that today, technological products are dominated by complex systems of which no one has total knowledge, so firms are not alone. “Extended innovation journeys” through societal embedding widens the collective action of product creation to societal actors, bringing to the learning process new ways of viewing problems and finding solutions.

The authors (citing Argyris & Schöln 1997) refer that the learning process is continuous and can happen in a single or double loop. They associate single loop to a control approach from technology developers and double loop to the one of orchestration. Stakeholders’ openness to the collective learning depends on their position in the supply chain.

This way once society is recognised as a stakeholder they get a constructive role in product creation process (PCP), e.g. they become part in the creation of value. However, they also note that the way firms manage “extended innovation journeys” depends on their positioning in the supply chain, where each location in the supply chain exerts different learning pressures. The authors state that practitioners of CTA have to address it.

2.2.5. Theoretical elements developed

Science and Technology Studies (STS) scholars, as well as engineers, have built on Deuten et al. (1997) by practicing and reflecting on the different elements of the approach of broadening product development processes.

Geels (2002) for example, addresses sector-level technological dynamics mobilising the work of Callon et al. (1992). He develops a multi-level framework for analysing the technology transitions, where this framework produces visualisations that are useful in showing the context of the technology development and assisting in the anticipation of its future developments. He demonstrates the framework through examining the ship industry and most recently electric vehicles (Geels et al. 2011) in similar ways as Nelson & Winter (1977) did for aeronautics.

Robinson and Propp (2008) and Van Merkerk and Robinson (2006) extend Geels approach through understanding the dynamics of path emergence, fuelled by promises and shaping the future evolutions of the field. They show that such analyses can feed into engagements with stakeholders, such as in CTA workshops (Krabbenborg 2013).

Te Kulve and Rip (2011) further reflect on how preparing pre-engagements between technological stakeholders and civil society (i.e. “timely” analysis and structuring of actors interactions) can be used for CTA purposes. The key point is that organizing and moderating stakeholder interactions is not enough. The author calls for the substance in those events, which requires preparation. The authors suggest pre-engagements to be moderated by third party agents (to avoid partiality) to address the heterogeneity between stakeholders and society. He does that by examining the emergence of nanotechnologies in food packaging sector.

In their PhD theses, Parandian (2012) and Robinson (2010) look at processes that will enable CTA to help bridge the gap between technology development and use. They suggest, following Garud and Rappa (1994) an approach to bridge between the heterogeneous perspectives and different timings enactors (proposing new options / push) and selectors (respond to promises / compare). The approach aims at pulling the heterogeneous actors in the same direction.

Most recently Justen et al. (2014) reflect on the inclusion of unknown-unknowns stemming from societal environment in futures analysis. This type of activity is visible elsewhere in management studies of design (Agogué et al. 2012) where structured assessment of unknown unknowns is supported as a management tool in the development of new products for new industries.

2.2.6. Contribution

Rather than CTA applied to a niche technology steaming form science, amidst speculation on open-ended futures, my PhD dissertation attempts to bring CTA into a mature technological field of application: the one of high-speed trains innovation system. The incremental nature of high-speed trains presents much more stable futures than many of the previous CTA studies prevailing in the field of nanotechnology. In this way, this dissertation contributes to broaden societal reflexive CTA into demonstration CTA.

In doing so, I will seek to verify the main propositions put forward by, of what is a central paper in my dissertation, Deuten, Rip and Jelsma (1997) for the high-speed train technology development process.

III. METHODOLOGY

This chapter presents the research questions and propositions as well as the methodology applied as to assure the scientific quality of results.

3.1. Research questions and propositions

The present research study arises from railway's discussions at European forums on the urge in the "market uptake" of new collective technological developments, in particular for high-speed trains. From observations, discussions often overlook the magnitude of societal constraints for effective market embedding of high speed trains, which becomes even more visible when taking into consideration the emergent direct pressures arising with the exponential digitalization of society. Such escalation in relevance, if one considers that those debates are at the heart of the SHIFT2RAIL[47] joint undertaking, sets a demand for new governance of research and development in this area from which will result a "new wave" of collaborative research projects, much more market oriented and potentially much more social oriented.

In order to positively contribute to this trend, it appears relevant the understanding on *i) How the industry might be falling short in considering embedding in society as part of their product development processes?* and *ii) How can it be improved?* Before however, it is imperative to establish the relationship between the high-speed trains and TA as the theoretical framework of my studies.

RQ.1. What is the relationship between the high-speed train technology and TA?

P.1. Proposition – Rail and TA intercepts at the level of actors' technological decision making (technology selection).

TA refers to "informed decision making" on new technologies as the ones being inclusive of society. Those decisions are made by governments, non-governmental institutions, corporations alone or in networks. Each one is covered by different TA strands.

Since 2001 high-speed train manufacturers became fully responsible for designing, manufacturing and commercialising the vehicles in collaboration with their network of suppliers.

[47] New governance structure for collective research and development launched in 2014. Link http://shift2rail.org/

TA presented different strands which selection depends on the addressee (governments, non-governmental institutions, firms, or their networks) and level of application (policy-making, science and technology, public engagements).

This proposition requires literature review on the various TA strands as to find the best suit.

RQ.2. How the industry might be falling short in embedding society in their product development?

P.2. Proposition – The case of the AGV and the ICE-350E, as explained in the introduction, appears relevant as the disappointing commercialisation of those trains after years of collective investments in their development has raised concerns in the railway industry on the market uptake of their new technologies, while fast emergent digitalisation of society is imposing new challenges.

Here justifies a case study analysis. The object of analysis being therefore the development process of those trains. The unit of analysis are their manufacturers, Alstom and Siemens, and collective of stakeholders' part in the technological chain.

CTA offers different layers for analysing the industry practices, which unfolds into four sub-research questions (SRQ.2.1, SRQ.2.2, SRQ.2.3, SRQ.2.4):

SRQ.2.1. What happens in terms of innovation journey?

P.2.1. Proposition – the AGV and the ICE-350E innovation journeys are about technological decisions made by Alstom and Siemens strategic intelligence feed from the aligned network of actors involved in the supply chain (as a collective exercise). Deuten, Rip, Jelsma (1997) model on social embedding in "new product creation" offer the analytical framework to understand if and how Alstom and Siemens address society within their product development processes.

SRQ.2.2. What has been the evolution in time?

P.2.2. Proposition – Strategic decision-making has not always existed in the development of high-speed trains. It is relevant to understand how decision-making in high-speed trains has evolved over time focusing in the societal element. Geels (2002) offers a model to study decision-making in the technological transitions. There is a strong link with the historical analysis.

SRQ2.3. What happens in terms of multi-level perspectives?

P.2.3. Proposition - The AGV and ICE-350E resulted from the alignment of the different technological perspectives from the various stakeholders. Geels and Schot (2007) analytical framework can be also applied here as to map stakeholders' perspectives and at which level alignments occur.

SRQ.2.4. What happens in terms of strategic formulations of future technological paths?

P.2.4. Proposition - The AGV and ICE-350E cases reveal the agendas of the industry in their collective visions and roadmaps. Robinson and Propp (2008) classification method offers a contribution for a taxonomy of those agendas.

RQ.3. Who in the R&D process has the propensity to address societal embedding?

P.2.3. Proposition – The actors that have a stake (direct or indirect decision makers) in the technological development of the AGV and ICE-350E do not have the same approach towards societal embedding. It is therefore relevant to conduct a survey around this issue build around the previous findings.

RQ.4. What recommendations can be made?

P.4. Proposition – The industry led joint initiative SHIFT2RAIL most likely continues overlooking society, which perhaps leads to a lack in the necessary instruments and expertise to address societal demands. The necessary instruments can be found in practice oriented exercises conducted under the banner of CTA (te Kulve and Rip 2011, Robinson 2010, Paradian 2012, Krabbenborg 2013, Justen et al. 2014). Here, ideas and approaches should be speculated about the contribution that CTA in practice can bring to the high-speed train development process.

3.2. Research framework

Constructive Technology Assessment (CTA) provided the analytical framework used to structure the research plan, figure 3.4 below.

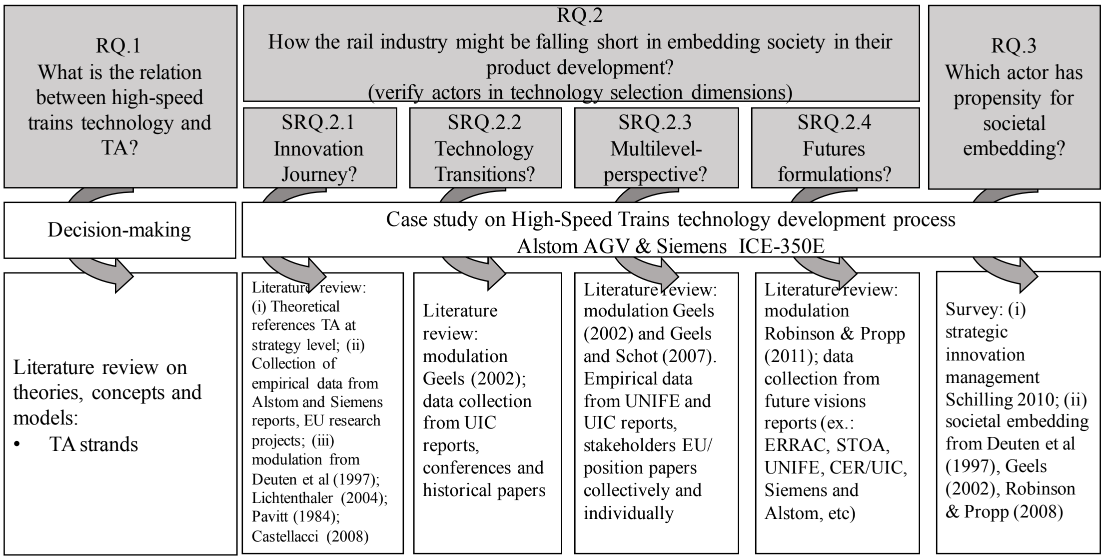


Figure 3.4. Research plan

Before addressing the central research question it was necessary to understand the relation between high-speed trains and Technology Assessment (RQ.1 in figure 3.4). With that purpose literature review was conducted on Technology Assessment theory, strands, concepts and models centred around decision-making.

The second step was to verify railway stakeholders approach towards societal embedding in the decision-making process during the technology development (RQ.2 in figure 3.4). The study was narrowed to the case of the high-speed train vehicles, the AGV manufactured by Alstom and the ICE-350E by Siemens, because they absorb the highest volume of investment in research.

Constructive Technology Assessment analytical framework lead to subdividing the central research question in sub-questions about the high-speed trains innovation journey, technology transitions, multi-level alignments and future formulations.

In terms of innovation journey (RQ.2.1 in figure 3.4) it was necessary to review literature on the strategic function of technology assessment as support to decision-making and collect empirical data on the manufacturers technology organisational structure and vehicles technology development process. Such data was found in Alstom and Siemens reports plus in other EU research projects. For the modulation and visualisation of the data collected support was found in Deuten et al. (1997), Lichtenthaler (2004), Pavitt (1984) and Castellacci (2008).

In its turn, the study of the high-speed trains technology transitions (RQ.2.2 in figure 3.3), required data collection mainly found in UIC reports and website, conference presentations and history records. The modulation of data was based on Geels (2002a).

The map on the multi-level perspectives of the various stakeholders involved in the AGV and ICE-350E technology development process (RQ.2.3 in figure 3.4) was constructed from the empirical data retrieved from UNIFE and UIC reports as well as stakeholders position papers at European level. The modulation of the data was made recurring mainly to Geels (2002) and Geels and Schot (2007).

The study on railways future formulations covering high-speed trains (RQ.2.4 in figure 3.4) addressed the methodologies used in the various reports produced by the railway industry (as from ERRAC, CER/UIC, UNIFE and Siemens) and the European institutions (the European Commission and the European Parliament). The classification of found reports referred to Robinson and Propp (2011) classification method.

A survey was conducted to extend the study to the broaden high-speed trains supply chain as to identify which actor in the AGV and ICE-350E technology development process had propensity for societal embedding while it was an instrument to validate the findings from previous (RQ.2.5 in figure 3.4). The survey was constructed in two parts. The first mainly referring to innovation management practices as found in Schilling (2010); and the second from societal embedding elements as mentioned by Deuten et al (1997), Geels (2002), Robinson and Propp (2008).

The construction of knowledge in this process was therefore a combination of the two dominant epistemological currents dominant in social sciences being, according to Hennen, Weinstein and Foard (2009), the interpretivism (qualitative), and positivism (quantitative). First by applying qualitative techniques such as observations, interviewing and documentary analysis. Here, Miles and Hubernam (1994) offered reference analytical tools and Yin (2003) a guidance in conducting case studies for research purposes. On the quantitative side was applied a survey as to extend the study to the broad of actors and validate results.

IV. THE CASES OF THE AGV AND ICE-350E DEVELOPMENT PROCESS

In this part of the dissertation I verify the propositions referred in the methodology chapter by applying Constructive Technology Assessment strand framework of analysis to the reference cases, the high-speed trains AGV and ICE-350E.

Therefore, it is covered in chapter 4.1. Alstom and Siemens strategic intelligence (section 4.1), technological transitions from one generation of trains to the next one (section 4.2), actors multi-level perspective during the development process (section 4.3) and future strategic formulation (section 4.4).

This chapter follows a structure replicated in the sequent chapters: introduction, theoretical reference, analysis and findings. Results in this and following chapters will be later validated by the survey.

4.1. Strategic intelligence

4.1.1. Introduction

Today design, development, assembly and supply of high-speed trains are in hands of the European manufacturers[48]. They are renewed private multinationals whom are market oriented in developing the trains in collaborative networks of suppliers[49]. Their technology management rely more than ever on strategic innovation management tools to decode the complex system in which they need to integrate their technologies under liberalised market conditions[50].

This resulted from the previous reference to the European Commission regulatory push exerted since 2001 on member states to make high-speed rail the backbone of a unified European long-distance passenger transport system[51]. The main determinants for this directive were the grand challenges of European foreign oil dependency, traffic congestion, climate change and territorial integration yet far from the direct social pressures of today.

Looking at public data from the European Commission (2010) and the International Union for Railways (2010a, 2010b, 2015) one can actually recognize the dimension that railways revitalization took.

Over 40% of the European passenger transport traffic for medium-length distances is now made by high-speed trains. The commercial speed has reached a maximum of about 300 km/h for the majority of installed systems (Germany, Italy, United Kingdom), 310 km/h in Spain and 320km/h in France[52].

---

[48] The definition of High-Speed Train is found in the Council Directive 96/48: "A high-speed train is a train capable of reaching speeds of over 200 km/h on upgraded conventional lines and of over 250 km/h on new lines designed specifically for high speeds". They are train set mainly serving cross border international routes. See also Campus et al. (2006, p.5-8:21).

[49] Their origins are found in the under-invested metalwork-engineering firms dependent from their national governments.

[50] Cadet, 2011.

[51] Several initiatives on the liberalisation of the railway market took place, stating in 1991 with the Directive 91/440/EEC giving open access operations on railway lines by companies other than those that own the rail infrastructure, and later in 2001 with the European White Paper on Transport COM(2001)370 setting the strategy revitalising railways though an integrated trans-European network opened to competition, implemented so far by a sequence of four railway packages (2001, 2004, 2007 and 2013) and assessed by the EC Road Map COM(2011)144 also launching the Single European Railway Area (SERA).

[52] Source: Wikipedia, http://en.wikipedia.org/wiki/High-speed_rail, viewed in August 20th, 2012. For a comparative exercise one could also refer to the Japanese case. The Shinkansen reaches also 300 km/h (Wikipedia, http://en.wikipedia.org/wiki/N700_Series_Shinkansen, viewed in October 31st, 2012) and by the end of 2012 the commercial speed will be 320 km/h ("Tohoku Shinkansen Speed Increase: Phased speed increase after the extension to Shin-Aomori Station". East Japan Railway Company. 6 November 2007. Retrieved October 31st, 2012).

Europe doubled its fleet from approximately 620 operating units in 2000, to 1.243 in 2010, becoming the largest fleet in the world only to be overpassed in 2014 by China exponential growth; its dedicated network increased from less then 3.000km in 2000, to 6.214km in 2008 (European Commission, 2010), with an additional 8.705km planned (International Union of Railways 2010a, 2010b).

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

In a circuit of major European cities (Paris, London, Amsterdam, Koln, Frankfurt and Brussels) from 1989 to 2009, travelling time has been reduced from 4 hours and 2 minutes to 2 hours and 24 minutes[53] - a 38% decrease (European Commission, 2010).

Moreover, there were the business and organizational reforms opening the industry to competition and making it vulnerable to cost-pressures and customer demands, as well as shifting the vehicles design, maintenance and R&D from train operators to the manufacturers[54].

Besides the new regulatory and business demands, requiring for interoperable, modular and safe high-speed trains, the industry was confronted in 2001 with issues of environment, safety, public acceptability and other aspects of "social quality" (to use Schot and Rip1997 terminology).

To comply the rail manufactures were (and still are) investing about 500 million Euro a year in new developments (not only in high-speed[55]) from which have resulted the latest generation of high-speed trains with the ICE-350E in commercial operations since 2006 and the AGV since 2008.

Pressures on returns on investments and mitigation of market failure made their manufacturers Siemens and Alstom to adopt a strategic management approach in their technological development, putting aside the often used costly trail-and-error developments[56].

[53] 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 Köln-Frankfurt (from 2 hours and 10 minutes to 1 hour and 10 minutes, -46%). Today it is even possible to travel from Stuttgart to Paris in 3 hours and 41 minutes (source: Deutsche Bahn at http://reiseauskunft.bahn.de/bin/query.exe/d, viewed in June 8th, 2012).

[54] Pereira 2011 and Cadet 2011.

[55] Pereira 2011.

[56] Pereira 2011.

As referred already in the introduction, both manufacturers involved the collective of relevant stakeholders in the supply chain to develop off-the-shelf vehicles capable of running in all networks under the stimulus of the European Commission and Member States.

According to Pereira (2011) Alstom and Siemens had two main purposes in developing the existing vehicle platforms TGV and ICE-3 into the AGV and ICE-350E: improve performance and attractiveness (the last one, including compliance with regulations).

To solve performance problems, the manufactures together with the supply chain targeted technology developments, for example, those 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).

To foster more specific research tailored to achieve defined outcomes to make the vehicle attractive and compliant with the European Commission regulatory reforms and customer new requirements, the industry targeted technology developments in areas such as energy power, biomechanics, human/machine interface, environmental friendly technologies, safety and comfort.

As I will further refer to in section 4.1.2 of this same chapter, Technology Assessment constructivists (Deuten, Rip and Jelsma, 1997) argue that it is mainly on the attractiveness / "acceptance from users" aspects of technology development that societal embedding occurs, linked to the other dimensions as business and regulations.

At the time of development of AGV and ICE-350E social movements were limited to non-governmental organizations, civic movements or opinion-makers influencing mainly policy-making and regulations on specific interests. While travelers' mobile connection to social networks as we know it today emerged after those high-speed trains entered the market (in 2006 and 2008).

In this section of the dissertation I present the evidences found on the elements of CTA framework for societal embedding, as constructed in Deuten, Rip, Jelsma (1997), in the various dimensions of the innovation journeys of the AGV and the ICE-350E from 2001 to 2008.

This way the chapter starts by recalling on the relevant theoretical references covering CTA analytical framework allowing to identify societal embedding in the technological decision-making by Alstom and Siemens during the innovation journey of the trains (Section 4.1.2). A reference is made to the data collection (Section 4.1.3).

Societal embedding is then identified in manufacturers' organisational structure covering strategic intelligence and surveillance structure (Section 4.1.4) and development dimensions referring to technology transfer, technological system and decision-making trajectories (Section 4.1.5). Findings present a summary of the evidences found of societal embedding (Section 4.1.6).

A final note is to say that although the drastically increasing figures here presented on the growth of high-speed trains, this market-segment represents no more than 10% of manufacturers annual turnover and its growth forecast in Europe is steady (Rolland Berger 2014). However high-speed trains are worth to be studied, as it is where the industry makes its highest efforts embedding high-end technological solutions, due to the speeds the trains reach subject to tight safety and quality standards.

4.1.2. Strategic function of TA

Literature refers to Technology Assessment (TA) as part in the strategic innovation management of the technology promoters[57]. Kuhlmann et al. (1999) is the first conceptualizing on TA function within "strategic intelligence".

According to Kuhlmann TA providing the means to decode complex innovation systems is the equivalent to other strategic intelligence forms, namely, technology forecasting, technology foresight, evaluation and road mapping (Kuhlmann et al. 1999, Kuhlmann 2001).

Smits et al. (2008) further elaborates on TA distinctive elements from other forms such as: its focus on decision-making support (instead of technology developments as in forecasting and road mapping); problem orientation (as opposed to early-warning functions, or evaluation as in foresight); and intensive interaction with a wide variety of actors.

The strategic function of TA in its turn is built from Schot & Rip (1997) earlier extension from policy-making to non-governmental institutions. They transposed TA practices from impact assessment to anticipation from the early stages of the technology development process. See section 2.2.

Schot & Rip (1997) were responding to the required dialogue between the Dutch emergent nano-technology firms and interest groups to address inherent societal issues. The authors use anticipatory methods employing dialogue and early interaction between actors from an early

[57] TA community commonly refers to new technologies instead of innovations. I will be referring to both.

stage of what the authors called "product construction process"[58], to identify their distinctive technological interests and capabilities of intervention.

Rip further developed it with Deuten and Jelsma by elaborating on a general theoretical framework on how firms should address societal embedding in their product creation process (Deuten, Rip and Jelsma, 1997). From here emerged CTA strand which main argumentation has been explained in section 2.2.4.

Deuten, Rip and Jelsma (1997) CTA analytical framework for societal embedding in new product creation as introduced in section section 2.2.4 can be summarised as follows in figure 4.5.

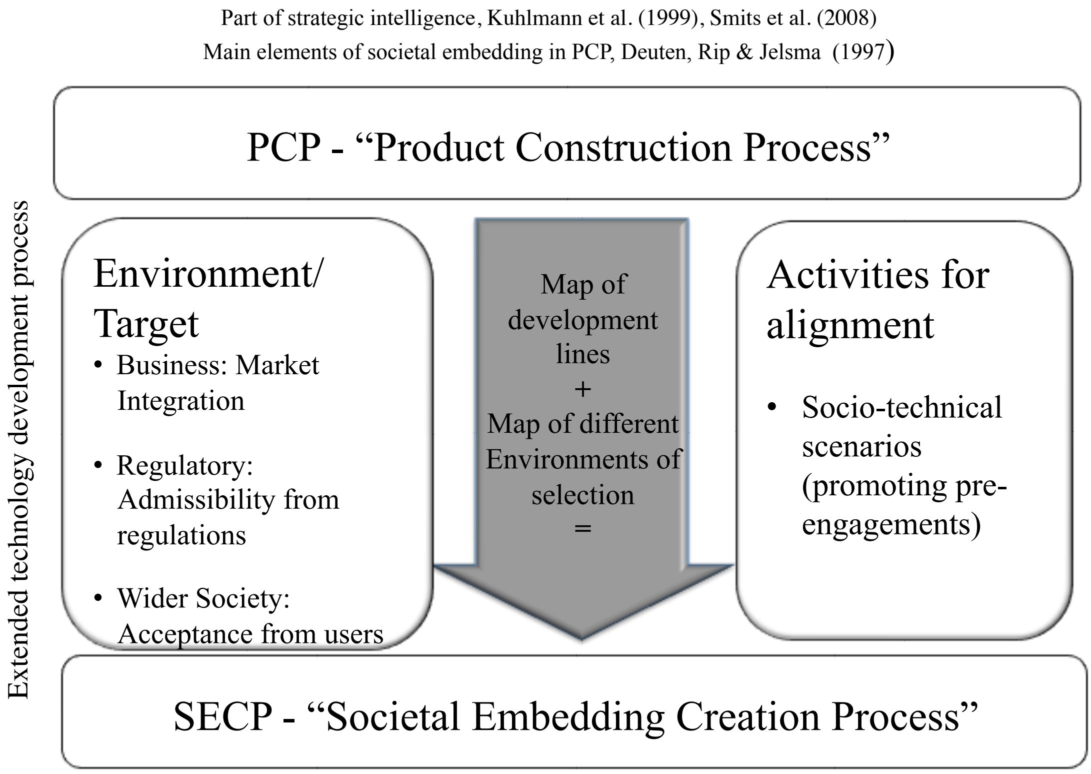


Figure 4.5. Extended Product Construction Process to society referred in Deuten et al. (1997)
Source: Author

As figure 4.5 shows in 1997, Deuten, Rip and Jelsma called for a broad notion of market success of new technologies by extending it to the participation of societal actors.

At the time, the authors referred to non-governmental organizations as customer organizations, environmental groups or even animal protection organizations (as they were addressing bio-technology) and also to opinion-leaders, media and independent scientists (Deuten, Rip and

[58] The same as technology development process.

Jelsma 1997). As it was also said for the AGV and ICE-350E, by the time these authors wrote their paper digital social networks as we know today did not existed yet.

Figure 4.5 left column represents Deuten et al. (1997) recommendation stating that new products to succeed have to meet three main targets each corresponding to specific environments of selection: market integration part of the business environment, admissibility with regulations in regulatory environment, and acceptance from users found in wider societal environment.

The central arrow in figure 4.5, refers to the product development process where the authors suggest that the firms should have a clear map on their product development organizational lines, as to know at which stage in the development process the technology is, while simultaneously addressing the three environments of selection.

The authors recognise that such simultaneous approaches towards the environments of selection causes the Collingridge Dilema (already explained in section 2.2.4) in particular when involving wider society from early stage of the development process.

As shown in the left column in Figure 4.5, the authors suggest activities for alignments which promotes pre-engagements, supported by what was latter called by Te Kulve and Rip (2011) socio-technical scenarios. Those scenarios should be constructed on bridging events orchestrated by a third party to which Paradian (thesis 2012) have contributed.

Finally, I would like also to introduce here Lichtenthaler (2004) that, despite not being linked to CTA authors, makes a very comprehensive structure on the technological surveillance frame that feeds strategic intelligence, by studding corporations including Siemens.

4.1.3. Data collection

The findings here presented result from the analysis of data collected from the industry annual reports and empirical data from informal interviews with privileged informers from Alstom and Siemens, sector associations (UNIFE and UIC) and academia.

It also results from my previous research work in Boavida, Cabrita and Moretto (2010) and Boavida and Moretto (2011). The first on the analysis of the decision-making process of the high-speed train project in Portugal and the other on the innovation assessment on a railway multinational subsidiary in Portugal.

It was observed that Alstom and Siemens presented similar patterns in the way they addressed society during the development process of their trains AGV and the ICE-350E. Therefore, distinction will only be made between them in the presentation of results in the aspects they differentiate.

4.1.4. Organisational structure

Societal embedding, if to be found in the AGV and ICE-350E technological development process, is at the level of strategic intelligence (Schot and Rip, 1997) feed by their technology surveillance structures (as conceptualised by Lichtenthaler, 2004).

a) Strategic intelligence

From corporate reports within the time period of the technology development of the AGV and ICE-350E (between 2001 and 2008), strategic intelligence was found as a structured and hierarchical process, allowing for some degree of informal practices, supported by a series of instruments such as knowledge platforms and partnerships, networks, R&D projects and education and training[59].

Figure 4.6 below represents a matrix on the different levels of constrains those manufacturers' strategic intelligence addressed. The circles and arrows highlights the societal elements found.

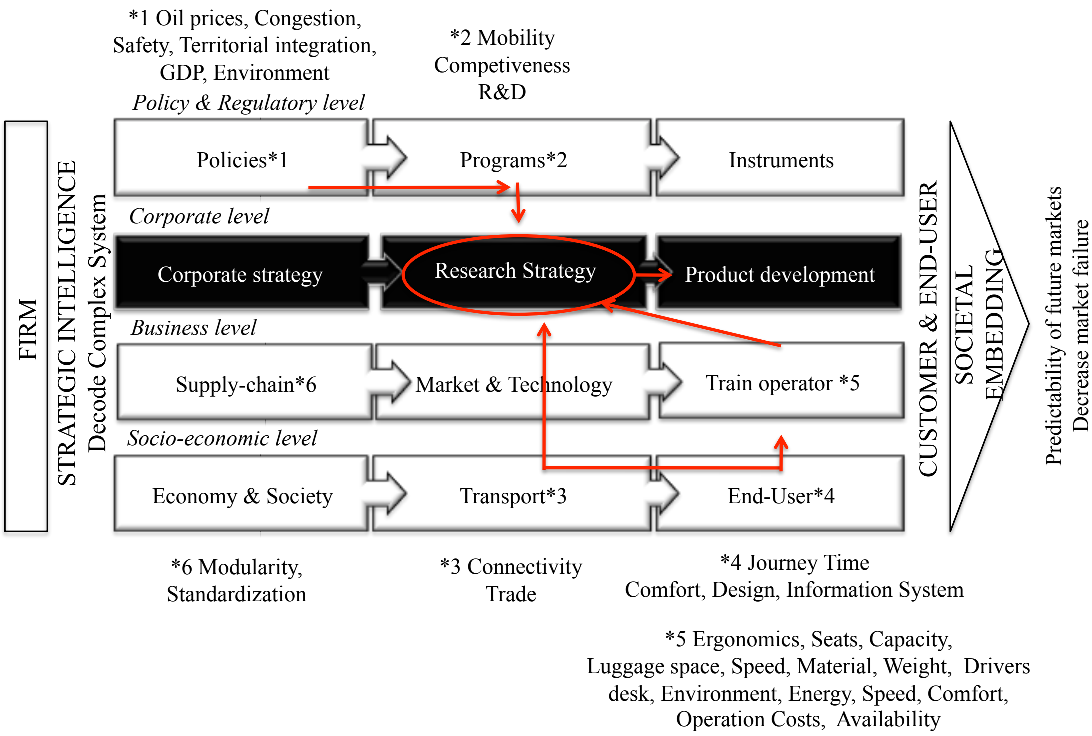


Figure 4.6. Societal embedding within strategic intelligence
Source: adapted from Moretto *et al*. (2012)

[59] The reasons were mentioned at the introduction (sub-section 4.1.1.).

As figure 4.6 illustrates, Alstom and Siemens strategic intelligence aimed to decode complex innovation systems, functioning as a filter of the different levels of external constraints that can be grouped at business, policy & regulations and socio-economic levels. Results are then instrument of management to support decision-making in preparing and implementing the technology development. Society was found at socio-economic level.

These levels roughly match with the "external environment of selection in which a new product has to survive", referred in Deuten, Rip & Jelsma (1997), being "business environment", "regulation environment" and "wider society" as introduced before in section 2.2.4.

Corporate level (in figure 4.6 high middle part of the matrix) correspond to "product development" in Deuten, Rip & Jelsma (1997) internal to the manufacturers organization. Not referred to by the authors, this level falls outside strategic intelligence. Strategic intelligence however feeds corporate strategies unfolding in R&D and commercial ones. Strategic intelligence adds to the firms' internal constraints (i.e. new product development process organisational aspects, design, engineering and commercialization). Manufacturers at this level focus on the internal elements that condition technology decision-making such as cost-reduction and internal resources.

Coming back to the external constraints, at socio-technical level (in figure 4.6 at the lower extreme of the matrix) is where wider society constraints were mostly found and addressed by strategic intelligence. At this level, strategic intelligence aims to decode future transport trends, in terms of connectivity and trade exchanges for instance, and end-users' expectations, such as journey time, comfort, design, and information system.

Societal constraints were also found at policy & regulatory level (in figure 4.6 at the top of the matrix). The main purpose of strategic intelligence at this level is to filter governments' policy drivers, such as decreased oil dependency, climate change and territorial integration, as a mean to anticipate programmatic and regulatory constraints, (e.g. specific norms targeting noise reduction or increased safety of high-speed train vehicles and funding to develop technological solutions). The societal aspects here addressed are demographics, GDP, internet penetration, etc.

At the business level (in figure 4.6 lower middle part of the matrix), strategic intelligence mostly filters market and technology constraints and surveys the activity of competitors with no direct concern for societal aspects. Societal constraints were not found. At this level, manufactures aim to decode the market structure and anticipate customers' technical specifications, such as train capacity and information systems. It is also used to detect new innovation trends within and outside the sector, for example from component suppliers and knowledge centers.

b) Technology surveillance

At organizational level feeding Alstom and Siemens strategic intelligence it was found technology surveillance agents. They perform monitoring the different levels of constraints just described, including wider society. They all have a common task: 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.

Deuten, Rip and Jelsma (1997) do not detail on the optimal organizational structure for better addressing societal embedding in product creation; rather, they limit to mention that managers are those who perform it and that bridging events between firms and societal actors should be mediated by external parties. This part of the dissertation can be seen this way as a contribution to the CTA framework. Here I will be applying Lichtenthaler (2004) technology surveillance structure. Lichtenthaler's structure results from his study of a pull of firms across different sectors, which included Siemens.

From this work resulted figure 4.7 below which aimed at presenting a systematic overview of technology surveillance agents. From there it will be identified the ones addressing society from what was observed in Alstom and Siemens.
Technology surveillance agents according to Lichtenthaler (2004) are grouped in sub-structures ranging from centralized, international, internal and external, which I have positioned in terms of degree of strategic relevance and degree of openness to collaborative R&D[60], as shown in figure 4.7 below. As for the previous figure, circles and arrows highlight the agents found dealing with societal aspects.

[60] For example, technology surveillance agents at centralized structures such as headquarters deal with strategic relevant technologies for the firms with little openness for collaborative actions are found in figure 6 at the left high corner of the graph.

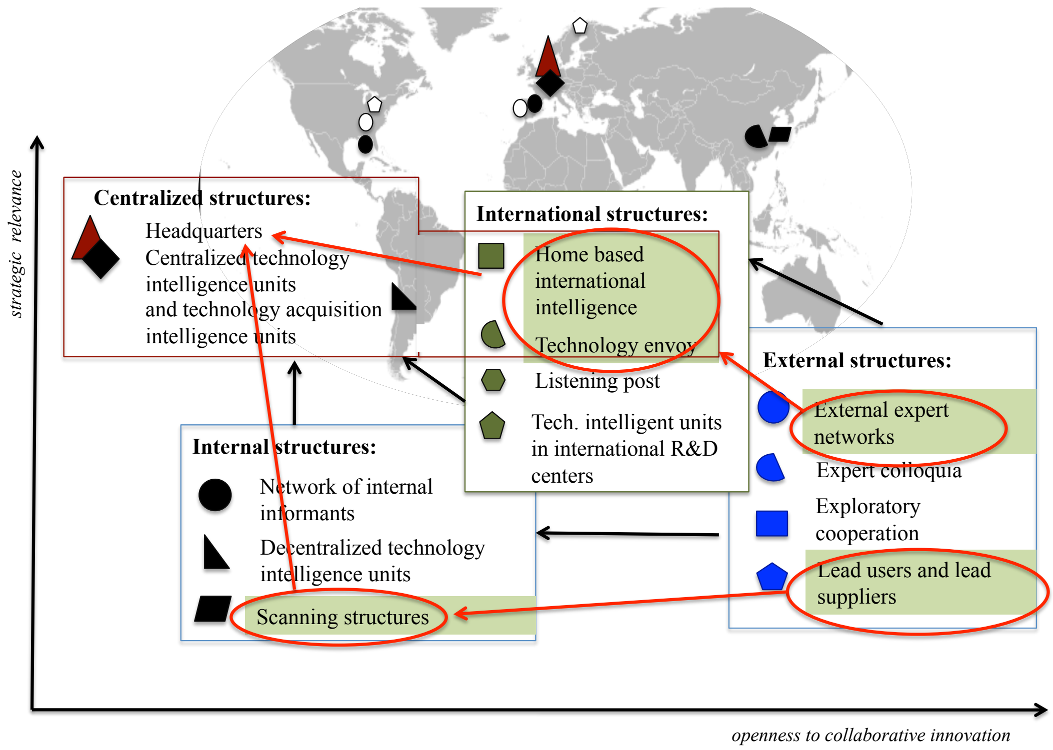


Figure 4.7. Societal embedding and the technology surveillance structure
Source: adapted from Moretto et al. (2012)

- *Centralized structures:*

What was found for Alstom and Siemens, shown in figure 4.7, manufacturing centers of excellence and design in core-technology areas were located at the headquarters or at the sites where the trains were assembled. They combine the "central technology intelligence unit" and the "central technology acquisition intelligence unit" who look at the business aspects of technology strategy-making and alliance-management processes such as start-up companies, university technology transfer and control of R&D projects. They are the higher structure to which top-management refers to. The instruments they employ are: reporting analysis and periodic meetings with the other structure forms, mapping of technology developments, R&D projects, and future exercises such as forecasting, scenario and road mapping. Societal embedding activities were not found as here agents mainly focus on the technology itself and its business aspects.

- *Internal structures:*

Figure 4.7 shows the agents part of manufacturers internal structures as in "networks of internal informants" in the different departments and subsidiaries spread around the world, "decentralized technology intelligence units" focus on middle management and non-core technology areas; additional information channels, such as "scanning structures" at different locations. Those agents are in most of the cases top-management at subsidiaries. These internal structures report back to the "centralized technology intelligence unit". The central unit can request the internal structures to address a particular subject or they can be initiators. The leadership of the internal structures depends on the strategic relevance given by the central structure and top management to the technology at stake. These internal structures are anchored in the departments involved in commercial projects or mature technologies, as it will be seen latter in the described technology trajectories. The instruments used are reports, meetings, R&D projects, site tests and certifications. Here societal matters are mostly dealt on impact assessments of the technology being promoted to the specific market.

Agents at "scanning structures" are the ones mostly addressing societal aspects as ways to monitor the local market. These activities include consultations to local relevant actors (industry, universities, train operators, certification bodies, associations, etc) and lead-users considering socio-economic aspects (employment, local policies, social constraints, environment, etc). Societal embedding activities range from a simple scanning on the local impact of the high-speed train technology to the complexity of customizing the train to the local market constraints. The participatory method of enquiries involving the people who use the train has been increasingly complemented by online debates in social networks.

- *External structures:*

Continuing the description of figure 4.7, Alstom and Siemens also have an external technology-intelligence organizational structure which includes: "external expert networks" (as in the case of the European Rail Research Council ERRAC); "external expert colloquia" (to identify possible technology directions from universities and consultants); "exploratory cooperation" (usually with suppliers from other sectors and universities, as means to test the application of matured technologies in the high-speed train, or to train potential local suppliers in areas subject to outsourcing); "lead users and lead suppliers" (that can also be considered as external experts for benchmarking purposes). The instruments used are the ones found in other structures, such as meetings, R&D projects, site tests, certifications and future exercises.

In anticipatory exercises, manufacturers address societal matters mainly at the level of "external expert networks" and "lead users and lead suppliers", with workshops, meetings, and technology agenda-setting and dissemination activities. At this level, information on trends is quite openly shared and has a long-term perspective.

- *International structures:*

The model in figure 4.7 also shows that, as multinationals, Alstom and Siemens have international intelligence units, such as "home-based international technology intelligence" located at the central intelligence unit, responsible for scanning pro-actively for relevant information from all the other organizational structures, including visiting those structures around the world and demanding information, rather than waiting for reports; and “technology envoys”, which are workers sent to a specific market to build up an external network with local clients and institutions. International centers of competence and design may also have technology intelligence units, if installed in a strategic leading market or region of knowledge. The most common instruments are R&D projects, future scenarios and scanning activities.

Finally, societal embedding is also found at the level of “home-based international technology intelligence” and “technology envoys”. Despite being oriented towards technology, like the 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 national (overlapping with “scanning structures”) or regional levels.

4.1.5. Technology development

The main elements of CTA analytical framework on societal embedding (Deuten, Rip and Jelsma, 1997) can also be found in the different technology development dimensions of the high-speed trains such as technology transfer patterns, product system and decision-making trajectories (technological and commercial).

c) *Technology transfer*

In Alstom and Siemens development of the AGV and ICE-350E it was observed an increase in outsourcing of technology sub-systems to third-party suppliers in respect to the previous models, generating new patterns of technology transfer. Pavitt (1984) calls it “innovation patterns”. Its application to Pavitt (1984) taxonomy as revised by Castellacci (2008) is illustrated in figure 4.8 below.

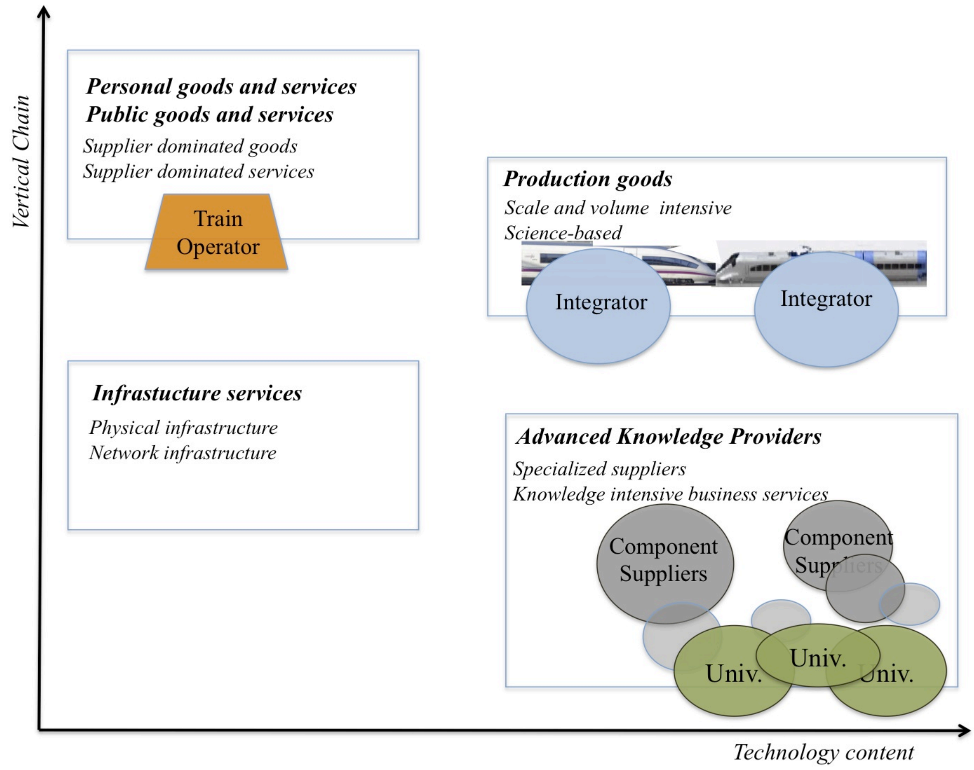


Figure 4.8. High-speed train multi-actor system
Source: adapted from Castellacci (2008)

Figure 4.8 aims at representing the AGV and ICE-350E supply-chain multi-actor technology system (their complex and interlinked relations will be described after in figure 4.9). Pavitt extended taxonomy to services (Castellacci 2008) is here applied to scale each actor's position within the value chain and the level of technology content their products and services provide.

The central actor of technology decision making found for the AGV and ICE-350E was the manufacturers Alstom and Siemens (at the right-center of figure 4.8). They are the technology integrator (or system integrator) assembling all the components into a vehicle capable of running on the tracks, knowledgeable on the overall vehicle technological system and less on its sub-systems as they subdivide. These manufacturers are found at the technology regime "production of goods", sub-pattern "scale and volume intensive". It is an intermediate level of the supply-chain, of high technology content[61].

High-speed train manufacturers are typically large companies, worldwide suppliers, with Siemens and Alstom sharing the market with few other players. They have a strong national

[61] According to Castellacci (2008) at that regime, firms receive technological inputs from "advanced-knowledge providers", including "specialized suppliers" and "knowledge intensive business services", while in turn they provide technological outputs (new products), which are used by "infrastructure services", as well as by "providers of goods and services".

identity defended by the headquarters (Boavida and Moretto, 2011). Profitability depends on their standardized production volume (Castellacci, 2008).

Similar to the automotive industry studied by Castellacci (2008), high-speed manufacturers have demonstrated capacity to develop new products and processes internally in their R&D facilities and also in conjunction with suppliers, or clients, or end-users.

Another actor are the component suppliers. It is found in figure 4.8 in the "advanced knowledge providers" technology regime (Castellacci, 2008), at the bottom of the vertical supply-chain. Some of these suppliers are from the same sector as the high-speed train manufacturers, working on an exclusive basis.

Also alike the automotive industry (referred in Castellacci, 2008), with the high-speed trains, those component suppliers are majorly "specialized suppliers" of equipment and precision instruments, with a high-level of technological capability, able to meet the tight requirements imposed.

In a smaller but increasing scale there were also found "knowledge-intensive business services" (Castellacci, 2008) such as providers of communication and navigation systems on board the train or providers of virtual maintenance systems. But that is not all, with the greater technology complexity of the AGV and the ICE-350E in respect to the previous models of trains and associated costs, it was found that manufacturers expanded the range of contracted services and relied more on these companies to design sub-systems.

In this same sub-pattern "knowledge-intensive business services" was also found academia in the form of academic spin-offs or knowledge centers. In the AGV and the ICE-350E development they become partners in commercial offers as contracted parts for knowledge-services by both manufacturers and component suppliers.

Another type of actor are train operators. Despite not being referred to in any of Castellacci's technology regimes, they easily meet the characteristics of "personal goods and services", sub-pattern "supplier dominated services", at the top-left of the chart in figure 4.8. It corresponds to a regime with low technology content and receiver of technology from the other described regimes.

It should be noted that the classification of the actors here presented is not so linear as traces remain on the sector's recent history, when the train operator steered the technology development. That was the case of the first French TGV and the first and second generation of the German ICE. However, the elements found for the AGV and the ICE-350E indicate that the role of train operators in this respect decreased (International Union of Railways 2010a)[62] with manufacturers taking the greater share.

Figure 4.9, below, adds to the previous figure knowledge exchanges between the identified actors involved in the AGV and ICE-350E development process. They go beyond the supply chain to include governments, end-users and educational institutions.

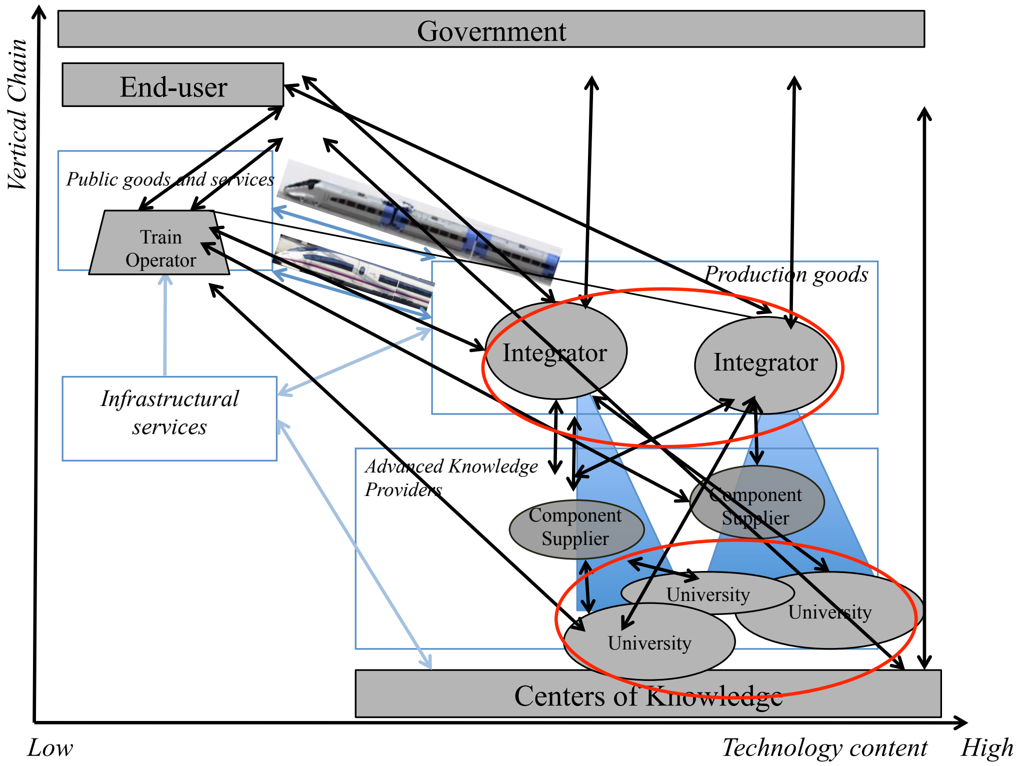


Figure 4.9. Societal embedding within high-speed train multi-actor relations
Source: adapted from Castellacci (2008)

Multi-actor technology relations in the AGV and ICE-350E development comprise mutual dependencies (conferring complexity) and interactions (interlinking actors). Those dependencies vary. They were found quite tight between manufacturers and the suppliers. But they were rather vague between academia and manufacturers and between the academia and suppliers, subject to discontinuities. Interactions, in its turn, occurred in all directions. They were conferring dynamics to the different technology regimes. Those interactions were found to be experimental or established.

The dominant type of multi-actor relations (of dependencies and interactions) was determined by the stage of technology development: if in a pre-competitive stage (scanning for technology developments and opportunities as well as for future market needs) or in a competitive stage (preparing a commercial offer).

[62] The reference is for Europe. Japan does not follow this trend as JRC combines in a single company engineering and operations as well as infrastructure and vehicle, developing their technology mainly in-house.

At pre-competitive stage (pre-tender) the combination of relations between actors revealed a variable geometry, reflecting vague dependencies and exploratory interactions. Technology relations were mainly focused at anticipating major technology needs, trends and opportunities in the medium future. Actors envisaged to anticipate others technology capacity and interests through collaborative research projects, market analysis and survey their competitors. Information was flowing quite openly, but its disclosure was selective. Competitors appeared in the same project, as for instance in collaborative research projects on non-core technologies or relevant technologies to set common standards.

At the competitive stage of development of the AGV and the ICE-350E, multi-actor relations 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 (or assembly manufacturer). However, a pyramid can also be lead by two major integrators as in the case of the AVE class S-102*, 2nd series, manufactured by Talgo and Bombardier or the ETR1000 by Ansaldo and Bombardier, both not addressed by this study.

The pattern followed by Alstom and Siemens shows that there are as many pyramid formations as number of bids for a particular call for tender. They integrate actors with demonstrated capacity of supplying the component or service required by the integrator, meeting tight specifications at low prices. Relations of mutual-dependencies become dominant here as such require a major technical and economic commitment from the supplier (in many cases a return is only seen in a long-term relation).

It was observed for the AGV and ICE-35E that each pyramid leader, Alstom and Siemens possesses almost all the technologies to bid and usually is the final interface with the customer, the train operator. Such confers to the leader the ability to acquire the technological knowledge and solutions required by the customer. The source of information is the tender specifications, if available, or, if not, anticipated by strategic intelligence. Then, the leader passes the information to the sub-levels, and those pass it on successively to the subsequent level of supplier, and so on. The sub-system suppliers' feedback the consortium leader with specific know-how and technology solutions they have in their specific fields.

It was observed that Alstom and Siemens, to overcome the complex multi-actor relations as described, practiced strategic intelligence in the terms already seen. It was observed mainly at the pre-competitive stage of the technology development process of the AGV and the ICE-350E.

Without explicitly referring to CTA, an informer from the industry referred that strategic intelligence actions developed at the time were mostly 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.

It was found that Alstom and Siemens looked upon universities as a partner in scanning for societal constraints as they appeared as a direct source of local users' expectations, also of emerging disruptive technologies, knowledgeable on local market constraints and they were in direct relation with the local governments.

Manufacturers also looked up to component suppliers, as they held enquiries to end-users. In particular, the ones supplying technologies impacting the riding experience of the train as interiors, comfort and telematics.

I will come back to figure 4.9 when analysing AGV and ICE-350E multi-level perspective (section 4.3.).

d) Product system

The high-speed train is a vehicle, defined as a highly sophisticated technology product system, nested in a complex integration of technology sub-system of components, subdividing to arrive to materials, each requiring different levels of technology intensity[63]. It was found that manufacturers attribute different degrees of relevance to each one reflected in their openness to collaborative developments, as represented in figure 4.10, below.

[63] The high-speed trains form what is called a large-scale technology (LST). For further information see Geels (2002), p. 1259] which provides a list of research works on this matter: Hughes (1983, 1987), Mayntz and Hughes (1988), Summerton (1994).

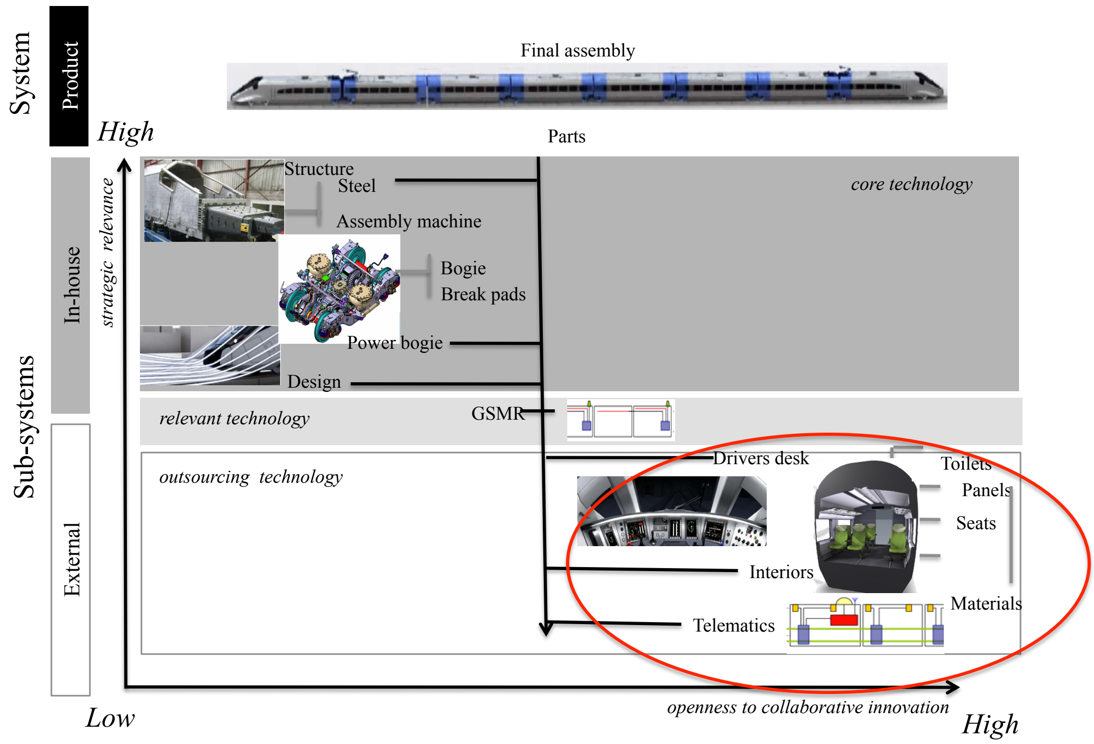


Figure 4.10. Societal embedding within the product technological system
Source: adapted from Moretto et al. (2012)

Figure 4.10 presents the high-speed trains AGV and ICE350E product tree using Pavitt (1984) products classification method.

The top of the product tree in Figure 4.10 are listed the core technology areas for Alstom and Siemens, such as structural parts, bogies, energy conversion and safety systems. They were mainly developed in-house by their centers of excellence and design, directly coordinated by the top-management and subject to a high level of secrecy and protection from competitors. At this level the few co-developments found were on a bilateral basis mainly with universities and subject to strict confidentiality agreements, with the manufacturer claiming ownership of the technology development.

In figure 4.10 at the middle range of the tree are found the sub-systems strategically relevant to the manufacturers but falling outside their core engineering capabilities, such as rail traffic signaling systems, telecommunications or virtual maintenance systems. At this level it was found that Alstom and Siemens tend to co-develop the technology, mostly on a bilateral basis, with other partners such as component suppliers or external knowledge centers and academia. The partners here are from the same sector (but not necessarily); and are restrained by an exclusive relationship with the integrator. The partners are located in the proximity of the production site of the manufacturer. It was also found that manufacturers were sending technology envoys to component suppliers located in a different region in the world. In this case, the level of co-development was rather low and ownership of end-results tended to be high. The instruments often used were bilateral confidential agreements between a manufacturer and a co-developer.

The technology subject to outsourcing, such as interiors and telematics is found in figure 4.10 at the bottom of the tree. For the AGV and the ICE-350E, Alstom and Siemens developed these technologies quite openly. It was found that for both manufacturers the local branch or special technology envoy informed the center of excellence and design of a technology development opportunity. Specific targeted groups were consulted, which included user groups, referred in CTA societal embedding activities, formed by end-users, customers, certification bodies, as well as other relevant entities; and collaborative research was promoted. Collaborative research was used to anticipate specific client needs, local market constraints and end-users' expectations. Technology development of these sub-systems of the AGV and ICE-350E mainly occurred in the world region of the potential client, with localy based suppliers. It was found that the level of co-development was high, and ownership of end-results was low. The relationship between Alstom and Siemens and their partners was dominated by consortium agreements on a relative open basis, not subject to exclusivity. In particular cases, such as those addressing modularization and standardization, technology development was also involving competitors. So, Alstom and Siemens have been also found in the same R&D projects.

e) Decision-making trajectories

The empirical observation of Alstom and Siemens development practices of the AGV and ICE-350E contrasted with the elements provided by anonymous informers. It was found that the development path[64] of the high-speed trains followed two different trajectories: technical and commercial. Both paths involved specific decision-making steps set by internal procedures. For one of the manufacturers here studied both paths occurred almost simultaneously.

Figures 4.11 and 4.12 describe decision-making steps in each trajectory. The circles in the figure indicated where elements from CTA societal embedding are found.

- Technical trajectory

[64] Technology path here refers to all the stages in the product creation from R&D development to product certification and operation (i.e. innovation journey).

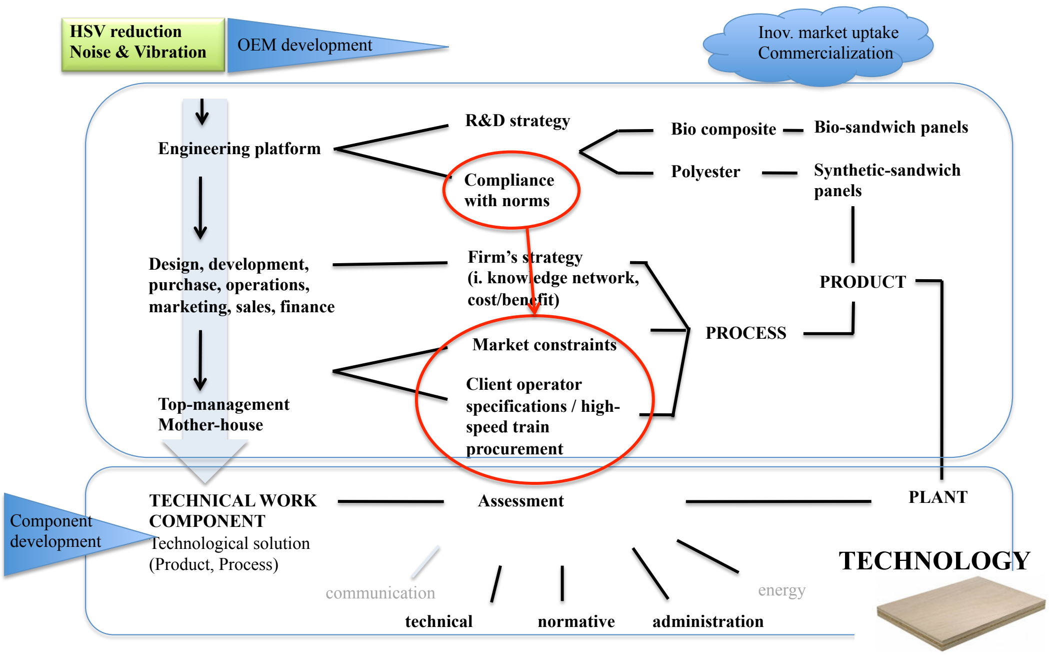


Figure 4.11. Societal embedding within the technical trajectory
Source: Author

Figure 4.11 represents the AGV and the ICE-350E technical trajectory initiated from a technology driver. This could have well been, for both Alstom and Siemens, the case of noise and vibration abatement of the rail cars using innovative sandwich panels. The trajectory starts in-house at the engineering platform located in one of the centers of excellence or design specialized in the subject. The engineers worked on two or more technology solutions of sandwich panels, with one on bio-materials and the other on synthetic materials. Neither Alstom nor Siemens manufactured the panels. The solution had to be found externally and adapted to the train.

As mentioned before, both manufacturers consider this type of technology a non-core technology, subject to outsourcing. It was found that the technology development was carried out in cooperation with panel suppliers (first-tier) and also at some point involved the materials suppliers (second-tier). At this stage, the platform of engineers was found in a strategically located center of excellence or design for one of the train manufacturers and in a geographically close to the headquarters for the other.

Once one of the technical solutions became mechanically viable, the technical director made a preliminary SWOT analysis, and a final verification of compliance with the manufacturer compliance norms. In this case fire and smoke. Once it was approved, the technical director presented it to the middle management responsible for decision-making, involving other units such as design, purchase, production operations, marketing, sales and financing. At this level, decision-making was found to be based on the sum of the different strategies guiding each one of the units and on a cost-benefit analysis. In one of the manufacturers it was found a transversal knowledge network formed internally, multiplying each individual knowledge network from its individual departments with external partners.

After this stage, the new technology solution, (i.e.: reducing noise and vibration of the high-speed train car) was no longer a technical matter only. In the case of one of the manufactures it happened that the final provider turned out not to be the one co-developing the solution selling the panel.

The new technical solution, accompanied with an interdepartmental analysis (normative, socio-economic and financial) was then brought to the top management for final approval. It is at this level that the technical decision-making trajectory crosses with the commercial one.

In figure 4.11 the circles show that at the technical trajectory the engineering platform was supporting its decision-making using elements provided by CTA’s societal embedding activities, in which concerned exploratory contacts with local universities and component suppliers to solve the referred technological problem.

However, within this trajectory, these CTA activities were mainly found to support decision making at top-management level when confronted with the final decision whether to integrate or not the technology solution in the train. It was found that top management used such information from “home-based international intelligent units” to confront the technology solution developed by its team of engineers with technology mega-trends. It was also found top-management using the information provided by technology envoys, scanning structures and external structures, in targeted markets (lead markets or potential markets), to check whether the technology developed in-house was meeting specific targeted market and expected procurement specifications.

- *Commercial trajectory*

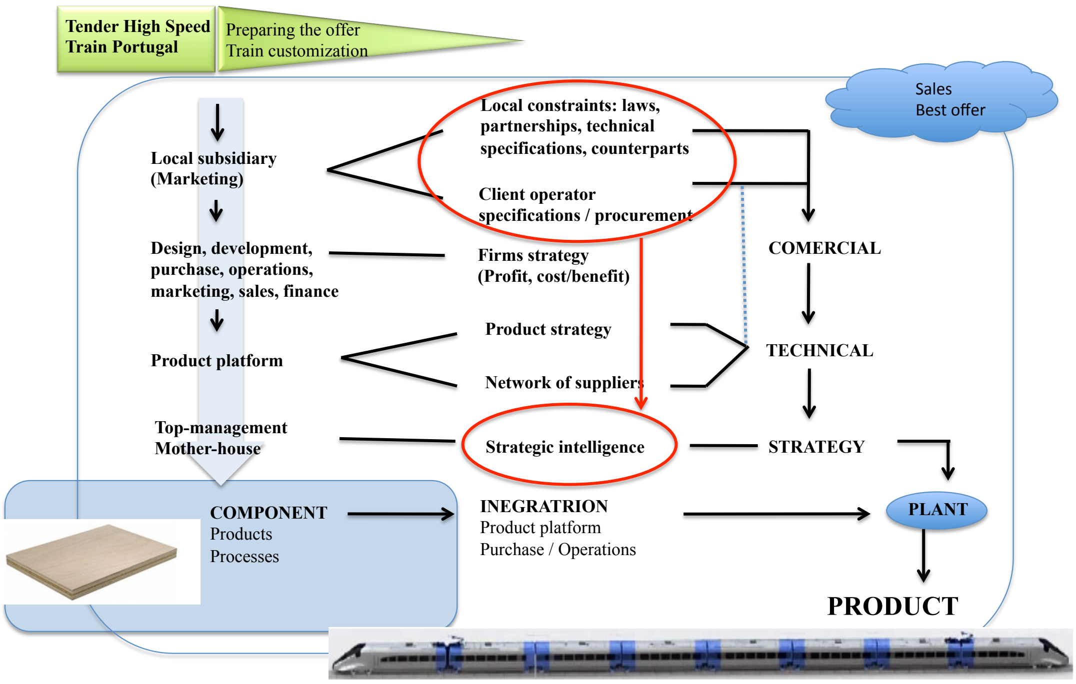


Figure 4.12. Societal embedding within the commercial trajectory
Source: adapted from Moretto *et al*. (2012)

Figure 4.12 represents the AGV and the ICE-350E commercial trajectory, initiated from a business opportunity. The case here represented is the Portuguese government announced intention in 2009[65] to buy high-speed trains for the planned high-speed rail link between Lisbon and Madrid, to which both Alstom and Siemens were intending to bid. The Portuguese tender end-up never taking place as the government suspended public investments in 2012 after changes in the government and being severely impacted from the global financial crises.

As figure 4.12 shows, the commercial trajectory began at both Alstom and Siemens when the local subsidiaries' sales and marketing divisions located close to the customer signalled the market opportunity to the headquarters. When doing it the subsidiary developed a series of activities to collect information from local informers which were part of their network on the technical and socio-economic elements of procurement, such as laws, partnerships and technical specifications, also counterparts, job creation, know-how retention or attraction of centers of excellence and design from the multinationals (Boavida and Moretto, 2011).

For both manufacturers, it was found that once the subsidiary (marketing and sales division) collected the necessary elements to build the offer an internal mechanism was in place to allow the headquarters to decide the vehicle model and the technology to adapt it to the local customer requirements. At this stage, the relevant units from headquarters, i.e. design, technical,

[65] "Railway Gazette: High speed programme axed". Railway Gazette International. Retrieved 23 March 2012.

operations and finance, take part in the matter. Decision-making is supported by a cost/benefit analysis in compliance with the manufacturer's corporate strategy (a common practice for many industries). Decisions at this level are then reported to the top-management in the headquarters. As in the technical trajectory, it was found that it is the responsibility of top-management to decide whether to go forward or not with the offer to supply their high-speed train, and to decide on the strategy to follow for the bid.

Also here it was found that it is at the final stage where this trajectory meets the technical one. It was up to the top-management of both Alstom and Siemens from the headquarters together with top-management from the involved subsidiaries to match the technical developments with the commercial offer, as way to build a competitive offer. In both trajectories, top-management in the headquarters was found functioning as referee, reserving the final decision using strategic intelligence.

Within the commercial trajectory, some elements from CTA framework for societal embedding was found at Alstom and Siemens as a mean to promote local actors' participatory and constructive activities; and as means to collect end-users' and clients' information on the technical and socio-economic elements of procurement.

Then, the results of this exercise were attempted by the subsidiaries of each manufacturer to be embedded in the technology development of the high-speed train vehicles being offered. The local subsidiaries in Portugal functioned for both manufacturers as a scanning structure, in interaction with local informers and universities; and as a promoter of participatory and collaborative activities to anticipate customers' technical and socio-economic elements of procurement and end-users' expectations. Top management, in turn, used societal aspects to some extent as an additional element for adapting the technical development of the high-speed trains with the commercial specifications provided by the subsidiaries.

In line with the above description, societal embedding practices were found mostly performed for both manufacturers when the two trajectories met, supporting top management's final decisions on the technology development options for their high-speed trains, by adding societal information, collected by their strategic intelligence, which is added to the technical and commercial ones. As already seen both trajectories also have in their process societal embedding performed at some stage in the described processes.

The decision to implement a new high-speed line and operating it was and still is a highly political matter for Portugal and for any other country. Constructing a new high-speed line and acquiring a certain number of high-speed trains represents a significant investment and public debt across generations. As a consequence, it is very often required that preferences, when possible, be given to the local industry and academia. In some countries such as in the United States of America with the "buy American act" it is mandatory that 60% of the value to be located in the country. Or the Portuguese law (Decreto-Lei n.º 18/2008) in place from 2008 to 2011 it required one percent of R&D investment for bids above 25 million Euro (Boavida and Moretto 2011). This explains why manufacturers consider local societal constraints and co-developments with local companies. Similar reasons are motivating cooperation with local universities, as they are providers of local content, can demonstrate R&D in local conditions and influence in decision-making at policy level.

4.1.6. Findings

Found evidences of societal embedding can be summarised as follows in figure 4.13 below.

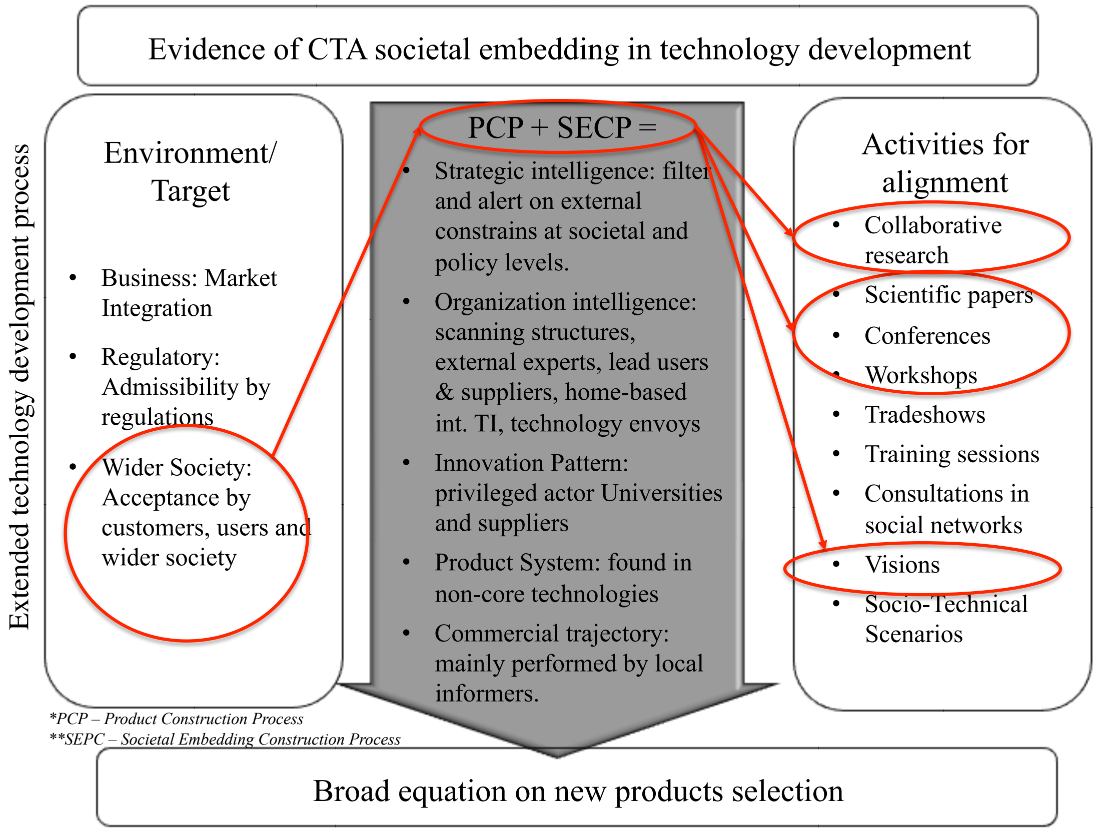


Figure 4.13. Overview of societal embedding in the different dimensions of the high-speed train technology development
Source: author

Figure 4.13 feeds to the previous figure 4.5 with Alstom and Siemens identified activities aligning with CTA framework for societal, as argued by constructive technology assessment (Deuten, Rip & Jelsma, 1997).

Firstly, it was found that both manufacturers addressed the societal environment of selection when developing the AGV and the ICE-350E as a means to cope with acceptance by customers, end-users and wider public (see figure 4.13, first column).

Secondly, in terms of implementation, it was found that both Alstom and Siemens located it at the level of strategic management of "product construction process" (PCP) (see figure 4.13, top of the central column).

Continuing with the implementation at organisational level (figure 4.13 top of central column), it was found that Alstom and Siemens strategic intelligence filters societal constraints mainly at socio-economic environments of selection and to some extend also at policy level.

Filtering societal constraints (see figure 4.13, central column) both manufacturers relied on their employees, agents at their technology surveillance structure mainly located at the subsidiary "scanning structures", and also on external "expert networks" and contacts with "lead users and lead suppliers". To a lesser extent were found employees at "home-based international technology intelligence" and "technology envoys".

At the level of technology transfer patters (see figure 4.13, middle of the central column), it was found that Alstom and Siemens privileged source on societal constraints were Universities and Knowledge Centers. Those actors have local knowledge on governments, customers, end-users, and society. Another relevant actor was Component Suppliers implicitly knowledgeable of societal constraints acquired, for example, from enquiries to travellers on specific technologies impacting the raiding experience of the trains.

At product level alignment with CTA societal embedding was found in which refers to the development of non-core technologies, such as interiors and telematics (see figure 4.13, low end of the central column). Alstom and Siemens promoted collaborative research, which included consultations to users group, customers, certification bodies and other relevant entities, mainly occurring at the world region of the client, promoted by the technology envoy or subsidiary scanning structure.

While in terms of decision making trajectories alignment with CTA societal embedding was mainly found at the level of the technology commercial trajectory, in particular at the interception point with the technical one (see figure 4.13, bottom of the central column). When preparing for an offer, the manufactures' subsidiary company interacted with local informers and promoted local participatory activities to collect customers, end-users and local public values and expectations that could impact its costumer's procurement, that would then be used to support top-management decision on which technology to offer.

Finally, activities of alignments (figure 4.13, right column) ranged from a simple organization of a workshop or the establishment of a local supply chain network to the complexity of embedding social constraints into their R&D projects customizing the train to the local market specific requirements.

Societal embedding type of activities were found in the practices of Alstom and Siemens strategic-intelligence management of the technology development process of the trains mainly associated to.

From above it can be concluded that Alstom and Siemens are strategically aligned with CTA, except for the technological decision making trajectories as they mainly covered societal alignments during the commercial trajectory and not during the technical trajectory. This might be an indication on Alstom and Siemens aim of societal anticipation for "promotion" and "control" (Deuten et al. 1997).

Moreover it is not clear at this stage to which extent societal constraints (filtered at strategic level retro-feeding the commercial trajectory) were embedded in the technology development process of the AGV and ICE-350E and at which technological readiness level it occurred[66].

From this exercise were not covered the network of stakeholders contributing to the technology development of the AGV and the ICE-350E.

[66] TRL stands for Technology Readiness Level. For detailed definition see chapter V on the survey.

4.2. Technology transitions

4.2.1. Introduction

Alstom AGV and Siemens ICE-350E build on the technology from its previous models. Literature commonly refers to three generations of high-speed trains. According to Zhou & Shen (2011) each generation is distinguished from its maximum commercial operation speed[67]: The first generation corresponds to a maximum of 250 km/h; the second generation is that of 300 km/h; the third one is above 350 km/h.

According to Zhou & Shen (2011) the reference vehicles worldwide are the Japanese Shinkansen, models S0, S500 and E5, manufactured by the Japanese consortium Hitachi, Nippon Sharyo and Kawasaki Heavy Industries; the French TGV, models PSE, MED and AGV, from the French Alstom; the German ICE, models 1, 3 and 350E, from the German Siemens; and the Chinese CRH, models 1, 2 and 380B, manufactured accordingly by the Canadian Bombardier, the German Siemens and the Chinese suppliers Tangshan Railway Vehicle and Changchun Railway Vehicles[68].

The combination between the different generations of trains and the reference units' worldwide is represented in the figure 4.14 below, plotting technology improvements measured in terms of speed and adoption in time.

[67] Giovoni (2006) argues that speed classification might be misleading and no longer valid for the next generation of high-speed trains. Commercial operation and track conditions already today do not allow maximum speeds as the one of 570Km/h reached by the AGV during tests. Such for reasons of safety, environment (noise) and costs associated. However, for simplification of analysis it was adopted Zhou & Shen (2011) classification.

[68] Chinese high-speed train manufacturers management approach have fast evolved from introducing a first generation of high-speed trains fully relying on imported technology from Europe and Japan, followed by a second generation of vehicles co-developed in foreign joint ventures and finally arriving to the introducing of a third generation of trains with their own technology. This in less than 8 years. The CRH380A was manufactured by Sifang Locomotive and Rolling Stock (belonging to the China Southern Locomotive and Rolling stock industry group); CRH380B produced by Siemens and Tangshan Railway Vehicle (belonging to the China Northern Locomotive and Rolling stock industry group) and Changchun Railway Vehicles; CRH380CL by Changchun Railway Vehicles (belonging to the China Northern Locomotive and Rolling stock industry group). CRH380D, also named Zefiro, by Bombardier Sifang.

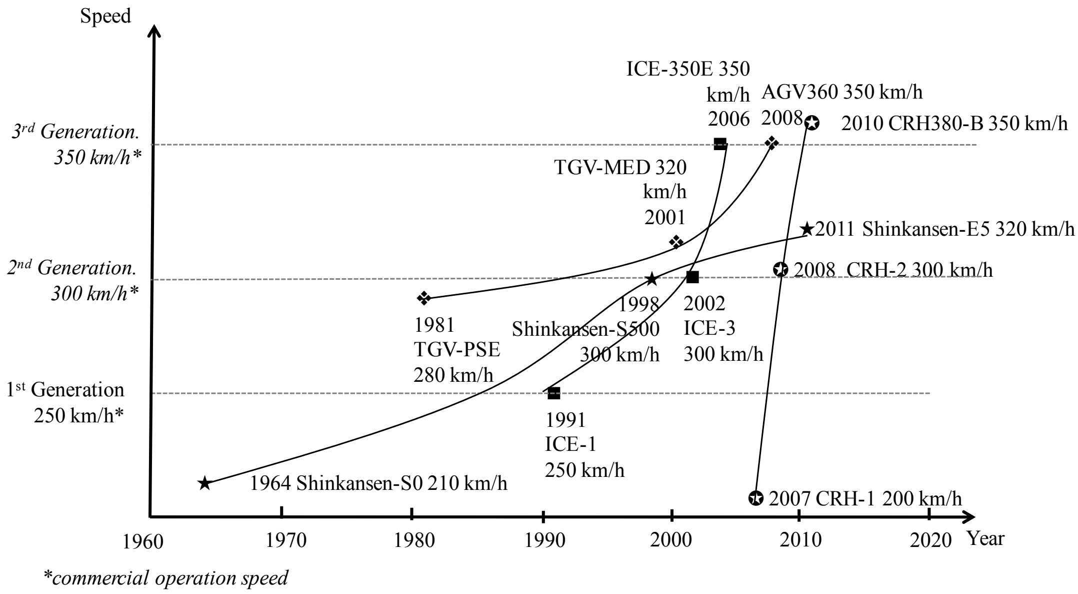


Figure 4.14. Technological transitions of the reference high-speed trains worldwide.
Source: Author

Interesting to find in figure 4.15 a clear convergence in time between the technology transitions of the different high-speed train and a temporal acceleration in the technology development between the second and third generations, meaning shorter development cycles and increased rate of adoption.

During the nineteen sixties, when introduced, the high-speed train technology system[69] was considered disruptive associated to long technology cycles and adopted only by few train operators, the innovator leaders. In figure 4.14 it is clearly visible with the Japanese Shinkansen (first mover[70]) and the French TGV (technology leader) with about 30 and 20 years of development cycle, contrasting with the Chinese CRH (late entrant) with only two years apart from its first and second generations of trains[71].

Latter, at the turn of this century their technology became incremental[72] with later developments shifting to improvements of existing technology while radical knowledge-base became more common and widely spread. New manufacturers emerged, as in China, and the technology became widely adopted by more train operators, the latte entrants.

[69] For the definition of high-speed train technology system refer to figure 4.10.

[70] For definitions of first mover, early follower and late entrant see Schilling (2010, p.93:1-318).

[71] China's has spent six years in the high-speed rail development that took others decades (Zhou & Shen 2011). Chinese leap-frog over Japan and Europe worth to be further studied.

[72] For definitions of radical and incremental innovation see Schilling (2010, p.50: 1-318).

Most likely since the introduction of the AGV and ICE-350E in 2008 and 2006 the technological curve will tend to flatten as for Japan, with Alstom and Siemens paying more attention to the attractiveness aspects of the trains.

The section 4.2.3 presents the events pushing and pulling[73] (emerging and stabilising conditions) those technology transitions leading to the French AGV and the German ICE-350E.

From here should result a clear understanding on the drivers for the technological changes over time and their promoters. While, it is identified possible links with societal aspects. Ultimately this retrospective exercise will then allow to contextualise societal embedding as it was found for the AGV and ICE-350E (in section 4.1.) while projecting it to the future.

4.2.2. Theoretical references

Understanding the process of the co-evolution of socio-technical systems is the central element of CTA, and this is where the technology transition and the multi-level perspectives analytical tools here introduced come in.

Spearheaded in the 1990s by Arie Rip, Rene Kemp (1998) and Johan Schot (1997) referred analytical models combined different levels of analysis drawing on the quasi-evolutionary model of technology and innovation (Dosi 1982, Nelson and Winter 1977, Abernathy & Clark 1985, van den Belt and Rip 1987, van Lente 1993) and combines it with actor-network theory (Callon & Latour 1981) and theories of alignment and stabilisation (David 1985, Callon 1991). Technology transitions and multi-level alignments prepares for socio-technical scenarios (Geels 2002a, Elzen et al. 2005, Robinson 2009) by combining the CTA approach to future-oriented technology analysis and evolutionary theory.

Looking at emerging and stabilising fields in this way, addressing a complex, heterogeneous, and multi-level socio-technical world, shifts the attention to the socio-technical alignments as the point to be addressed in this section 4.2 and also in the next section 4.3.

This section 4.2 is mainly supported by Geels (Geels 2002a, Geels & Schot 2007) technology transitions model of analysis, that will be here proved relevant to anticipate future developments in the development of high-speed trains. The model is a stylized visualization of the various

[73] See "R&D push" and "Market pull" theories found in innovation and technology management literature (Schilling, 2010).

arenas - landscape[74], regime[75] and niche[76] - in which actors within can produce events pulling and pushing for technology changes. Those events attributes can be hyper-turbulence, specific shocks, disruptions, regular changes or avalanches[77]. Which in its turn can be exogenous[78] or endogenous[79] to the technology regime. They can disrupt or produce incremental technology changes. Such events can occur at landscape arena produced by policy actors, regime arena produced by technological actors' part of the supply chain and niche arena produced by emergent specialized providers of technology both from and outside the technology regime.

Whilst the development of a high-speed train may be considered as an individual product development project, it is embedded in a broader system of actors and infrastructures which make up train-based transportation systems. New product development activities in the high-speed train sector appear in an existing context of rules and best practices which one can call a technological regime (Nelson and Winter 1977) will support the following section 4.3.

---

[74] Macro: Evolving sociotechnical landsacapes (Geels 2002, figure 4, p. 1252:1274).

[75] Mezo: A patchwork of regimes (Geels 2002, figure 4, p. 1252:1274).

[76] Micro: novel configurations (Geels 2002, figure 4, p. 1252:1274).

[77] For a detailed explanation and support graphics please refer to Geels & Schot 2007, figure 4, p. 404:417

[78] Exogenous renewals result from outside regime actors. They can be emergent transformation which arises from uncoordinated pressures, outside the regime, often driven by small and new firms. They can also be purposive transitions which are intended and coordinated change processes that emerge from outside the existing regime (Geels & Schot 2007, p401:417).

[79] Endogenous renewals result from regime actors making conscious and planned efforts in response to perceived pressures, using regime-internal resources In its turn those can be reorientation of trajectories which results from a shock, either inside or outside the incumbent regime, followed by a response from regime actors, using internal resources (Geels & Schot 2007, p401:417).

A regime represents the ways of doing research and development, the way value is assessed, in short, the rules and routines that embody action and use a technology. Rip and Kemp (1998) described regimes as the "grammar" that shapes emerging technology development. See figure 4.15, below.

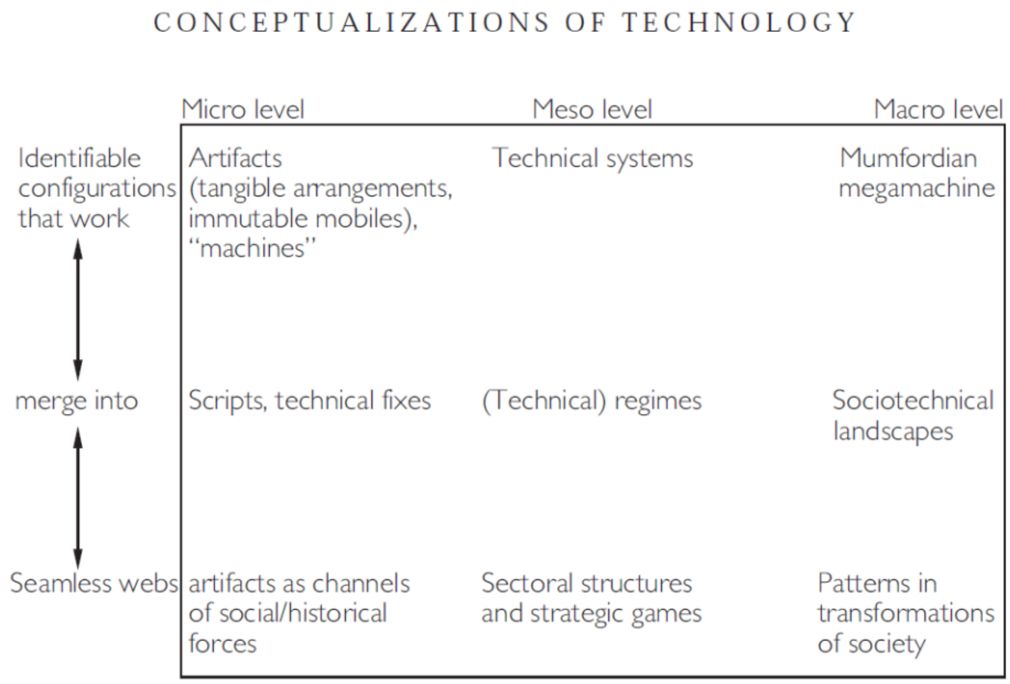


Figure 4.15. Rip and Kemp micro-meso-macro approach to locate technology transformations.
Source: Rip and Kemp (1998, figure 6.1, p. 339:329-399)

Figure 4.15 shows Rip and Kemp (1998) multi-level visualisation of the processes of socio-technical change which brought together a number of perspectives on technology dynamics into the same model. In his PhD thesis, Frank Geels took this work, as others such as Van de Poel (1998), van Lente (1993) and Deuten et al. (1997), creating his own version of this multi-level visualisation.

The Multi-Level Perspective (MLP) was developed to understand large socio-technical system changes, such as transitions from sail boats to steam ships. In this perspective, Geels drew on notions of strategic niche management (Schot and Rip 1997) to understand how new "protected spaces" would emerge within established technology regimes, protecting new technology options, until they were successfully embedded into existing regimes (fitting into existing regimes) or changing the established regime to accommodate this new technology novelty (stretching the regime). Thus, taking the figure above, Geels replaces "scripts and technical fixes" with "niches" to create a niche- regime-landscape model.

This MLP approach has been widely taken up since 2002 and even has its own journal[80]. Therefore, I apply the MLP perspective as a way of understanding the evolution of new technological options within the existing regime, with the benefit of the approach being used quite widely in understanding transformations of large socio-technical systems.

The referred theories and models will be here applied to the high-speed trains AGV and ICE-350E. The historical reconstruction of events and technological developments are built from Constant (2006), Zhou & Shen (2011), Ebeling (2005), the International Union of Railways (2010) and Giuntini (2011); also to some extend Meunier (2002) and Keseljevic (2015).

4.2.3. Technology transitions AGV and ICE-350E

a) From the TGV to the AGV:

Seventeen years after Japan, France was the second country who succeeded to commercially run in 1981 high-speed trains, the TGV-PSE (or TGV Sud-Est), from Paris to Lyon at a top operations speed of 280 km/h[81]. Twenty years after, in 2001, France over-passed Japan becoming the technology leader in this train segment with the introduction of the TGV-MED (or TGV-Atlantique), running at a commercial speed of 320 km/h from Valence to Marseille. Technology leadership position was reassured in 2008 by the model AGV running at a commercial speed of 350 km/h.

The vehicle technology transitions are represented in figure 4.16. The figure was built by applying Geels (2002a, p. 1263:1257-1274) analytical model.

---

[80] The journal of Environmental Innovation and Societal Transitions : http://www.journals.elsevier.com/environmental-innovation-and-societal-transitions/

[81] In 1989 and 1994 France completed TGV-A rolling at a speed of 280 km/h and TGV-N at 300 km/h. Both belong to the technology of first generation.

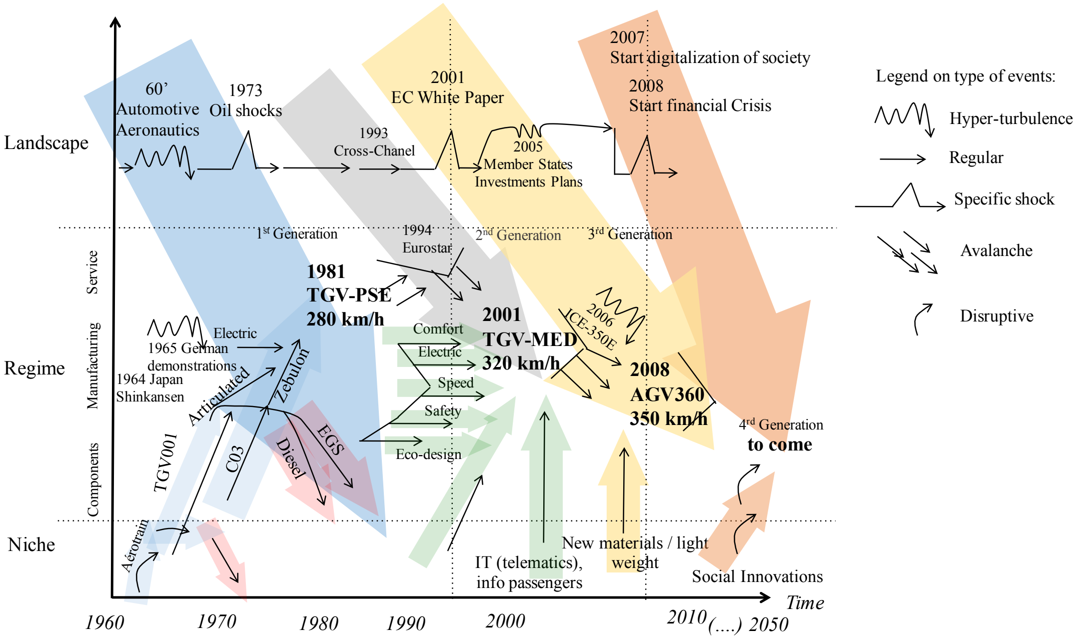


Figure 4.16. The French TGV/AGV technology transition
Source: Author

- The first generation of trains: the TGV-PSE

Starting with the description of figure 4.16, a series of events pushed and pulled in the 1960s and 1970s the introduction of the high-speed train in France. Those events imposed competitive pressures to the French railways even if in a monopolistic position.

The initial registered event during the 1960s was the increasing competition from faster and attractive automotive and aeronautic transport modes accessible to travelers (Constant 2006). It was a landscape "hyperturbulence" [82] event exogenous to the railway regime.

Another "hyperturbulence" [83] occurred this time within the regime arena in 1964 with the success of the Japanese Shinkansen, running at a speed of 210 km/h; and in 1965 with the German demonstration of the DB Class 103 hauled trains rolling at 200 km/h at the International Transport Fair in Munich (Ebling 2005).

In response, the French government played a key role creating the necessary conditions allowing for the technology race to happen in France. At niche arena it funded a disruptive technology with the Aérotain[84] (1965-1977). While, at the regime arena it funded SNCF's

[82] For the definition see Geels and Schot (2007, p. 404).

[83] For the definition see Geels and Schot (2007, p. 404).

[84] The Aérotain was invented and developed from 1965 to 1977, by a research team lead by the engineer Jean Bertin (Société Bertrin et Cie, founded in 1955) dedicated to aeronautics and innovative transports. The goal was the same as the magnetic levitation, to diminish vehicle resistance from track by suspending the train. This project was in parallel to other two incremental projects of SNCF.

incremental research efforts enabling its trains to run fast on existing conventional tracks with the TGV001[85] (1964-1967) and the project C03[86] (1963-1973). This last one, it was at the origin of the first generation of French high-speed trains.

Continuing the description of figure 4.16, in 1973 a second landscape event occurred this time with the "specific shock" [87] of the global oil crisis significantly impacting the different ongoing research options. French policies in 1974 on energy self-sufficiency and nuclear energy narrowed research to full electric engines, renouncing research on increasingly costly gas turbines projected for the TGV001 and on the costly infrastructure required to run the Aérotrain (Constant 2006).

In 1974 the incremental technological solutions developed by SNCF "wins the race" with Zébulon train. This vehicle was prepared to run on electricity at maximum speeds of 306 km/h, while it integrated other developments from the abandon TGV001, such as brakes, aerodynamics, signaling and articulated system specifically addressing high-speeds. Such represents an "endogenous renewal" of technology, using Geels terminology, resulting from regime actors adopting conscious and planned efforts in response to perceived pressures, using regime-internal resources (Geels and Schot, 2007, p.401).

Two years after, in 1976, the French government authorizes the SNCF to place an order to the group Alsthom (today Alstom), Francorail and MTE and funds the construction of the high-speed line (LGV) Sud-Est linking Paris-Lyon. In 1981 the TGV-PSE became the first high-speed train in commercial operation in Europe, classified as the first generation of high-speed trains. The TGV-PSE sets the first world speed record in test tracks of 380 km/h, but its commercial operation speed was only 280 km/h. Soon after France expanded it to Belgium, the Netherlands and the UK (Constant 2006).

In figure 4.16 the TGV-PSE is found at services sub-regime, on the top of the regime arena. That is justified from the fact that the operator company SNCF appears as the primary stakeholder in the development of the TGV-PSE. The same also occurs with the German high-speed train as it will be seen.

[85] From 1964 to 1677 the DETMT (petrol and engine studies department of SNCF) research on modifying a diesel power car with gas turbines. From this work resulted the TGV Turbotrain Grand Vitesse, contracted by SNCF to GEC-Alsthom which model TGV001 reached a speed of 230 km/h in 1967.

[86] From 1966 to 1973, the SNCF research department developed the C03 project looking at technology solutions enabling its trains to run at faster speeds. The C03 is at the origin of the TGV-PSE (or TGV Sud-Est), in service since 1981.

[87] For the definition see Geels and Schot (2007, p. 404).

In figure 4.16 one can see that this first generation of trains falls within the tactical decision making approach, in response to (not in anticipation) the technical challenges raised from the events at landscape arena. Here were found only *ex-ante* cost-benefit analysis.

Not so different from what happened with the introduction of the steam engine, the decision on the TGV-PSE technology development was resources oriented determined by costs of complements[88] such as available infrastructure and energy prices essential to run the train. That approach would remain until the second generation of trains.

- Between the first and the second generation of trains: The Eurostar

Eurostar (also called class 373 in the UK) entered in service in 1994 linking London Waterloo International Station, Paris Gar du Nord, Brussels Midi and Lille Europe, crossing the channel tunnel. As figure 4.16 illustrates such results from the "regular change" [89] registered at landscape with the diplomatic agreement for a rail-channel-crossing between Britain and France (1993 year of Eurotunnel construction). That is why in figure 4.16 this vehicle appears at the very top of the regime arena at service level.

The Eurostar's TGV new technical features were "endogenous renewals" [90] of incremental innovations of the TGV-PSE as a way to address the UK's and the tunnel crossing's own specificities (such as smaller cross section, British designed asynchronous traction motors and fireproofing). That is why in figure 4.16 the Eurostar is illustrated as an intermediary step between the first and the second generation of trains.

It also meant a new geopolitical alignment in the supply chain with the first formation of a multi-national manufacturing consortium composed by GEC-Alsthom in La Rochelle (France), Belfort (France) and Washwood Heath (England).

Alike for the TGV-PSE, the Eurostar results from a tactical decision, but driven this time by the landscape event of a political agreement between countries imposing the technical challenge of having a high-speed train running across different countries.

- The second generation of trains: The TGV-MED

[88] For concepts see Schiling (2010) when referring to Porter (2001) five market forces.

[89] For the definition see Geels and Schot (2007, p. 404).

[90] See Geels and Schot (2007, p. 401).

Zhou & Shen (2011) classify the TGV-MED (or Atlantique) introduced in 2001 as the second generation of French high-speed trains due to its commercial speed of 320 km/h. This vehicle broke the world record speed above 515 km/h during tests in 1990.

The transition to the second generation of trains resulting with the TGV-MED was due to regime "regular" [91] events imposed by feedback from service operations, requiring improved aerodynamics, larger wheels, improved brakes, reduced number of power cars and changes in the articulation of carriage configurations.

The TGV-MED was this way an "endogenous renewal" [92] focused in enabling technologies making the train sustaining a good performance at increased record speeds.

Also for this train technology decision-making was tactical. As in the past it was technical oriented and resources driven. SNCF was still at the core of its development in cooperation with French manufacturer Alstom integrating greater amount of knowledge than in the past acquired from its international experience as described. This justifies that in figure 4.16 this generation of trains appears at regime area in between sub-regimes service and manufacturing.

- The third generation of trains: The AGV

The AGV (Automotrice à Grand Vitesse) is the third generation of French high-speed trains (Zhou & Shen 2011). It broke the world speed record of 574 km/h during tests in 2007. Despite conclusion of its development in 2008 it only started commercially running in 2011 when bought by the Italian private operator NTV (Nuovo Transporto Viaggiatori), servicing at a commercial speed of 360 Km/h the lines Turin-Milan-Bologna, Rome-Venice, and Bologna-Florence-Rome-Naples.

As figure 4.16 shows the AGV is a clear strategic response from the manufacturer Alstom to the landscape arena "specific shock" [93] event of the European White Paper (COM(2001) 370 final, European Commission 2001) and associated "hypeturbulence" of landscape events caused by European Member States announcing massive investment plans on their corridors part of the integrated trans-European high-speed rail network. The most significant was in 2005 with the Spanish government investment plan (PEIT 2005-2010) visioning by 2020 the large majority of the Spanish population (90%) being served by high-speed trains.

[91] For the definition see Geels and Schot (2007, p. 404).

[92] See Geels and Schot (2007, p. 401).

[93] For the definition see Geels and Schot (2007, p. 404).

Moreover, figure 4.16 shows that the AGV is also a clear reaction to regime arena "hyperturbulence" resulting from increase competitive pressures mainly from the German manufacturer Siemens, simultaneously developing its third generation of vehicles (in 2006 the German manufacturer Siemens launched the ICE-350E slightly before Alstom's conclusion of the AGV). For the first time Alstom and Siemens were developing their high-speed trains in direct competition. Their aim was to gain all the markets in the European countries converting to high-speed networks.

In figure 4.16 the AGV is found at the level of manufacturers sub-regime. Differently from its TGV relatives developed in collaboration with SNCF, the AGV was fully designed and build by Alstom own teams and financial resources in a clear anticipation to the European Union's Railway Packages implementing the White Paper on Transport, ruling financial restrictions to state aid, requirements for technical interoperability and high safety standards, standard gauge and electric multiple units. Modularity is also an important element in the AGV, with the manufacturing Alstom aiming at cost reduction, improved components technology interfaces, as well reduction time for assembly and life cycle cost.

The AGV represents the "reorientation of trajectories"[94] towards European standard vehicles. Behind AGV modern design relies hours of engineering work and strategic meetings at European level between Alstom staff and other stakeholders mainly from the supply-chain at regime level and even with its direct competitors, to promote adoption of Alstom technology as European standard. The AGV integrates results from European research collaborative projects, build up on Alstom and also Siemens technology, such as MODTRAIN[95] and the EUDD Drivers Desk[96] and other technical joint works as from the former AIF (Association Européenne pour l'interopérabilité Ferroviaire), which have become dominant standards.

---

[94] See Geels and Schot (2007, p. 401: 399-417).

[95] MODTRAIN stands for Innovative Modular Vehicle Concepts for an Integrated European Railway System. The integrated project was the first of its kind in the railway industry. Started in February 2004 and ended in April 2008 with a budget of 30Million Euros, 37 partners from the supply chain, associations and consultants, coming from 10 European countries. The project 8 work packages addressed the 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). From this project resulted relevant standards (prEN 15380) and harmonization of procedures. Another very important development was the unprecedented creation of new working relations between academia, the rail industry and operators, both complementary and competing between each other creating a new culture contrasting with the traditional reluctant to information sharing. While contributing to a more balanced distribution of traffic across modes, better service for travellers and stronger industrial base in Europe. Retrieved (March 2013) from http://www.modtrain.com.

[96] EUDD European Driver's Desk improving interoperability in European cross-border railway traffic. The research work involved 16 partners, 28 months (ended in 2008). Retrieved (March 2013) from http://ec.europa.eu/transport/projects/items/euddplus_en-htm.

Without the traditional order from a specific client but rather a pre-commercial policy challenge of a sustainable trans-European high-speed train network, decision-making on which technology to embed in the train became strategic. As previously referred in the description of figure 4.16 the emergence of manufacturers strategic intelligence and emergence of societal assessment was introduced during the development of the AGV (2001-2008). They reflect regime arena stakeholders' alignments and present visions for technology transitions from the second to the third generation of trains and beyond.

There is a paradigm shift in decision-making from technological/tacit to policy & regulatory driven/strategic. Rachel Piccard from SNCF called it the transition from hardware to software technological development.

b) From the ICE-1 to the ICE-350E

Ten years after France in 1991, Germany introduced its first high-speed train, the ICE-1 Intercity-Express running at a speed of 250 Km/h on the dedicated line Hannover-Wurzburg. Eight years after, in 2000, it introduces the second generation of trains with the ICE-3 running at a commercial speed of 300km/h, in line Frankfurt-Cologne. In 2006 the third generation enters in service with the ICE-350E running in the Spanish line Barcelona-Madrid at a speed of 350 km/h (Zhuo & Shen 2011).

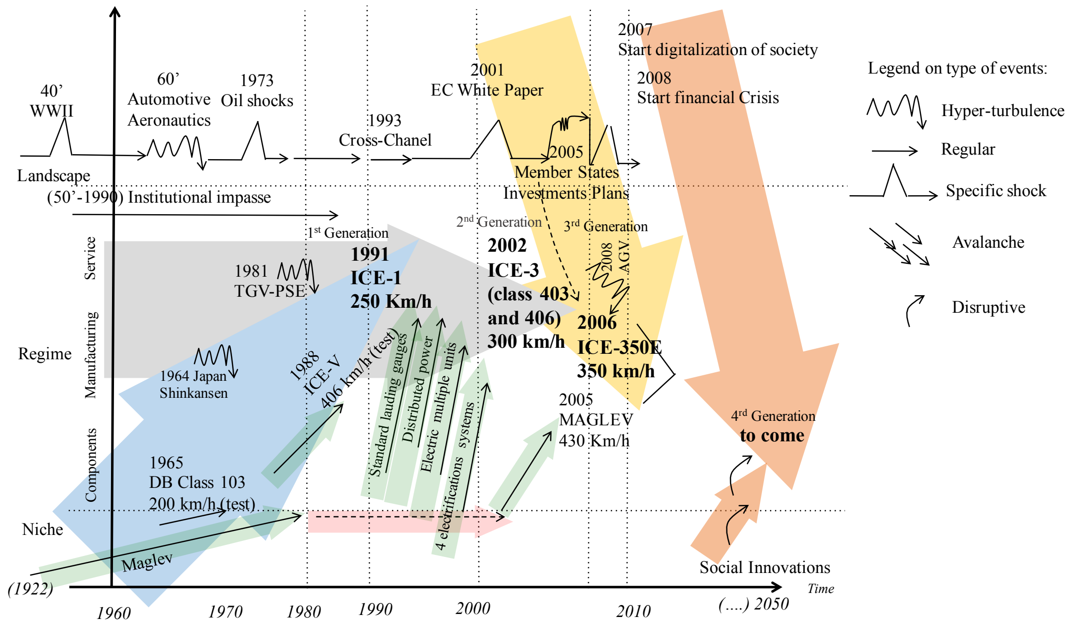


Figure 4.17. German ICE technology transitions
Source: Author

- First generation of trains: The ICE-1

In 1991 the first generation of German high-speed trains was introduced with the ICE-1 running in Hannover-Würzburg line at a commercial speed of 250 km/h. Since Germany became the second country in Europe to have a high-speed rail in service.

Sixty years passed from Germany's early development tests of trains running at higher speeds and the deployment of the ICE-1. Figure 4.17 clearly illustrates such long development trajectory. That was due to two main obstacles at landscape arena, the Second World War and later impasse between the operator company and the government in terms of adopting or not dedicated lines for freight and passengers transport.

Similar to the French TGV, the first generation of the German high-speed train was pulled by the "hyperturbulence" event at landscape by greater competition from automotive and air transports (Ebeling 2005, is consensual with Constant 2006). Moreover, Germany was pushed in 1964 by Japan's Tokaido Shinkansen start operations and latter in 1981 also by the French TGV.

The German ICE-1 deferred from the French TGV mainly on the use of the classical two bogies per car and possibility of changing the length of the train.

The ICE-1 changed the fundamentals of the German railways (Ebeling 2005), resulting from years of research, using the ICE-V prototype that broke the world speed record of 406 km/h in 1988. The prototype was fully developed by Deutsche Bundesbahn and Siemens.

The ICE-1 and latter model ICE-2 were very much oriented to the German high-speed network with loading gauges exceeding that recommended by the UIC standards. It was after the ICE-2 that DB AG for costs reasons decided to develop new distributed-traction electric motor units (EMUs) alike to the Japanese Shinkansen pushing the German high-speed train to its second generation of trains.

As for the French vehicles, also for the German first and second generations of trains the decision-making relied on the railway operator adopting a tactical approach responding to the technical challenges, resources driven, with the train manufacturer increased technological competence. That justifies the position of the ICE-1 at the level of service sub-regime and the ICE-3 slightly down in between the sub-regimes of services and manufacturing.

- *The second generation of trains: The ICE-3*

The ICE-3 (also called Velaro) first full-scale model happened in 1996, known as ICE-M. However, it only started operations in 2000 between Frankfurt and Cologne at a commercial speed of 300 km/h, on time for the Hannover Expo. The ICE-3 overcomes its predecessors by its smaller loading gauge required outside Germany, meeting the UIC international standards. It introduces electric multiple units (not locomotive power-trains) with motors distributed under the floor, making it the first vehicle of this kind in Europe (Siemens 2010).

Siemens manufactured two classes of vehicles. The ICE-3 class 403, intended for domestic operations and the ICE-3M class 406, prepared to run under four different railway electrification systems existing in Europe assuring Deutsche Bahn's international services. Later, in 2006/2007, China used ICE-3 as carriage technology reference to build its own technological capacity[97]. Also, in 2009 Deutsche Bahn received permission to run the ICE-3M across the Channel Tunnel.

As in the past, also for the second generation of high-speed trains, Deutsche Bahn was at the core of the technological development in cooperation with its flag-manufacturer Siemens. The German operator followed the traditional technical approach, resources driven. As a result, the ICE-3 new features essentially addressed the German national specific requirements and the perspective of extending operations to neighboring countries. Siemens started during this period its international co-development strategy gaining with it more technological competences beyond its national customer (Siemens 2010).

- The third generation of trains: the ICE-350E

In 2006, ICE-350E, also called Velaro-E by its manufacturer Siemens or AVE-Class 103 by the client Renfe Operadora, running in the line Barcelona-Madrid at a commercial speed of 350 km/h corresponds to the third generation of German high-speed trains.

The distributed power car is an incremental development of the technology used on the ICE-3M/F manufactured by Siemens to Deutsche Bahn. In 2011 the improved model Velaro-D was developed to assure Deutsche Bahn international services from Germany.

Alike with what was happening with the French AGV, the German ICE-350E is the result of Siemens strategic technology decision to develop a train with no order or request for tender (Siemens 2010). Motivating it were the series of turbulent events as described for the AGV

[97] According to Takagi (2005) China used Siemens ICE-3 reference carriage technology as well as it used the Swedish high-speed commuter train Regina built by Bombardier of Canada and the JR East Hayate E2- 1000 built by Kawasaki Heavy Industries. The author refers that the method involves modifying the designs to suit Chinese needs in areas such as body width and interior fittings. The author continuous by referring that as part of China ambition to develop its worn high-speed technology for all models introduced, about 20% of the parts are made in the countries of origin and the other 80% are made in China under license.

subsequent to the White Paper on Transport (COM(2001)370 final), with European countries, in particular Spain announcing massive investments for rail projects.

To support the development of the ICE-350E in the described new conditions it was found that Siemens adopted a strategic intelligence approach as described for Alstom's AGV. Siemens was promoter and partner in the industry emergent collective visions and proliferation of collaborative research projects. Siemens was pushing for its technological solutions to become widely adopted as European standards. The manufacture also integrated co-developments in the ICE-350E development process. Besides the collective action, Siemens was also very active in producing their own visions and expectations on the future technologies addressing the high-speed trains, including links to other sectors such as energy[98].

Both trains the French AGV and the German ICE-3050E trains represent a paradigm shift in decision-making from technological to policy & regulatory driven. Rachel Piccard[99] from SNCF called it the transition from hardware to software technological development. Cross-border corridor driven, Alstom and Siemens developed these trains in the race to dominate vehicles supply to the trans-European high-speed networks and have their standards dominate.

- The Maglev

Continuing the description of figure 4.17 at the niche arena (bottom of the graph) the Maglev technology slowly emerged in parallel to the ICE development, without however raising technological competitive pressures over the different generations of the ICE.

In 1922, where the technology was invented, Hermann Kemper first considered replacing train wheels by electromagnets. The idea of "flying zero altitude" was patented in 1934 (Ebeling 2005). Latter during 1971 the Japanese joined the German efforts. But just after, in 1977 DB AG for economic reasons abandoned the project of building a magnetic train link Hamburg-Berlin.

In 2001 China bought from Siemens the Maglev for the link Shanghai's new district and Pudong Airport, in operation since 2005 at a commercial speed of 430 km/h, while test records have reached 500 km/h. Differently from the French Aérotrain the magnetic levitation was commercialized.

d) The transition to the fourth generation of high-speed trains:

---

[98] Should be noticed that Alstom does not make public their reports as Siemens.

[99] Key-note speech at the opening ceremony of the UIC World Congress on High Speed Rail, Tokyo, 7.07.2015 (Picard, 2015).

Currently we are at the technology transition to the fourth generation of high-speed trains resulting from the "specific shock"[100] with the financial crises occurred since 2008 and followed by the hyper-connectivity from the increase digitalization of society and social innovation, causing an "hyperturbulance" of events. The European Commission policy initiative on the Roadmap to a Single European Transport Area is the first policy document pointing to the emergence of this new trend (COM(2011)144 final, European Commission 2011).

As referred by Rachel Picard (2015) the digitalisation of society is precipitating railways into a new transition, this time socialware driven technologies. To cope with, SNCF train operator have announced major efforts to create a digital eco-system door-to-door for TGV travellers. While, in its turn Alstom and Siemens are assessing how to integrate digitalization and social innovation in the development process of their high-speed trains, which most likely will produce a transition to a fourth generation of high-speed trains. This became very clear at the 9th UIC World Congress on High-speed Trains, 7-9 July 2015[101], from the interventions by Rachel Piccard, Director of SNCF Voyages; L. Baron, Alstom mainline technical director; and Jurgen Bandes, Siemens CEO, mobility division.

Moreover as responses to these challenges, the collective of the industry, of which is part Alstom and Siemens, is now setting a new governance structure for R&D in SHIFT2RAIL.

4.2.4. Findings

High-Speed trains technology transition from one generation to the other results from decisions taken on which technology/technologies to support. Those decisions have shifted from tactic responses to strategic. This way the transition from the first generation of high-speed trains to the second respond to occurred events. They were driven from practices of a tactic management approach. In its turn the most recent transition from the second to the third generation of trains occurred as anticipation to emergent challenges, supported by a strategic management approach.

This reflect the evolution of the drivers pulling and pushing the industry to develop new technologies, from hardware innovation to software innovation and most recently to socialware innovation, further developed in section 4.4.

---

[100] For the definition of specific shock see Geels and Schot (2007, p. 404: 399-417).

[101] link: http://www.uic-highspeed2015.com/

The tactical approach addresses technical challenges, resource driven (past legacy). The strategic approach addresses policy challenges, project driven (present-times) and most recently emergent societal challenges, mobility driven (emergent). Those approaches coexist in time.

Strategic management including anticipatory activities surged here as support tool to technology decision-making.

This way the commercialization of the German ICE-350E in 2006 and the French AGV in 2008 is a result of stakeholders alignment from 2001 in view of anticipatory co-engagements to meet the set European policy challenge on interoperability, modularity, sustainability and safety (COM (2001) 370 final), seeing it as an opportunity to promote their technology as European standards. It corresponds to the first technology transition from traditional tactical decision-making process to a strategic approach.

Moreover, it worth to note that the development cycle of these trains occurred only in 4 to 7 years, in contrast with the 15 to 20 years in the past generations TGV-MED (commercialised in 2001) and ICE-3 (commercialised in 2002). Contributing was the strategic approach through anticipation in obvious combination with computational advancements such as on virtual testing, validations and homologations.

Soon after the commercialization of the ICE-350E and the AGV, the 2008 financial crises' and ICT advancements emergent digitalization of society is pushing the high-speed trains into another technology transition from which can arise a fourth generation of vehicles. The vague and unbound nature of resulting events is creating a new wave of unprecedented framework conditions in this industry reinforcing the importance of the adopted strategic decision-making approach to this new social pressures.

At this stage, it worth to extend the analyse in the next section 4.3 to the multi-level perspective of the different stakeholders involved confined to the period of the technology development of the AGV and ICE-350E.

4.3. Multi-level Perspectives

4.3.1. Introduction

In this chapter my analysis focus on the multi-level perspective of the various technology actors during the development of the AGV and ICE-350E (2001-2008), during which it was observed the emergence of collectively aligned strategic decision-making approaches monitoring policy challenges introduced by the 2001 White Paper (COM (2001) 370 final). The objective was to identify how far out those multi-level-perspectives embedded society.

To modulate the data, I further apply Geels levels of system innovation (Geels and Schot 2007) articulated with Pavitt revised taxonomy of innovation (Castellacci 2008). The result is a visualization about the AGV and the ICE-350E multi-actor system (figure 4.8) and knowledge exchanges within (figure 4.9).

4.3.2. Analysis

The shift to a collective strategic approach in support of decision making during the development of the AGV and ICE-350E have produced a series of documents in the form of strategic technological agendas ranging from individual stakeholders, as with Siemens reports, or from groups of stakeholders, as with UNIFE's railway market outlooks or ERRAC visions. See figure 4.18 below.

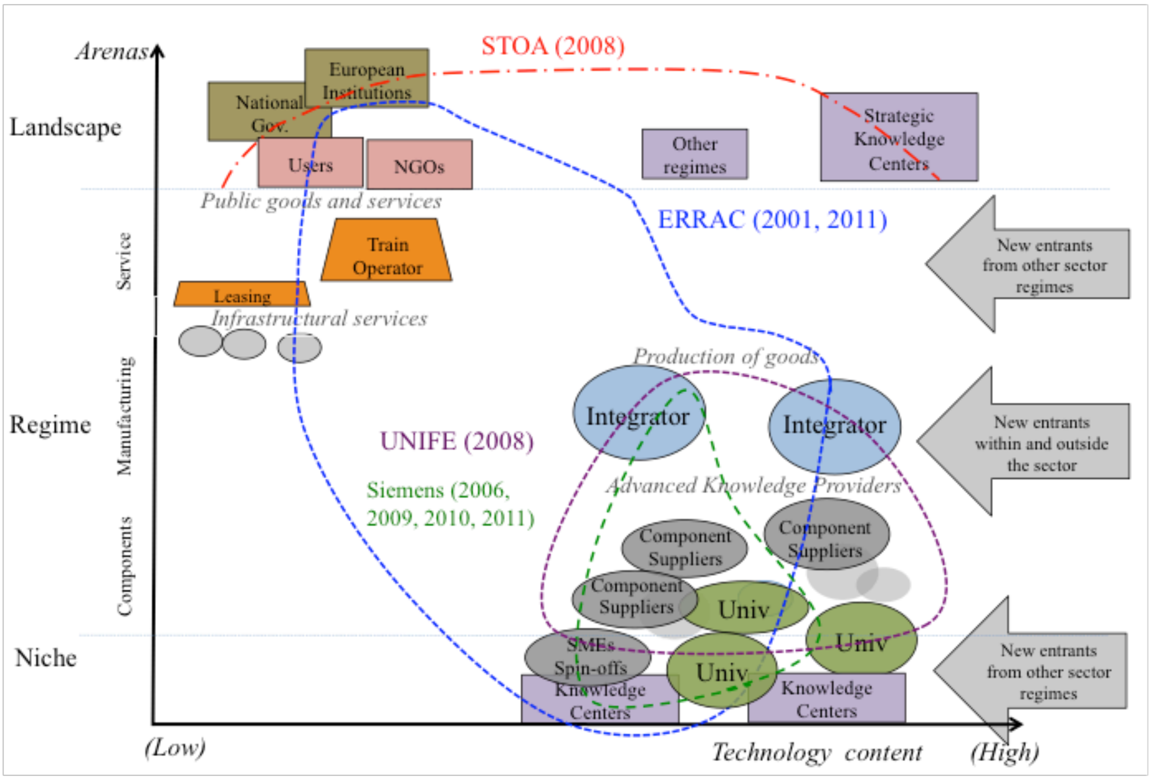


Figure 4.18. The AGV and ICE-35E multi-level perspective from 2001 to 2008
Source: author

From figure 4.18 it can be seen a hype in the production of strategic reports at regime level, each reflecting stakeholders' technological perspectives and expectations on the necessary technology developments to meet the policy challenges set by the 2001 White Paper (COM (2001) 370 final).

a) Landscape arena

At the top of the graph in figure 4.18 is the landscape arena, which is supra systemic to the high-speed train regime framing national governments, the institutions of the European Union, centers of knowledge, non-governmental organizations and end-users (Moretto et al. 2012). Also visible are entities from other sector regimes, such as from energy, aeronautics, automotive and materials impacting high-speed trains' technology development.

At this arena interests and expectations are exogenous to the high-speed train technology regime. Policy institutions are concerned about defining and meeting great challenges, associated to policy initiatives (sustainable transport system, decoupling transport growth from its negative environmental impact and energy dependency and boost competitiveness). End-users (individuals) are concerned about meeting mobility needs (connectivity and accessibility, reduction in travelling time and seamless journeys). Non-governmental organizations and centers of knowledge are looking at specific interests within their areas of action.

These actors are capable of producing framework changes. They can occur in different forms such as "regular, hyper-turbulent, specific shock, disruptive and avalanche" (Geels and Schot 2007, p. 404). From what was described in the previous section for the AGV and the ICE-350E technological transitions, landscape stakeholders produced changes at regime level impacting sub-regime actors approaches towards technology decision-making, supply chain alignments and technology transition from one generation of high-speed trains to the other.

Within the landscape arena strategic reports can be found, such as foresight exercises. They are commissioned by policy actors to external bodies with the purpose of political guidance in which technology to support meeting policy challenges and most recently meeting emergent societal challenges.

One example found is the STOA report (Schippl, et al. 2008). The STOA report was commissioned by the European Parliament aiming at presenting scenarios on the future of medium to long distance transport system. From the bibliographic references and the list of stakeholders participating in their workshops no evidence was found of links with the other prospective exercises produced at the regime level. Instead report citations and stakeholders invited appear to come from policy and research institutions acting within the landscape such as the European Transport Conference and the European Commission Eurobarometer. This way it can be considered as an exogenous assessment to the high-speed train industry on the future.

STOA is a report in which scenarios are constructed on an intended combination between quantitative and qualitative indicators to address the societal dynamics of sustainability, using backcasting, following a methodology aligned with constructive technology assessment.

b) Regime arena

Continuing the description of figure 4.18, at the middle of the graph is the regime arena corresponding to the AGV and ICE-350E supply chain. It is formed by the sub-regimes services, manufacturers and components, which have mutual and variable relations of dependency (see sub-section 4.1.5 c) technology transfer). It is at the regime level where knowledge is transferred between stakeholders from different sub-regimes (Moretto et al. 2012).

At the top of the regime arena, the sub-regime of public goods and services is visible. Stakeholders located here are train operators, leasing companies and new entrants in railway operations. They are service companies who establish the train-vehicle specifications required to run the train in a dedicated national or international high-speed rail-corridor or just buying or leasing the train out of the shelf (e.g. standardised). According to the released data by the

UIC (2013) it exists in Europe over 20 high-speed train operators. They range from a private open access operator as the Nouvo Transporto Viaggiatore[102] (NTV) in Italy, to the franchising schemes such as Virgin Trains[103] in the UK, to consortia of national railway companies such as Eurostar[104] or Thalys[105] and commercial branches of those same national operators such as SNCF[106] or Deutsche Bahn[107].

The liberalization of the European railway has pushed aside train operators from controlling technology decision-making process transferring it to the manufacturer. Operators now focus on the service aspect of the business, with almost no technology ownership. This is even more evident in leasing companies and new entrants from other sectors, which mainly look for standardised trains and have no demands or competences for the technology development or design. Overall, interests and expectations from these stakeholders are to overcome technical operational problems, compliance with the track-infrastructure and regulations (interoperability, safety, modularity, homologation, energy, weight, noise emissions, end-of life, maintenance) as well as attractiveness to passengers (speed, comfort, availability, ticketing prices).

---

[102] NTV is a private company pioneer in open high-speed train access service existing since 2011. It runs the Italo ETR 575, AGV family manufactured by Alstom and Alstom Italia, at a commercial top speed of 360 Km/h, in the Italian high-speed network. It is in direct competition with the state-owned operator Trenitalia. Major stakeholders are MDP holdings 33,5%, IMI Investimenti S.p.A from Intesa Sanpaolo S.p.A (20%), SNCF French Railways (20%), Winged Lion Fund from Assicurazioni Generali (15%). Retrieved from Wikipedia (2013) NTV.

[103] Virgin Trains UK is a franchising company who started in 1997, running the BR Class 390 (Pendulino manufactured by Fiat Ferriviária) at a speed of 201 km/h and BR Class 220, 221 and 222 at a speed of 201 km/h (also name Voyager by its manufacturer Bombardier). It is owned by Virgin Group (51%) and Stagecoach (49%). Retrieved from Wikipedia (2013) Virgin_Trains.

[104] In 1994 it was launched Eurostar cross-channel services linking London Waterloo International Station, Paris Gar du Nord, Brussels Midi and Lille Europe. Until 2010 Eurostar was operated jointly by the national railways of France SNCF and Belgium NMBS/SNCB and the Eurostar UK Ltd (EUKL) a subsidiary of London and Continental Railways (LCR). By 2010 Eurostar became a single corporate entity called Eurostar International Limited (EIL). EIL is owned by LCR (40%), SNCF (55%), and NMBS/SNCB (5%). Eurostar fleet was build between 1992-1996, with TGV 373 units (named class 373 in the UK) manufactured by Alstom but assembled in different sites in France and UK, running at a top commercial speed of 300 km/h. In 2010 the fleet was extended to Velaro e320 manufactured by Siemens to operate in the extended rout network London, Cologne and Amsterdam, at a commercial top speed of 310 km/h. Retrieved from Wikipedia (2013) Eurostar.

[105] Thalys International, based in Brussels, started operations in 1996, initialling servicing the link between Paris and Brussels. Today it reaches Amsterdam and Cologne. The trains run at a commercial speed of 300 km/h. Its fleet is composed by TGV units manufactured by Alstom. Its capital is divided between SNCF (62%), NMBS/SNCB (28%) and Deutsche Bahn (10%). Retrieved from Wikipedia (2013) Thalys.

[106] SNCF Société Nationale des Chemins de Fer Français is the French national state-owned railway company. The SNCF operates the country national rail services including the TGV. As it will be further described it was SNCF during the nineteen seventies that began the development of the TGV, in collaboration with the French manufacturer Alstom. Latter in 1981 SNCF first started in Europe operations of high-speed trains. Retrieved from Wikipedia (2013) SNCF.

[107] DB Deutsche Bahn AG, based in Berlin, a private joint-stock company (AG) with the German federal government as the main stakeholder. It is the holding of DB Fernverkehr that operates long-distance passenger travellers including high-speed Inter-City-Express (predominantly running in Germany) and EuroCity (international). It was founded in 1999 in the second stage of the privatisation of German Federal Railways. Its fleet is composed of ICE trains, or Velaro, manufactured by Siemens, running at a speed between 280km/h to 320km/h.

These actors may cause technological “regular changes” to the framework conditions, but likely to be confined to the regime arena, while tending to resist to events that change the *status quo*. Such contrasts with their vulnerability to landscape “turbulences, specific shocks and disruptions”, such as the European railway packages and changes in mobility patterns.

Continuing the description of the regime arena, in figure 4.18 in the center-right, the sub-regime of production of goods is visible. Stakeholders here are the assemblers of high-speed train technology (the vehicle manufacturer) capable of providing turnkey projects. In Europe they are Alstom Transport (French), Ansaldo (Italian), Siemens Mobility (German) and Talgo (Spanish)[108]. These firms are global players in today’s railway open markets but of a strong national identity yet reflected by decades of nationalized business conditions.

High-speed train manufacturers are the technology owners inherited, in most of the cases, from their national counterpart operator company. Their overall interests and expectations are the reduction of costs, compliance with regulations and attractiveness to customers and most recently to end-users (such as access to markets, low costs in development and manufacturing, standardization, modularization, safety, recyclability and end of life, energy savings, weight, noise abatement, power distribution, wheel rail contact fatigue, interiors, materials and aerodynamics).

Also at this sub-regime manufacturers might introduce “regular changes” from landscape pressures, but also and most important, they can cause technological “disruptive” changes to gain strategic markets. They are subject to “avalanche” pressures from the sub-regime of knowledge providers and in particular situations from the niche arena. However due to the large and complex technology system is a demanding, costly and time consuming task for train assemblers to integrate disruptive technologies in the vehicle. An invisible force can be also felt from potential new entrants such as manufacturers from other parts of the world or component suppliers with increasing technology capacity resulting from outsourcing or their market scales.

Finally, at the bottom of the regime arena in figure 4.18, is found the advanced knowledge providers’ sub-regime. Stakeholders here cover different tiers of the technology supply-chain, ranging from *tier one* of component suppliers of the high-speed train technology sub-systems, such as Knorr-Bremse (pneumatic, hydraulic and electronic braking systems), Bosh (coolers and cooling systems, hydraulic travel drivers), Voith (wheel sets, couplings, gears, cooling systems) MTU (engines), Efacec (telecommunication systems, power supply system) Bochumer Verein and Bonatrans (wheel sets), Faiveley (air conditioning, coplers,

[108] Despite the relevant presence of Bombardier in Europe it is a Canadian company, not an European one.

electromechanic door and gates systems), Saft (accumulators, industrial cells and supercapacitors), Selectron (control systems), to the *tier two* and so forward, such as Amorim Corck Composites (bio-composites for car body sandwich panels, floor and isolation from noise and vibration). This sub-regime also includes knowledge suppliers resulting from University spin-offs.

In Europe component suppliers from *tier one* might even pair in turnover and technology capability with their clients, the technology assemblers. In the past decade the increase in outsourcing from train manufacturers conferred to them a greater weight in the technology development. As a result those firms became capable of producing from "regular" to "disruptive" pressures and changes to the arenas of regime and niche. At the same time they became more vulnerable to landscape changes. Also here an invisible force comes from potential new entrants and moreover from firms' alliances and acquisitions.

Component suppliers of technology and knowhow main interests and expectations are similar and might be confused with those of the train manufacturers, in which respects to reduction of costs, compliance with regulations, reliability and attractiveness to customers. This occurs because they are specialized suppliers of a particular technology sub-system of the high-speed train. They are subject to tight quality standards requirements and certification procedures imposed by the assemblers of the vehicle. With this purpose in mind, the International Railway Industry Standard[109] (IRIS) was formed in 2005.

Within the regime arena, stakeholders tend to cluster in professional associations at European level, acting like clubs of shared visions, perceptions and interests. During the past two decades they have multiplied and professionalised. Those include the UIC the International Union of Railways (rail operators, leasers and infrastructure managers) and UNIFE the Union of European Railway Industries (manufacturers and component suppliers of vehicles and infrastructure). More targeted interest associations are ERWA the European Rail Wheel Association of Manufacturers, EIM European Rail Infrastructure Managers, CER Community of the European Railways and Infrastructure (policy wing of UIC), ETF European Transport Workers Federation and EPITOLA the European Passenger Train and Traction Operating Lessors Association. National associations have also to be considered as for example FIF the French Railway Industry Association or RIA the United Kingdom Railway Industry Association and the VDB, the German Railway Industry Association.

Each of those listed associations serve specific groups of stakeholders, which sometimes overlap in members and mission. Others such as ERRAC, the European Rail Research Advisory

[109] For more information see www.iris-rail.org.

Council, combine all of the existing associations plus landscape stakeholders as member states representatives and end-users, sharing the same goal of an integrated rail research area to foster innovation in the rail sector.

At regime arena were found three types of future exercises. The first type is visions and road maps, such as ERRAC[110] visions (ERRAC 2001 and 2007), produced at regime level by the railway community, combining interests and expectations of sub-regimes plus actors from landscape and niche arenas. Forecasting exercises, such as UNIFE market outlook 2020 (BCG 2008) commissioned to consultants at sub-regime level by the association of providers of services or manufacturers, as means to jointly anticipate market trends and future technology needs. And finally individual market outlooks and forecasting, such as Siemens (reports 2006, 2009), with the same character as the previous one, differing only the fact that it results from the interest of a stakeholder alone to anticipate its future positioning in the market and defend its only interests and expectations.

It was found that those reports have in common a techno-centric vision about the future, in clear contrast with the one found for STOA report. They are inclusive of each other prospective exercises, meaning that for example UNIFE market outlook aggregates data from its members individual forecasting exercises, combining them together at sub-regime level. In its turn ERRAC visions integrates those professional associations forecasts 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 seems to disregard results from exogenous prospective exercises such as STOA. Only Siemens clearly referred to other sector's Delphi results such as for energy. Moreover, found reports methodology reflect commissioning stakeholders' life cycle cost approach based on quantitative indicators, bypassing qualitative elements inherent to today's emergent societal challenges.

c) Niche arena

At the arena stakeholders are mainly from academia and private research institutions, spin-offs and SMEs, all of which are providers of basic and frontier research of potential application in the railway vehicle technology system and sub-systems. They are quite diffused, as those institutions do not dedicate exclusively to railways. The EurNEX European Rail Research Network of Excellence is a joint initiative, driven by operators and industries supported by the European Commission, to group such diffused scientific actors from all over Europe in the area

[110] ERRAC comprises 45 representatives from each of the major European rail research stakeholders: manufacturers, operators, infrastructure managers, European Commission, European Union Member States.

of transport and mobility. Among their members is Chalmers University of Technology, Technical University of Lisbon, Technical University of Berlin, Newcastle University, Politechnical University of Madrid, University of Valenciennes, Technical University of Viena, Czech Railway Research Institute, to name a few. It was interesting to find spin-off companies as INECO (transport engineering firm).

These types of stakeholders are classified as advanced knowledge providers but falling within the specific niche arena (therefore outside regimes). However, the frontier between the two in the specific case of the high-speed train is very blurred as stakeholders' part of advanced knowledge providers are motivated by the problems from existing sub-regimes. Specifically in the railways radical novelties, even if stabilized, do not easily breakthrough in the regime arena. Only if a window of opportunity arises from pressures from the landscape arena, radical novelties are implemented and new players can enter.

The high-technology content and complexity of a high-speed train combines different areas such as mechanical engineering, computational, materials, managerial expertise, finance, to name a few. Moreover, due to the large scale of the technology system and traditional protectionism towards information sharing, in many cases the technology has evolved from already tested and matured solutions at regime arena rather than breakthrough research from the niche one.

In contrast with the other two arenas, no prospective exercises were found. In fact, the stakeholders from this arena are brought into regime or landscape level discussions to undertake the studies or are invited to take part in the collective elaboration of visions. That is clearly the case of the ERRAC visions or the STOA report.

4.3.3. Findings

From the analysis of the multi-level-perspective during the development period of the AGV and ICE-350E it became evident that each report reflected the technological arena of the commissioning stakeholders. Those reports were mainly produced at regime level to meet the strategic purposes of understanding the future business conditions introduced by the liberalization of the railway market in Europe, while aiming at influencing future technology developments favorable to the commissioning stakeholders. Less covered by the reports were the perspectives from landscape where societal actors could be found. During this particular period those societal actors were mainly non-governmental organizations and specific interest groups.

It is relevant to note that two dominant groups of reports were observed: collective and individual techno-centric visions (endogenous to the AGV and the ICE-350E supply chain), and policy foresight reports (exogenous to the AGV and the ICE-350E supply chain). Such represents a discontinuity in the alignment of the different multi-level perspectives. This requires additional research, by extending the reports studied beyond the development period of the AGV and the ICE-350E and further studding the methodology they apply and the composition of their experts. These will be addressed in the next section (4.4) covering the anticipation though future strategic formulations.

4.4. Anticipation through future strategic formulations

4.4.1. Introduction

As it was seen in the section 4.2. about technology transitions, the White Paper on Transport (COM (2001) 370) was widely seen as a wake-up call for railways to embrace modernisation and foster new technological developments by developing the AGV and the ICE-350E high-speed trains.

To tackle the announced new market conditions, those two high-speed trains reflect the new technical requirements (of modularity, interoperability, sustainability and safety) and new alignments in their manufacturers decision-making approach (from tactical to strategic).

From this phenomenon emerged in this industry greater anticipation (aiming and influencing and knowledge exchange) in the form of prospective reports and visions, as introduced in section 4.3 on multi-level-perspective. I found that over a dozen of relevant public reports had been produced since[111], such as STOA scenarios (2005, 2013) and TRANSvisions (2009) commissioned by the 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, are the reports from the European Technology Platform for railways (ERRAC)[112,113]. 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. We can call it a new "technological path" (Robinson and Propp, 2008) due to 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 ICE-

[111] The wide spread of FTA across Europe has its origins in the UK, introducing scenarios in the late 1990s (Potter and Roy, 2000) to assist the privatization of its railways during 1993 (Armstrong and Preston, 2011).

[112] http://www.errac.org.

[113] Actually ERRAC scenarios directly benefitted from UK experience due to Network Rail Chairmanship.

350E and the AGV series launched in 2006 by Siemens and in 2008 by Alstom, integrating some of results from projects as MODTRAIN[114] (modularity), EUDD[115] (interoperability), RAILENERGY[116] (sustainability) and Safeinteriors[117] (safety).

The promise of 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 information and communication technological advancements further challenged the railway system, particularly the rapid rise and societal uptake of digital technologies, to include, for example, the connected traveller.

These supra-systemic and diffuse waves of events revealed a gap between techno-centric exercises in future technological strategic formulations (e.g. Future Technology Analysis - FTA – as referred by the European Comission Joint Research Center) of predicting technological trajectories (Dosi 1982) and the new open-ended diffuse societal challenges.

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 the latest initiative SHIFT2RAIL joint undertaking occurring in June 2014.

In this most recent process of reorientation in railways, future strategic formulations became even more relevant, requiring this time to go beyond alignments within the techno-centric supply chain.

---

[114] http://modtrain.com/

[115] http://ec.europa.eu/research/transport/projects/items/euddplus_en.ht

[116] http://www.railenergy.org/

[117] http://www.eurailsafe.net/

In this section I will be further boarding the study of prospective reports extending the time period from 2001 to our days, the methodology they apply and the composition of the experts. The purpose is to understand if they miss the adequate methodlogies to bridge techno-centric visions with the new emergent societal challenges.

4.4.2. Methodology

This section is about a qualitative study on FTA practice in the railways sector by referring to the case of the AGV and ICE technology system. A characterization is made on the types and role of FTA in the European high-speed railway technology system by analysing and characterising found reports and contrasting them with actual developments of the high-speed railway sociotechnical system. The analysis draws on a broad range of concept models arising from different theoretical streams in the sociology of innovation, science and technology studies and constructive technology assessment.

As a first step I classify public available FTA reports addressing the high-speed train technology system, based on Robinson and Propp classification (2011, p.23, table 2) to which I added two main elements “function” and “approach”, besides “year of issue” and “stakeholders” involved. In the construction of the element “function” I bring in my interpretation on Schippl (2013, p.3) function of scenarios. While for the “approach” I base on the type of stakeholders’ inputs to the report. Calling on Grunwald (2011) I attribute “function” to “outputs” while “approach” to “inputs” from stakeholders exogenous or endogenous to the supply chain.

I further proceed locating the types of activities on the high-speed train innovation trajectory (transitions) over time using the s-curve model. I consider the high-speed train performance based on the speed (Zhou and Shen 2011) and adoption (number of service providers operating high-speed trains).

Then I contextualize FTA in the multi-level framework referring to the transition to the third generation of high-speed trains. I make use of the multi-level framework of Geels (2002) in combination with Pavitt (1984) technology transfer taxonomic model, extended to services by Castellacci (2008).

I further narrow down the deployment of FTA in the high-speed train technology system by referring to the specific collaborative research project MODTRAIN as ways to understand FTA contribution.

Finally, I conclude reflecting on constructive technology assessment bridging function between technology and wider society (Schot and Rip 1997, Rip and Schot 2001), which will feed the conclusions.

The data and facts here presented are based on secondary data retrieved from the identified public available reports and inside views from the commissioning authors and drafters, collected at different occasions.

4.4.3. FTA and the European High Speed Railway system

- *Classification*

Public 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 I 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		ERRAC Secretariat, ERRAC members: associations UNIFE, CER, EIM and individual value chain firms and national gov.	Rationale 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 **	2000* 2007* 2012**	Strategy-making		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 4.1. Classification of reports on future oriented technology assessment (FTA) referring to the high-speed train system

From the classification of the reports in table 4.1 I found two types of reports: a) endogenous, the great majority, with a total of 14 reports and b) exogenous, the minority, only 3 reports.

The endogenous reports, of industry inputs and initiatives, are about techno-centric exercises, serving mainly as output strategic purposes (selecting promising technologies, engagements, influencing technological directions) and present these strategic aims in a descriptive nature (communicating capabilities, expectations and values on certain issues, mutual learning).

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 as seen in table 4.1 include ERRAC visions (2001, 2011) strategic agendas (2002, 2007) and roadmaps (2012), UNIFE market outlooks (2006, 2008, 2010, 2012, 2014) and 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 (techno-centric) 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). See table 4.1.

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 centers. 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.

- *Future strategic formulations within the high-speed trains innovation trajectory*

Since 2001, future strategic formulations emerge in the high-speed train innovation trajectory (s-curve of performance and adoption).

Figure 4.19 below adds the future strategic formulations to the technological transition dynamics of the TGV and ICE seen in the previous section 4.2.

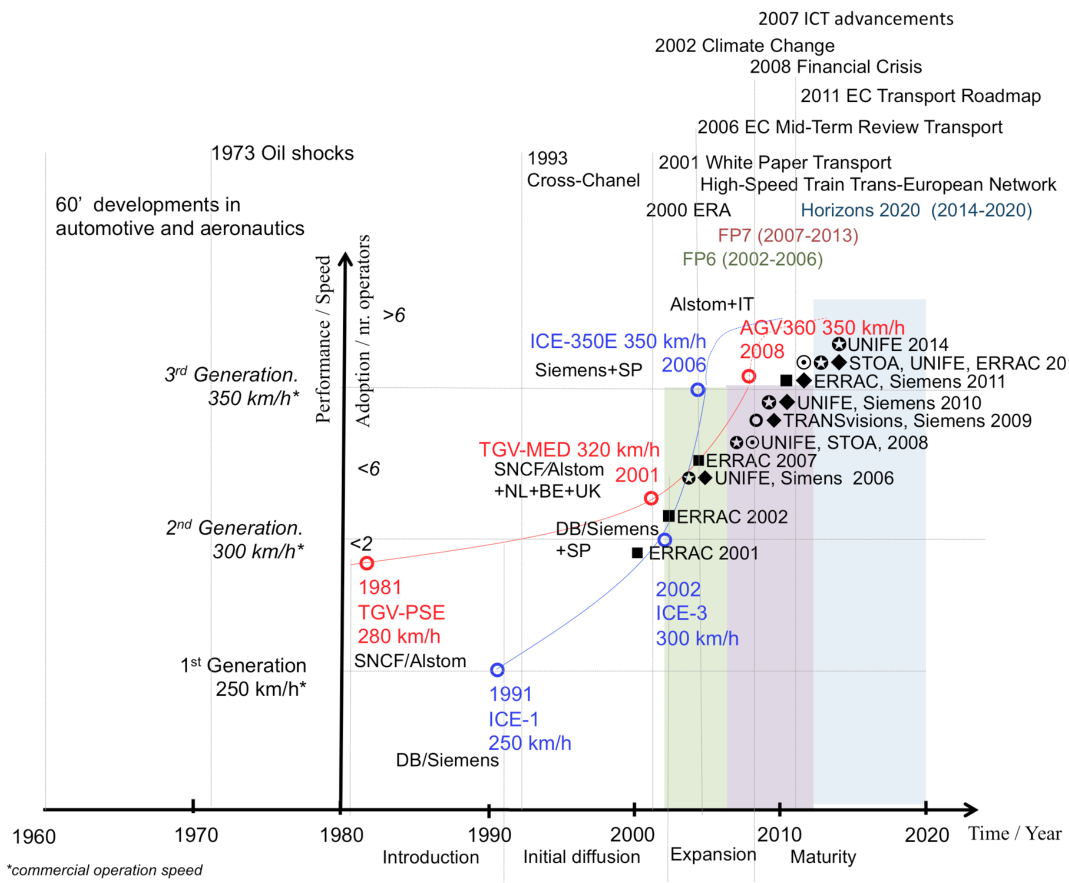


Figure 4.19. High-speed trains technology innovation over time (s-curve)
Source. Author

As figure 4.19 illustrates, there are 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 overtime: a) Introduction; b) initial diffusion; c) expansion; d) maturity.

Future strategic formulations, as we can see in figure 4.19, 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 accepted.

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

As seen before in Europe the two train operators the French SNCF and the German BD have been the pioneers in increasing the speeds of trains, lasting since the 1950's to our days. They introduced the first generation 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 manufacturer (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 CC7100 electric locomotives of higher power already in 1954 but only in 1981 the first high-speed train was introduced to service).

At this stage future strategic formulations were not actively pursued, only cost and benefit analysis ex-ante on specific corridor projects to justify governmental decisions. 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 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 ex-ante cost-benefit analysis undertaken by governments. First step is however given towards future strategic formulations across railways in Europe when UK first introduces scenarios (Potter and Roy, 2000) to identify 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 new open market conditions. 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.

Future strategic formulations surged here, opening the way for those interactions to happen. The first exercise was ERRA 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 MODTRAIN and the EUDD Drivers Desk and other technical joint works as the former AIF 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 future strategic formulations 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 future strategic formulations a privileged instrument of anticipation, influence and knowledge exchange to cope with this new market and regulatory conditions.

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 4.19.

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 future strategic formulations reports, which were targeted at managing this uncertainty through anticipatory coordination.

Manufacturers and operators became aware of the strategic relevance of future strategic formulations 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 future strategic formulation provided input for the generation of new research projects under the 7th framework programme such as TRIOTRAIN projects[118] (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.

- *Future strategic formulations and the high-speed train multi-level perspective*

Future strategic formulations exercises are the expression of multi-level perspectives. They reflect, collective or individual, assumptions (on users, markets, regulation and 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 instrument used to attract attention and resources from other actors.

Figure 4.20 below develops figure 4.18 by introducing strategic reports issued after 2008.

[118] TRIOTRAIN (2009-2013) http://www.triotrain.eu/index.htm

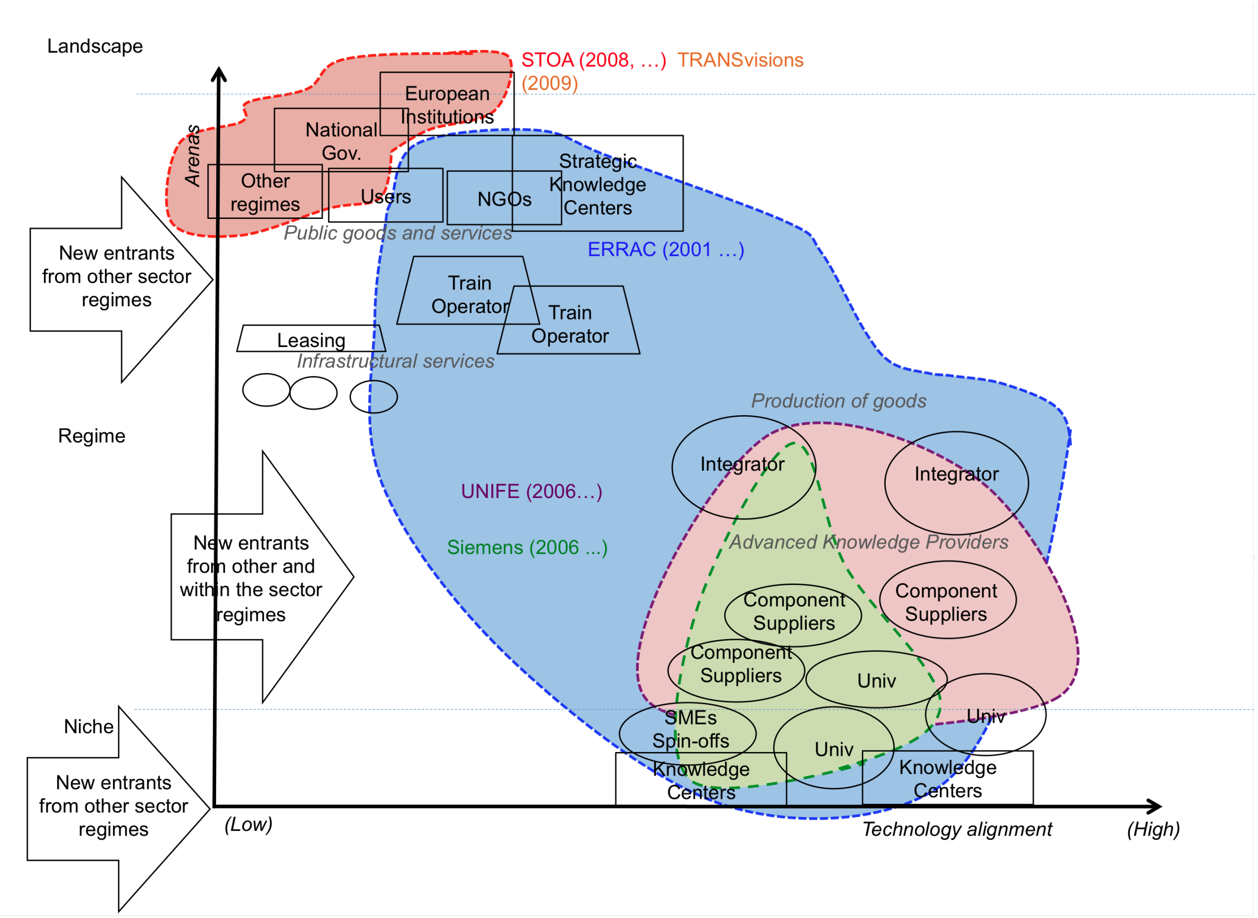


Figure 4.20. Future strategic reports and multi-level perspective since 2001 to our days
Source: author

From figure 4.20 one can observe that future strategic reports are for the majority industry initiatives occurring in the regime arena at meso-level. Here I follow the multi-level framework of Geels (2002). Evidences show that future strategic reports at this level describe the overall interests and expectations from its participating stakeholders. Moreover it can be seen 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. Another 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 the academy looking to further develop knowledge in this area; where member states are considering territorial cohesion and GDP growth.

It was found that ERRAC reports are drafted internally by its secretariat. Their contents result from plenary workshops and focus groups where ERRAC members meet. In these workshops, members identify future technological areas of common interest and enabling conditions 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 (mainly from the past Six frame-work programme for research 2002-2006 and the Seventh 2007-2013; continuing to the current one Horizon 2020 from 2014-2020); 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.

Less broad in stakeholders, 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 technological areas of shared interest. Their methodology is based on technological-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 lower is the engagement from different stakeholders.

However, the above said seems to disregard exogenous prospective exercises such as STOA or TRANSvisions. Only Siemens clearly referred to other sector’s Delphi results as for 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 report 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 that are outside 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. To note is that in STOA report (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, those reports do not make any reference to the industry ones and the involved stakeholders are not the same.

- Future strategic formulations and the high-speed train technology system

The technical innovations introduced by the third generation of high-speed trains system AGV and ICE-350E were driven from future strategic formulations.

As referred before (sub-section 4.1.5) the high-speed train vehicle is a very complex technology system[119] in itself, integrating hierarchical[120] 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.

Future strategic formulations coincide 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-systems themselves sub-divide.

Manufacturers attribute different strategic relevance to sub-systems (as shown in figure 4.10). 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 confidentially agreements. On the other hand, outsourced technologies such as interiors or materials provide a situation conducive to greater openness to

[119] 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".

[120] Simon (1962, p. 469) " (...) parts within parts structure".

collaborative innovation and broad consortiums exist which are ruled by cooperation agreements.

As we mentioned previously, the ICE 350E and the AGV integrate collaborative research projects results meeting FTA orientations. The most referred to example is MODTRAIN[121] integrated collaborative project (FP6), conducted between 2004 to 2008, involving 36 partners, of a total budget of 30 million Euros (which 16 Million were 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 about the risk that new trains were 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 and 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 level[122].

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

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

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

maintenance, as well as for a higher level of standardisation at the interfaces of the main train subsystems[123].

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 norms[124].

The policy ramifications is that MODTRAIN builds on and adds to the European Commission's previous legislative packages supporting the rail sector integration and increase 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 network[125].

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 regulations[126].

Despite the great accomplishment by MODTRAIN here referred as well as from other projects (EUROPAC[127], EUDD[128], 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)[129]. 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.

4.4.4. Findings

As seen in this section visions, roadmaps and other forms of future strategic formulations are playing an increasing role in the high-speed railway system, contributing to the revitalization of railways as a facilitator of a new industrial dynamics and integration of policies mainly on Transport and Research at European level, unprecedented in this particular industry. Such is evident in the enhancement of the high-speed train innovation system transition to the third

---

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

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

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

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

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

[128] http://ec.europa.eu/research/transport/projects/items/euddplus_en.ht

[129] Source ERRAC informer.

generation of vehicles (2001-2008) at an historical pace of only seven to five years, contrasting with twenty years in the past.

Future strategic formulations have played a significant role in recent years, particularly as certain technical and infrastructural elements began reaching their limits since 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 intelligence for anticipatory coordination, it has also been shown that there is a dominance of endogenous future strategic formulations, where exogenous approaches would provide intelligence necessary to encompass and speak to broader policy challenges, including societal challenges.

Currently, the railway technology platform (ERRAC) provides a 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 and 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 ICE-350E trains becoming part of the dominant designs and voluntary norms.

However, there is still a long way to go. The need for forums such as ERRAC and now SHIFT2RAIL to move beyond the dominance of endogenous roadmaps (highlighted in this paper) to a mix of endogenous and exogenous roadmaps and other forms of future strategic formulations (such as the STOA type of activities) is becoming a pressing issue. This call for more exogenous future strategic formulations is further amplified by other shifts in the socio-technical system of high-speed railways. For example, I have shown in this section that initially the railway operators and their manufacturers once held a strategically important position of being knowledgeable of the whole supply chain. However today they are no longer knowledgeable about the whole technological system. They moved from totally in-house production by the major manufacturers to outsourcing, pressed by 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), which places an emphasis on designing socio-technical systems by combining controlled foresight, with more stakeholders and with knowledge of how technological innovations and sectors co-evolve[130], would allow for more exogenous input into roadmaps, smart coordination and also advanced assessments of options based on the whole value chain. Approaches like CTA, would be effective at the collective level of industry associations, European technology platforms and other sector specific locations for knowledge sharing and coordination (Robinson 2010). Being more specific, CTA could certainly contribute to the ERRAC road-mapping process.

However, the inclusion of CTA as a support for high speed-railway system road-mapping also brings with it challenges: key elements of the railway system show a high level of competition between actors and scale and complexity of the technology system, 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 coordination with the national ones and ability to bridge techno-centric visions. This gains further relevance from the empowered society, liked by the digital networks, changing our perception of new technology selection and becoming increasingly prominent on the policy agenda. This, I argue, is a "wake up call" in road-mapping for the high-speed railway sector. It is possible to address it, especially if one locates "CTA for sectoral roadmaps" at the meso-level of consortia contributing to the European Technology Platforms and to the industry latest research governance initiative SHIFT2RAIL (joint undertaking).

[130] 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 roadmaps in high-speed railway, see earlier) towards a process of better informed anticipation. CTA (Schot and Rip 1997, Rip and Schot 2001) was developed with an emphasis on anticipation, articulation and feedback into ongoing processes. 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. 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) telehealth 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.

V. SURVEY

In this chapter the object of the study is extended from the two manufactures, Alstom and Siemens, to the wide industry part in the AGV and ICE innovation chains. The aim is to assess *who* in the innovation chain addresses societal embedding and at *what* stage in the technology development process it occurs.

This chapter is divided into introduction (5.1), data collection (5.2), unit of analysis (5.3), preliminary opinions from respondents on social embedding (5.4), results (5.5) on innovation management (A.) and social embedding (B.) and summary of the main results (5.6).

5.1. Introduction

The concept of innovation has extended beyond products and processes to include other criteria and values, as environment or ethics (Von Schomberg 2013, Robinson 2009). Thus, analysts of technology emergence include wider non-market aspects into their conceptual frameworks and theories (Nelson & Winter 1977, Dosi 1982, Rip and van der Belt 1987, Geels 2002).

Societal embedding has been suggested as a way of broadening analytical frameworks by including in new product creation processes the broad notion of market success. The "one that includes integration in relevant industries and markets, admissibility according to regulations and acceptance by the public", opening the possibility for actors to constructively "anticipate and work towards a desirable societal embedding" (Deuten, Rip and Jelsma, 1997, page 131).

Social embedding in new product development requires anticipation (Deuten, Rip & Jelsma, 1997) by means of strategic intelligence (Huff, 1979). Firms' central management and product development teams are required to go beyond formal structure of the organization (including regulatory affairs and public relations departments) to include direct interactions and alignments with external stakeholders (Deuten, Rip and Jelsma, 1997 following on Rosenberg, 1979).

The environments in which new product development has to survive has been articulated as 3 components (Deuten, Rip and Jelsma, 1997): "Business environment", which includes "input-output" relations with firm's suppliers, customers, research institutions, governments and its agencies; "Regulation environment" where regulatory stakeholders (involve local, regional, international actors); "Wider society" where stakeholders are consumers or social organizations, environmental groups, public opinion leaders, media and independent scientists (Deuten, Rip & Jelsma, 1997, page 133). See figure 5.21 below.

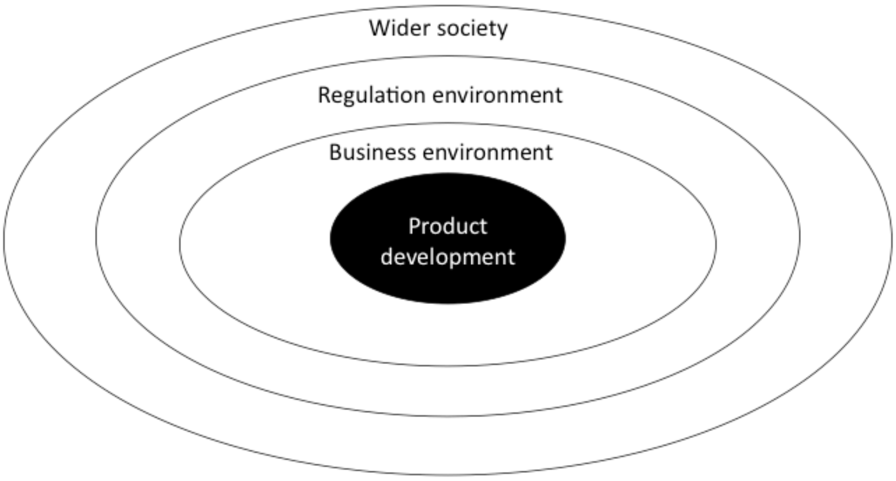


Figure 5.21. Product development process environments
Source: Deuten, Rip and Jelsma (1997, page 143, figure 2)

Deuten, Rip and Jelsma (1997) point out that, during product development, environments are not dealt with simultaneously but sequentially accentuating the unbalances and asymmetries with the other environments. For broad market success Deuten et al. (1997) recommend simultaneously seeking alignments between environments, creating path dependencies from early stage of product development. The high-speed train "broad market acceptance" is a new trend for the industry, as observed previously on the technological transitions of the two main models of high-speed trains, the French TGV/AGV and the German ICE, (see also Moretto et al. 2014a, Moretto et al. 2014b). At this stage I am now in the condition of applying Deuten, Rip and Jelsma figure to this technology. See figure 5.21 below.

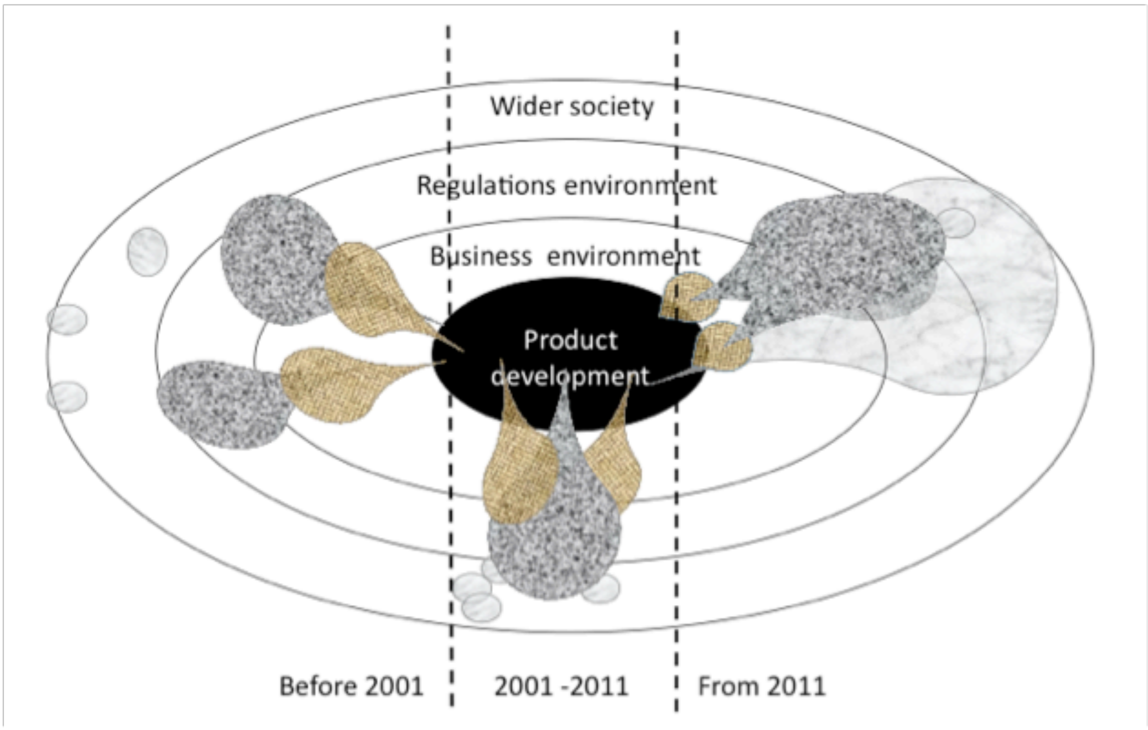


Figure 5.22. High-speed train product development process environments of selection in time.
Source: adaptation from Deuten, Rip & Jelsma (1997, page 143, figure 2)

The adapted figure 5.22 from Deuten, Rip & Jeslama (1997) to the high-speed train product development process in time shows that:

- For the high-speed trains in Europe prior to 2001, technology was developed to serve national transportation networks. Innovation was centred on the desire for increasing speeds, leading to a linear and incremental development trajectory. This was visible in 1981, in France with the TGV Paris-Lyon link and also visible in 1991 with the German ICE Hannover-Würzburg link. At that time railways were addressing only (national) business and regulatory environments with train developers applying a tactical responsive approach.

- Since 2001, with the advent of the announcement of a trans-European network for high-speed trains, vehicle technology development reached a phase where integration between different national high-speed systems was required. This notably involved co-developments of the TGV to run in trans-national links such as the Eurostar operated in the Paris - Lille - London link and Thalys running the Paris - Brussels - Antwerp - Rotterdam - Amsterdam rail link. Product development processes became dominated by European collaborative research and development activities with overarching alignments between the (European) business and regulatory environments.

- From 2011, global financial shocks and proliferation of some new technology fields (particularly new ICT developments) increase exposure of this industry to the wider society during their considerations in new technology development process. Wider society become less vague and unspecific, and clearly identifiable communities became visible, such as car-sharing or connected travellers. New emergent demands from wider society are less reactive to existing technology, but proactive in voicing potential design requirements at an early stage of product development.

5.2. Data collection

This survey aims to understand, from the widest range of actors involved (directly or indirectly) in the technology development process of high-speed trains, how far-close their institutions are from societal embedding in the new product development process.

The survey was designed in 2012, having as main reference Deuten, Rip & Jelsma (1997) work on the societal embedding in new products development process, as conceptualised in Constructive Technology Assessment, as mentioned.

In April 2012, the survey was first tested, in a face-to-face format, on a sample of eight stakeholders taking part in the technology development system of high-speed trains, speakers at the Conference RAILWAYS 2012. Due to the nature of the conference the respondents were mainly from research centers and academia. Yet some of them with overviewing the overall technology development process as DHL, undertaking a research project on the future high-speed train. In a smaller number there were component suppliers as Critical Software, also interviewed.

The online survey[131] was launched on the 24 February 2014.

Invitations were initially sent to the wider railway community (e.g. train operators, manufacturers and component suppliers, infrastructure suppliers and managers, users, policy makers, regulatory and certification bodies, railway associations, consultancies, academia and research centers).

Later in August of the same year the survey was extended to the technology assessment community, from which 80% of the respondents were affiliated to research centers and 20% from national parliaments.

[131] http://www.surveygizmo.com/s3/1542466/Innovation-Management-in-High-Speed-Trains-and-Societal-Aligment

The survey closed on the 31 January 2015.

A total of 326 personalized invitations were sent by e-mail. For the first round of invitations I used my “Linked In” database with 150 contacts in the railway sector (directly or indirectly related to high-speed trains). For the second round of invitations I used my personal address book with 60 contacts; I also used public available e-mails, 50, from the institutions participating or coordinating research projects addressing high-speed trains, funded by the six and the seven framework programmes for research from the European Commission DG RTD (sustainable surface transport); I also contacted a group of 28 experts advising the European Commission, DG MOVE responsible for transport policy[132]; Finally as a third round of invitations, the survey was sent to 38 people from the technology assessment community, and from research centers and national parliaments of members states of the EU. The majority participants at the PACITA Conference 2013 in Prague. On the top of it, my PhD supervisors supported disseminating the survey to their relevant contacts. Also, UNIFE and UIC secretariats disseminated the survey to their members.

Due to the low rate of responses I did a second and, in some cases, a third request for reply. The survey closed with 74 respondents registered, representing a 22% response rate.

The questionnaire was divided into eight major groups of questions, with none of the questions being mandatory (meaning, respondents were given the option to skip questions) and allowing for multiple responses.

The first group of questions (from Q1 to Q3) aimed at construct the unit of analysis by groups of respondents and country distribution.

Respondents were asked in Q1 to choose the category of stakeholder they belong to from which they could select “users of high-speed trains”, “technology stakeholders” or “policy makers”.

It was however observed that many respondents who had selected “users” continued replying to the survey due to their professional affiliation (technological stakeholders and policy-makers involved in the technological development of high-speed trains).

As a result, the unit of analysis was constructed not from the category groups resulting from Q1, as initially planned, but from the institutional affiliation asked in Q11. This will be further explained.

---

[132] http://ec.europa.eu/transport/modes/rail/events/doc/2013-09-12-hearing-rail/minutes.pdf

The second group of questions, from Q2 to Q3, collects respondents' personal opinion on the involvement users and wider society should have in the technology development of high-speed trains. This group of questions is mostly targeting "end-users" of the high-speed trains for whom it is not relevant to reply to the following group of questions designed to technology stakeholders and policy makers directly or indirectly involved in the technology development of high-speed trains. The results of this group of questions from technological stakeholders and policy makers was also used to confront with their answers to some the questions addressing specifically societal alignments in the technology development of the high-speed train.

The third group of questions from Q4 to Q9 aimed at detailing the identification of respondents, such as name, affiliation, job-function, country and e-mail. To the respondents was assured the confidentiality about their identity.

From this group of question onwards the survey was designed to address the railway stakeholders and policy-makers involved in the technological development process of high-speed trains.

The forth group of questions from Q10 to Q12 enquired about respondents' institutional affiliation and from Q13 to Q16 was profiling their institutional technological development activities.

In this group, Q11 became the source of the unit of analysis for this survey, where respondents were asked to select the type of institution they worked for, either "certification body", "component supplier", "consultancy", "government", "infrastructure", "manufacturing", "railway association", "regulatory body", "research center", "train operator" or "university". Therefore, also the country of origin was based on respondents' affiliation location, asked in Q12.

The fifth group of questions, from Q17 to Q21 aimed at characterizing the respondents' technological development approach. Respondents were asked to rank the frequency in the purpose of their technology development activities, existing practices, if done alone or in networks and the relevance given to collaborative research. The main objective in this group of questions was to understand if innovation was mainly done in-house or open to collaborative research, and how far the respondent was integrated in the innovation chain.

The sixth group of questions, from Q22 to Q25, addressed the technology drivers leading to the technological change during planning and implementation. Respondents were asked to rate in relevance the factors driving their research, at which technology readiness levels they were considered, and which support instruments they used. The objective here was to find a pattern for each type of stakeholder.

The seventh group of questions, from Q26 to Q28, narrowed the above to societal drivers. Questions were built on the elements addressed in Deuten, Rip & Jelsma (1997) on the technology development process alignment with societal actors and their articulation with future exercises. Again, the objective was to find a pattern for each type of stakeholder.

The last group of questions, from Q29 to Q32 focused on futures. This way questions aimed at pattern the industry future formulations, by covering their sources of intelligence, methods used and variables considered as well as expected outcomes.

The finally remark is to say that the weaknesses of the survey are the low rate of participation from railway operators, 5%, and the high number of questions they did not respond, 11 out of a total of 33 questions.

5.3. Unit of analysis (Q1, Q11, Q12)

The survey targeted professionals from railways and from the technology assessment communities. From 326 invitations sent 74 replies were collected, of which 83% from railways and 17% from technology assessment community.

As seen, the high-speed train is a complex technology system formed by a series of subsystems hierarchically nested, covering competences ranging from the broad of providers of services to the tiniest material used in the high-speed train. They form the supply chain, here covered, in a nest of partnerships integrating specific knowledge. Societal embedding extends these partnerships to non-railway actors as users and wider society.

The survey's unit of analysis includes 13 types of stakeholders.

- certification body,
- component supplier,
- consultancy,
- government,
- infrastructure manager,
- infrastructure supplier,
- manufacturing,
- railway association,
- regulatory body,
- research center,

- train operator,
- university,
- end-user (including wider society).

This section presents the unit of analysis, determined by respondents' institution type in Q1 and Q11 and country of origin Q2.

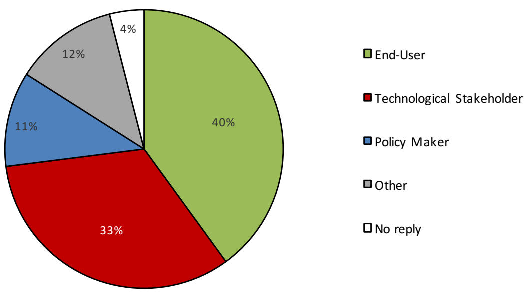
Q1 and Q11 - Classification of respondents

The survey starts in Q1 by asking respondents if they were replying as "technological stakeholders", "policy makers" or "users".

Each group included:

- Technological stakeholders: manufacturers assembling the vehicle, the component suppliers of sub-systems (parts and materials), the train operators providing the service, the infrastructure managers and suppliers, the consultancies, the certification bodies which ensure that new technologies comply with market requirements and regulations, the railway associations, railway research centers and universities providers of very specific knowledge on the high-speed train technology.
- Policy makers: governments such as the European Commission and national parliaments setting policies, also regulatory bodies implementing regulations for the enforcement of those policies.
- End-users and wider society: individuals that make the choice of taking the high-speed trains when travelling, extended to the wider society, including consumers' associations, environmental groups, virtual communities, etc.

As a result, 40% of the respondents selected "end-users", 33% "technological stakeholders", 11% "others", 11% "policy makers" and 4% made no selection. See graph 5.1.



Graph 5.1. Respondents categories (Q1)
(% total responses)

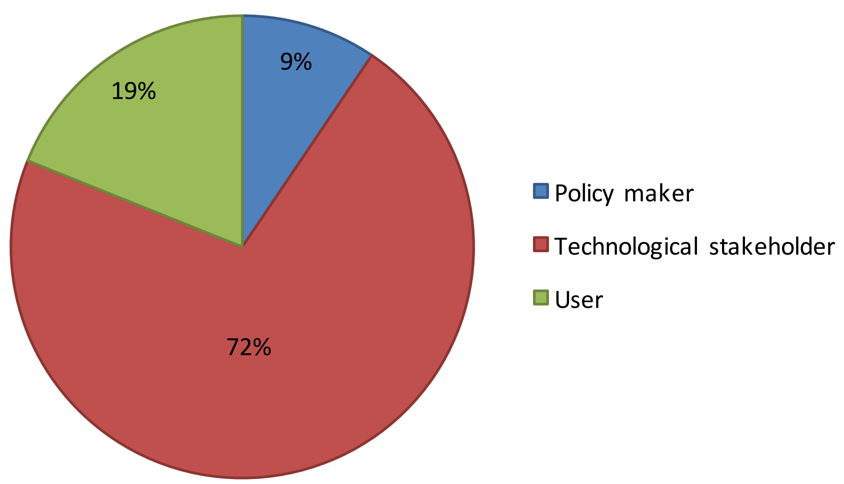
“End-Users” appear with the highest representativeness accounting with 40% of respondents. However it was noticed that some of the respondents selected both ”user” and “technological stakeholders” and continued responding to the survey as “technological stakeholders”. Such questioned the representativeness of results in Q1.

One can speculate on the reasons for which that happened, such as respondents non ownership on technological developments of high-speed trains or simply because they were responding to the survey on a personal basis and not on behalf of their institution.

To overcome this problem, Q1 results were crosschecked with respondents’ institutional affiliation type asked in Q11. In Q11 respondents could only selected one of the categories proposed being “certification body”, “component supplier”, “consultancy”, “government”, “infrastructure”, “manufacturing”, “railway association”, “regulatory body”, “research center”, “train-operator”, “university”, “user” and “others”.

In order to make Q11 comparable with Q1, the categories of stakeholders were then grouped in the 3 categories “technology stakeholder” (including certification body, component supplier, consultancy, infrastructure, manufacturing, railway association, regulatory body, research center, train-operator, university), “policy maker” (including government) and “user” (extended to wider society and including research centers advising policy not part in the high-speed train industry).

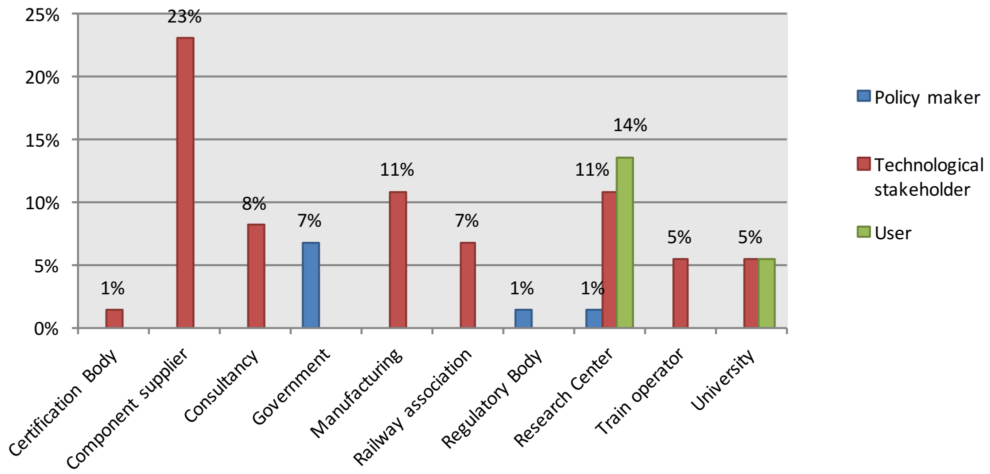
Results are shown in graphs 5.2 and 5.3, below.



Graph 5.2. Respondents categories resulting from their institutional affiliation (Q11)
(% total responses)

Results in graph 5.2 were considerable different from graph 5.1. Here “technological stakeholder” takes the largest share of respondents, 72%, embracing respondents from institutions part in the high-speed train innovation chain. “End-users” drop to the second place with 19% of respondents, from which respondents were affiliated to institutions not directly involved in the technology development of the train. Finally, “Policy maker” take 9% share of the respondents.

More details can be found below in graph 5.3 breaking down the three main groups of respondents by their institutional affiliation.



Graph 5.3. Breakdown by respondents’ institutional affiliation (Q11)
(% total responses)

From graph 5.3 one can see that respondents as “users” are affiliated to research centers and universities, where policy makers split between governmental and regulatory bodies as well as research centers.

Continuing the analysis of the results from graph 5.2, in which respects the technological stakeholders (including certification bodies, component suppliers, consultancies, manufacturing, railway associations, research centers, train operators and universities) and policy makers (governments, regulatory bodies and universities), one can also observe the pyramidal structure of the sector.

This way “Component supplier” appears as the most participative institution of technological stakeholders accounting with 23% of respondents. Component suppliers include providers of interiors, ICT and materials, such as Montemiao, SISCOG and Thales.

Also in the group of technology stakeholders is “manufacturing”, the assemblers of the high-speed trains, which come in second accounting with 11% of respondents. The institutional affiliation of respondents is split between Alstom, Siemens and Bombardier. As there is a higher concentration of institutions in manufacturing there is more than one respondent per manufacturer.

Moreover, part of technological stakeholders there are "research centers" running research projects on railways and specifically to high-speed trains. They share the same place in terms of representativeness as manufacturers accounting with 11% of respondents affiliated to institutions such as DRL and Fraunhofer.

However, 14% of respondents from research centers participating in this survey are affiliated to institutions not directly involved in the technological development of high-speed trains, such as the Institute of Technology Assessment and System Analysis (ITAS) of the Karlsruhe Institute of Technology (KIT), not technological stakeholders for this matter, participating as end-users.

Coming back to technological stakeholders, in third place we find "consultancies" dedicated to railways with 8% of respondents. Just after in fourth there are "railway associations" with 7% of respondents affiliated to UNIFE[133], UIC[134]/CER[135] and EIM[136].

"Train operators" and "universities" both take the fifth place representing 5% of respondents each affiliated to the main train operators SNCF, DB and Ferrovie dello Statto and Universities dedicated to railways and specifically to high-speed trains.

Finally, yet within technology stakeholders, respondents were found from "Certification Body" with 1% participation.

Continuing with graph 5.3, the category "end-users" accounted with 19% of respondents affiliated to "Research Centers" and 5% of "Universities" not involved with railways.

"Policy-Makers" in its turn accounts for the minority of respondents with 9%, split between "governments" 7% such as the European Commission (DG RTD and DG MOVE) and national parliaments, "regulatory bodies" 1% including the European Railway Agency and a University dedicated to parliamentary technology assessment.

It should be noticed that there was more than one respondent per institution; and institution types "infrastructure" and "others" accounting with 0% of selected responses.

[133] UNIFE stands for the Association of the European Rail Industry [Union Internationale des Industries Ferroviaire].

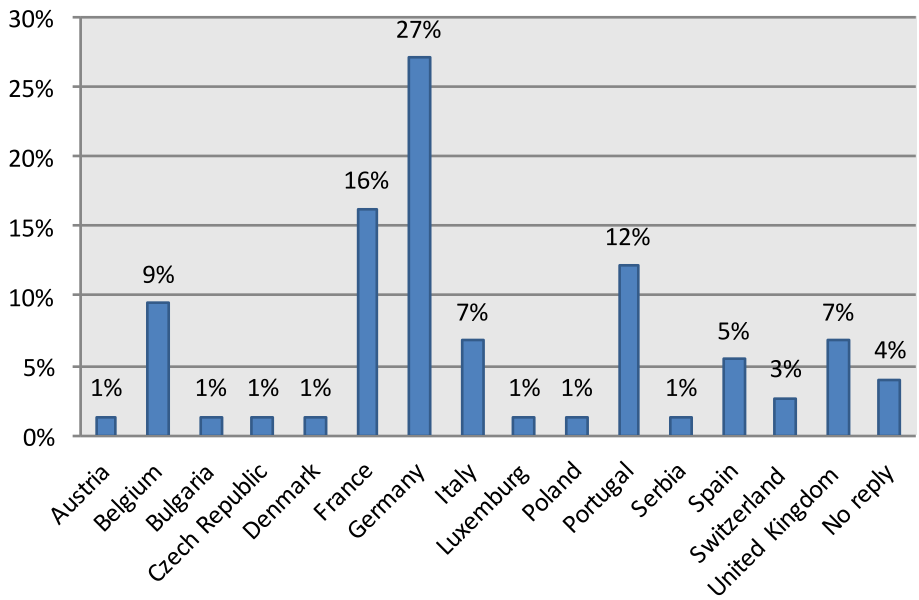
[134] UIC stands for the International Union of Railways [Union Internationale des Chemins de Fer].

[135] CER stands for the Community of European Railway and Infrastructure Companies, the policy harm of UIC.

[136] EIM stands for the European Infrastructure Managers Association.

Q12 - Distribution by country

Looking to the geographic breakdown, in graph 5.4, one sees reflected countries' weight in high-speed train technology system.



Graph 5.4. Country distribution (Q12)
(% of the total of responses)

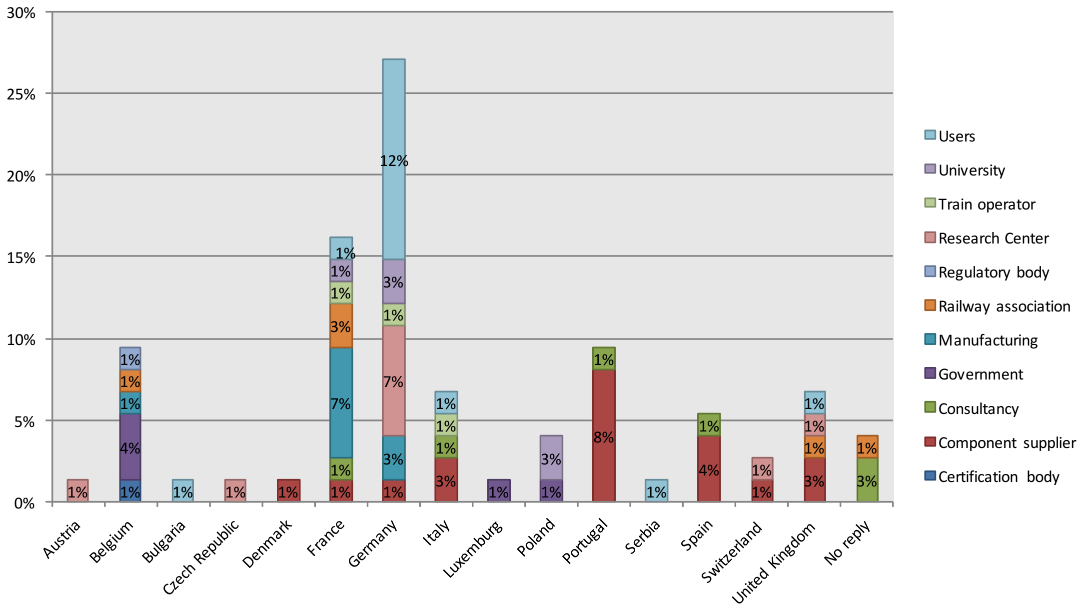
Germany, 27%, and France, 16%, score the highest, as one could expect, reflecting their leadership in high-speed trains due to the length of its network, number of trains, countries of origin for the main manufacturers, location for dedicated research centers and engineering universities.

An exception is Portugal, home for 12% of respondents' institutions. Portugal is clearly over represented as it is a country with no expression in high-speed trains.

Belgium comes next, with 9% respondents, home for many policy and regulatory institutions, such as the European Commission key player in the revitalization of the railways and promoter of a high-speed train trans-European network, from where were a good number of participants to the survey.

At the middle of the ranking it is UK and Italy both with 7% of respondents, followed by Spain with 5% and Switzerland with 3%. All of these countries with a significant high-speed train market.
A less participative group of countries with 1% of respondents were Austria, Bulgaria, Czech Republic, Denmark, Luxemburg, Poland and Serbia.

The breakdown of countries by institutional types, shown in graph 5.5, reinforces the results in graph 5.3 reflecting the industry structure, and in addition it detects unbalances in respondents' representation.



Graph 5.5. Country distribution by institution (Q12)
(% total of responses)

For instance, as one can read for graph 5.5, Germany covers the majority of stakeholders in the supply chain, it is however over represented by "end-users" and it is under represented by component suppliers. In its turn Portugal is over represented by component suppliers, mainly from interiors and ICT, while Spain is under represented in terms of operators and manufacturing. France is the most balanced country with a fair coverage of stakeholders part of the supply chain.

Results (Q1, Q11, Q12)

The unit of analysis is robust because:

It is constructed from the institutional affiliation of respondents, where certification body, component supplier, consultancy, government, infrastructure, manufacturing, railway association, regulatory body, research center, train-operator, university, users" and others (Q11).

The survey is representative of the universe of stakeholders concerned with the technological development of high-speed trains and reflects the technological structure of the sector. That is quite clear for the technological stakeholders, to whom this survey was designed (Q11).

Finally, the institutional representativeness of respondents is credible as they cover the institutions participants in relevant EU integrated research projects, existent so far, on high-speed trains such as MODTRAIN and RAIL ENERGY. Except for component suppliers as in this survey they were mainly from materials, ICT and interiors.

Respondents were 11% from manufacturers of high-speed trains, from the main players in Europe - Alstom, Siemens and Bombardier assembling and supplying the vehicles TGV/AGV, Velaro and Zefiro. Also, 23% of respondents were affiliated to component suppliers, ranging for example from materials to interiors and telematics. Moreover, 11% of participants were affiliated to research centers plus 5% to universities, dedicated to high-speed trains, very specialized knowledge providers to this industry like DLR and Fraunhofer.

5.4. Respondents preliminary view on the survey topic

Questions Q2 to Q3 collect respondents' opinion on the involvement of users and wider society in the technology development of high-speed trains from early stage (covered in the section 4.1.4 and referred in Deuten, Rip & Jeslma, 1997). Those two questions mainly target respondents in the category of "end-users" of the high-speed trains, as it is the only questions in the survey they were asked to reply. As referred before the survey was designed to technology stakeholders and policy makers directly involved in the technology development of the train-speed trains.

The results of this group of questions are latter used to confront with the ones from the questions addressing specifically societal alignments in the technology development of the high-speed train as it will be covered in part B of this survey[137].

Q2 - Main aspects valued for taking the high-speed train

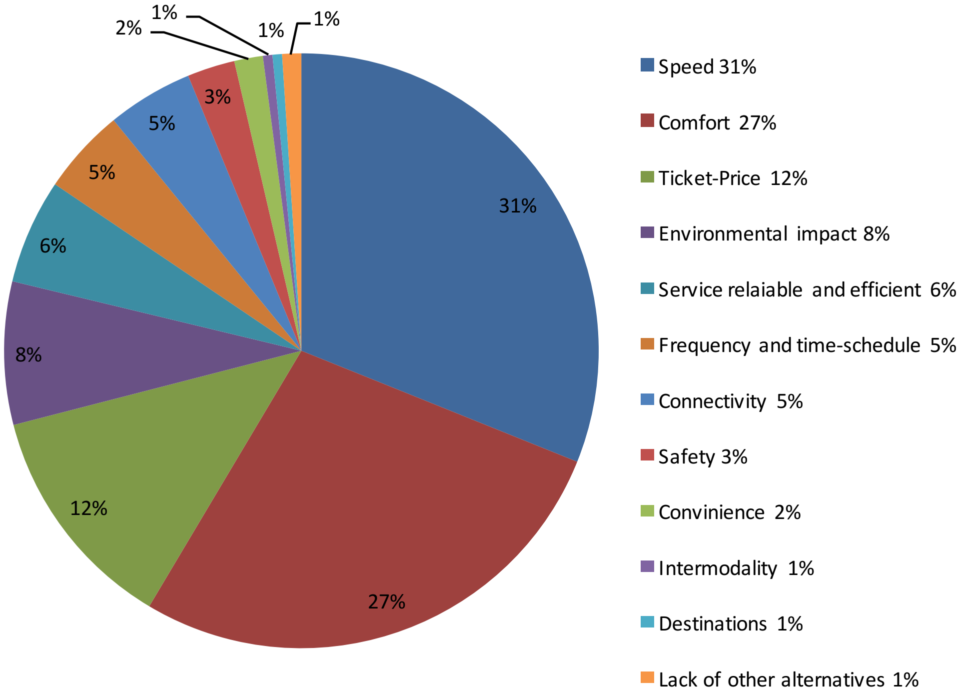
The survey asks in Q2 the aspects valued in the decision to take high-speed trains.

Respondents were given an open area of text where they could list their three top preferences. Their responses where then coded as: speed, comfort, environment, intermodality and safety, ticket price, frequency and time schedule, service reliable and efficient, destinations, connectivity, convenience and lack of other alternatives.

Q2 places all the respondents as users of the train. Yet results show differences between the different types of users' institutional affiliation (to be further explained).

[137] As mentioned at the introduction, the survey has two parts: part A enquiring about strategic innovation management and part B enquiring specifically about societal embedding on the relevant aspects of strategic innovation management.

The aggregated results are shown in graph 5.6. Results are breakdown by the three groups of stakeholders, in graph 5.7, and then by the ten institutions types, in graph 5.8.



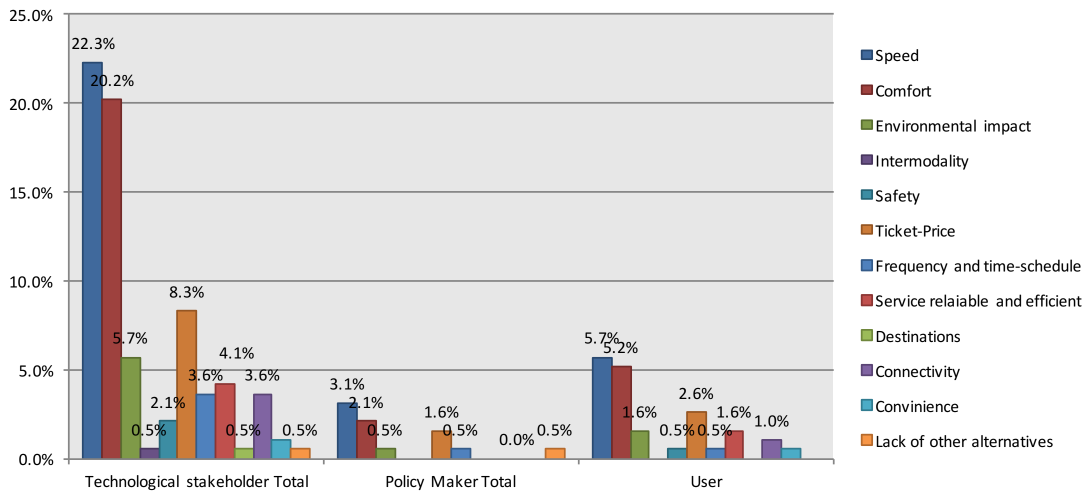
Graph 5.6. Aspects valued when decision is made to take the high-speed train (Q2)
(% of the total of responses)

As one could expect speed (31%), comfort (27%) and ticket-price (12%) are the three main criteria respondents valued. The majority of respondents referred to speed as time saving, while for comfort many referred to the possibility to work in the train, low noise in the cabin and on-board services.

Environment, including energy efficiency and CO2 emissions, is not considered a top priority, with only 8% of respondents referring to it. Maybe because environment does not impact the riding experience of the train and users of the train do not actually see energy costs reflected in their ticket prices as they see when buying their plane tickets or fueling their cars. Also who rides a high-speed train is not aware of the impact a railway line has on the communities it crosses as noise, soil vibration and particles emissions, to give some examples.

The most surprising result however is on intermodality and connectivity with city centers, each with less than 1% of respondents considering it. This can be an indication that this aspect is yet to be improved, despite efforts from policy-makers and train-operators to accomplish it.

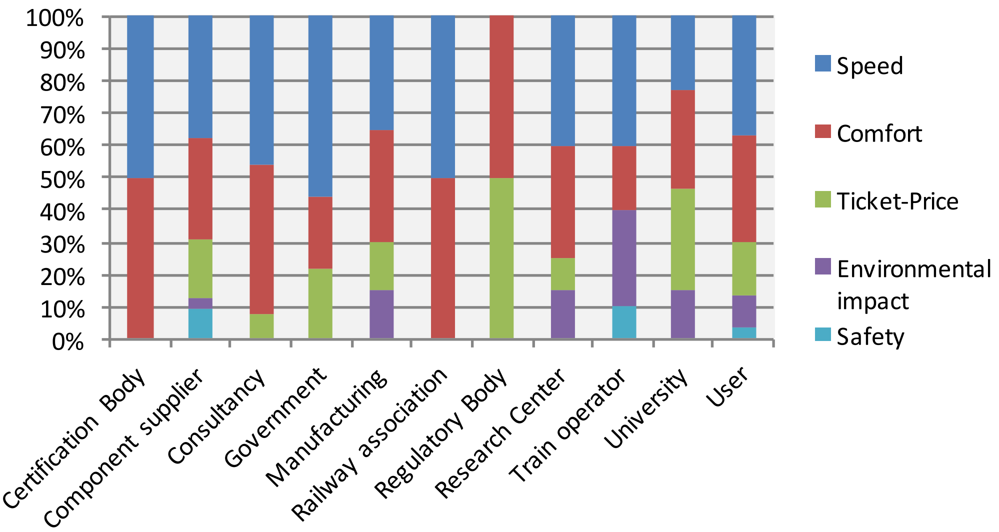
The breakdown by the three main stakeholder groups (technical stakeholders, policy makers and users), shown in graph 5.7 below, reinforces what was just mentioned.



Graph 5.7. Aspects valued when decision is made to take the high-speed train, breakdown by groups of stakeholders (Q2)
(% of responses per stakeholder group)

Graph 5.7 confirms speed, comfort and ticket price as the three main aspects for all the three groups of stakeholders with a significantly high relevance attributed by technological stakeholders. Environmental impact remains fourth listed preference. However, for policy makers it has an equal relevance to frequency and time-table while for users it is paired with service reliable and efficient.

The following graph 5.8 narrows the above results to the four most ratted categories and brakes it by institution types.



Graph 5.8. Aspects valued when decision is made to take the high-speed train, breakdown by institutions types (Q2)
(% of the total responses per category of stakeholder)

Graph 5.8 splits results by user's affiliation type. Speed if the most important criteria for all stakeholders, except for regulatory bodies that give more importance to comfort 50% and ticket price 50%.

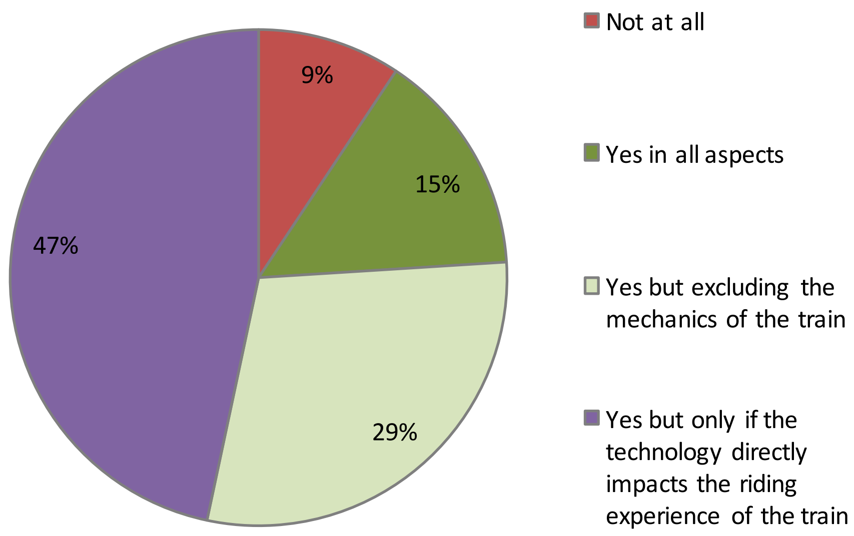
There is no significant deviation from the responses provided by users affiliated to railway stakeholders and users not affiliated. Such verify the technology areas highlighted for end-users in figure 4.6, section 4.1.4.

It is interesting to observe that environmental impact is not considered by users affiliated to governmental institutions, when those are the ones actually promoting environmental policies and regulations. Opposite to them are respondents from train operators the ones considering as the second most important criteria environmental impact 30%. The others showing some interest in environmental impact are manufacturing research centers and university, all with 15%.

Another aspect is safety, only listed by component suppliers 9% and train operators 10% and users with no affiliation to any of the stakeholders 3%. Surprising is that manufacturers do not list safety if considered that in this industry safety is highly requested by customer requirements and regulations.

Q3 - Should users and wide society have a say from early stage in the technology development of the high-speed train

Often one sees references to user consultations, at times when train operators envisage to improve services, or when governments plan the construction of a particular high-speed train link. Less referred is the consultation to users and society in general from early stage of technological development process. Graph 5.9 below shows respondents opinion about it.



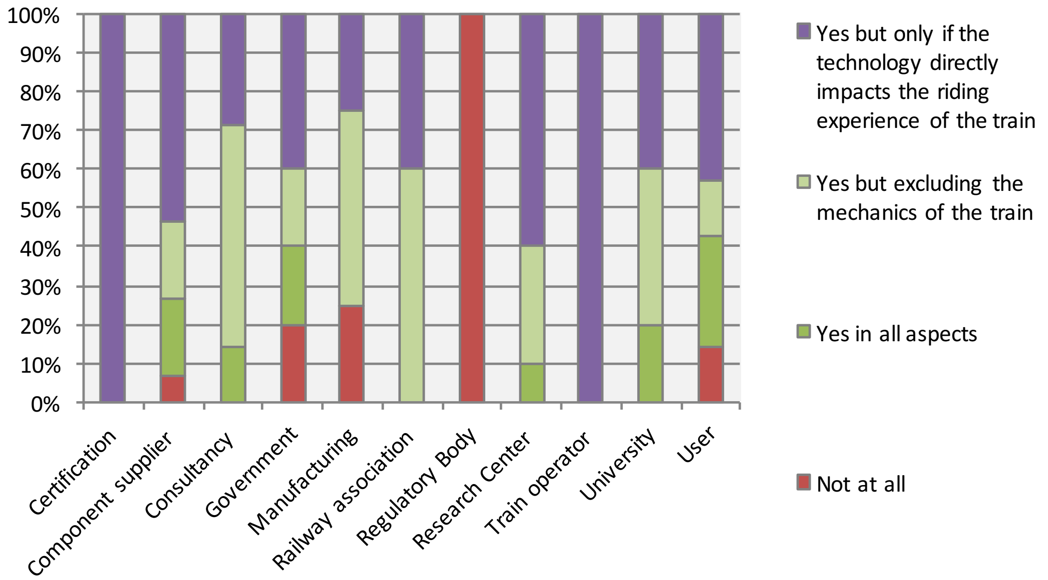
Graph 5.9. Should users and wide society have a say in the technology development of the train (Q3) (% of the total of responses)

The great majority of respondents are supportive of consultations to users and society at large from early development process of the high-seed trains. A respondent from a railway association observed that "it is always useful to ask users for their opinion. Asking users might lead to better use of the train as well as might lead to new ideas". A component supplier also comment that "if they [users] do not like the experience they can get other alternatives".

Support to user consultations is not free from limitations. Only a small percentage of 15% of respondents was supportive of a consultation in all aspects. While the great majority 45% stated that it should exclude the mechanics of the train and 29% of respondents supported a more restricted consultation limited to the technology directly impacting the riding experience of the train. A respondent from a University mentioned that "dialogue with all stakeholders and society at large is always interesting, but this is different from a kind of wide-spread popular governance", clearly indicating that the final decision should be left with the ones knowledgeable of the technology.

Not supportive at all were found 9% of the respondents. A respondent from a regulatory body referred that "for users the specific technology is not important, only the result counts". Here there is an anticipation of lack of interest and lack of whish from users to participate in the technological development of high-speed trains, leaving the technology decision to the experts.

Interesting to notice that in the open text box left for comments there is no reference to potential costs of consulting users and wider society, as well as no reference to the economic and technological limitations to accommodate their expectations and interests.



Graph 5.10. Should users and wide society have a say in the technology development of the train, breakdown by respondent affiliation type (Q3)
(% of the total responses per category of stakeholder)

Graph 5.10 shows that technological stakeholders do not support early consultation to users and wider society in the same way.

Manufacturers are the least supportive of all. A greater percentage of manufacturers, 50%, gave preference to consultations to users and wider society excluding the mechanics of the train. One respondent justified stating that “User in terms of passenger does not have the competence to deal with technical issues”. Moreover, 25% of manufacturers replied “no involvement at all” from users and wider society. And other 25% “only if the technology directly impacts the riding experience of the train”.

The most supportive stakeholder resulted the component suppliers, yet attributing higher relevance to consultations “if the technology directly impacts the riding experience of the train”, with 53% of them selecting this option against 20% “supporting in all aspects”. This high support contrasts with a minority of them, 7%, “not supporting it at all”. Such result might reflect the fact that the majority of components suppliers are providing technology solutions directly impacting users, such as interiors, materials and information to passengers. One should consider the possibility of a different outcome if other type of component suppliers happened to participated to the survey.

Looking at policy makers, regulatory bodies are the least supportive to user consultations, with 100% of them selecting as response no support at all.

In which concerns users (with not affiliation to a rail institution), 14% of them were not interested at all to be involved in consultations against 29% of them stating they were interested to be involved “in all aspects” of the high-speed train technology development. Yet 11% are supportive of their involvement in the “technological development impacting the riding experience of the train” while 43% “excluding the mechanics of the train”.

Results (Q2, Q3)

Q2 and Q3 collecting respondents’ personal view on the survey topic (innovation management and societal embedding) reveal the following:

Speed, comfort, and ticket-price were the most valued criteria by respondents when deciding to take the high-speed train for their medium to long distance journeys (graph 5.6). Contrastingly environment scored low in preferences. Such it was unexpected, if considered that it has been the major comparative advantage of high-speed trains in relation to other transport modes, and the policy argument for the revitalization of railways during early 2000’s. In its turn, intermodality and connectivity, at the bottom of the list of preference, revealed that such policy objectives are yet far from being accomplished.

Users not affiliated to any of the railway technological stakeholders or policy makers follow the general pattern in terms of their top references (speed, comfort, ticket price, environment and safety).

The aspects valued by the train users are related to specific technologies. Speed for example is related to the traction-power, aerodynamics, weight of the vehicle, while comfort corresponds to design, materials, telematics. Only ticket-price is not directly related to technological solutions but with finance and economic models. This indicates that user preferences are inevitably linked to technological matters and therefore compelling to involve them in the technology development process.

As shown in graph 5.9 The majority of stakeholders from the industry supported societal embedding, but limited to the aspects directly impacting to the riding experience of the train, leaving to rail experts the decision on the core technical aspects of the vehicles.

The graph 5.10 reveals that manufacturers were quite reluctant to consultations to societal actors. Half of them attributed preference to consultations in areas that excluded the mechanics of the train and a quarter not supporting consolations at all.

Moreover, one third of users replied not having interest to be consulted. That is a quite representative percentage if considered that only one quarter of them were interested to be consulted in all aspects of the technological development of the train.

In its turn, quite surprising to observe that components suppliers gave high relevance to users and wider society consultation from early stage in the technology development of the trains, if considered that they are not directly interfacing with them. As said this can result from the fact that the majority of the component suppliers participating to the survey were mainly from materials, interiors and ICT.

In conclusion, users (both affiliated and not affiliated to technology stakeholders) valued the most technological aspects impacting the riding experience of the train (as speed and comfort) in detriment of customer services (ticket price) and core technical aspects (environment and safety) in their decision to take the high-speed train.

5.5. Results

A. STRATEGIC INNOVATION MANAGEMENT

This part of the survey refers to strategic innovation management literature found in Schilling (2013) and organizational structure in Lichtenthaler (2004) covered in section 4.1.4 b) technology surveillance. This body of literature informs ways to characterize industry product creation management, here applied to high-speed trains.

i) Technology development characterization

High-speed trains are a high-end technology product for the railway industry, due to the speeds it reaches, the trans-national corridors it serves and the medium to large distances it traverses whilst transporting passengers. Safety, energy efficiency, signaling, distribution-power, reduced noise and vibration are just a few examples of the most recent technological advancements shaping and driving innovation in this industry.

In this part of the survey, a characterization of the technological development approach in the high-speed train industry is made by asking the respondents about the percentage of turnover invested per year in R&D (Q13), R&D strategy (Q14) and technology surveillance structure (Q15) and technology surveillance agents (Q16).

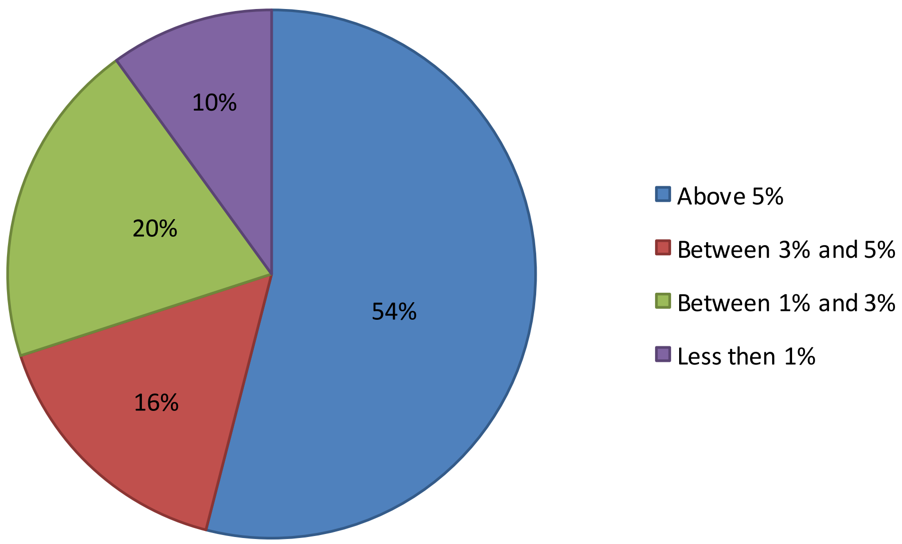
For the purpose of representing the results, in this part of the survey "end-users" affiliated to institutions not representative of the sector who are not involved in the technology development of high-speed trains have been excluded.

The main objective with this group of questions is to allow the characterisation of the high-speed train technology development where the social dynamics addressed in part B of this survey occurs.

Q13. R&D expenditure

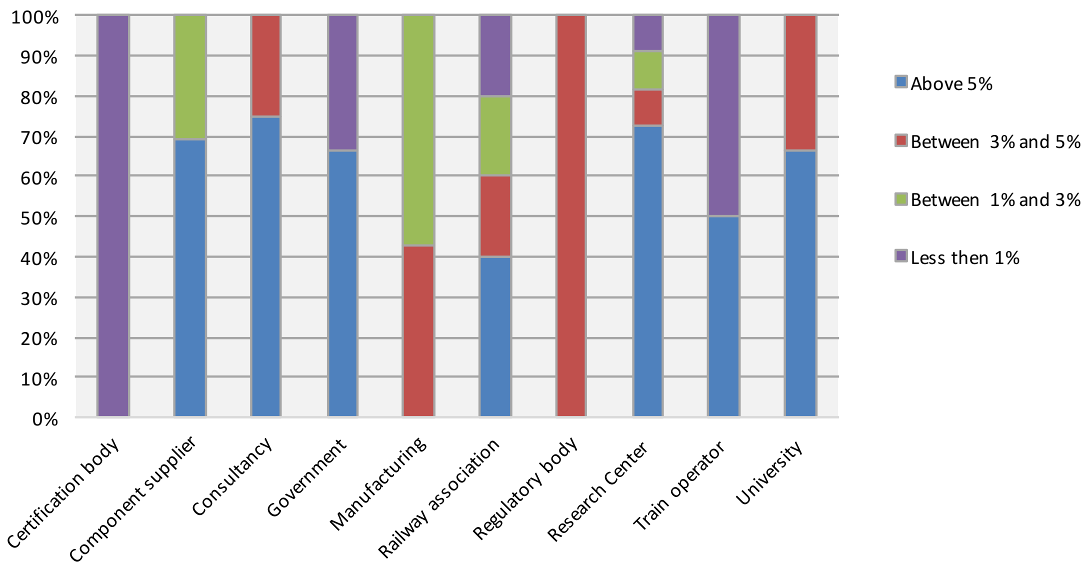
R&D expenditure in terms of percentage of turnover has been widely used as an indicator measuring innovation efforts and innovation capability of firms (OECD 2005). Very innovative firms, such as pharmaceutical or consumer electronics, spend above 5% of their annual turnover while more conservative firms, for example automotive, spend less. R&D is here considered in a broad notion including products, services, processes and marketing (OECD 2005).

Graph 5.11 below, shows the levels of R&D expenditure from the respondents to this survey, where respondents are either technological stakeholders or policy makers engaged in the technology developments of high-speed trains.



Graph 5.11. High-speed train industry expenditure on R&D as a % of total turnover (Q13)
(% of the total of responses)

Graph 5.11 shows high-speed industry as R&D intensive, with more that 54% of respondents spending above 5% of their annual turnover in such type of activities. One should be cautious when interpreting these aggregated results, since they could be read as implying that the high-speed industry is very innovative. However, when breaking down the results by institution types, as shown in graph 5.12 below, such aggregated results are only valid for component suppliers and research centers.



Graph 5.12. High-speed industry expenditure on R&D as a % of annual turnover. Breakdown (Q13) (% of the total responses per category of stakeholder)

In graph 5.12, the main R&D spenders (spending above 5% of their annual turnover) are consultancies 75%, research centers 73%, component suppliers 69%, government 67% and universities 67%. Manufacturers are divided between a medium-low expenditure with 57% of respondents spending between 1% and 3% of their annual turnover in R&D and a 43% of them declaring a medium-high expenditure of 3% to 5%. This is a clear indication that the surveyed manufacturers outsource technologies to component suppliers and research centers.

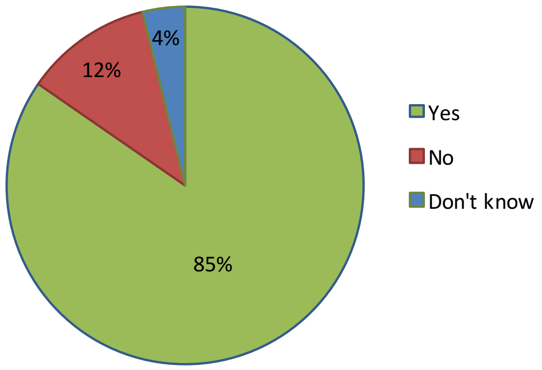
Train operators, in contrast, are split between two extremes in levels of R&D expenditure, 50% responded spending above 5% and the other 50% responded spending below 1%. This confirms the previous sections of this dissertation referring to a shift in train operators technological path from hardware technology to services. While, the split between two levels of R&D expenditure reflect the heterogeneity in which that is happening. However, this results can be challenged as train operators participation to this survey is low.

Q14. R&D strategy

According to Pisano (2012) "A strategy is a system approach in solving a problem. An R&D strategy is defined as a coherent set of interrelated choices across decisions concerning: organizational architecture, processes, people, and project portfolios".

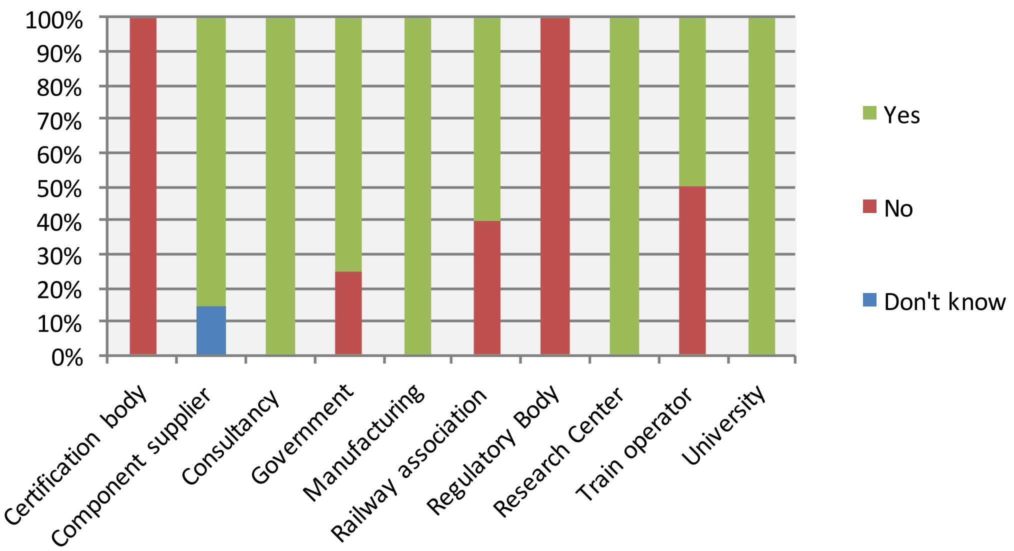
R&D strategies also include assessing a firms' position and defining strategic directions, whether the firm will collaborate on development activities, choosing a collaborative mode and monitoring partners, whether protecting or diffusing technological innovation via patents or trade secrets (Schilling 2013 and Pisano 2015).

For the high-speed industry, R&D strategy is found as a widespread practice across the different stakeholders, as shown in graph 5.13, below.



Graph 5.13. Does your institution have an explicit R&D strategy? (Q14)
(% of total of responses)

The great majority, 85% of respondents stated having an explicit technological development strategy. This is not surprising considering that high-speed trains have a long developed and life cycle, that lasts up to 30 years. Developments are in the hands of large long standing incumbent industries with solid organizational structures and business models, technology intensive. Yet, 12% of respondents replied as not having an R&D strategy. The reason can be found by breaking down of the results by stakeholders.



Graph 5.14. Does your institution have an explicit R&D strategy? Breakdown (Q14)
(% of the total responses per category of stakeholder)

The breakdown in graph 5.14 revealed that found 12% respondents not having an R&D strategy were mainly from the totality of respondents from certification and regulatory bodies, each with 100% of responses. To a less extend from railway associations 40%, governmental institutions 25% and train operators 50%.

The lack of a R&D strategy by regulatory and certification bodies is justified by the nature of their mandate to implement regulations and standards set by industry and governments, either driven from policies or sector strategies.

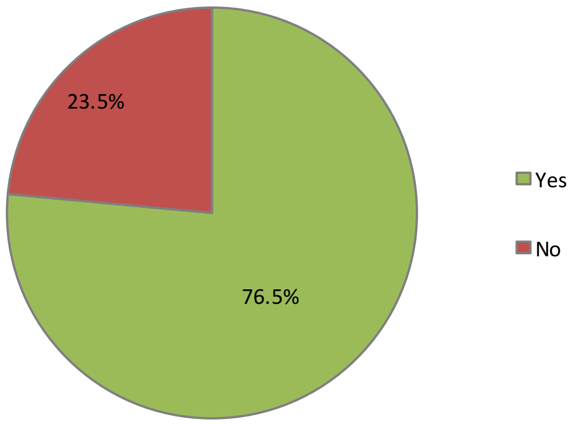
What is divergent is to find some respondents from governmental institutions and train operators stating not having an explicit R&D strategy. That might be justified by the respondents' personal perception on their institutional practices or lack of understanding of the question. There is evidence that governments and train operators have R&D strategies for high-speed trains which results are accounted in their annual reports made available to public or investors.

Q15. Technology surveillance

Often firms and governments develop and implement their R&D strategies through technology surveillance agents. Lichtenhaler (2004) provides an excellent classification of those agents here used as reference. This surveillance/intelligence refers to scanning activities seeking future technology opportunities, anticipations on external market conditions, as well as to inform the alignment of R&D strategies with other strategies internal to the organisation, such as sales and marketing.

According to Lichtenhaler (2004), technology surveillance can be incorporated in the organization structure of firms as tasks given to dedicated job positions, or hybrid when performed in a particular R&D project lasting until the term of the project. They can also be incorporated informally into the organization structure, not subject to an explicit nomination.

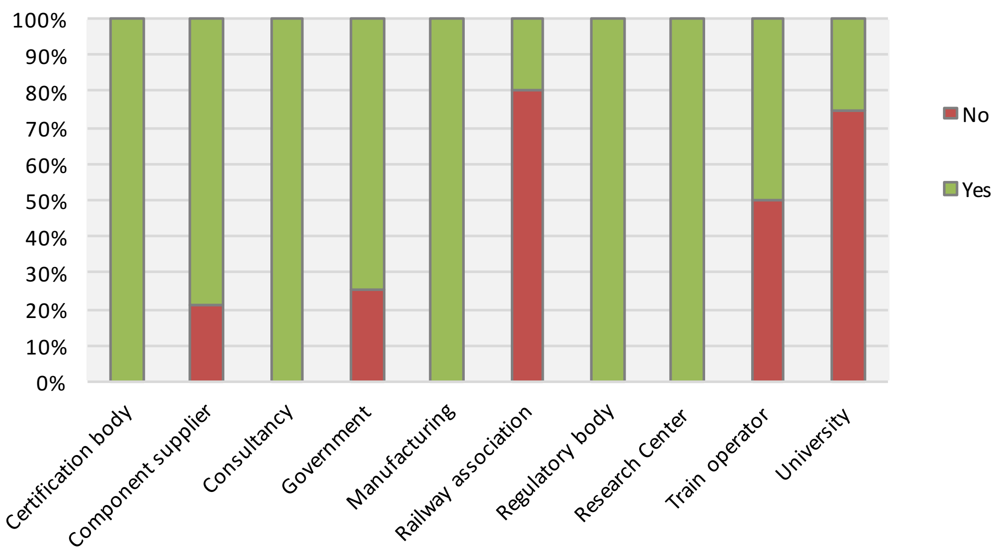
The high-speed train industry (as previously mentioned in section 4.1. b) has a tradition of using technology surveillance practices as way to cope with the complexity of the technological system of the vehicles it supplies. Those practices have been increasingly structured in the organizations as ever-tighter regulations and requirements were imposed in terms of safety, modularity and interpretability since 2001 as well as new customer specifications arising from the liberalization of the railway market (Moretto et al. 2012). Graph 5.15, below, provides evidence of this.



Graph 5.15. Does your institution have an explicit technology surveillance structure? (Q15)
(% of total of responses)

As shown in graph 5.15, the majority of respondents, 76.5%, stated that their institution had an explicit technology surveillance structure, which to certain extend reflects the previous explicit R&D strategy. According to Lichtenhaler (2004) there are variations in terms of the structure, which can be either centralised or more distributed, but all of which help to acquire external expert know-how and acquire international intelligence.

The 23.5% of respondents not having a technology surveillance structure in their organization should read in two ways. Such structure might not exist at all or that it can be informal or specific to an R&D project.



Graph 5.16. Does your institution have an explicit technological surveillance structure? Breakdown (Q15)
(% of the total responses per category of stakeholder)

In graph 5.16, the breakdown of the technological surveillance structure reveals that 100% of respondents from consultancies, manufacturing and research centers had formal surveillance structures. Their responses match with previous graph 5.14, with 100% of the same respondents stating that had a formal R&D strategy Q14.

Non-existent or unstructured technology surveillance is found in the majority of railway associations, with 80% of responses, and universities, with 75%. For these two stakeholders technology surveillance tends, in its majority, to be hybrid and limited to specific R&D projects. An indication of that that is a registered high percentage of responses, 60% for railway associations and 100% for universities stating that they had an explicit R&D strategy in Q14, graph 5.14.

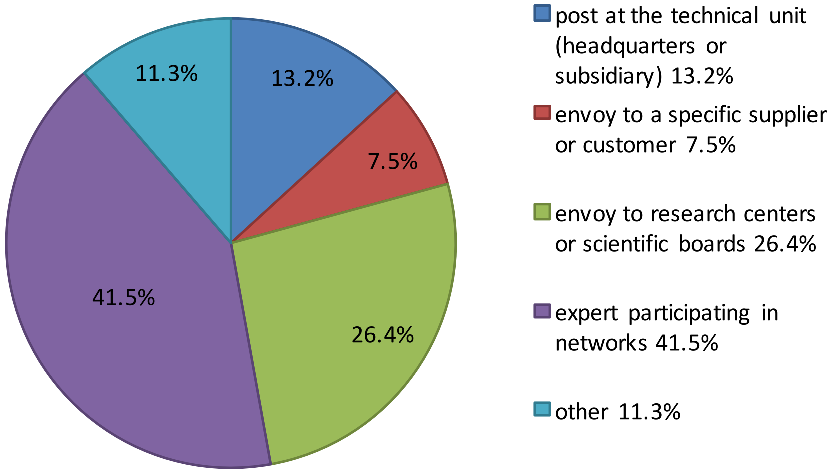
In graph 5.16, manufacturing had no informal nor hybrid technology surveillance despite an observed participation in research projects, described in the previous chapter. This might be interpreted as a sign of centralisation of R&D activities.

Railway operators were even in practices of structured and informal technology surveillance, with 50% each. Such reinforces the previous results in graph 5.14, referring to an explicit R&D strategy. In its turn the totality of certification and regulatory bodies stated that their institution had a formal surveillance structure contradicting their responses to the previous Q14, found in graph 5.14, where the totality of them said their institution had explicit R&D strategy Q14.

Q16. Posts in technological surveillance

Technology surveillance is in its turn distributed between different posts in the organization (Lichtenhaler, 2004). Individuals (also called agents) can be working at the technical unit of the headquarters, or sent as an envoy to the customer or supplier facilities when engaged in a co-development project. Those agents can also take part in networks that leverage knowledge and resources from the all of the industry.

Graph 5.17 below shows the most recurrent technology surveillance posts in the high-speed train industry according to the respondents.

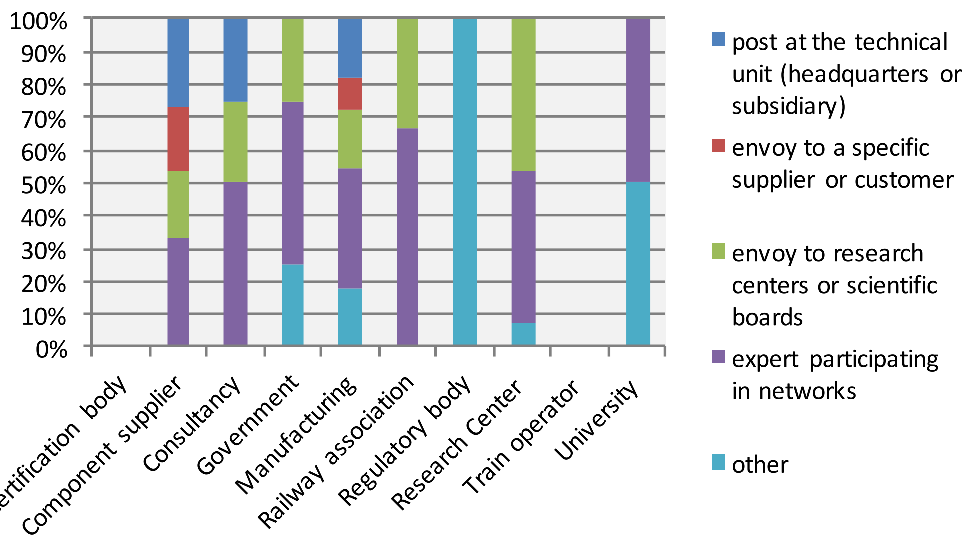


Graph 5.17. You or a colleague take part in technological surveillance as follows… (Q16)
(% of total of responses)

Graph 5.17 shows for the high-speed train industry a dominance of technology surveillance performed by individuals participating in networks, accounting with 41.5% of responses. This reflects many of the respondent's involvements in European technology platform ERRAC and participation in industry associations at European or national level.

In addition, also highly rated in the technology survey structure is the post of envoy to research centers or scientific boards, with 26.4% of responses. This confirms for this industry found dominance of collaborative research and development (e.g. technology development held by industry networks).

The breakdown by institutions type is provided in graph 5.18 below.



Graph 5.18. You or a colleague take part in technological surveillance as follows… Breakdown (Q16)
(% of the total responses per category of stakeholder)

Graph 5.18 reinforces what was observed in the previous graph 5.17 but this time across all the institutions. Collective surveillance posts are the most recurrent among respondents, except for regulatory bodies. Railway associations are the ones most represented in networks with 67% of responses.

Other stakeholders distributed their responses through the various options yet selecting in higher percentages their participation in network, as for governments 50%, consultancies 50%, and manufacturing 36%.

Only component suppliers and manufacturing referred to the post of envoy to specific suppliers or customers, with respectively 20% and 9% of responses, yet below participations in networks.

Results (Q13-Q16)

Technology development is a core part of the high-speed train business, as it is for any other industries to survive in present market conditions. The high-speed train industry is R&D intensive with more than half of respondents spending above 5% of their annual turnover in such type of activities (graph 5.11). The main R&D spenders found (graph 5.12) were consultancies 75%, research centers 73%, component suppliers 69%, government 67% and universities 67% stating that their spending in R&D was above 5% of their annual turnover. Manufacturing shows much lower expenditure, with 57% of respondents spending between 1% to 3% and other 43% between 3% to 5%. This can be a clear indication of outsourcing in development to component suppliers and research centers. Train operators were split between the higher and lower rates of R&D investment, with half of them spending below 1% and the other half above 5%. Operators reflected higher focus on service developments and demand for turnkey trains.

Elaboration and implementation of R&D strategies is a wide spread activity in this industry (graph 5.13), practiced by the majority of respondents. High-speed trains are a long existing technology, developed since the late 60's and running since 1981 in Europe. Technology developments are in hands of large incumbent industries present in the market for over a century with solid organizational structures and business models.

R&D strategies are supported by technology surveillance practices as way to cope with the complexity of the technological system of the trains. Those practices have been increasingly structured in the organizations as, since 2001, tight regulations and requirements were imposed in terms of safety, modularity and interpretability and new customer specifications arise from the liberalization of the railway market (as it was observed in section 4.1.4 of this dissertation and can also be found in Moretto et al. 2012).

As of today, 76.5% of respondents replied having an explicit technology surveillance structures (graph 5.15). The totality of manufacturing, consultancies, research centers and a majority of component suppliers stated having formal surveillance structures (graph 5.16). The remaining ones from railway associations and universities responding in its majority not having an explicit technology surveillance structure (graph 5.16). Such reflecting an unstructured technology surveillance, which can be of an informal character or hybrid when associated to a specific research project (Lichtenhaler, 2004). Train operators responses break even between technology surveillance as structured, hybrid or informal.

Technology surveillance is mostly performed by individuals (e.g. agents) participating in networks (graph 5.17). This reflects many of the respondents involvements in ERRAC technology platform and participation in industry associations at European or national level. Railway associations are the most participative in networks (graph 5.18). They are the house for the industry research networks and serve a secretariat for collaborative research projects at European level. Also with a significant participation in networks are consultancies, governments, universities and research centers (graph 5.18). Only component suppliers and manufacturing have referred to the post of envoy to specific suppliers or customers. However, manufacturers preferred in participating in networks was higher than sending envoys, reinforcing in this industry the collective relevance of technology developments and collaborative exchanges.

ii) Technological development multi-level dynamics

New technologies arise from various sources to meet many different requirements. They may emerge from individuals, as the classic image of the inventor solving a particular problem or even users who design solutions for their own needs. More often, innovation is a collective process, which evolves over time in multiple interactions within an evolving network (both intra and inter-firm). Thus, looking at actor-networks and the relationships between them are important, particularly with a view to an understanding of the dynamics pulling and pushing technological transitions (Rip 2012, Schilling 2013).

Technology development dynamics is here explored in the high-speed train. Respondents were asked for the reasons that drive their development of new technologies (Q17), including existing practices (Q18) ranging from basic and applied research to market entry, on their own or in networks (Q20) covering different stages of the technology development process (Q21).

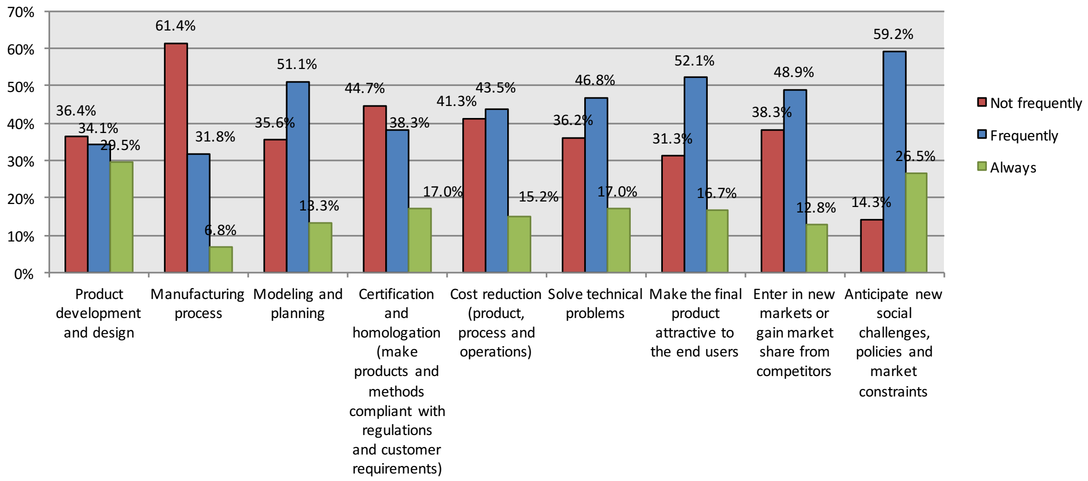
The main objective in this group of questions was to understand the dynamics of technology development in the high-seed train industry across the different stakeholders in the innovation chain. This way users were excluded from the unit of analysis.

Q17. The purpose for undertaking technology developments

For any industry in an open market the main purpose for technical advancements are market entry or survival and to gain or maintain competitive advantage (Schilling 2013).

The high-speed train industries however have historically been incumbent oligopolies, serving national railway systems. Only in the past 16 years the industry has started its transition to a liberalized market for passengers, with the concerned European directive in force since 2010, requiring technology developments addressing the integration between those national systems (for example Eurostar Paris - Lille - London and Thalys Paris - Brussels - Antwerp - Rotterdam - Amsterdam). Moreover this industry is using innovation to maintain their market position and enforce their technologies as dominant standards.

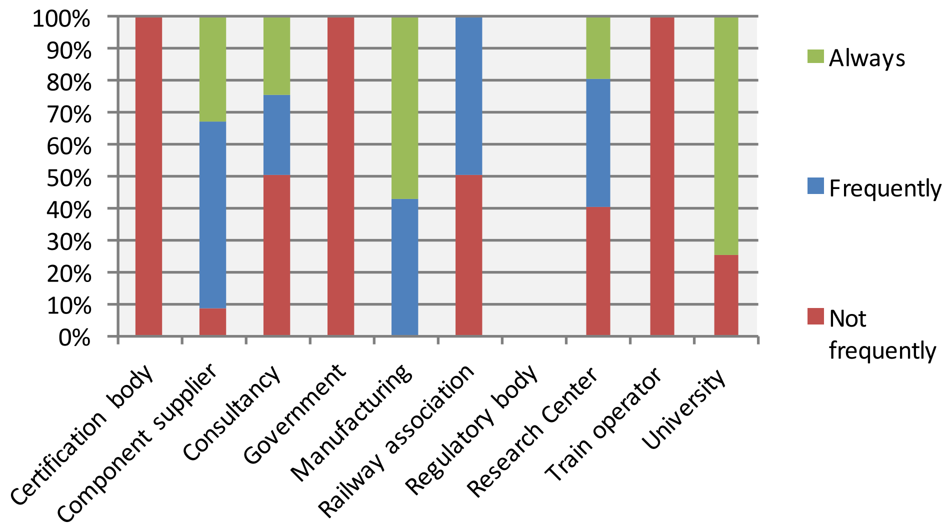
Graph 5.19, below, reveals the railway industry main purposes when undertaking technology development activities.



Graph 5.19. Purpose for undertaking technology development activities (Q17)
(% for each option of responses)

Graph 5.19 shows that the "anticipation of new societal challenges, policies and market constraints" take the highest share, with 59.2% of responses stating that they are frequently a reason to embark on anticipation activities and 26.5% stating that they are always a purpose for undertaking technological developments. The least selected reason is the improvement in manufacturing process. Overall graph 5.19 shows less technical are the purposes most frequently they are considered by respondents.

The graphs below, from 5.20 to 5.28, break down results by "purpose" and institutions type.



Graph 5.20. Purpose for undertaking technology development activities: Product development and design (Q17a)
(% of the total responses per category of stakeholder)

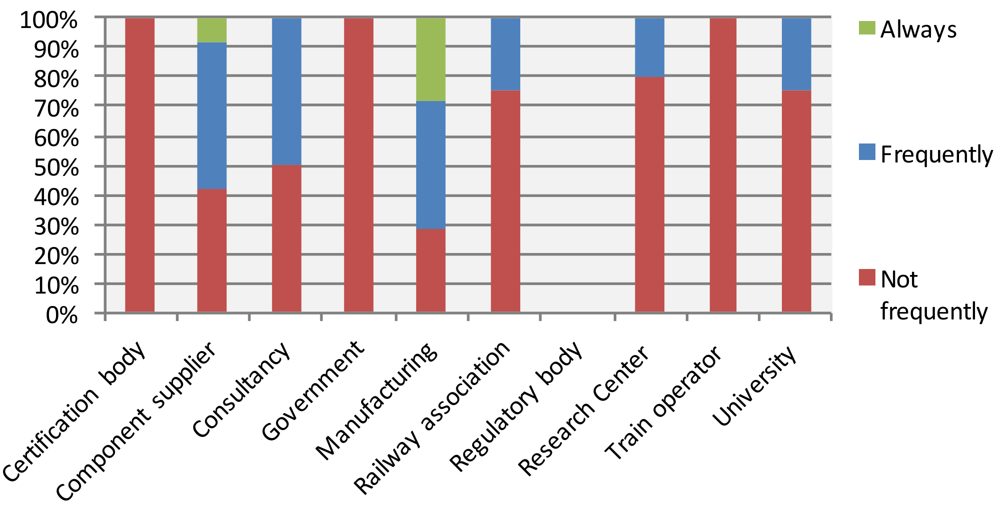
Product development process and design purposes (Q17a) appears at the middle of the aggregated results in the previous graph 5.19.

The brake down of results on product design, in graph 5.20, reveals that universities, manufacturers and component suppliers deviate from the general pattern, "always" considering product development and design as a purpose to undertake technology development activities, with 78%, 57% and 33% of respective responses.

The very high percentage of responses from universities justify from the fact those responding to the survey were mainly from engineering schools. While for component suppliers can be interpreted as an indication on the outsourcing from manufacturing.

These results contrast with the dominant "not always" responses given by respondents affiliated to the other types of stakeholders. The most striking contrasts being governments and train operators each with the totality, 100%, of their respondents "not" considering it as a reason for undertaking technology development activities. Just is well justified by their focus of activity, once services and the other policy-making.

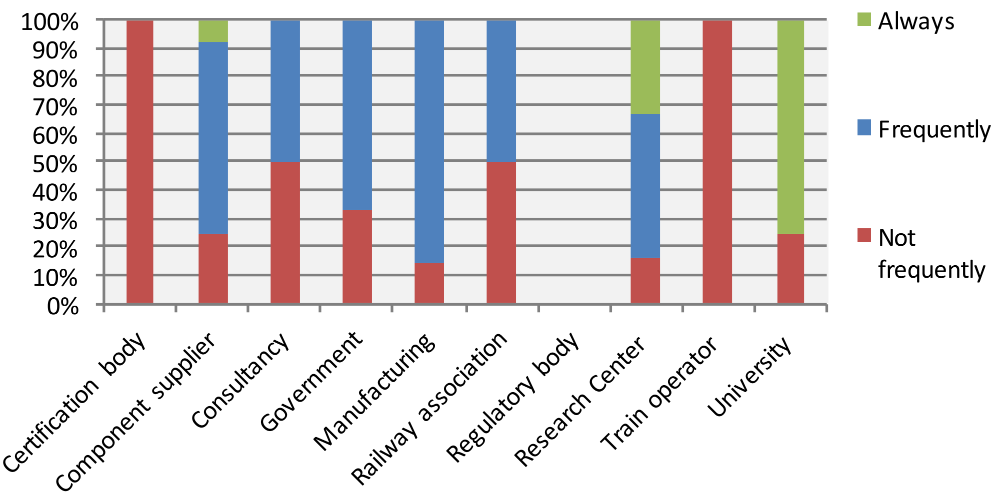
This shows that component suppliers and manufacturers have in hands the technology development of the high-speed train either as a full system or sub-systems.



Graph 5.21. Purpose for undertaking technology development activities: Manufacturing process (Q17b)
(% of the total responses per category of stakeholder)

Improvements in the manufacturing process as purpose for technology development in this industry were the least considered in graph 5.19 aggregating the total of results.

In line with the product development and design, also here one can see in graph 5.21 manufacturing and component suppliers high percentage of positive replies contrasting with the negative ones from other types of stakeholders. Those two "frequently" and "always" considering it, with 29% plus 43% and 50% plus 8% of responses respectively. Manufacturers are the ones that most frequently pursue this purpose, as shows the greater differential between the "not frequently" and "always" & "frequently" replies. They are constantly looking for more efficient integration and assembling of components.



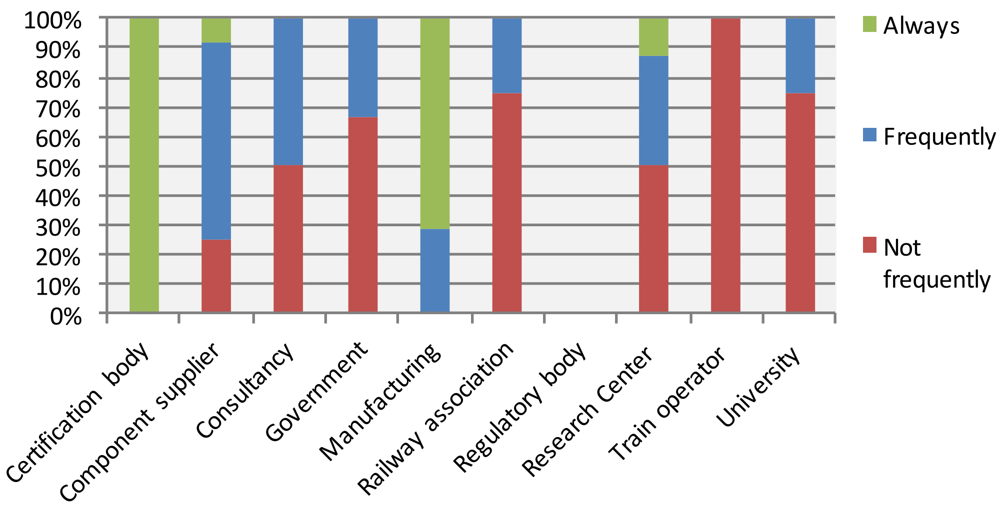
Graph 5.22. Purpose for undertaking technology development activities: Modelling and planning (Q17c)
(% of the total responses per category of stakeholder)

Modelling and planning purpose appears in graph 5.19 of aggregated results as the third purpose out of the nine mostly considered.

Graph 5.22 shows component suppliers, "frequently" 67%, manufacturing, "frequently" 86%, research centers, "frequently" 50%, and universities, "always" 75%, were the main stakeholders in pursuing developments in planning and modelling (including simulation software and other computational methods) in product design, data analysis, and manufacturing processes.

Traditionally, manufacturers have addressed technology development of the high-speed trains by trial-and-error but with the introduction of software such as CAM and CAD and other computational tools they have reduced development times as well as labor and mock-up costs.

Also high percentage of responses from governments, with 67% responding frequently perusing technology development activities for modelling and planning. This is not a surprising result if considered that transport planning and modelling is one of their main tasks.



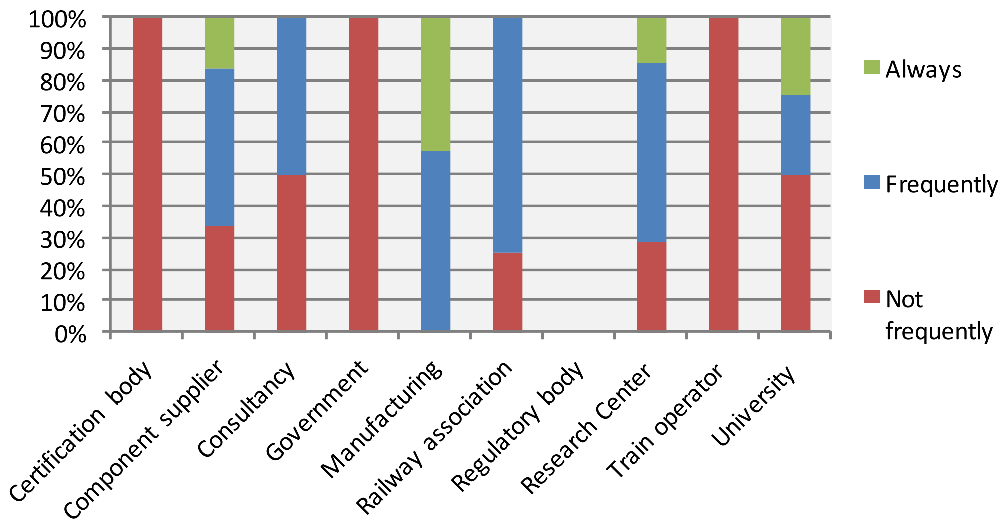
Graph 5.23. Purpose for undertaking technology development activities: Certification and homologation (Q17d)
(% of the total responses per category of stakeholder)

Certification and homologation appeared in graph 5.19 of aggregated results as the least of the purposes in pursuing technology developments in this industry.

Graph 5.23 reveals manufacturing and component suppliers highly perusing technological improvements to comply with certification and homologation requirements. Certification and homologation is always peruse by 71% of the manufacturers and frequently peruse by 67% of component suppliers.

For certification bodies this purpose is the only one they look at when involved in technology developments (certification bodies have not responded to the other purposes). This reflects their systemic function within the innovation chain.

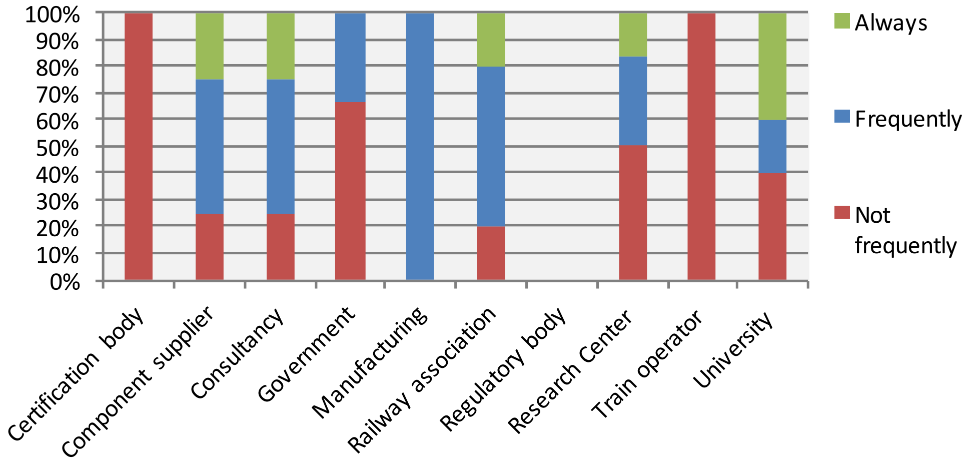
It should be noted that from components suppliers and manufacturing this is the most frequent of the listed purposes for undertaking technology development. Demonstrating that in this industry technology advancements are incremental and not radical.



Graph 5.24. Purpose for undertaking technology development activities: Cost reduction (Q17e) (% of the total responses per category of stakeholder)

Cost reduction appeared in graph 5.19 of aggregated results as one of the least considered purposes in pursuing technology developments in this industry.

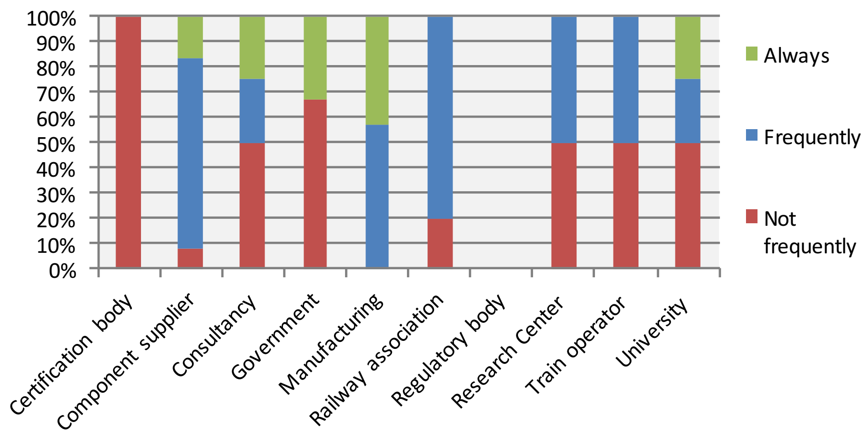
However, as graph 5.24 shows, in contradiction to the general trend, finding ways for cost reduction are highly perused by manufacturing, with total responses distributed between 57% frequently and 43% always, reflecting their business based on narrow profit margins. Half of Research centers, component suppliers and consultancies were also found pursuing frequently.



Graph 5.25. Purpose for undertaking technology development activities: Solve technical problems (Q17f)
(% of the total responses per category of stakeholder)

Solving technical problems appeared already in graph 5.19 as the least of the purposes in pursuing technology developments in this industry.

Graph 5.25 clearly shows that manufacturers and component suppliers are the ones most concerned in solving technical problems. Manufacturers were unanimous in responding that they frequently pursue this purpose, accounting with 100% of all their responses. While component suppliers were split in their responses between 50% frequently pursuing this purpose, and always & not always pursuing it both with 25% of responses. This way it can be said that technological developments for vehicle enhancements is the pattern for the stakeholders bearing the technological task of producing and assembling the technology in a system which sub-systems interface and work.



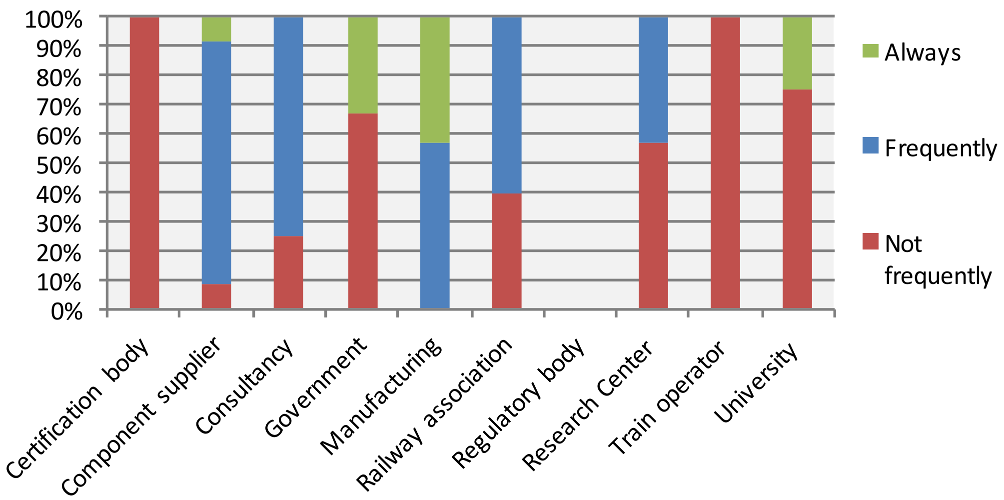
Graph 5.26. Purpose for undertaking technology development activities: Make the final product attractive to users (Q17g)
(% of the total responses per category of stakeholder)

Making the final product attractive to end users appeared in graph 5.19 of aggregated results the second most frequent reason for pursuing technology development in this industry.

Railway associations and component suppliers have the highest rate of responses in frequently making the final product attractive to end users with 80% and 75% of responses respectively. Followed by manufacturing with 57% of respondents frequently doing it and 43% always pursing it.

Train operators here shift their pattern in their purposes for technology developments as they increase their positive responses. They are however split between frequently and not frequently pursing technology developments for product attractiveness, 50% each.

Component suppliers here score high as the majority responding to this survey are supplying interiors components or ICT solutions. Those are technologies visible by the user of the train and directly impact their travel journey. Maybe these results could change if there had been greater participation from others types of component suppliers.

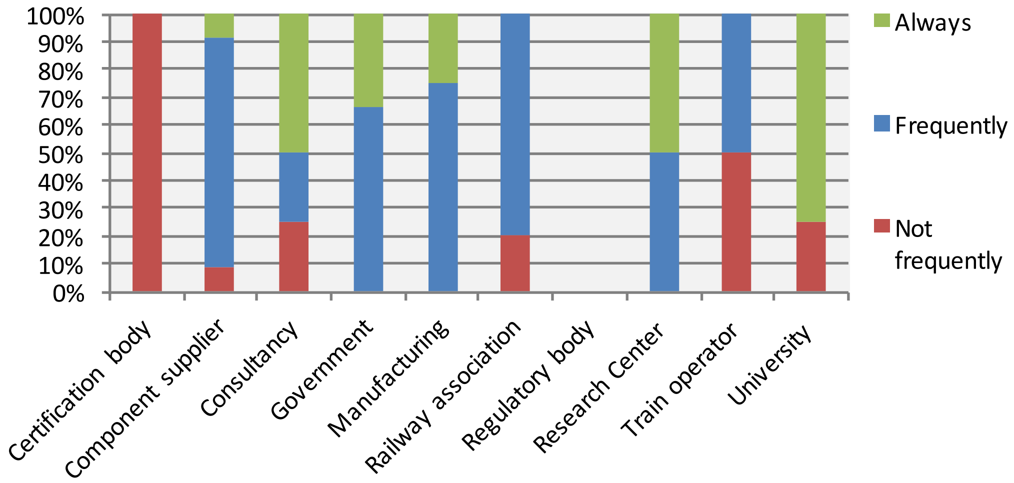


Graph 5.27. Purpose for undertaking technology development activities: Enter new markets or gain market from competitors (Q17h)
(% of the total responses per category of stakeholder)

Entering new markets or gain market share from competitors appeared in graph 5.19 of aggregated results at the middle of the reasons for pursuing technology developments in this industry.

Manufacturers are the ones pursuing it the most it with 57% of respondents frequently doing it and 43% always doing it. Followed quite close by component suppliers with 83% frequently, and 8% always doing it.

This is an indication of competition introduced since the liberalisation of the railway market in 2001, with incumbents in the supply chain aiming at maintain their dominant position. Whilst for manufacturing, they have fewer numbers of direct competitors with only two to three, which dominate the market. This reflects the industry history as well as the complexity of the technology at stake (Moretto et al. 2014 and referred in section 4.3 multi-level perspective).



Graph 5.28. Purpose for undertaking technology development activities: Anticipate new societal challenges, policies and market conditions (Q17i)
(% of the total responses per category of stakeholder)

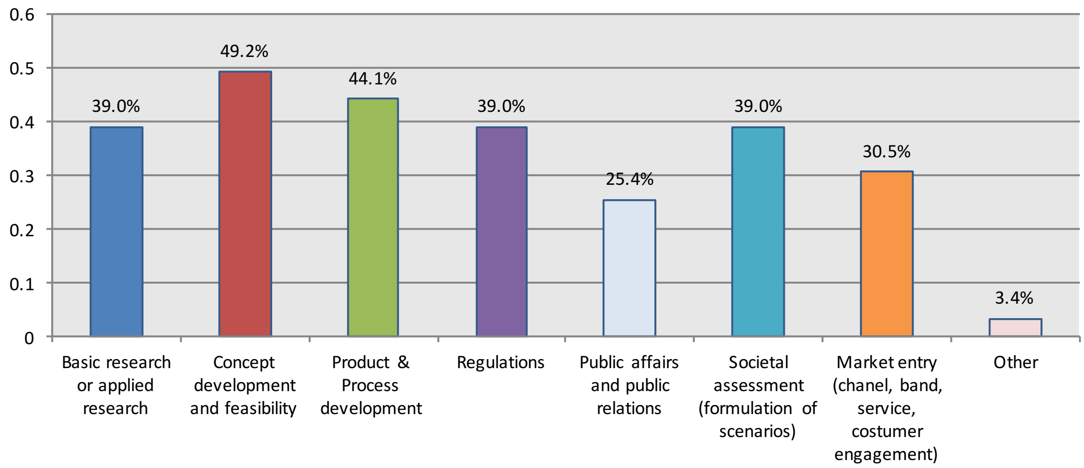
Anticipating new societal challenges, policies and market conditions appeared in graph 5.19 of aggregated results as the most frequent reason of all in the technology development of high-speed trains.

Graph 5.28 shows governments, manufacturing and research centers the ones following the most this purpose, trailed closely by component suppliers. Train operators split between 50% “not always” and 50% “frequently” pursuing it.

Q18. Existing technology development practices

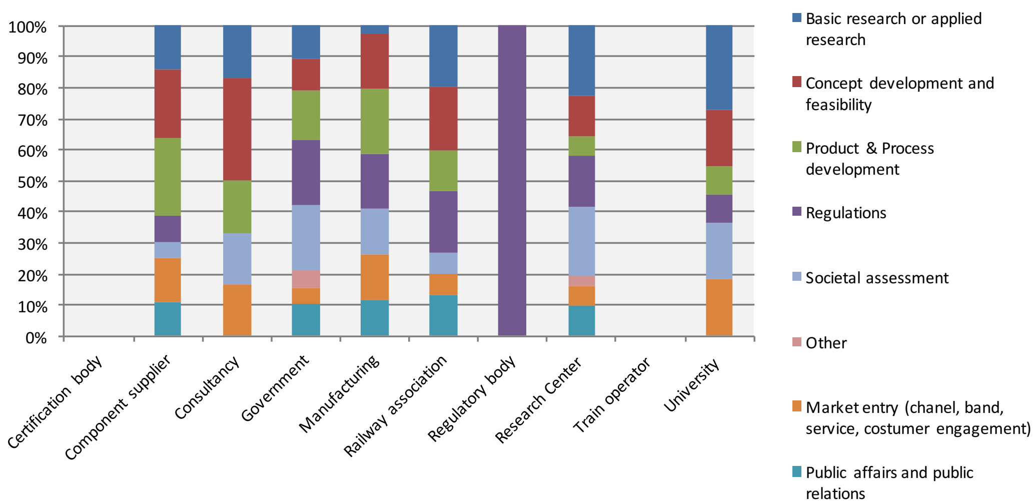
Technology development embraces a series of practices such as basic research, concept and development feasibility, product and process development, regulations, public affairs, market entry, among others. The predominance of each one of those depends on the stakeholder positions within the innovation supply chain and the objectives it wants to accomplish (Schilling 2013).

Graph 5.29 shows the overall results for the high-speed train industry.



Graph 5.29. Existing technology development practices (Q18)
(% of total of responses)

Graph 5.29 shows that for the high-speed train industry technological development practices mainly occur on concept and development feasibility of new solutions with 49.2% of replies and on product and process development with 44.1%. Basic research, regulatory alignments and societal assessments come in third, each with 39% of responses. Research for market entry has one of the lowest percentage of responses, 35.5%, reflecting the monopolistic positions of incumbent stakeholders and limited new market opportunities.



Graph 5.30. Existing technology development practices. Breakdown (Q18)
(% of the total responses per category of stakeholder)

Graph 5.30 shows that concept development and feasibility is a wide spread practice by all the stakeholders represented in the survey, but not the dominant one at individual level.

As one could expect, components suppliers and manufacturers higher percentage of responses on developing products & processes, with 25% and 21% of responses respectively. Component suppliers also attributed relevance to concept development, accounting with 22%. Also expected was research centers and universities prevalence on basic research with 23% and 27%

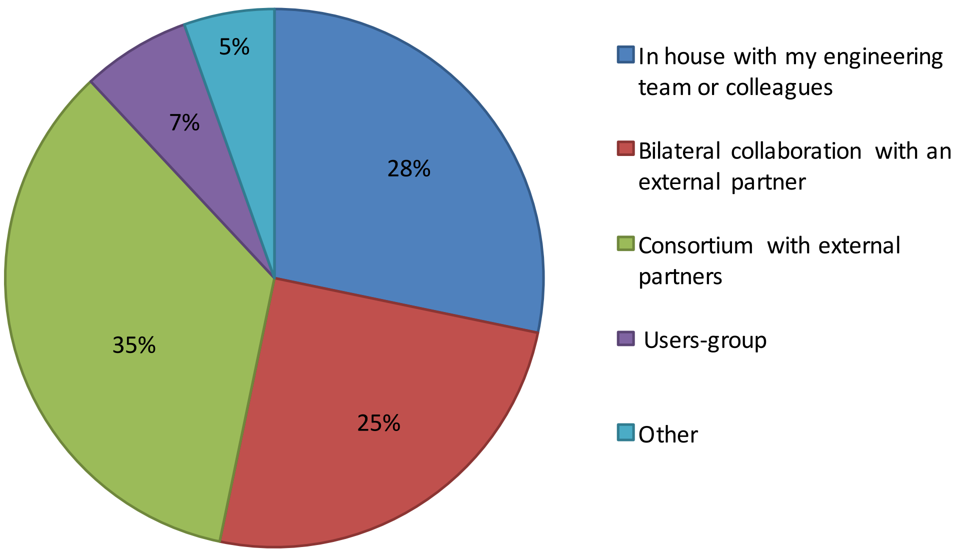
of responses. To note that research centers was high in responses on societal assessment, with 23%, resulting even with basic research.

Also as expected governments are split between social assessment and regulations both at the top if their replies with 21% each.

Train operators did not reply to this question.

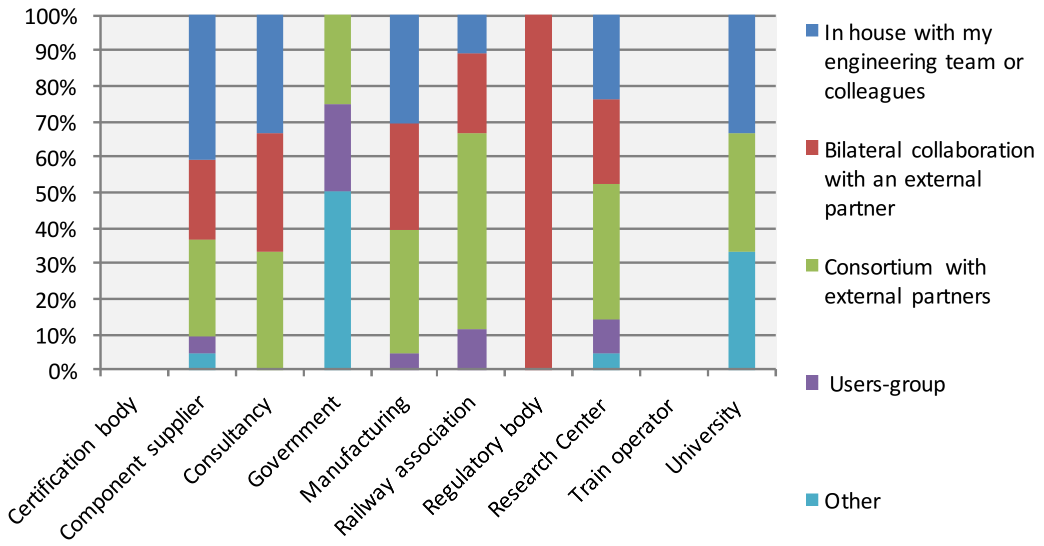
Q19. Openness to collaborative research

Stakeholders often face decisions about the scope of activities to perform in-house or in collaboration with other partners (Schilling, 2013). Such decisions are recurrent in high-speed trains having a significant portion of technological developments arising from the integration of different solutions requiring different capabilities. Graph 5.31 below aims at assessing to which extent that results from collaborative efforts between the multiple stakeholders, bilateral collaborations, involvement of specific groups as users or in-house.



Graph 5.31. Openness to collaborative research (Q19)
(% of total of responses)

Graph 5.31 shows prevalence in this industry of collaborative R&D, with 35% of respondents doing it in consortium and 25% bilaterally, against 28% of them doing it by themselves in house.



Graph 5.32. Openness to collaborative research. Breakdown (Q19)
(% of the total responses per category of stakeholder)

The breakdown of results reveal that for component suppliers give preference for performing technology developments in-house, with 41% of responses. Only 27% of them stated doing it in consortium of multiple partners and 23% bilaterally. They go against the overall trend resulting in higher number of responses on research in consortium.

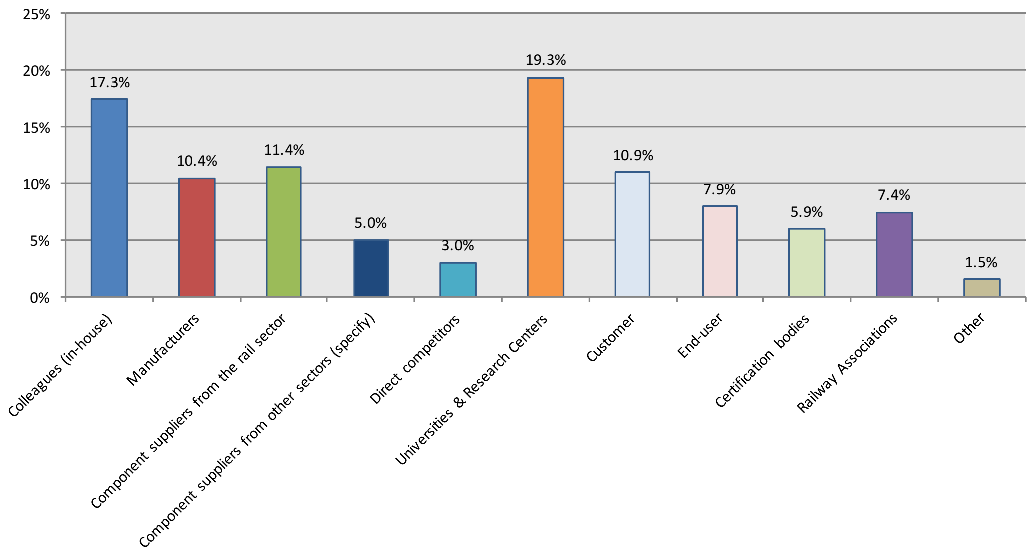
Such is the case of manufacturers, with collaborative developments in a consortium prevailing, with 35% of replies, above in-house or on a bilateral basis, each with 30% of responses. These results can be read as an indication of outsourcing practices by manufacturers, looking for the integration of subsystems they buy from suppliers or looking for specific knowledge falling outside their competences in collaboration with their component suppliers and train operators. It can also be interpreted a way to ensure the dominance of their design and standards trough collaborative projects.

Research centers follow the same pattern as manufacturing. In this industry, research centers have specific knowledge and the complexity of the high-speed train technology system requires interface with other providers of complementary know-how.

As expected governments are the ones who pursue the most user engagements, with 25% of responses in this category.

Q20. Technological partnerships

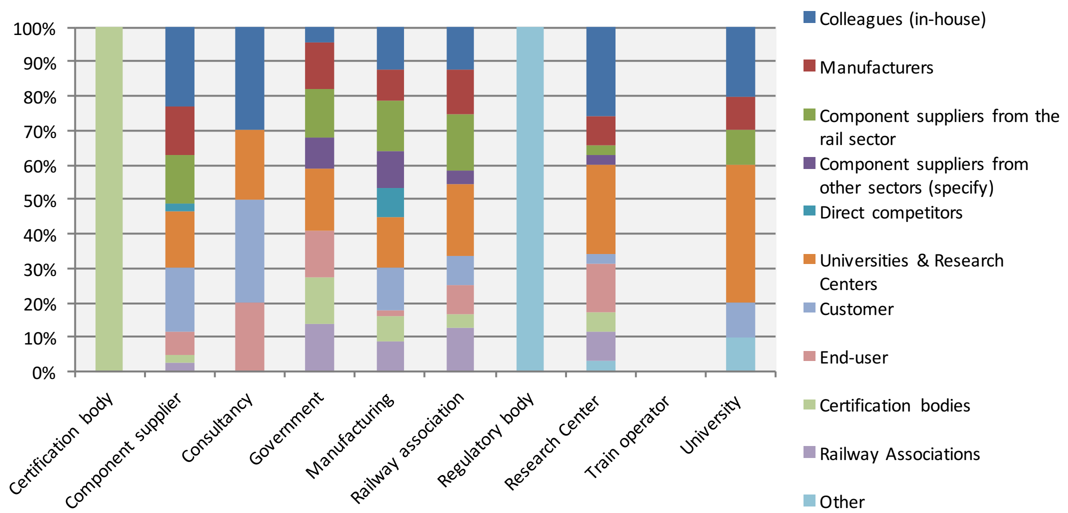
Technological partnerships involve a number of stakeholders with a variety of competences. Graphs 5.33 below reveal the most prominent partnerships in the development of high-speed trains as overall industry and graph 5.34 breaks results down by stakeholder.



Graph 5.33. Technological partners (Q20)
(% of total of responses)

Partnerships with specialised technological providers as universities and research centers prevail in high-speed trains industry, with 19.3% of responses. Also in-house partnerships with colleagues are prominent with 17.3% of responses. This confirms previous results, where prevailing collaborative activities with external partners to the institutions.

In which refers to the split made between collaboration with component suppliers from the rail or other sectors, graph 5.33 shows a greater preference for component suppliers from the same sector, with 11.4% of responses, over the ones from other sectors, with 5%, such as aeronautics, automotive, ICT, materials and energy. This reveals this industry distance from external technology advancements from other sectors.



Graph 5.34. Technological partners. Breakdown (Q20)
(% of the total responses per category of stakeholder)

Graph 5.34 shows component suppliers mostly favoring in-house research and development, with 23% of responses. While research centers, were found to split their preferences between in-house and collaboration with other universities and research centers, with 26% of responses each.

In manufacturing prevails collaborative research and development with component suppliers as well as with universities and research centers, each with 14% of responses. Manufacturers also shows a high percentage on collaboration with component suppliers from other sectors, with 11% of responses, significantly above other stakeholders.

Collaboration with customers and end-users scores quite differently between respondents' types. While component suppliers and manufacturing privilege collaborations with customers, respectively fifth in their ranking, end-users were privileged mainly by consultancies 20%, governments and research centers, both with 14% of responses. Here manufacturers score the lowest with only 2% of replies and train operators not even replying. This clearly indicates a distance of the major players in this industry from users and society in the technological development of the train. This will be further addressed in the survey by the questions specifically addressing societal embedding.

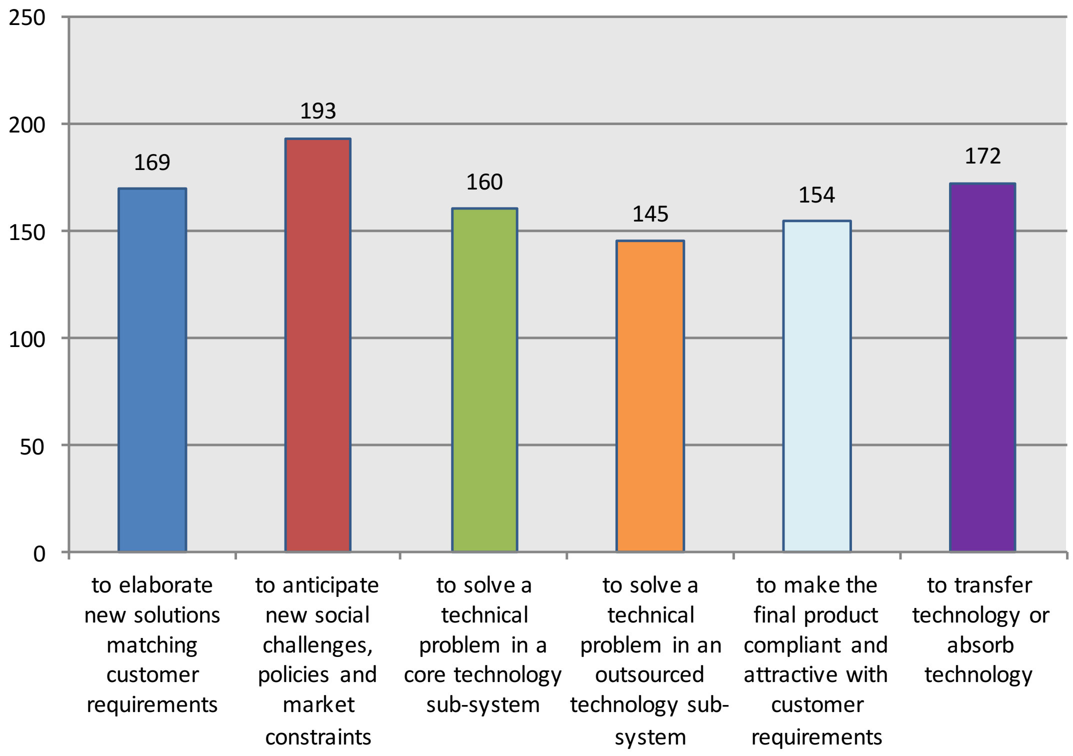
Direct competitors were selected only by manufacturing, 9% of responses, and by component suppliers with 2%.

Train operators did not reply to this question.

Q21. Relevant factors for conducting collaborative research

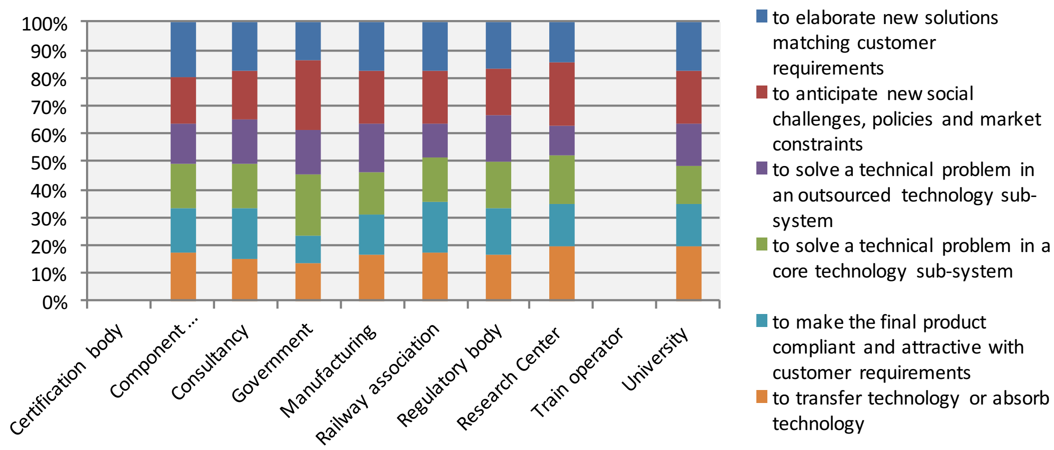
Collaborative research is better known as a way to understand complex problems or anticipate then and how to design and implement research-based responses to those problems (Schilling 2013).

Graph 5.35 shows that for the high-speed industry the relevant factors for conducting collaborative research.



Graph 5.35. Relevant factors for conducting collaborative research (Q21)
(Ranking: sum of attributed points)

In graph 5.35 the anticipation of new societal challenges, policies and market constraints"] was ranked as the most relevant factor. They corresponded to the environments of technological selection listed in Deuten et al. (1997).



Graph 5.36. Relevance of collaborative research. Breakdown. (Q21)
(Ranking: sum of attributed points per category of stakeholder)

In graph 5.36 the breakdown by stakeholders is homogeneous. The most considered of factors, anticipation of new societal challenges, policies and market constraints are the first for governments, 25%, researcher centers 23%, manufacturing railway association and universities with 19%. For the other stakeholders these factors are ranked second among their reasons for collaborative research.

Results (Q17 – Q21)

With the technology of high-speed trains in the hands of manufacturing the survey shows that their main purpose for conducting technology advancements (Q17) are product and design improvements (graph 5.20), modelling and planning (graph 5.22) and certification (graph 5.23). This contrasts with other stakeholders, not directly in charge of technological development process. The anticipation of societal challenges, policies and market constraints, are for manufacturers relevant but not systematic (25% frequently versus 75% occasionally, graph 5.28).

Results from graph 5.29 reflect incremental innovations as dominant in this industry performed by the incumbent stakeholders in monopolistic positions. The high-speed train industry is mainly focus on concept development and feasibility and only then on product and process development (graph 5.29). Societal alignments come only after, aside with regulatory alignments (graph 5.29). Market entry as it appears is the least considered (graph 5.29) reflecting the dominant position of incumbents and low degree of market openness. Research centers and governments were the most supportive to societal assessment practices (graph 5.30) aside to regulations (governments) and basic research (research centers).

When assessing the openness of this industry to collaborative research, graph 5.31 reveals a split between research and development done collaboratively, slightly dominant, and in-house. Manufacturers and research centers preferences are for consortia (graph 5.32). In contrast, component suppliers mainly perform technology development in-house (graph 5.32). User engagement in the technology development is however quite low across all the stakeholders with governments the only ones committed to involve them (graph 5.32). As stated this shows the industry distance from users and society in general.

In terms of types of institutions for forming partnerships, graph 5.33 shows an overall preference by the high-speed train industry for partnerships with specialised technological providers as universities and research centers, which confirms the findings in section 4.1.5, b) about technology transfer. Such results mainly from universities and research centers but also from research centers and manufacturers (graph 5.34). Manufacturing also attribute high relevance to the collaboration with components suppliers from railways and from other sectors, such as aeronautics, automotive, ICT and energy. While component suppliers and manufacturing privilege collaborations with customers, second and third respectively in their rankings, end-users were privileged mostly by consultancies, governments and research centers (graph 5.34). Collaboration with direct competitors was selected only by manufacturing and by component suppliers (graph 5.34).

The anticipation of new societal challenges, policies and market constraints was ranked by the sum of all respondents scores as the most relevant factor for conducting collaborative research (graph 5.35), ranked as first or second by all stakeholders (graph 5.36). From the low rating in collaborative research and development "to solve a technical problem in a core technology sub-system" one could assume that this is a type of development mainly done in-house or in a bilateral cooperation as found in section 4.1.5 d) on the vehicle technological system.

B. SOCIETAL EMBEDDING

This part of the survey draws from the literature of innovation studies, in particular innovation journeys as found in Van de Ven et al. (1999), Schot and Geels (2008), Robinson and Propp (2011), Rip (2012). These authors share that innovation is journey like, traversing different landscapes of development. A journey that traces on innovations history, its dynamics and tools for managing them. By revisiting innovation journeys these scholars assesses what successful innovations are about.

Deuten, Rip & Jelsma (1997, p.133) refers to the broad notion of success of an innovation journey by including three dimensions: integration of new products in relevant industries and markets, admissibility by rules and standards set by governments and agencies, acceptance by the public. The authors consider public acceptance as key dimension embedding technology in markets, but often ignored, which is then linked to the other two dimensions.

The authors recognize that anticipating on societal embedding brings with this the challenge of uncertainty and vague collective action, and thus are often omitted from firm strategies, as they are difficult to control. To overcome the challenge the authors suggest mapping internal and external alignments through interactions with societal actors, as it creates mutual learnings. For this to succeed it should be as an orchestration activity for learning and managing directions better rather than a control, with emphasis on anticipation. This is directly related to Constructive Technology Assessment literature (Rip et al 1995, Rip and Schot 1997, Robinson 2010, Rip and Robinson 2013) emphasizing on managing innovation processes in real-time, through collective anticipation and a knowledge of dynamics of technical change fed into the process to improve both anticipation and learning. In this way it is a reflexive support tool. Reflexive in terms of learning about different perspectives, and reflexive in terms of learning about other actor's motivations and practices.

For this reason, societal embedding, as defined by Deuten et al. (1997) provides a framework for the next part of the survey on the *iii) drivers and alignments in technology change*. The question on societal embedding is explored during two main periods of technology development: (a) the strategic planning (aiming anticipation of societal drivers) and (b) the technology development process (aiming interventions on alignments based on societal requirements).

In part *vii) societal alignments in the strategic management approach* questions focus on the institutionalization of societal embedding during development practices, as to understand if they are formally structured or informal.

iii) Drivers and alignments in technology change

Design and development drivers define the agenda for technology change. Drivers, as agendas, for technical change become requirements when a new product is created (Deuten, Rip, Jelsma, page 134, 1997). Both refer to two different moments for strategic management of technological innovation. It corresponds (a) to the timing of *anticipation* and (b) to requirements for the timing of *alignment*.

The survey asked respondents to rank in relevance the drivers that could trigger a technology change (Q22) and then to rate their relevance in terms of alignment at the different levels of the technological development (Q23) known as Technology Readiness Levels (TRL). Also in this part of the survey, respondents were asked about drivers as sources of information (Q24) and the type of alignment appraisal instruments frequently used (Q25).

The objective of this group of questions is to understand the relevance attributed to alignment with the wider society environment by the high-speed train industry during the technology development process of the vehicle, from its early stage of concept to its readiness for entering the market.

Q22. Drivers for technology change

Drivers that trigger firms' technology changes may have their origin external to the industry, or internal to the industry or even intra-organizational.

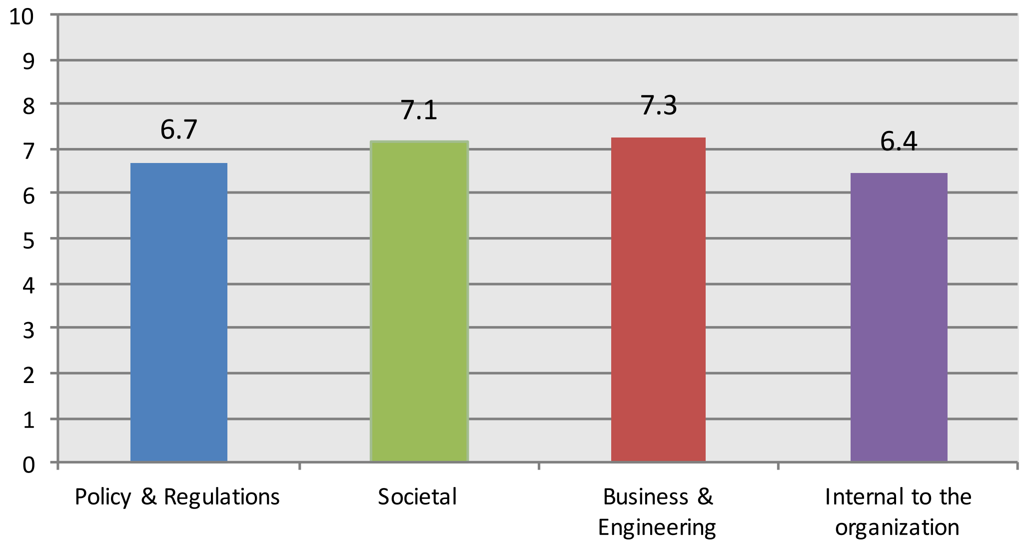
External drivers to the industry are mainly societal including demographic changes, shifts in mobility patterns, climate change and energy, connected travelers, etc.

While those internal to the industry are mostly related to policy changes, such as the introduction of new regulations, liberalization of markets, funding schemes, and business &

engineering drivers, including access to new markets, threat from new entrants or new customer requirements.

Intra-organizational events correspond to firm's change in strategy, cost reduction, acquisitions, new operation practices, etc.

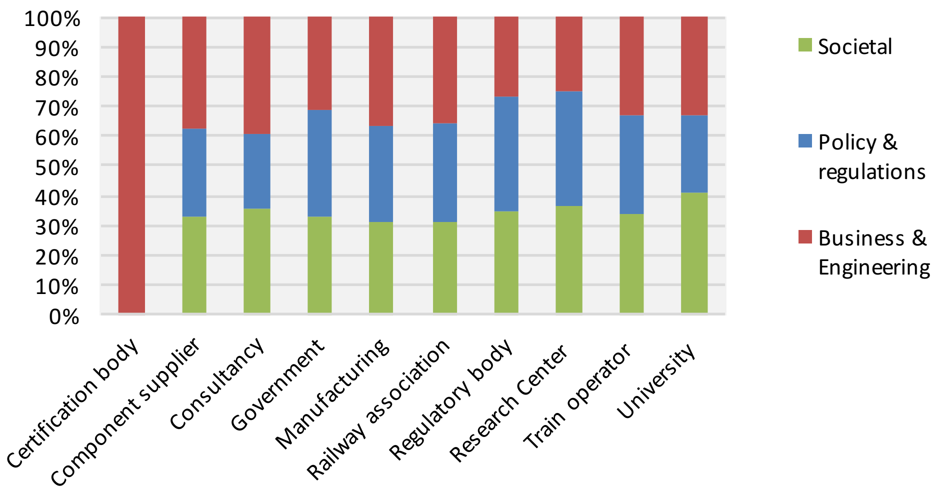
Respondents were asked to rate in relevance the drivers for technology change. Results are found in graph 5.37 below.



Graph 5.37. Rate in relevance the factors driving your research and development (Q22)
(Ranking: 1 low to 10 high)

Graph 5.37 shows business & engineering as the most relevant of the drivers with 7.3 points. Other drivers follow closely with less than a point difference. Societal drivers with 7.1 points, policy with 6.7 and internal to the organization with 6.4 points.

Each driver is related with different aspects considered in the technology development, as seen before. Policy is related with compliance, societal drivers with attractiveness, business & engineering with competitiveness and intra-organizational with efficiency. This way, from the scores in graph 5.37 the main driver is competitiveness, followed by attractiveness and compliance. Efficiency is the last of drivers.



Graph 5.38. Drivers for technology change. Breakdown by institutions (Q22)
(% of the total responses per category of stakeholder)

For simplicity of analysis graph 5.38 focus on the three main drivers for technology change as identified in the previous graph 5.38, being policy, societal and business & engineering.

Graph 5.38 reflects railway stakeholders' position in the supply chain. As one could expect manufacturing, 28%, and component suppliers, 28%, attribute higher relevance to business & engineering (competitiveness) when monitoring for technology changes. Manufacturing registered a slightly lower response rate on policy and societal drivers, 24% each. While component suppliers, selected societal drivers 24% over policy and regulations 21%.

In graph 5.38, governments and regulatory bodies rate of responses was higher for policy and regulations drivers, 31% and 29% respectively, followed by societal drivers 29% and 26%, and only after business and engineering 27% and 21%.

Universities are the only group of stakeholders responding to this question considering societal drivers the most relevant factor for technology change, 34%. It reinforces findings in chapter 4.1 referring to universities as the privileged partners of manufacturers to scan for wider society. Research centers would be expected to align with universities however they do not. They aligned with governments' responses.

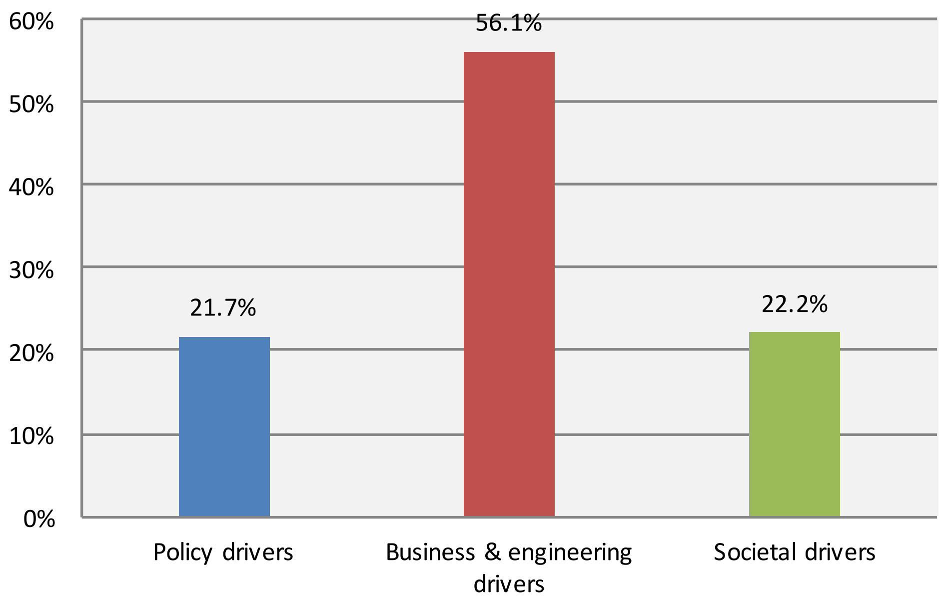
Train operators have a low participation to this question (Q22) attributing the same score to all of the drivers, which makes it difficult to arrive to any conclusion on their respect.

Q23. Requirements for technology change

Drivers become requirements when a new research project is launched and they are integrated as assessment criteria in the technology development process.

Each technology development process is framed by a project, which foresees different readiness levels (TRL), ultimately leading to the technological maturity. Those levels are gated by requirements of alignment (or indicators) aimed at control the quality of research and development project and ensure that it is being executed in an efficient manner (Schilling 2013).

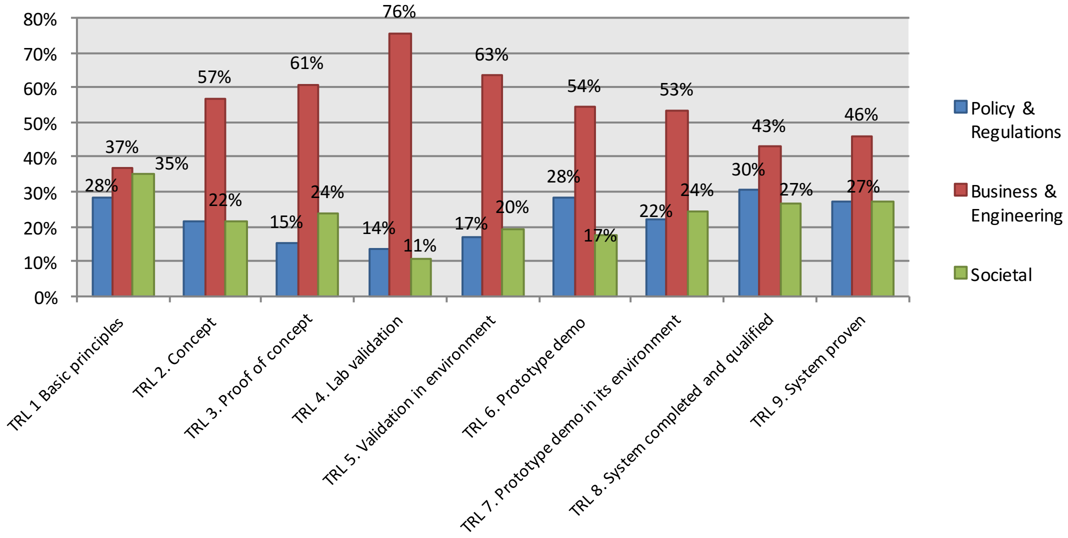
The following graph 5.38 presents the aggregated results on the relevance attributed to the identified drivers at the different TRL. This question differs from the previous as its focus is on the actual process of technology development, while the other was on the anticipation during strategic formulations (meaning, respondents' perceptions on the drivers leading to technology change).



Graph 5.39. When developing a new technological solution (TRL) which requirement for alignment you consider? (Q23)
(% of total of responses)

Graph 5.39 shows that at the time of implementation business & engineering requirements accentuates importance, synonym of this industry techno-centricity.

In the following graph 5.40 the relevance on the requirements for technology change are detailed for each TRL, with graph 5.41 to 5.49 further showing results by institution types.



Graph 5.40. When developing a new technological solution for the high-speed train at which technological readiness levels (TRL) you consider identified requirements for alignment? (Q23) (% of total of responses)

Graph 5.40 shows that business & engineering requirements change in an inverted "U" shape curve while societal and policy requirements vary in an imperfect "U" curve. This means that at early stage of technology development, in TRL1, where basic principles are considered and reported business & engineering score their lowest in relation to other TRL, 36.8%, and societal and policy requirements score their highest, 35.1% and 28.1%. Then business & engineering requirements increases relevance to a maximum 75.7% in TRL4 while societal and policy driver decrease to a minimum 10.8% and 13.5% respectively also in TRL 4. Business & engineering lose momentum in particular in TRL8 and TR9 while societal and policy requirements regain.

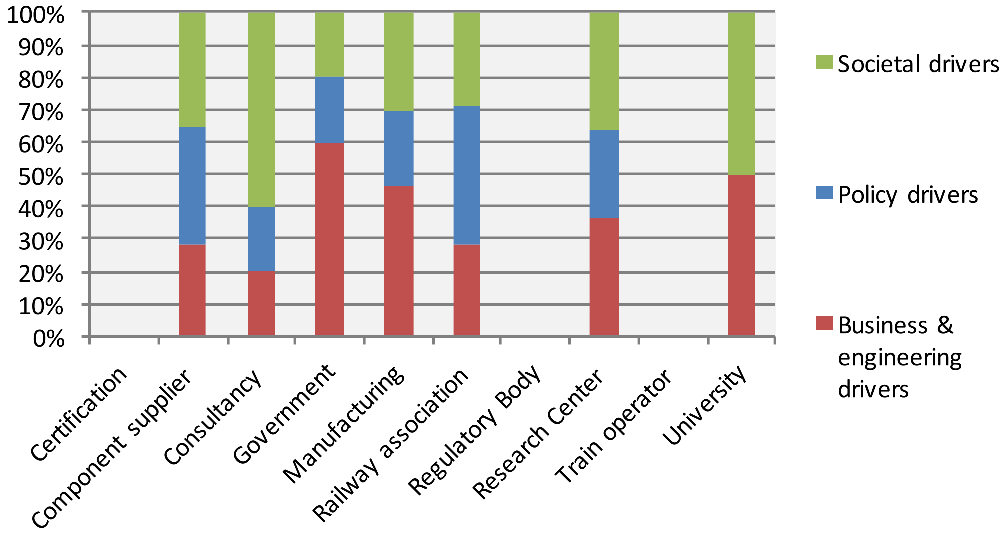
Such fluctuation in the relevance of environments confirms the sequential alignment in firms practice as detected in Deuten, Rip & Jelsma (1997) studies and here referred.

It is important to note that TRL1 results are similar to the ones in graph 5.37 referring to the drivers for technology change, with business & engineering slightly above societal and then policy requirements. This happens because of the anticipatory character of TRL1 where developers look for the societal trends required to bring basic research principles to applied research. Also for TRL8, by the time technology becomes matured, societal requirements aiming in this case at impact assessments also regain relevance but not to the levels of TRL1. This implies that societal requirements are in demand as anticipatory function rather than for impact assessments.

A respondent underlined that TRL 4 corresponds to the engineering process selection conditioned by business & engineering requirements. Another respondent comment added that societal requirements are brought back only in TRL 8 and 9 when the technology matures, requiring assessing the technology impacts.

In TRL8 it is observed a higher attention to policy requirements then to societal as at this stage technology developers are looking at compliance with regulations and standards of the new technology being developed.

The following graphs 5.41 to 5.49 further breakdown each TRL by institution types.



Graph 5.41. Requirements relevance at TRL 1. Basic principles observed and reported (Q23)
(% of the total responses per category of stakeholder)

TRL 1 corresponds to the initial stage of technology development when basic principles are observed and reported. It is when basic research begins to be translated in applied research and development. Examples might include paper studies of a technology's basic properties[138]. The main outputs are reports and papers.

As it was seen previously in graph 5.39, at this level, policy and societal drivers scored their highest, 28.1% and 35.1% accordingly, yet below that of business & engineering 36.8%.

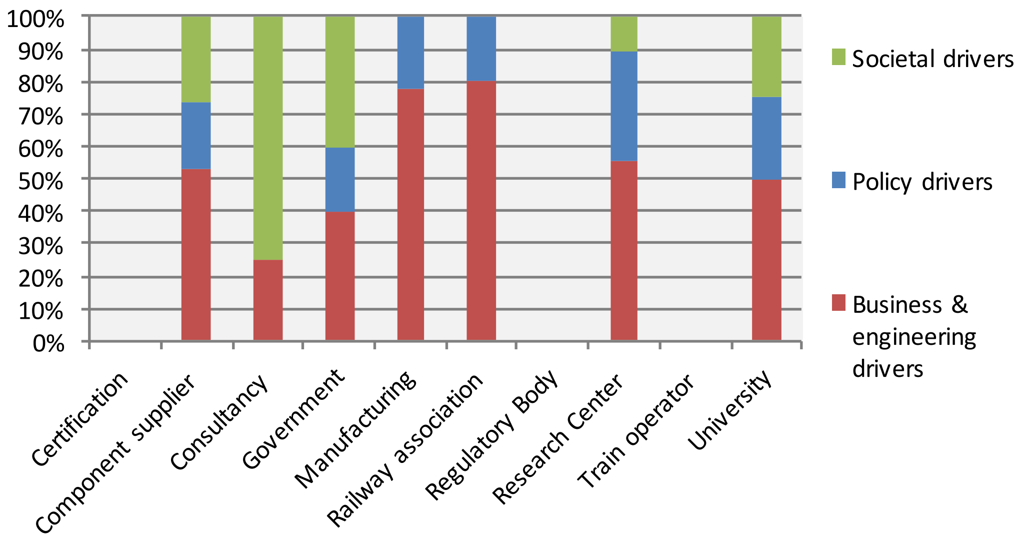
The breakdown of results by institution type provides an indication of the practices in the industry. At this level consultancies scan for societal trends 60% and railway associations mainly policy drivers 43%, such as new regulations, standards and funding. Also component suppliers are looking to policy 36% and societal drivers 36% as internal exercises. While manufacturers mostly look at responses to a technical problem or scanning new business

[138] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

opportunities 46% at this stage. Research centers and universities are equally split between societal drivers and business & engineering, 36% and 50%.

Contrasting with manufacturers, component suppliers attribute, at this TRL, a higher relevance to policy & regulations 36% and societal requirements 36% than to business & engineering 29%. This is because component suppliers to this survey are mainly on interiors, materials and ICT, supplying also for aviation and automotive. Component suppliers are required to develop and adapt their technologies to societal trends and policy/regulations specific to high-speed trains. While for the manufacturers, in its turn, societal and policy/regulations pressures are attenuated by their dominant position and relative direct competition.

Contrary to what one would expect governments mostly consider in TRL1 business & engineering requirements 60% instead of policy 20% and societal 20%. This may be explained as, at this stage, there is little intervention or knowledge from governments on the technology being developed by component suppliers and manufacturers.



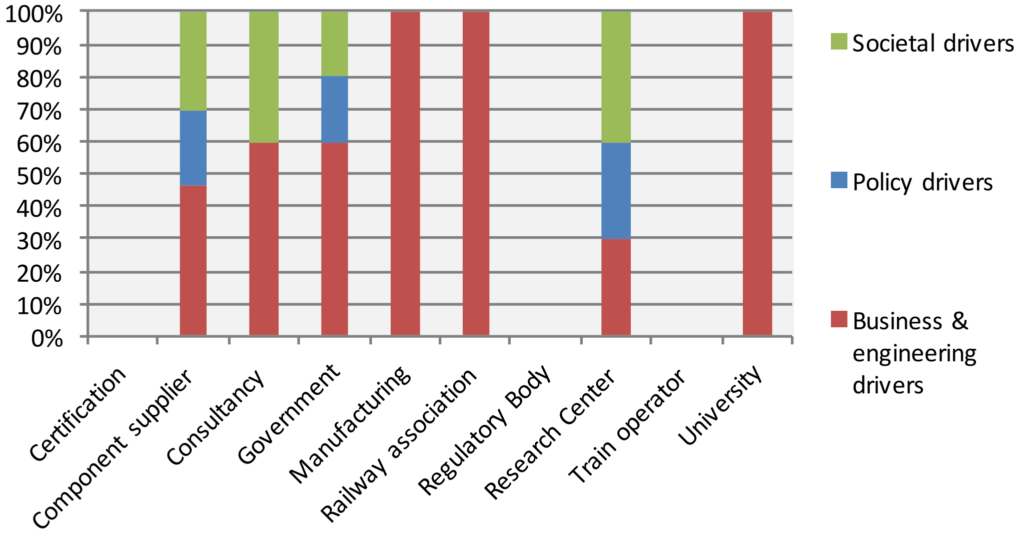
Graph 5.42. Requirements relevance at TRL 2. Technology concept formulated (Q23)
(% of the total responses per category of stakeholder)

TRL2 corresponds to the moment when the technology concept (and/or application) is formulated. Developers are looking to fields of application. Examples might include publications or other documents that outline the application being considered and that provide analysis to support the concept[139].

As it was seen previously in graph 5.40, at TRL2 policy and societal requirements reduce their scores, 21.6% each, while business & engineering increase 56.9%. This is particularly striking

139 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

for component suppliers, railway associations and research centers. Manufacturing at this stage focuses mainly on business & engineering 78% with a smaller percentage on policy drivers 22% and none on societal 0%. Against this trend are consultancies and governments paying increase attention to societal requirements, 75% and 40% respectively.

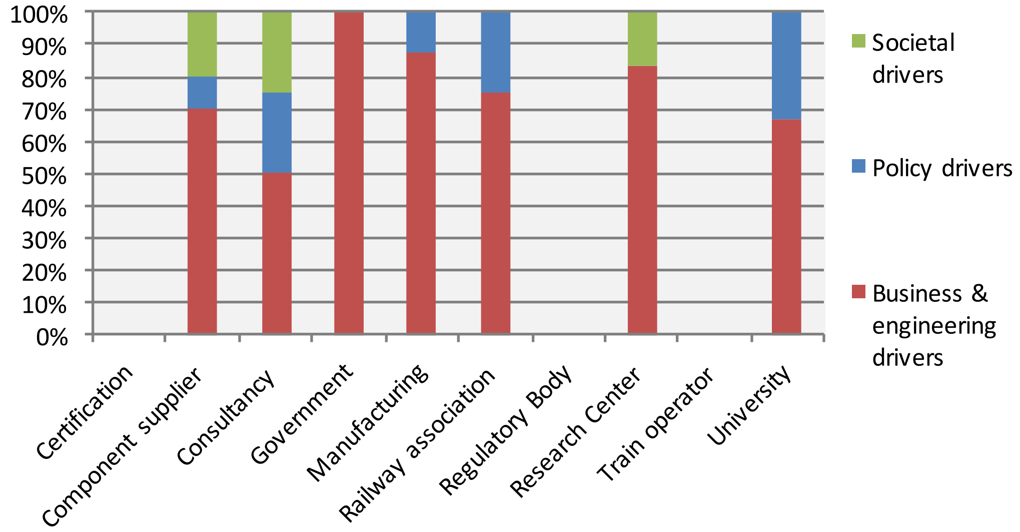


Graph 5.43. Requirements relevance at TRL 3. Experimental proof of concept (Q23)
(% of the total responses per category of stakeholder)

TRL3 is the level at which the activity of R&D is initiated with the experimental proof of concept[140]. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.

At this stage business & engineering requirements increase focus of attention for the majority of stakeholders except for research centers, with societal requirements gaining relevance 40% in respect to the previous TRL 2.

140 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf



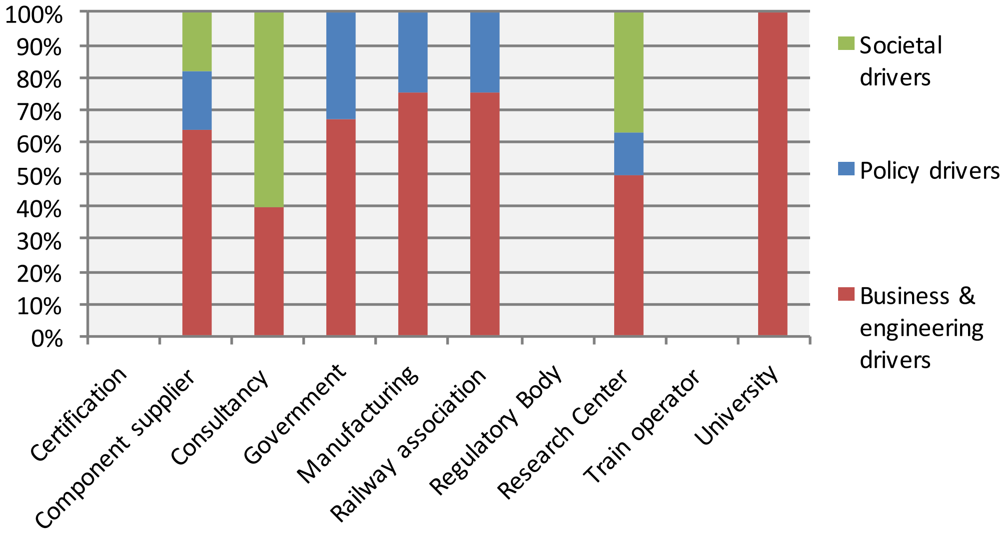
Graph 5.44. Requirements relevance at TRL 4. Technology validation in laboratory (Q23)
(% of the total responses per category of stakeholder)

TRL 4 is the peak of engineering where technology is validated in laboratories or workshops[141]. Basic technological components are integrated to establish whether they will work together. Examples include integration of ad hoc hardware in the laboratory.

At this level manufacturers and component suppliers are mostly concerned with proving the functionality of the solution while ensuring compliance with technical requirements. This is clearly reflected in the graph 5.44 with business & engineering at their maximum level of relevance for component suppliers 79% and manufacturing 88% as well as for research centers 83% and universities 67%.

As was already seen for graph 5.40, societal and policy drivers are at their minimum of relevance for all the stakeholders 13.5% and 10.8% respectively. Yet policy requirements score a bit higher than societal for manufacturers, 23% vs 0%, railway associations, 20% vs 0%, and universities, 33% vs 0%, looking at compliance with regulations. Societal requirements were only considered by components suppliers 20%, consultancies 25% and research centers 17%.

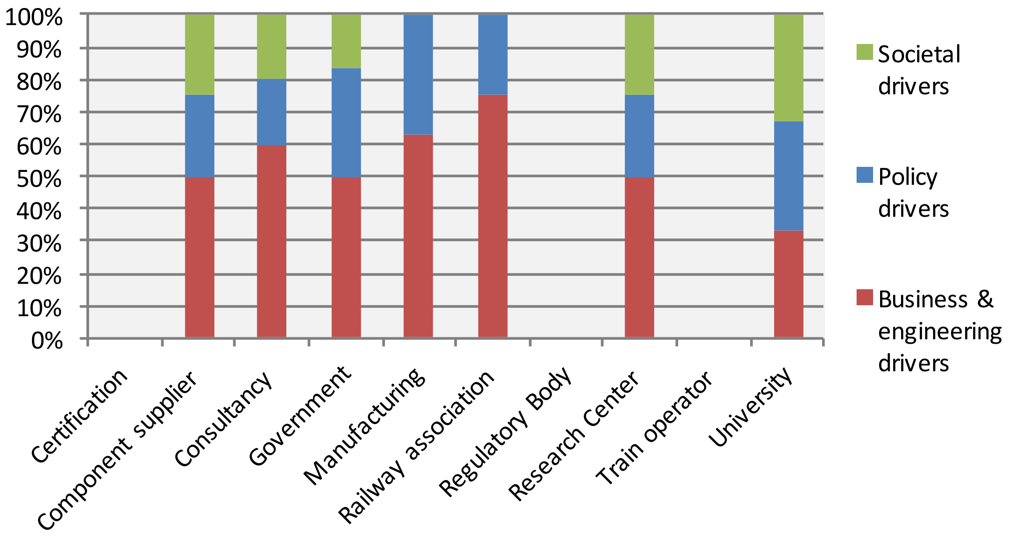
[141] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf



Graph 5.45. Requirements relevance at TRL 5. Technology validation in relevant environment (Q23)
(% of the total responses per category of stakeholders)

TRL5 refers to the technology validation in relevant environments[142]. Breadboard systems (a base for prototyping) are integrated with other supporting elements in a simulated operational environment.

In graph 5.40 business & engineering requirements slightly decrease in relevance to 63.4% and societal and policy slightly increase to 19.5%. Graph 5.45 results per stakeholders shows societal and policy requirements registered a high percentage of responses from research centers 38% and consultancies 60%.



Graph 5.46. Requirements relevance at TRL 6. Technology demonstration in a relevant environment (Q23)
(% of the total responses per category of stakeholders)

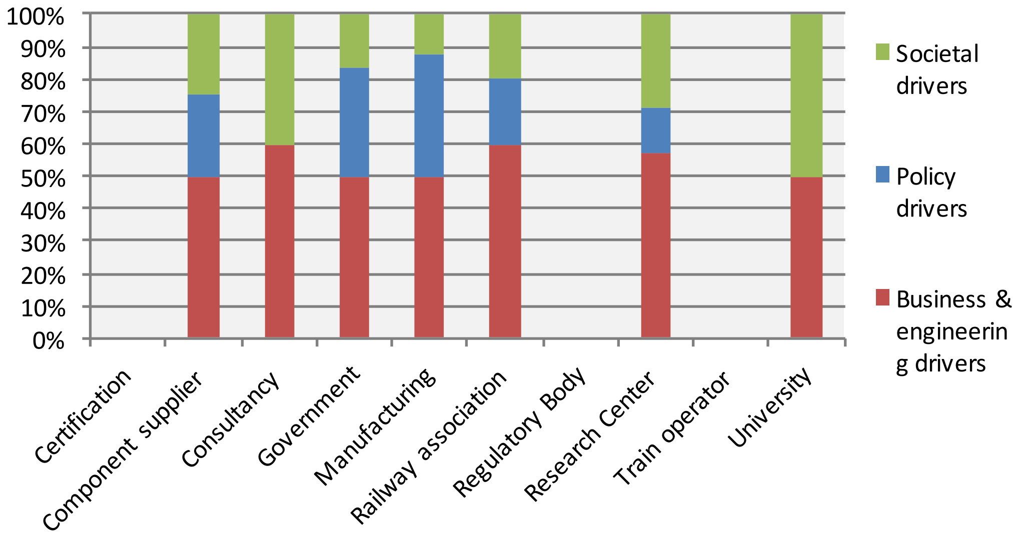
[142] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

TRL 6 is when technologies (system and subsystems models or prototypes) are demonstrated in a relevant environment[143]. They are tested on their readiness to enter a market and reach society. Examples include testing a prototype in a laboratory environment or even in a simulated operational environment.

Technology at this stage is maturing. Stakeholders shift their attention from business & engineering requirements to policy compliance and societal alignment, both concerned with ensuring the technology readiness for introduction in market. Policy requirements reaches the same relevance as in TRL1 in graph 5.40, 28.1%

Graph 5.46 shows that for the majority of the stakeholders' business & engineering are yet kept high in respect to other requirements. Universities are the exception, pairing all of the three requirements in terms of relevance, 33%.

Governments increase their interest from TRL6 on societal requirements as they are concerned at this stage with acceptance and impacts of the technology solution by wider society – it is becoming a more pressing policy concern.



Graph 5.47. Requirements relevance at TRL 7. System prototype demonstration in an operational environment (Q23)
(% of the total responses per category of stakeholders)

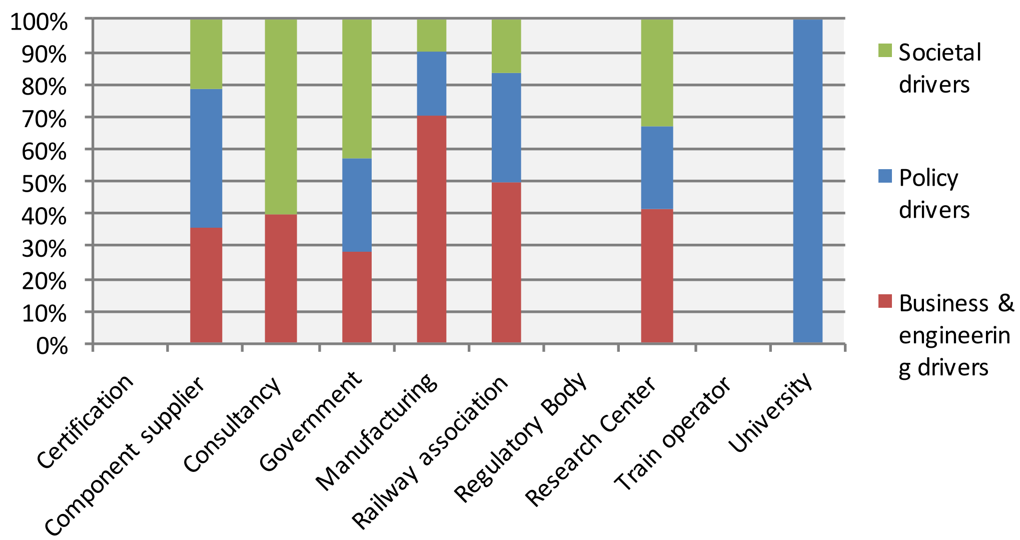
143 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

In TRL 7 the prototype is getting closer to an operational system[144]. It represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g. in a train vehicle or on a track).

Following TRL6 trend, business & engineering and policy requirements decreases but only slightly, 22.2% and 53.3% accordingly, while societal requirements increase 24.4%, as shown in graph 5.40.

The breakdown of these results by stakeholder in graph 5.47 show that for manufacturing business & engineering further decrease in relevance to 50%, while societal drivers emerge to 13%. Policy drivers remain at 38%. At this stage manufacturing confirms compliance with specific regulations and customer requirements.

Component suppliers keep their attention high with regards to business & engineering, 50%, especially if supplying parts in non-core technologies for high-speed trains operations such as interiors.



Graph 5.48. Requirements relevance at TRL 8. System completed and qualified through test and demonstration (Q23)
(% of the total responses per category of stakeholders)

In TRL8[145] the technology is proven to work in its final form and under expected conditions. It represents the end in the development process. Examples include developmental tests and evaluation (DT&E) of the technology system in its intended operations to determine if it meets design specifications.

---

144 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

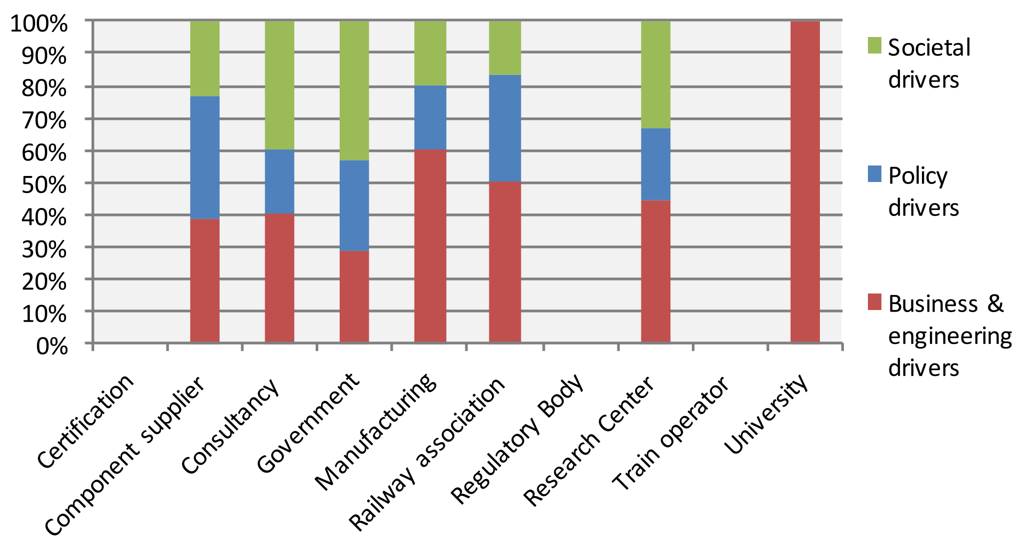
145 http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

At TRL 8, as it was found in graph 5.40, policy requirements regain momentum reaching its maximum of relevance with 30% of responses, over passing its relevance in TRL1. Policy requirements also overpassed societal aspects even though there was an increase of the last to 27%. Business & engineering requirements decrease to 30%.

In which concerns the same results by stakeholder, in graph 5.48, one sees that the increase in policy driver relevance is mainly an outcome of universities paying greater attention in TRL8 to regulations and standards, with 100% of responses, above all the others. Also component suppliers increase their attention to policy requirements in ways of impact assessment, 43%.

Contrasting manufacturers registered an accentuated increase in attention to business & engineering climbing to 70% of responses. Policy and societal drivers droped to 20% and 10% of responses as these stakeholders start considering placing the technology in the market and scan for opportunities.

At TRL8 governments significantly increase their attention to societal constraints, 43% overpassing for the first time policy and business. The same will apply to TRL9, as it will be shown.



Graph 5.49. Requirements relevance at TRL 9. Actual system proven through successful mission operations (Q23)
(% of the total responses per category of stakeholders)

In TRL 9[146] the actual application of the technology in its final form occurs under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational conditions.

[146] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

For the high-speed train industry TRL 9 might even correspond to the stage when a tender has been issued by a train operator wishing to buy high-speed trains to serve in a specific corridor, requiring homologation by certification bodies and customisation to the operator image and end-users culture.

As could be expected, results in graph 5.49 show manufacturers, the ones making the technology offer to the train operator, considering the most business & engineering requirements 60% (yet slighting decreasing from TRL8 which registered 43%). Manufacturers increased their attention to societal requirements 20% to the percentage of policy making (while in TRL 8 societal was 10% and policy 20%).

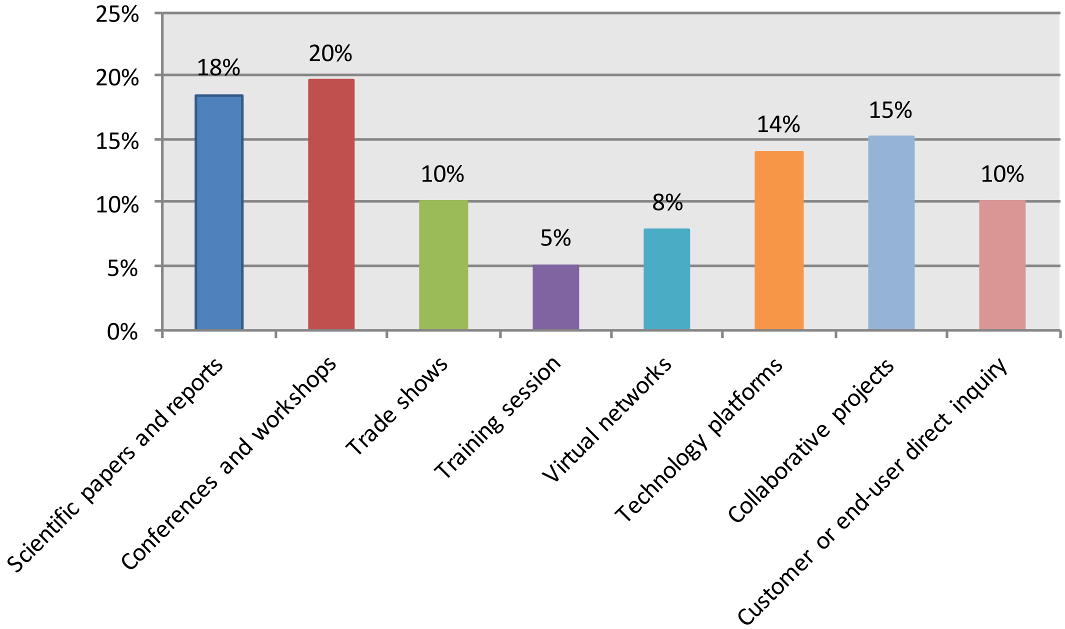
Component suppliers at this TRL pair their business & engineering with regulations at the top of their concerns, each with 38%. At this stage they are quite concerned to prove compliance with all the standards and homologations when required.

Research centers and universities are now favoring more business & engineering with 40% and 100% respectively. While governments have the same percentage of responses as in TRL8, 28%, favoring societal constraints.

Q24. Sources of drivers and requirements

Firm's or government drivers and requirements of alignments for technology change originate from different sources ranging from personal contacts to conferences and trade shows. They can be specific to the industry or external, covering technological matters to soft issues such as management, or addressing specific topics as environment and energy or broader societal trends.

Respondents were asked to indicate their sources of information. Results are shown in graph 5.50, below.



Graph 5.50. Indicate your sources of information on technological drivers and requirements (Q24) (% of total of responses)

Graph 5.50 shows that conferences and workshops are the main sources of information for the high-speed train industry, with 20% of responses. The second most relevant source are scientific papers and reports, with 18% of replies, not so far apart from the previous. Those two sources of information tend to be very specific to the sector, for example as Innotrans[147], referred as the most relevant trading event for the industry, or scientific papers and reports produced by the engineering schools in journals and conference proceedings, as it could be the International Journal for Railway Technology (IJRT[148]).

Of particular interest is the technology platform, collectively producing strategic visions on the future technological developments based on the selection of drivers relevant to this industry, are over passed by collaborative projects, such as the emblematic MODTRAIN[149], of a more technical and instrumental function, 14% *versus* 15%. Yet both sources are quite specific to the industry.

Customer and end-user enquiry appeared at the low-middle part of the chart, with 10% of responses. That is a clear indication of the endogenous and techno-centric nature of the technology change. Only if they were placed at a higher position in chart one could say that the sector was considering exogenous sources.

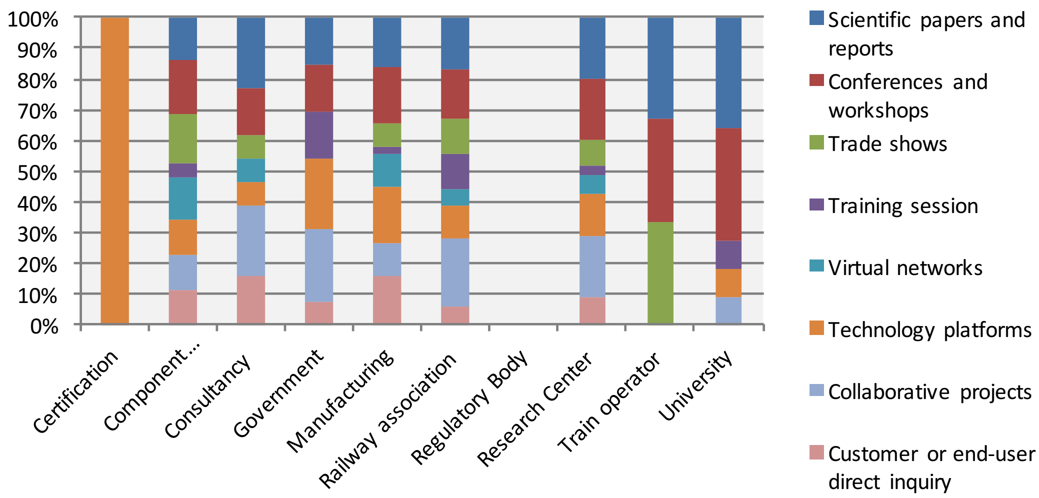
---

[147] http://www.innotrans.de/en/

[148] http://www.saxe-coburg.co.uk/ijrt/

[149] http://ec.europa.eu/research/transport/news/items/_modtrain__delivers_final_results_en.htm

It is worth exploring in the next graph 5.51 below, the breakdown of sources of drivers by institution type, to see which actors are considering endogenous or exogenous sources of information.



Graph 5.51. Indicate your sources of information on technological drivers and requirements. Breakdown (Q24)
(% of the total responses per category of stakeholders)

All the stakeholders are quite endogenous and techno-centric in their sources of information. However, as graph 5.51 shows manufacturers the highest of responses for consultations to customers and end-users, with 16% of responses. The results pair with scientific papers and reports, also with 16%, quite technical and produced by universities or research centers covering a specific field. Yet at the top of manufacturers preferences are conferences and technology platforms with 18% each of responses.

Component suppliers also pay attention to consultations to customers and users however this one appears 4th place in their list, with 11%, even with collaborative projects and technology platforms.

It should be noted that governments attribute the highest attention to technology platforms, such as ERRAC, and reports from collaborative projects, with 23% each. This is a reflection of the participation to this survey of respondents from the European Commission DG RTD and DG MOVE, promoters and funding entities for these types of activities. As referred, also manufacturers consider technology platforms as the most relevant source of information a side with conferences and trade shows, each with 18%.

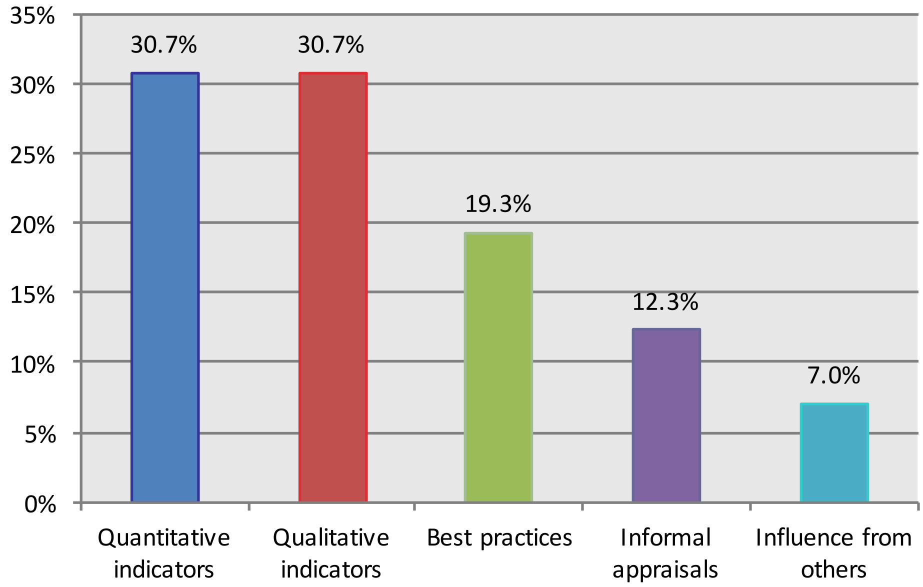
Another aspect relates to train operators not selecting technology platforms, collaborative projects and direct consultations to end-users as source of information. They rather concentrate their responses on scientific papers and reports, conferences and workshops as well as trade shows, with 33% each.

Component suppliers clearly scan for drivers and requirements at business and engineering level from its prioritization to conferences 18% and trade shows 16%.

Regulatory bodies were the only stakeholders not replying to Q24, which could be explained by their regulatory function implementing policies set by governments or the European Commission, rather than scanning for technology changes.

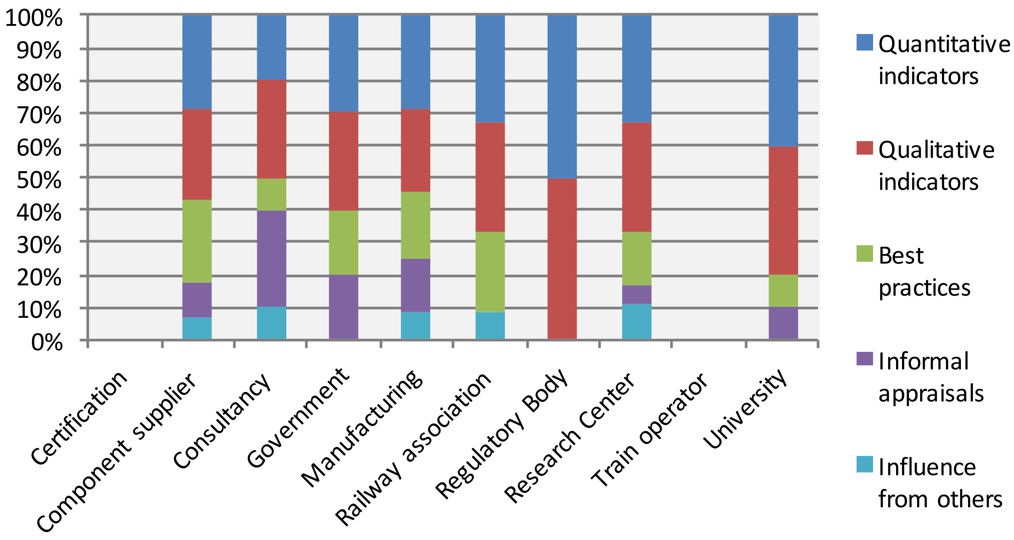
Q25. Appraisal instruments

Developing new technologies is expensive, time-consuming and risky. Firms have to take decisions on which technology option to support. To make such choices, firms use a series of appraisal instruments, often in combination, that vary from informal to well-structured and from entirely quantitative to strictly qualitative (Schilling 2013).
The following two graphs 5.52 and 5.53 show the results for the high-speed train industry on their preferences on the appraisal instruments.



Graph 5.52. In which type of instruments you base your technology decisions? (Q25)
(% of total of responses)

As graph 5.52 shows, the high-speed train industry seems to equally consider qualitative and qualitative indicators as main instruments. Distinctions arise when breaking down the graph by institution type as shown graph 5.53 below.



Graph 5.53. You base your technology decision on which type of instruments. Breakdown (Q25) (% of the total responses per category of stakeholders)

In graph 5.53, stakeholders seem to use a mix of methods. Component suppliers, governments, railway associations, regulatory bodies, research centers and universities, break-even between decision-making supported by quantitative and qualitative indicators, prioritizing them in respect to the remaining instruments.

Manufacturers in their turn have a more distinctive prioritization of appraisal instruments valuing quantitative indicators over qualitative, 29% vs 25%, followed by best practices, with 21% of the preferences.

None of the train operators and certification bodies replied to this question.

Results (Q22 to Q25)

At the time of anticipating technology changes, respondents attributed very similar degrees of relevance to the different drivers presented, with business & engineering slightly higher in relevance than societal aspects and policy (graph 5.37). From this, one could say that at strategic level, societal anticipation is highly considered by the high-speed industry.

The breakdown of results by institution type (graph 5.38) reveals that business & engineering drivers were highly rated by component suppliers and manufacturing. In its turn policy drivers were highly ranked by governments and regulatory bodies (graph 5.38). A better result would have been expected for societal drivers, as they appeared second in the aggregated results (graph 5.37). Universities were in greater number ranking them higher than the other drivers (graph 5.38). Manufacturing scored policy equally above societal drivers (graph 5.38).

When referring to time in implementing the technological development process (or product creation according to Deuten, Rip & Jelsma, 1997), at the time when drivers become requirements for alignment, business & engineering were the most considered by respondents (graph 5.39). Societal and policy requirements got a much lower percentage of responses (graph 5.39). There is therefore an observable difference between strategy and development.

From the breakdown of the results by technology readiness levels (graph 5.40) it was observed an inverse relation between responses on business & engineering and responses on societal and policy requirements. Across the different technology readiness levels (TRL) business & engineering fluctuate in an inverted “U” curve while society and policy present a normal “U” shape (graph 5.40). Concerning business & engineering requirements, stakeholders attributed a lower relevance in TRL1 (the early stage of technology development when basic principles are observed and reported) which then progressively increases arriving to its maximum in TRL4 (corresponding to the pick of engineering activities with the validation of results) and then decreases to a minimum in TRL8 (corresponding to the stage when the actual technological system is completed and qualified through tests and demonstrations). Business & engineering requirements slightly increase in TRL9 when the actual system has been proven successful is matured and ready to be introduced in the market. The opposite happens for societal and policy requirements across the TRL (graph 5.40). They are highly considered at TRL1 and TRL8 and the least considered at TRL4. It should be highlighted that societal requirements reach their maximum percentage at TRL1 (almost the same percentage of responses as for business & engineering). In TRL1 societal requirements yet have an anticipatory function while in TRL8 and also in TRL9 they serve an impact assessment purpose.

Moving to the breakdown of the listed requirements for technology change at the different TRLs, from graphs 5.41 to 5.49, it was found that manufacturing have, from all stakeholders, the highest rate of responses on business & engineering requirements at all the TRLs and the lowest on societal requirements. Only in TRL1 manufacturing register a higher percentage of responses on societal requirements, even above policy yet below business & engineering, which demonstrates that manufacturers seem to value only the anticipation function of societal requirements at the early stage of the technology development process, not considering so relevant its impact assessment at a later stage of development. Also component suppliers and universities value the anticipatory character of societal requirements in TRL1. While governments value the impact assessment function of societal requirements with their highest percentage of responses in TRL8 and TRL9. Consultancies and research centers have the highest percentage of responses of all stakeholders on societal requirements across all stages of the development. Train operators did not reply to the relevance of the listed requirements in new technology developments (Q23).

Now passing to the sources of information on drivers and requirements for technology change, results (in graph 5.50) show that respondents are quite endogenous and techno-centric in their search. They mostly refer to their own industry conferences and workshops followed by scientific papers and reports, collaborative projects and technology platforms visions and agendas. Customers and end-users direct inquiry account with a less percentage of responses in respect to other sources for each stakeholder, except for manufacturing (graph 5.51) where they appear in the second place even with scientific papers and reports.

In terms of appraisal instruments, (in graph 5.52) respondents equally considered qualitative and quantitative methods, using a mix of both. Manufacturing however stands out from other stakeholders by prioritizing quantitative methods (as financial and economic) over qualitative ones (graph 5.53).

iv) Societal elements in the strategic management approach

Deuten, Rip & Jelsma (1997, p.143-148:219-236) state that firms openness to societal alignments (mutual learning and exploration of interactions) is dependent on two elements: the firm's "learning pressure" and "room for learning", which can occur in a "single loop" or "double loop".

The authors consider that "learning pressures" are high when it is about a core technology for a firm or they are close to the consumer or even if their technology is easy to reproduce by competitors. In its turn the authors say that "room for learning" is small if firms depend on one or few products or services or also are pioneering new technologies due to scare management resources. The authors continue saying that room for learning is small when technologies require a fast product development, against the ones with 10 years or more to develop a new product.

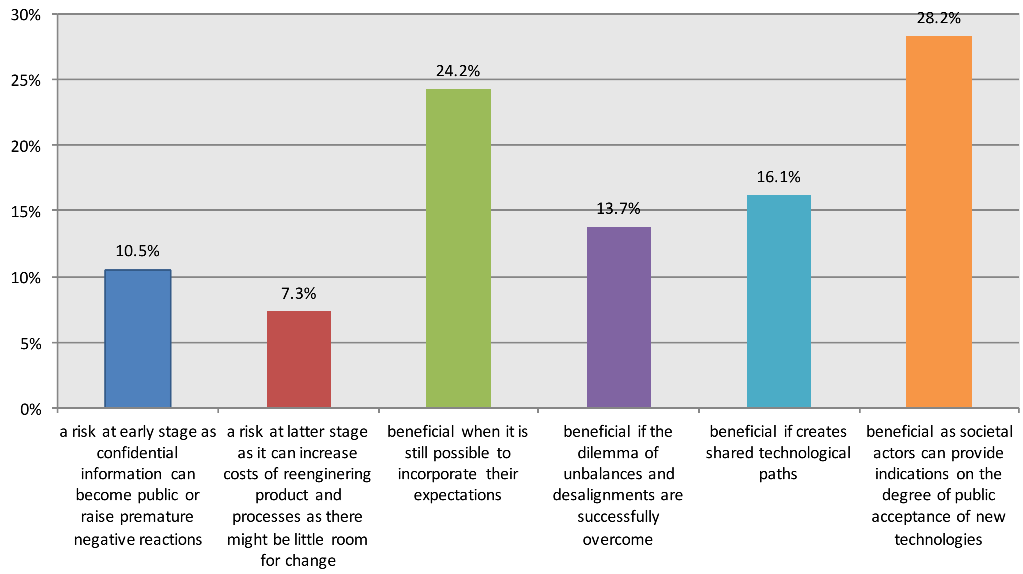
Citing Argyris & Schöln (1978) the authors say that "single loop learning" aims to improve ways and means to *achieve* firm's goals; while "double loop learning" experience and reflection lead to the *consideration* of one goals. They further refer that those interactions between firms and wide society are strategic games.

This part aims at addressing the underlying aspects on high-speed train industry strategic games and necessary alignments with wider society. To this end, respondents were asked what societal alignment represents for them (Q26); how formal or informal their interactions with societal actors are (Q27); and if respondents include societal requirements *gates* in their technology strategic planning and development activities (Q28).

Q26. What represents alignment with societal actors?

A broader consideration of market success of new technologies implies that society has or gets a stake in their development and introduction. Consequently, societal actors become a stakeholder (Deuten, Rip & Jelsma, 1997).

It is expected that societal stakeholders have different interests, culture and expectations than the ones developing the technology imposing difficulties to introduce them in the technology development process. Respondents were asked what societal alignment represented for them. Results are shown in graph 5.54 below.

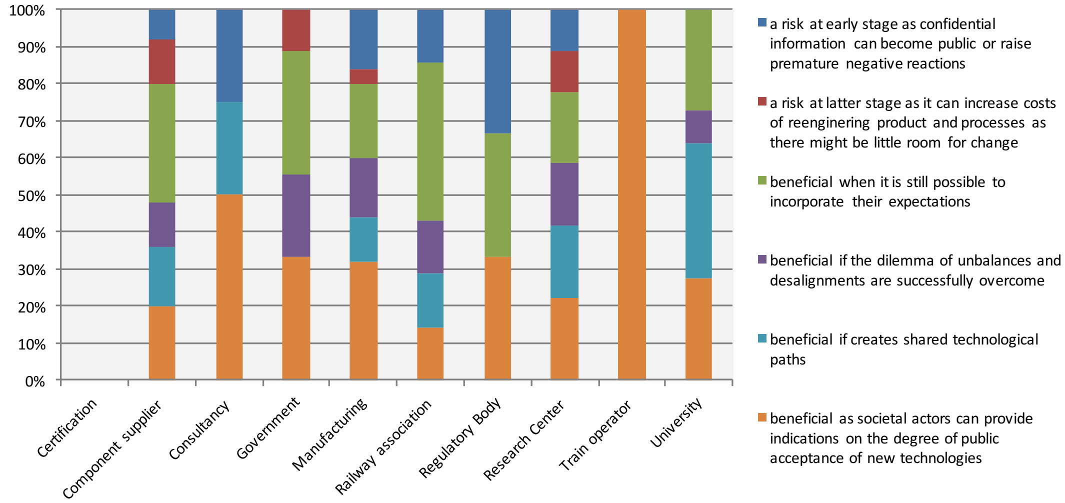


Graph 5.54. What represents technology alignment with societal actors? (Q26)
(% of total of responses)

Graph 5.54 results show that respondents are positive towards societal actors inclusion in the technology development. A relevant percentage of respondents, 28.2%, considered that alignment with societal actors a way for risk mitigation of technology failure when new technology enters the market. Nevertheless 24.2% of respondents limit the benefit to the stage when it is still possible to incorporate their expectations during the development process.

The minority of respondents, who have shown concerns over societal actors inclusion in the technology development of the train, fear mostly the risk of disclosure of confidential information and creation of premature negative reactions, with 10.5% of responses, over the additional costs that it could bring to the development process 7.3%.

The breakdown of results in graph 5.55, below, shows the differences between respondents. These differences result from respondents learning pressures and room for learning (Deuten, Rip & Jelsma, 1997).



Graph 5.55. What represents technology alignment with societal actors? (Q26)
(in % of the total responses per category of stakeholders)

Graph 5.55 shows that manufacturers considered the most alignments with societal actors beneficial for public acceptance, 32%, and beneficial when it is still possible to incorporate their expectations, 20%. Which is in line with the aggregated values in the previous graph 5.54. However, manufacturers registered less responses, 12%, recognising the benefits in the creation of development paths with societal actors. Only universities resulted in the most supportive stakeholder with 36% of responses.

Most likely societal alignment represents for manufacturing a "single loop of learning", providing single ways of meeting their goals as being the degree of public acceptance of a new technology and their ambition of control rather than orchestrating the uncertainties and collective actions.

Differently, component suppliers rather consider societal alignment relevant if it is still possible to accommodate their expectations, 32%. This clearly links with their lower learning pressures from wider society than for the manufacturers as described, reflecting their position far from direct contact with customers of the train, the train operators, and the end users. Their room for learning is even lower than the manufacturing industry as many of them are dependent on a single technology subsystem with a shorter technology development cycle than for the assembly of a full train.

Yet for component suppliers the path creation with societal actors is considered by a greater percentage of respondents than for manufacturing, 16% vs 12%. For component suppliers this might mean a "double loop of learning" considering one's requirements and their ambition to accommodate rather than control.

In its turn train operators unanimously, 100%, considered the benefit in the involvement of societal actors in the technology development process as provider of acceptance for new technologies. One can speculate that one of the reasons is mostly exposed to customer and wider societal pressures as providers of the service. Room for learning is high with train operators looking for pre-acceptance of their train services. The lack of reference to path creation can be interpreted as an indication of the single loop learning as mentioned for manufacturing, as they bare no risks with societal actors involvement during the technology development process in hands of manufacturers and component suppliers.

Governments, the guardians of society, equally considered the benefits of societal involvement for public acceptance of new technologies and the benefice it brings when it is still possible to incorporate their expectations, each with 33%. Their pressures for learning are high. Alike for train operators no reference to path creation can be interpreted as an indication of the single loop learning as mentioned for manufacturing and train operators.

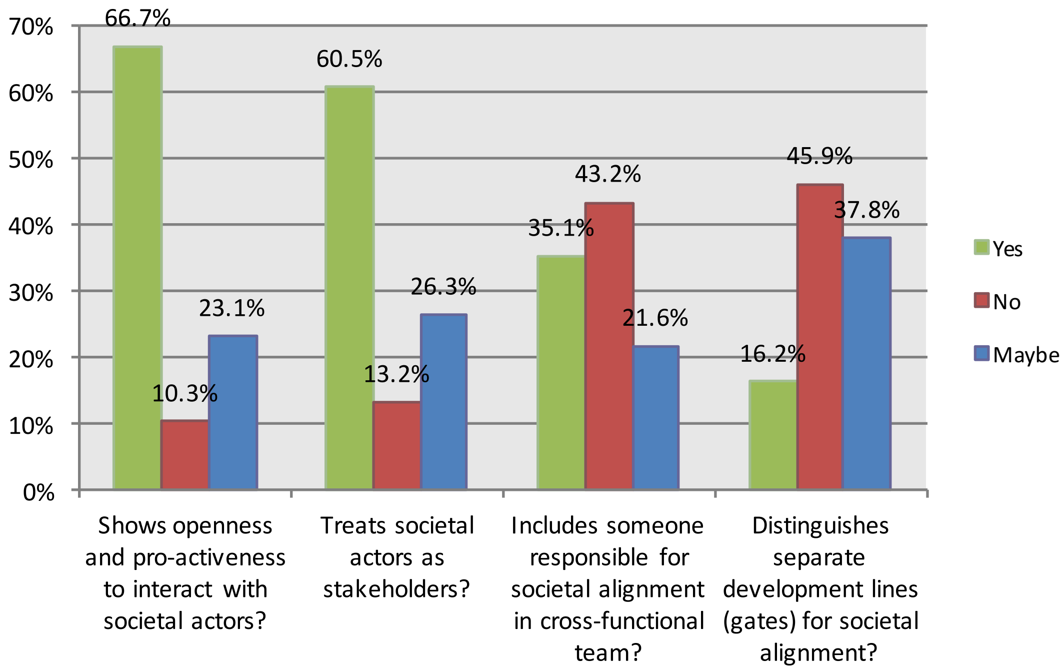
Q27. Management for societal embedding

Supporting dialog with societal actors to increase mutual learning is not straightforward. Firms and societal actors often have conflicting interests, different norms and values and different ways of interpreting the situation (Deuten et al. 1997). In addition, societal actors have little or no interest to discuss with firms unless they see that their involvement triggers a change (Rip et al. 1995). When exposure and openness to societal embedding is high large firms employ individuals who are responsible for communicating with societal actors and institutionalise the practice in their organizational structure.

In order to assess the above referred in the high-speed train industry respondents were asked if they consider or not distinctive *stage gates* during technology development process to align with societal actors; if they have someone in their institution responsible for societal alignment; if they treat societal actors as a stakeholder; if they are open and pro-active to interact with societal actors.

The questions were retrieved from part of table 2 in Deuten, Rip and Jelsma paper (1997, table 2, page 145) where the authors list the elements of societal inclusion approach in the management of product creation. The second part of the table is used latter in this survey in Q28. The authors call attention to the relevance of the mix, rather than considering them separately.

The results are presented in graph 5.56 below.



Graph 5.56. Technology management includes the following elements? (Q27)
(% of total of responses)

Graph 5.56 can be split into two parts. On the left side of the graph are two informal management elements of embedding societal actors in technology development refereeing to "openness and pro-attractiveness to interact with societal actors" and "treatment of societal actors as stakeholders" as they do not imply an institutionalized nor formal structure inside the organization. While on the right side of the graph are the two formal elements referring to "inclusion of someone responsible for societal alignment" and "consideration of gates for societal alignment" requiring the institutionalization and a formalization of societal inclusion in the management of technology.

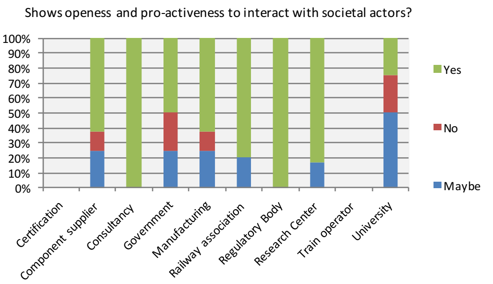
Graph 5.56 shows a clear inflection between informal elements and formal elements. Meaning that positive responses (Yes) have higher scores on informal elements and negative answers (No) have higher scores on formal elements.

Graph 5.56 reveals that a high percentage of respondents replied positively to informal elements covering their institution openness and pro-activeness to interact with societal actors, 66.7%, as well as in considering societal stakeholders per se as a stakeholder, against a small percentage of negative responses, 10.3% and 13.2% respectively.

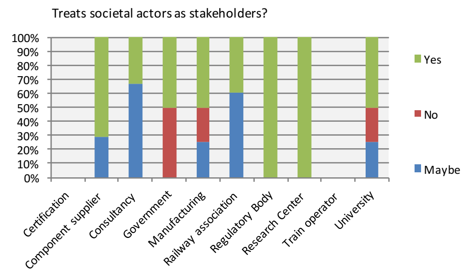
On the other hand, results from graph 5.56 reveal that a high percentage of respondents replied negatively to formal elements, namely the nomination of an employee in their institution responsible for societal alignment, 43.2%, and distinguishing separate assessment gates in technology development for societal alignment 45.9%, against a fewer percentage of positive replies, 35.1% and 16.2% respectively.

When analyzing the results breakdown by the different institution types one can find differences between them for the reasons referred in the previous section (greater exposure to societal actors, competition pressures, technology complexity, etc). See graphs 5.57, 5.58, 5.59 and 5.60 below, grouped in two, informal and formal elements.

a) Informal

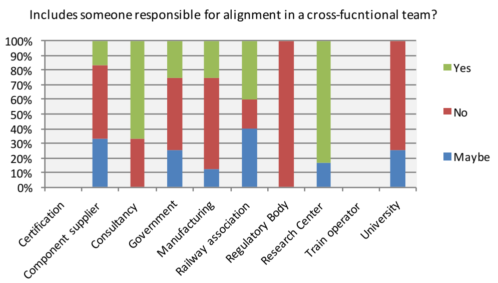


Graph 5.57. Technology management includes the following elements? Breakdown (Q27a) (% of total responses per category of stakeholders)

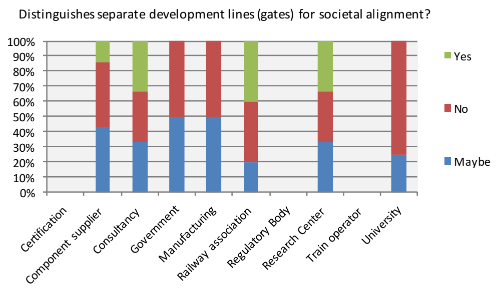


Graph 5.58. Technology management includes the following elements? Breakdown (Q27b) (% of total responses per category of stakeholders)

b) Formal



Graph 5.59. Technology management included the following elements? Breakdown (Q27c) (% of total responses per category of stakeholders)



Graph 5.60. Technology management included the following elements? Breakdown (Q27b) (% of total responses per category of stakeholders)

Focusing on formal practices of societal embedding in technology management, graphs 5.59 and 5.60, research centers were the most supportive. The majority of them 83% stated employing someone responsible for societal embedding. It was also found 67% of consultants employing a person who is responsible for societal alignment. Those consultants are often commissioned to undertake public consultations and assessments of behalf of the clients mostly for national governments.

Finally, it should be noted that in relation to graphs 5.59 and 5.60, manufacturing and component suppliers, even if in a small percentage, have someone employed to address societal embedding (25% and 17%). Manufacturers do not consider gates for societal alignment in technology development process 0%. Component suppliers however have a small percentage of respondents considering it 14% referring to end-user surveys.

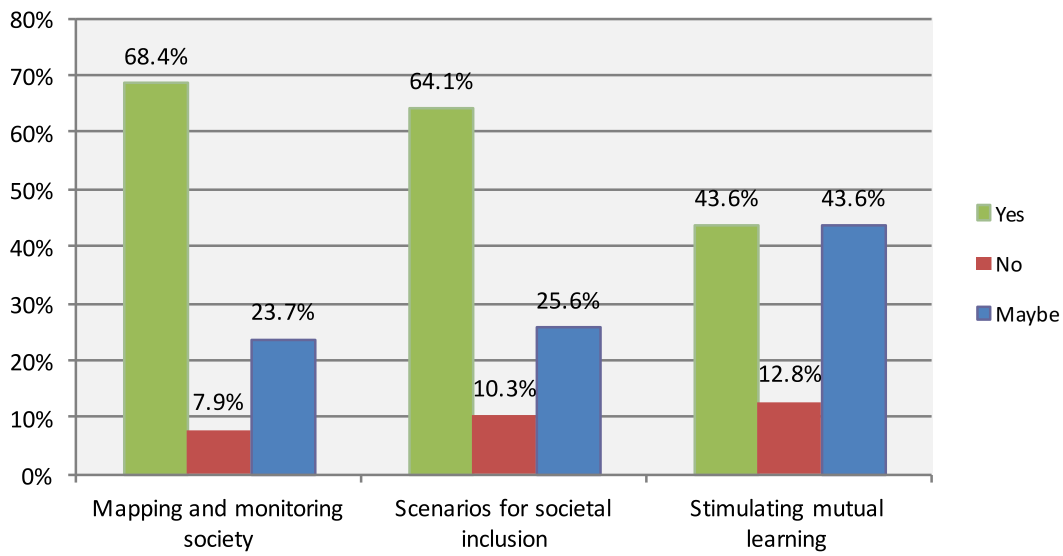
Q28. Dealing with the anticipation dilemma

Societal embedding in the technology development process introduces greater uncertainties, unknown-unknowns of vague constraints, creating the dilemma of anticipation (or Collingridge dilemma). According to Deuten, Rip & Jelsma (1997) the dilemma can be overcome by the articulation and monitoring of scenarios for societal embedding, mapping the relevant societal environment and stimulating alignments. The existence of these elements extends technology management traditional environments (business & engineering and policy & regulations) to the societal environment.

Question 28 was retrieved from the second part of table 2 in Deuten, Rip & Jelsma paper (1997, table 2, page 145), where the authors present the element for management of societal inclusion in the product construction process.

Graph 5.61 below presents the results for the high-speed train industry on the extended management to include the societal environment.

A "Yes" reply means that such activities are an institutionalised practice at the institution to which the respondent is affiliated. A "No" reply means that they are non existent. A "Maybe" means that they exist but informally.

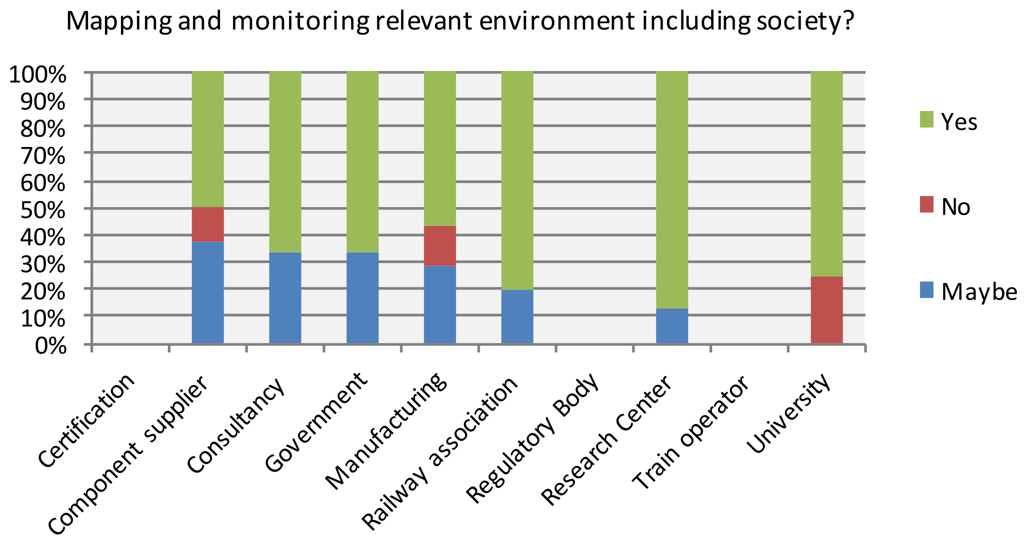


Graph 5.61. Do stakeholders pay attention to societal embedding when setting their technology strategy? (Q28)
(% of total of responses for each question)

During technological strategy setting, respondents replied that they are paying higher attention to mapping and monitoring relevant environments including societal actors with 68.4% of replies, but much less in the interaction with them with 43.6% of replies.

Also in graph 5.61 at strategic level there is a distinction between the intention and implementation of societal embedding less accentuated than it was at technology development level in the graph before (graph 5.56).

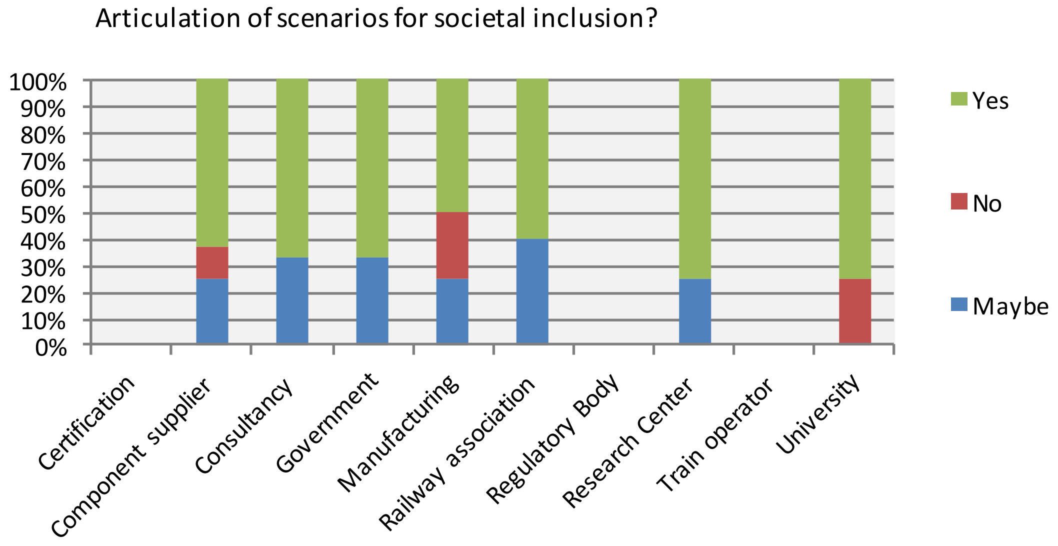
Results breakdown by institution type of respondents are shown in the graphs 5.62 to 5.64, below.



Graph 5.62. Mapping and monitoring relevant environment including society? (Q28a)
(% of total responses per category of stakeholders)

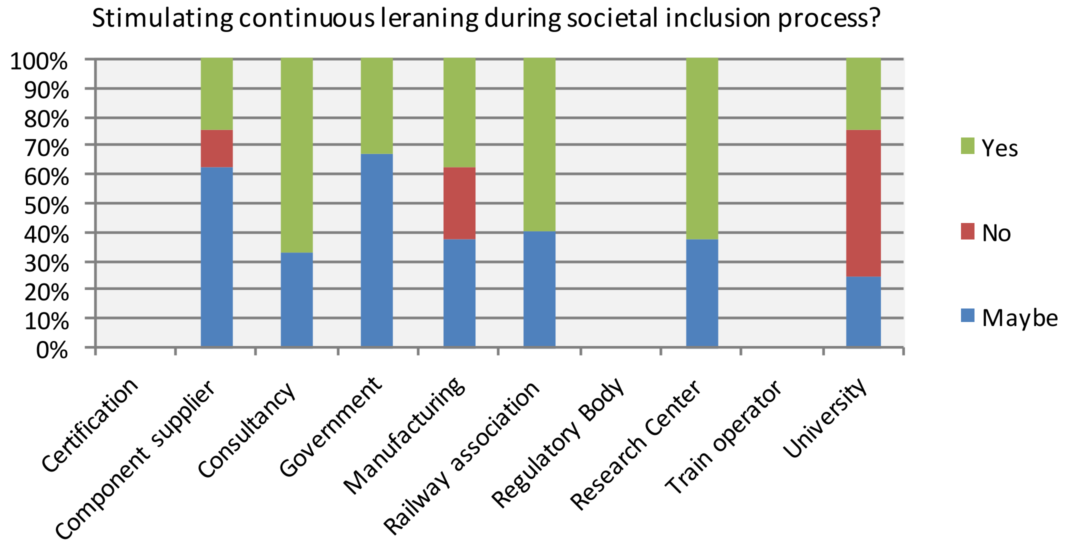
From graph 5.62 results one can say that mapping and monitoring societal environment is a wide institutionalised practice across all stakeholders. In particular, for research centers 88% and railway associations 80%.

The only negative responses to this question were from manufacturing 14% and component suppliers 13%, yet much below the positive ones 57% and 67%. Also from Universities, which registered a high percentage of negative responses 23% contrasting with the high percentage of positive ones 77%.



Graph 5.63. Articulation of scenarios for societal embedding? (Q28c)
(% of total responses per category of stakeholders)

In which respects the articulation of scenarios for societal inclusion, graph 5.63 shows an increase in "maybe" responses, meaning informal practices, across all stakeholders in respect to the previous graph 5.62. It also shows a moderate increase in the percentage of negative responses. The most significant one was found for manufacturing with 25% of responses.



Graph 5.64. Stimulating continuous learning during societal inclusion process? (Q28d)
(% of total responses per category of stakeholders)

When it comes to interaction with society by learning about their expectations, values and cultures, the percentage of "yes" responses decreases across all stakeholders, especially for component suppliers which have preferred to respond as "maybe" 63% instead of "yes" 25%. The informal character of this activities increases this way.

Results (Q26-Q28)

The overall balance for the high-speed train industry is positive towards societal actors inclusion and their recognition as a stakeholder (graph 5.56).

They adopt an extended technology management approach to address societal environment, during the technology development process (graph 5.56) and strategic planning (Q61), which is informal and unstructured.

The break down by institutions however has shown that there are differences between each stakeholder group, reflecting that each one has different learning pressures and room for learning depending on their positioning in the supply chain.

In terms of technology development process (graphs 5.57 to 5.60) the formal extended approach is practiced by a much smaller percentage of stakeholders (graph 5.59 and 5.60). Responses referring to the "inclusion of someone to address societal embedding" is mostly selected by research centers (graph 5.59). Governments, railway associations, manufacturers and component suppliers also accounted with positive replies but with a much smaller percentage. Manufacturers and component suppliers negative responses overtook the positive ones (graph 5.59). When referring to the inclusion of "societal assessment gates" during technology development (TRL), positive responses decreased to even smaller percentages, especially for component suppliers, governments and railway associations (graph 5.60).

In terms of the breakdown by respondents institutional affiliation of the extended strategic planning to societal environment (in graphs 5.61 to 5.64) results here show that if mapping and monitoring societal environment is relevant (graph 5.62), it is not so much so when it comes to the articulation of scenarios allowing for societal embedding, especially in which concerns for manufacturing, and stimulation of learning from societal actors, especially for component suppliers. Stakeholders in the railway industry reveal this way not having this practices institutionalized in their organizations lacking a structured approach.

v) Futures

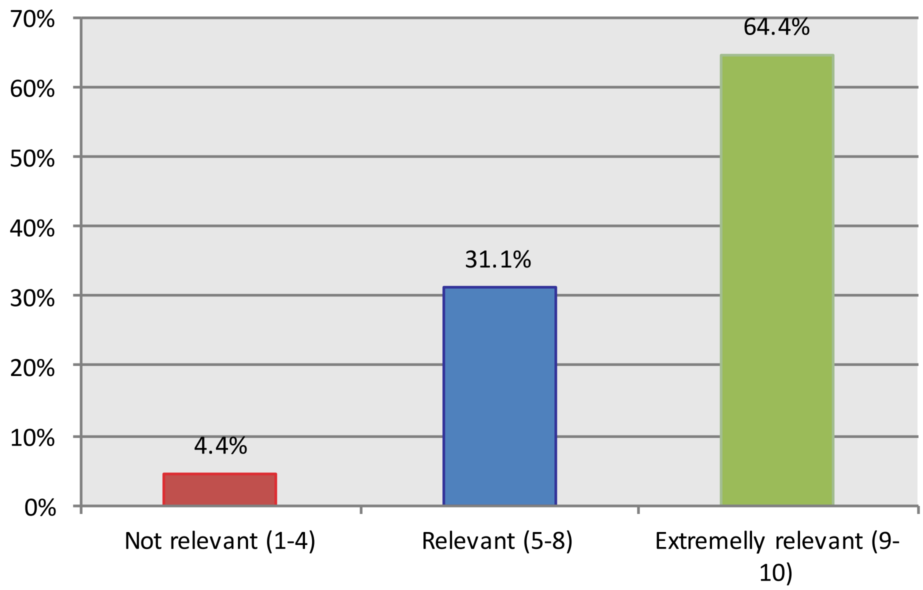
Social embedding in new product development requires anticipation (Deuten, Rip & Jelsma, 1997) by means of strategic intelligence (Huff, 1979). Besides enquiring the high-speed train industry on the societal inclusion in the setting of technology strategies and development process it is also relevant to enquire on their practices on future technology assessment and how they interlink with societal environment.

The objective in this part of the survey is to assess the way in which high-speed train technology scenarios are coping with the direct exposure to the societal environment. Since 2007 fast emerging ICT advancements empowering public inclusion[150] introduce greater complexity and broadening the collective of stakeholders.

This part of the survey questions the relevance of visioning the future (Q29), sources of information about future emerging drivers and constraints (Q30), the methods mostly used (Q31) and variables considered (Q32) as well as expected outcomes (Q33).

Q29. Visioning the future

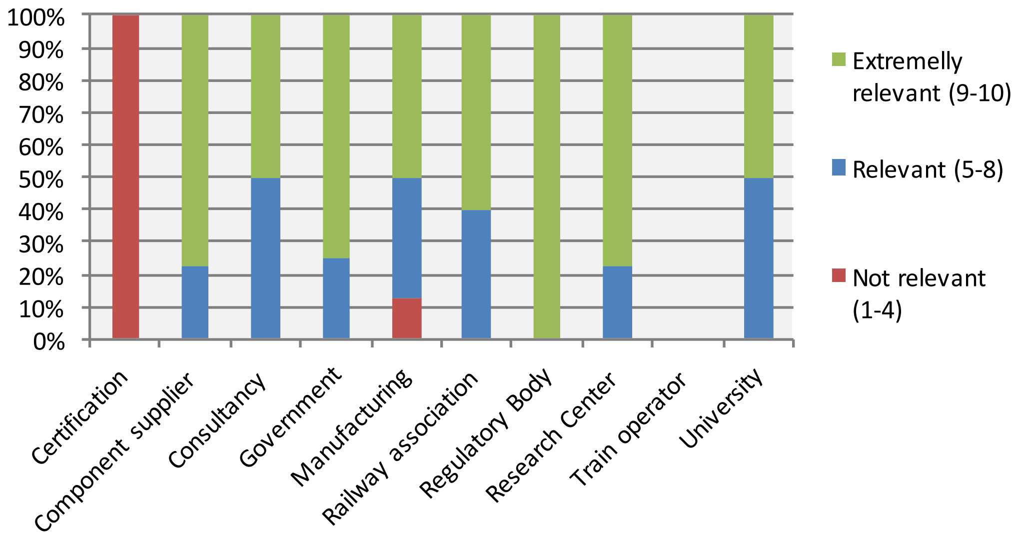
Future studies, of which a variety of methods can be grouped under the umbrella of Future-Oriented Technology Analysis (FTA), are used to improve the quality, robustness and legitimacy of decisions, by assessing potential effects of policy interventions and innovations (Schippl & Fleischer 2012).



Graph 5.65. Relevance in visioning the future (Q29)
(% of total of responses)

[150] Moretto et al. (2014) refered that for the high-speed train industry scenarios emerged from late 1990's expectations of a liberalized and integration across Europe of until then fragmented railway markets. From that time the industry shifted to tactic management of technology, covering national systems, to strategic, embracing the whole of Europe. Scenarios have contributed to a more informed strategy articulation through deepening and broadening the understanding of the changes in technical, market and regulatory conditions (i. e. environments). ERRAC visions and European railway associations market outlooks are the most referred examples yet by many criticized as ways of incumbents to control of new technology requirements. Moretto et al. (2014) continuous referring to the fast emergence since 2007 of ICT advancements empowering society by linking individuals in virtual communities as connected travelers and car sharing resulting in first time ever direct exposure of the high-speed train industry to the societal environment. These have enlarged the complexity and the scope of the collective of action.

Graph 5.65 above shows that the majority of enquired stakeholders consider futures extremely relevant (64.4%) compared to a small minority considering it not relevant (4.4%). Results breakdown by institution types are shown below.



Graph 5.66. Relevance in visioning the future. Breakdown (Q29)
(% of total responses per category of stakeholders)

The small percentage of respondents attributing no relevance to futures corresponds to certification bodies 100% and manufacturing 13%.

One could expect from certification bodies less relevance given to future exercises, as their mission is to enforce new technologies compliance with existing technical requirements at the time of their entry in the market. Certification bodies have an operational function, less of a strategic one. However, the same cannot be said for manufacturers, even the percentage was quite low, if considered that they develop technologies lasting 30 to 35 years.

Train operators here have not replied to this question. This might well reflect their dominant positions with some of the manufacturers and train operators seeing in futures a threat rather than an opportunity.

The highest percentage of responses attributing extreme relevance to futures comes from component suppliers 78% and research centers 100%.

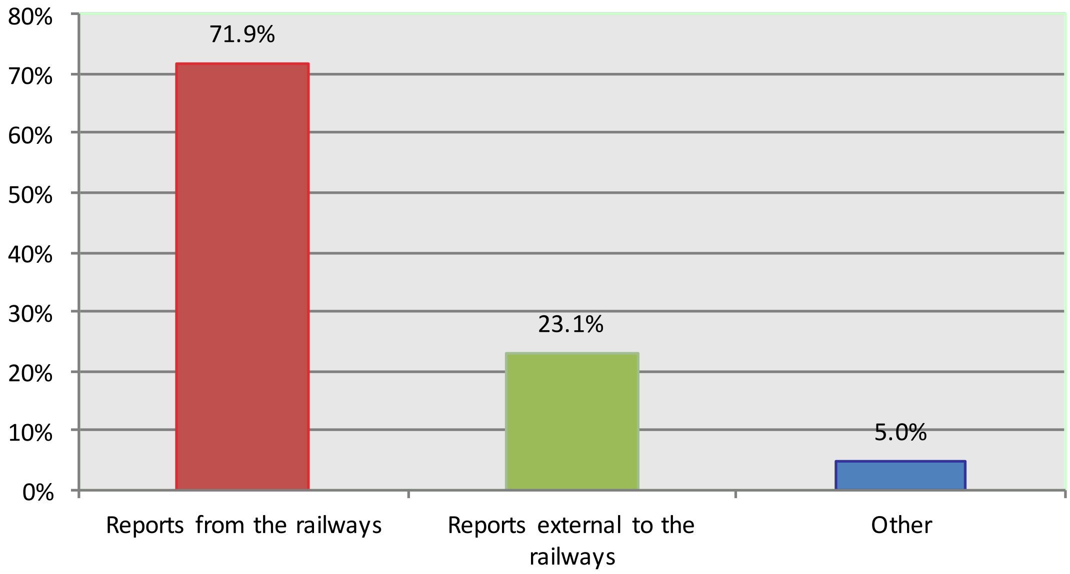
Results from research centers are inflated due to the high participation from non-engineering ones, dominated by providers of technology assessment which includes futures as part of their core activities. High consideration of futures is expected from them. Universities provide a more realistic picture on the relevance of futures from its participation of respondents affiliated to both social and engineering schools, with 50% responses on relevant and 50% on extremely relevant.

Component suppliers, with 78% of responses considering it extremely relevant, also attribute high-relevance to futures from their increased learning pressures and room for learning (discussed before).

Q30. Sources of future reports

There are many different sources of future reports. They can be internal or external to the industry or even a mix of both.

The graph 5.67 below presents the relevant sources of information on futures according to respondents from the high-speed train industry.



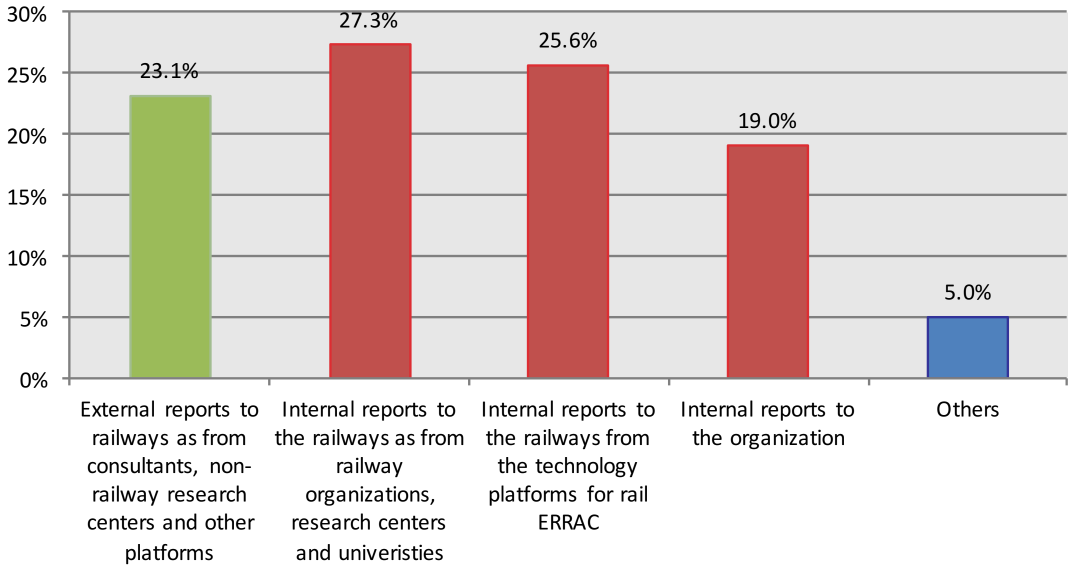
Graph 5.67. Futures sources of information (Q30)
(% of total of responses)

Reports elaborated by the railway industry stand in graph 5.67 as the main source of information 71.9%. They range from collective visions as the ones issued by the European railway technology platform ERRAC, or the manufacturers association UNIFE outlooks and railway operators scenarios as from CER-UIC, to individual foresight exercises as from Siemens made public or internal. They produce endogenous and techno-centric orientations for future technology developments and are dominated by incumbent stakeholders.

Future reports external to the industry have less percentage of replies. They include reports from third parties such as consultancies, multidisciplinary research centers or other sectors as from energy, materials and disciplines as social sciences. They also include reports commissioned by governmental bodies as the European Commission, European Parliament and national parliaments. They tend to cover a broad societal environment addressing greater uncertainties and broad spectrum of actors.

Others, accounting for 5%, are actually a mix of both internal and external reports to the railways, ranging from scientific papers, including the ones on meta-trends, customer needs and current problems, are the examples referred by some respondents.

Before breaking down the results by institution type, it is worth first further distinguishing the reports from the railways such as the ones from associations, research centers and universities from those coming from the rail technology platform ERRAC. Results in graph 5.68 below.

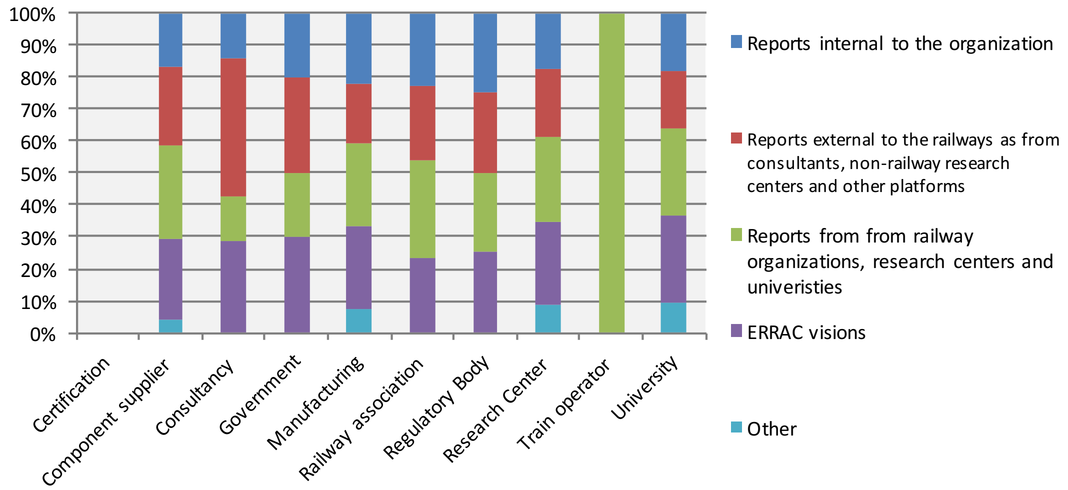


Graph 5.68. Futures sources of information, breakdown internal reports (Q30)
(% of total of responses)

Future reports from the railways' organization, research centers and universities are prevalent sources of information, with 27.3% of replies. They range from collective exercises, in its majority not covering the full value chain, as it would be UNIFE outlooks, to individual ones as could be a report from a research center. ERRAC visions follow with 25.6% of responses. They have a collective character contributing to it all the stakeholders in the value chain. As they lack involvement of an external third party they produce endogenous visions of what the railways would like the future to be, suggesting new technologies they can control.

Future reports external to the railways, such as from consultants, non-railway research centers and non-rail technology platforms, come third with 23.1% of responses, only above reports internal to the organizations. Those include the ones commissioned by governmental bodies as the European Commission, European Parliament and National parliaments. Those types of reports involve external actors to the railways producing external visions with links to unknown constraints and technologies to the sector.

In the graph 5.69, below, follows the breakdown of results by institution type.



Graph 5.69. Futures sources of information. Breakdown by institutions (Q30)
(% of total responses per category of stakeholders)

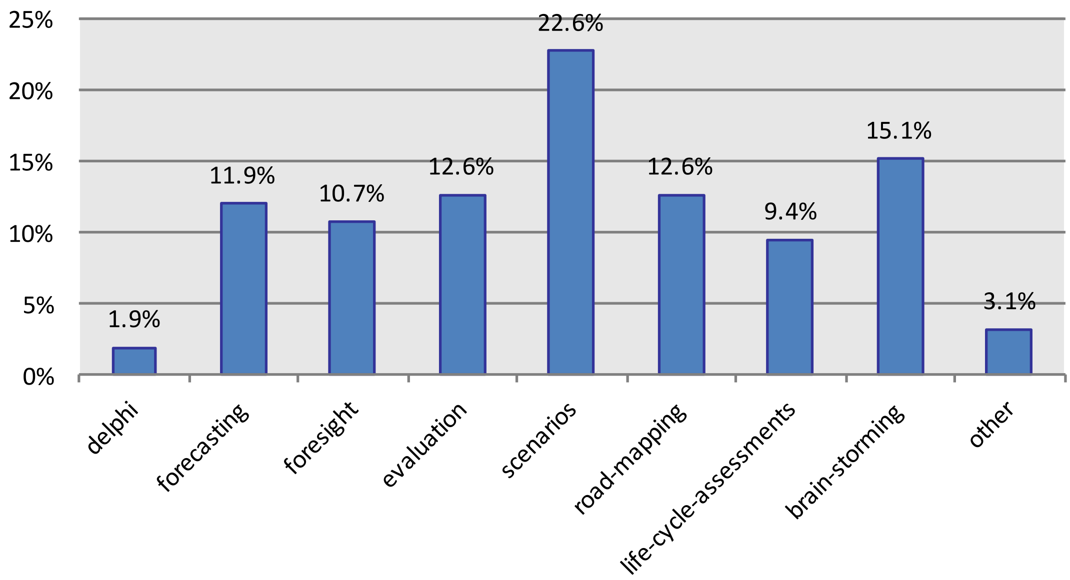
Graph 5.69 shows that all stakeholders recurred to external reports, with consultancies having the highest percentage of all 43%. It is the only stakeholder which external reports are their main source of information.

Governments also attribute relevance to external reports, even to ERRAC visions, each their main source of information with 30% of responses. Here one could speculate that ERRAC meets its purposes as their visions mostly target policy-making.

Component suppliers 29%, manufacturing 26%, railways associations 31%, research centers 26%, train operators 100% and universities 27% showed preference for reports from railways. With manufacturing, research centers and universities attributing the same percentages to ERRAC visions. It is interesting to notice that train operators did not refer at all to ERRAC visions while the remaining respondents did.

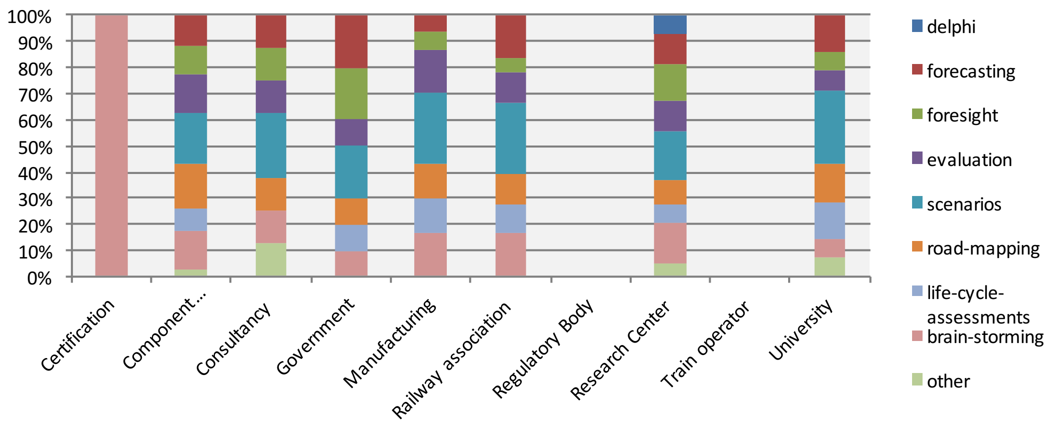
Q31. Methods to access futures

Future studies include a wide range of methods such as Delphi, forecasting, foresight, evaluation, road-maps, life-cycle-assessments, brain-storming. Respondents were asked which ones they used. Results are presented in the graph 5.70 below.



Graph 5.70. Methods used in futures (Q31)
(% of total of responses)

Graph 5.70 shows scenarios as the most referred method, with 22.6% of responses, such as the ones used by ERRAC visions. Further down with 15.1% is brain-storming, as performed by some railway associations, 12.6% road-mapping found for example in ERRAC, also with 12.6 % evaluations, 11.9% forecasting as the one issued every two years by UNIFE, 10.7% foresight like those of Siemens, 9.4% life-cycle-assessment and only 1.9% Delphi.



Graph 5.71. Methods used in futures. Breakdown (Q31)
(% of total responses per category of stakeholders)

Scenario methods clearly outweigh other methods in the application of future studies by the majority respondents part in the technology supply chain, particularly for manufacturing 27%, universities 29% and railway associations 28%, component suppliers 20%.

At the other extreme, train operators seem not to be involved at all in futures formulations from their lack of selecting futures methods. One can assume that they delegate this task to their associations as UICs, part of the stakeholders group called railway associations, and consultancies. This can suggest a division labor also existing in this industry formulation of futures.

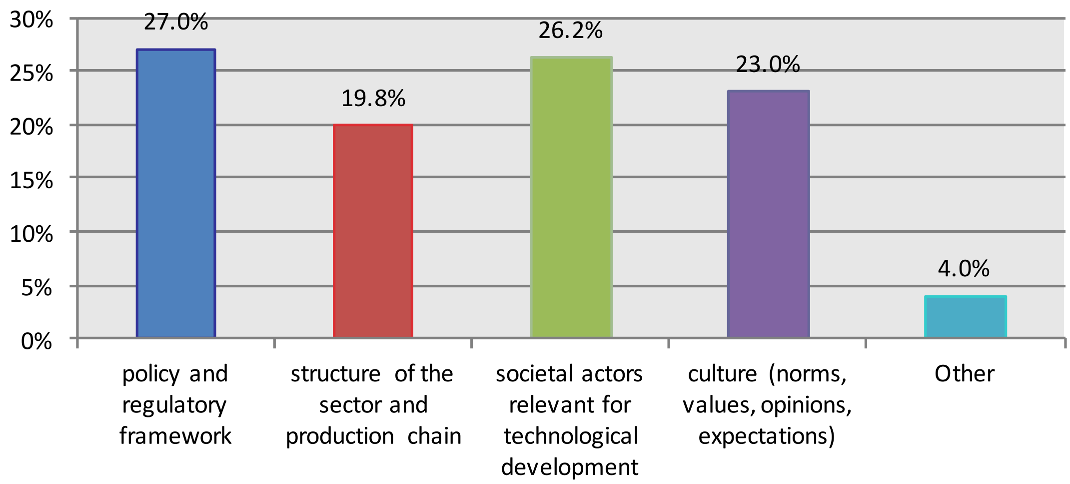
Regulatory bodies, also with no selection of methods, indicate that they delegate the formulation of scenarios to governments, as is the case of the European Railway Agency sourcing information from the European Commission or European Parliaments reports.

Other types of methods listed by respondents from universities, research centers, consultancies and component suppliers were backcasting, listening the user and gut feeling.

Q32. Futures should consider

Deuten, Rip & Jelsma (1997) and later Robinson (2009) refer that futures address environments of selection for new technologies, being the business environment (such as the structure of the sector and production chain, technology trends) the regulatory environment (including policy, regulation and standards) and societal environment (such as societal actors and cultures, values, opinions, expectations).

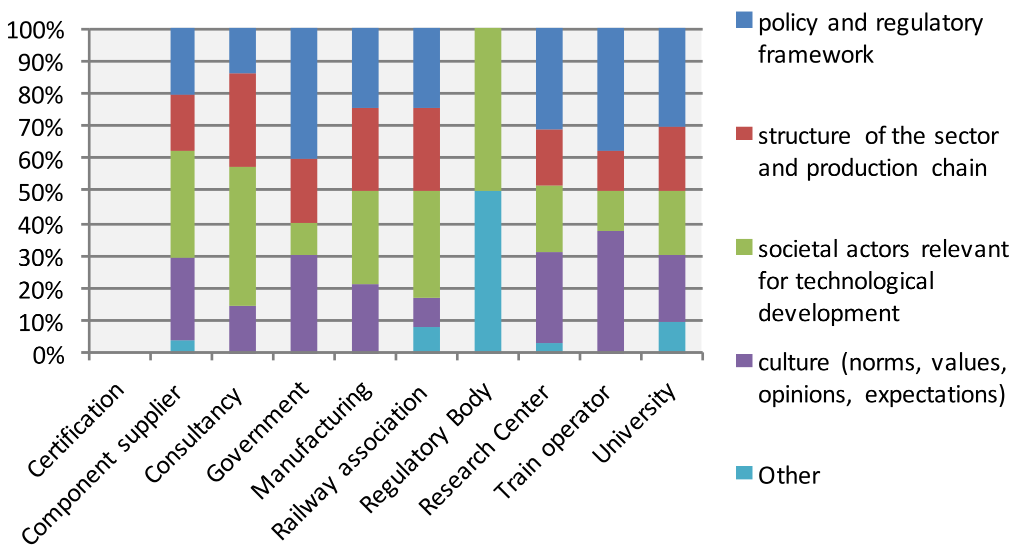
The graph 5.72 below shows results for the high-speed train industry, representing the industry's desired anticipation for control.



Graph 5.72. Aspects futures should consider (Q32)
(% of total of responses)

These elements of anticipation for control which had the most weight were for the high-speed industry policy and regulations 27%, followed closely by societal actors relevant for the technology development 26.2%.

The lowest percentage of replies on the supply chain (19%) can reflect the considerable stability of the supply chain with few new players emerging, as incumbents do not feel vulnerable to potential threats form far landscape.



Graph 5.73. Aspects futures should consider. Breakdown (Q32)
(% of total responses per category of stakeholders)

Graph 5.73 reveals policy and regulatory framework the priority for governments 40%, research centers 31% and universities 30%, with the highest rate of responses. Also train operators highly consider it but aside to culture, each with 38% of responses.

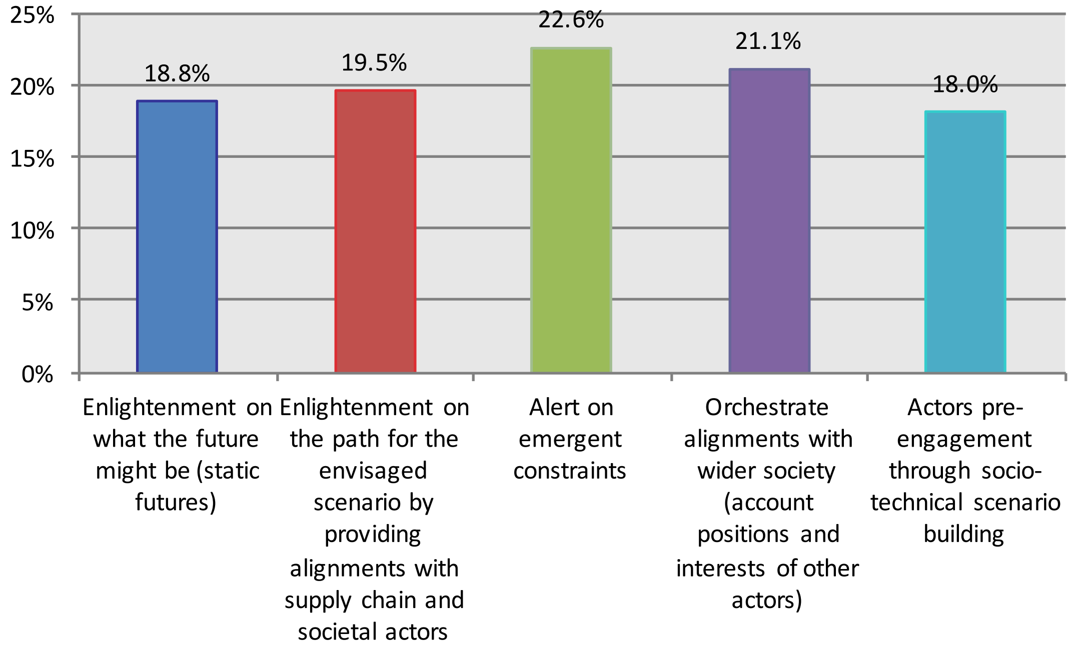
Manufacturers, component suppliers and railway associations place a high weighting on societal aspects above the other options. A reason for this could be because, in the case of manufacturing and component suppliers they feel societal technological selection pressure much more than other stakeholders

This is not the case for the train operators. They equally prioritize policy and regulatory framework as well culture, 38%, each above societal actors and structure of the sector both 13%.

Q33. Futures expected contribution

Expectations in relation to contributions of futures studies reflect two main attitudes from stakeholders, the one of control and the one of orchestration. According to Robinson (2009) control refers to futures for the articulation and emphasis on desirable end points, while orchestration focuses on revealing underlying dynamics of co-evolutions and supporting mutual learning. Formalised expectations on the future, such as roadmaps, alert on emergent constraints and opportunities reflecting a position of control (Robinson and Propp 2008). Orchestration usually occurs through structured interactions and between stakeholders through brainstorming, horizon scanning workshops and other forms of interactive future assessment.

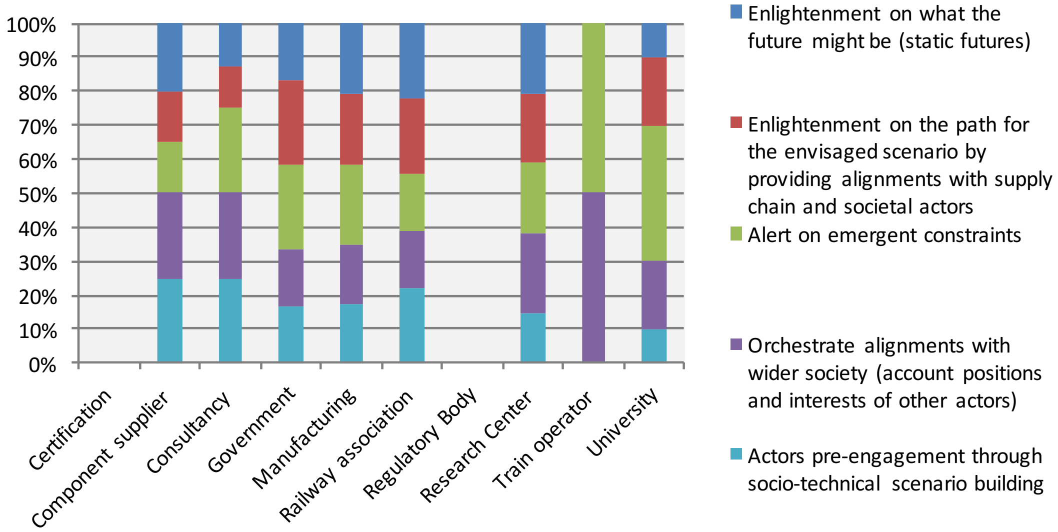
The graph 5.74 shows the results for the high-speed industry.



Graph 5.74. What futures should consider (Q33)
(% of total of responses)

Graph 5.74 shows stakeholders expectations when formulating scenarios are dominated by control of emergent constraints 22.6%. Yet the stabilization character of futures comes just after with the orchestration of alignments with wider society with 21.1%.

Interesting to note is that none of the respondents selected others nor gave comments, which might be an indication that did not well understood the question.



Graph 5.75. What futures should consider. Breakdown (Q33)
(% of total responses per category of stakeholders)

For each stakeholder group, dominant expectations reflect its positioning in the technology supply chain.

For example, components suppliers expect futures to establish pre-engagements and alignments on technological developments they control 25%.

While on the other hand manufacturers expect anticipation of emergent constraints from areas outside their control, as they might not see it from where they are at regime level 24%. Manufacturers have a control position across the supply chain, which justify orchestration and pre-engagements the lowest of their concerns both with 17% of responses.

Train operators, in their turn, value the alert mechanism 50% it provides as well as orchestration 50%, which one could speculate on futures as a tool of direction.

Railway associations' expectations actually reflect their mission towards serving their members interests by enlightening their members on the possible futures and engage them on a common direction with an approximated distribution of responses across all the criteria.

Results (Q29-Q33)

Futures are considered by the highs-speed train industry as extremely relevant 64.4% against a small minority considering it not relevant 4.4% (Q29).

The most referred type of reports were those endogenous to the industry with (Q30) with 71.9% of respondents referring to them against 23.1% referring to external reports. They range from collective visions such as the ones issued by the European railway technology platform ERRAC, or the manufacturers association UNIFE outlooks and railway operator scenarios as from CER-UIC, to individual foresight exercises as from Siemens made public or internal. They produce endogenous and techno-centric orientations for future technology developments and are dominated by incumbent stakeholders. Of those internal reports to the industry the most referred to where the ones from railway organizations, research centers and universities 27.3%, ERRAC visions 25%. External reports only came after with 25% of responses, considered the most by consultancies, governments and regulating bodies.

Scenario methods clearly top other methods with 22.6% of responses for key stakeholders in the technology supply chain, which are research centers, manufacturing, universities, component suppliers and railway associations (Q31).

The elements of anticipation for control (Q32) are for the high-speed industry policy the regulations 27%, followed closely by societal actors relevant for the technology development 26.2%. The lowest percentage of replies on the supply chain 19% can reflect the considerable stability of the supply chain with few new players emerging, as incumbents do not feel vulnerable to potential threats from areas distant from their expertise and core action space.

Component suppliers are actually the ones mostly concerned about societal aspects in future visioning in relation to the other listed aspects they consider. Maybe because they feel much more their selection pressure from the type of technology they supply, in this survey mainly on interiors, ICT and materials impacting comfort.

Respondents expect from futures exercises to control for emergent constraints 22.6%, followed by stabilization of the future through orchestration of alignments with wider society with 21.1%. Each respondent dominant expectation reflects its positioning in the technology supply chain. For example, components suppliers expect futures to establish pre-engagements and alignments on technological developments they control. While on the other hand manufacturers expect anticipation of emergent constraints from far landscape as they might not see it from where they are at regime level. As manufacturers have a control position over the supply chain orchestration and pre-engagements are at the lowest of their concerns. Train operators in their turn value the alert mechanism it provides as well as orchestration, which one could speculate on futures as a tool of direction.

5.6. Survey main results

Technological related aspects, - speed, comfort and ticket faire - are the main reasons for making people deciding to take a high-speed train in their medium to long distances travel.

The survey corroborates that the development of those technologies are in hands of component suppliers, manufacturers and research centers (Q11), mainly from Germany and France (Q12). They have a relative interest to involve users and wider society (Q3), except for component suppliers. Also users have expressed little interest to be consulted on the technical aspect of the train unless they impact their riding experience (Q3).

A. Main Results – Strategic Innovation Management

This part of the survey validates the finding in chapters 4.1 dedicated to technological strategic intelligence and chapters 4.3. on multi-level perspective in knowledge exchange and deepened the learnings there captured.

- The survey demonstrates that higher levels of R&D spending (Q13) are found not within the manufacturers but within component suppliers and research centers and that train operators are heterogeneous in their spending.
- The industry reports to strategic intelligence guidelines (Q14) informed by formal channels of technology surveillance (Q15) mainly positioned in networks (Q16).

- Their main purpose for undertaking technological developments is to survive in open market conditions mainly by anticipating societal changes, policies and market constraints and then to make the final product attractive to the end-user (Q17). Manufacturers, however, are in contrast by mainly pursuing technological development for product and design improvements, manufacturing optimization and cost reduction (Q17).

- The industry is dominated by incremental innovations, reflecting the monopolistic and incumbent nature of their stakeholders (Q18).

- The industry is split in their openness for collaborative research (Q19) with manufacturers and research centers mainly expressing preferences for R&D in consortia while component suppliers in-house. User engagement in the technology development is however quite low across all the stakeholders enquired (Q20), with research centers expressing the highest interest to involve them. Preference goes to collaborative research performed with specialized knowledge providers as research centers and universities (Q20).

- Societal challenges, policies and market constraints are the main factors leading for collaborative research with technical problems left to be solved by in-house research (Q21). At collaborative level manufacturers are aligned with the general trend (this did not occur in Q17).

B. Main Results – Societal embedding innovation management

This part of the survey narrows strategic technology management to societal aspects, related to a high degree of "reflexive" anticipation and therefore validates the finding in chapters 4.4 dedicated to future oriented technology assessment.

- The high-speed train industry attributes high levels of relevance to the societal environment, above policy & regulations. However business & engineering dominates (Q22).

- Societal requirements are relevant at the initial stage (Q23) of technology development process (TRL1) when basic principles are observed and data collected. Then their relevance progressively declines to its minimum (TRL4) when the technology is validated. Latter they regain momentum when the new technology has matured, ready to market (TRL8 & TRL9). Different from manufacturing, component suppliers tend to consider societal requirements in all stages of development.

- Alignment with societal actors are considered by a great majority of respondents as way of risk mitigation of technology failure (Q26). Manufacturing and researcher centers showing the highest of support but also of concerns. The benefits of shared technological paths it is the least considered by manufacturing.

- Societal embedding is dominated by informal practices (Q27) with a great percentage of respondents stating openness for interaction with societal actors and their recognition as a stakeholder in the technology development. Only a few however referred employing someone responsible for societal alignment, mainly coming from research centers. Even fewer mentioned technology assessment gates to address them, such as a minority of component suppliers, consultancies and railway associations.

- (Q28) Mapping and monitoring societal environment is relevant for the industry. However the articulation of scenarios allowing for societal embedding and stimulation of learning from societal actors is the least referred, except for research centers. The industry rather controls than orchestrates their dialogue with societal actors.

- Results here show that the most referred type of Future Technology Assessments are endogenous to the railways presenting their techno-centric visions to an envisaged future they aim to control (Q.30). Exception goes to governments and some consultancies referring the most to external reports more inclusive of the wider society and capable of covering wider collective of stakeholders.

- In terms of methods used (Q25) respondents equally considered qualitative and quantitative approaches. Manufacturing however standout from other stakeholders by prioritizing quantitative methods, less appropriated in assessing vague and not-known for the industry societal requirements.

In the broadening of selection environments of new high-speed train technologies to the wider society it was not observed that technology options assessment nor strategic agenda setting shifting in the same way. Today assessment of technology remains focused on market uptake of new products and services, overlooking opportunities that can arise from embedding societal capabilities in the product development process and review them at all stages of development.

Strategy intelligence in this industry requires this way to adapt to the brother equation of product selection by promoting a reflexive systemic anticipation of controlled speculation based on exploring the co-evolution of the high-speed train socio technical system of an extended spectrum of stakeholders, which ultimately generates value.

VI. FINDINGS SUMMARY

In this chapter relevant findings are presented, with the purpose to contribute to the railways debate on the urge for the market-uptake of new technologies. I do it by calling attention to the societal environments of technology selection requiring the bridging of the network of high-speed train technology stakeholders and the emergent digital society (as connected travelers and sharing communities) in ways that creates value for the industry.

To meet that purpose Constructive Technology Assessment (CTA) stood-out from the various TA strands identified, providing the adequate framework of analysis. This is because it addresses technology as the construction of networks of actors, which act at the level of science and technology, constraint by different environments of technology selection (business, regulatory and societal). CTA is therefore applicable to the high-speed train technology development which results itself from the assembling of various stakeholders' technological capabilities in a system that works.

CTA proposes a strategic intelligence model to extend the network of technological stakeholders to society from early stage of development process. CTA has been positioning itself as a way to overcome the institutionalised division of labor between promotion and control of technology, referred to as the Collingridge dilemma. It deals with the inherent asymmetries between "impactors" (insiders, at the source of the technology) and "impactees" (outsiders, impacted by the technology) with heterogeneous expectations and capabilities (as well as different powers, timings, interests, resources, etc).

CTA proposes doing it by bridging events between those heterogeneous actors orchestrated by a third party, to probe each others assessment worlds (supply-chain plus in Robinson & Propp 2008), and ultimately arrive to socio-technological scenarios of aligned visions (Te Kulve & Rip 2011). Those scenarios not only take actors initiatives and interactions into account but also their surroundings. They are not used to extrapolate particular developments into future (control function) but rather to enhance the flexibility of stakeholders regarding their strategic decisions (mutual-learnings), which in its turn is what modulates technology developments.

As it was seen CTA offers a two-fold application (i) analysis making (e.g. setting the scene: problem identification, phase in which is the technological development, actors involved and mapping on their expectations); and (ii) practice-oriented (e.g. models for interventions allowing for technological future formulations embedding society).

CTA methods for analysis range from data collection and interviews allowing placing concerned innovation journey in context (main reference Deuten, Rip & Jelsma 1997), to define multi-level-perspectives (as further developed by Geels 2002) and to determine collective strategy formulations (elaborated by Robinson & Propp 2008). CTA practice-oriented methods refer to socio-technical scenarios (elaborated by Te Kulve & Rip 2011) supported by methods including bridging events (Parandian 2013); third party mediation of pre-engagements (te Kulve and Rip 2012); bridging gaps between technology development and use (Paridian 2012, Robinson 2010); backcasting (Schippl 2008); inclusion of unknown unknowns (Justen et al. 2014).

In this dissertation I apply CTA analysis-making function to the high-speed train technology development process, as to find evidences of societal embedding practices in this industry. CTA practice-oriented on strategic future agendas was left out from this dissertation. Such because in itself constitutes another research enterprise as could well be a post-doc that could be conducted within SHIFT2RAIL or even ERRAC.

This dissertation fills a gap in CTA literature, which has been mainly focused on basic research in nano-technology, by extending it to mature innovations and further bring its application from the science domain to the technology area.

Moreover, the analytic framework structure of the dissertation could be tested in other train models, as light-rail and rapid transit, or even other sectors as e-mobility.

The application of the theoretical framework of analysis offered by CTA to the cases of the AGV and ICE-350E unfolded in manufacturers strategic intelligence, technology transitions, multi-level perspective and future formulations.

Theory places Technology Assessment in strategic intelligence. Kuhlmann (1999) is the first conceptualising it. Smits et al. (2008) further elaborate on its distinctive elements (as focus on decision-making support, problem orientation, intensive interaction with the wide of actors. Schot and Rip (1997) reinforce the element of anticipation from early stage of development. While Deuten et al. (1997) formulate the previous on the new product creation process extended to society. I found however that Deuten et al. (1997) do not detail the optimal organisational structure of firms or its networks to conduct societal embedding. To overcome such a theoretical gap, I referred to Lichtenthaler (2004) technology surveillance studies.

By studding Alstom and Siemens strategic intelligence organizational structure and technology development process it was found that Alstom and Siemens strategic intelligence broadly aligns with CTA societal embedding recommendation. Both manufacturers filter societal constrains at socio-economic and to some extent policy levels; they have in place surveillance structures of employees working mainly at the subsidiaries; they also have professionals participating in external expert networks and in contact with lead users and suppliers; their privileged partner for societal surveillance are universities and component suppliers; and they give preference for societal embedding in non-core-technologies as interiors and telematics.

In which Alstom and Siemens did not seem aligned with CTA societal embedding principle was on the technological decision-making trajectory. For both manufacturers it was found societal alignments occurred mainly during the commercial trajectory at the interception with the technical, by the time the technology was matured and ready to commercialise. Constructivists advocate that it should rather occur much earlier in the development process (Deuten et al. 1997). This is an indication that during the development of the AGV and the ICE-350E Alstom and Siemens monitored societal constraints for a purpose of "promotion" and "control" rather than product alignments (Deuten et al. 1997).

Despite the above referred, evidence was not found at which technological readiness level societal embedding actually occurred. Also missing was the study on other stakeholders part of the supply chain of Alstom and Siemens. Both aspects were later covered by the survey.

Technology transition and the multi-level perspective are central analytical tools as they feed the main function of CTA in the understanding of the co-evolution of socio-technical systems. They were introduced in the 1990's. Technology transition by Rip and Kemp (1998) and Johan Schott (1997) and Multi-Level Perspective by Rip and Kemp (1998). It was proved very useful with Geels visualisations (2002a and Geels & Schot 2007) further developing both models.

By applying CTA technology transition model it became evident that both trains, the French AGV and the German ICE-3050E, represented a shift in Alstom and Siemens strategic decision-making. They refer to the transition from hardware to software technological developments as policy and regulatory constraints became the primary trigger for technology change. Alstom and Siemens developed these trains in the race to champion supply to the trans-European high-speed networks and have their standards a reference in interoperability. It was also possible to visualise the first signs in the emergence of a new approach in Alstom and Siemens technology decision-making that most likely will precipitate them to socialware developments driven from the exponential digitalisation of society and social innovations they arise.

To explore the multi-level perspective between the various actors in terms of technological knowledge exchanges happening during the development process of the AGV and ICE 350E (2001-2008) I further applied Geels levels of analysis (niche, regime, landscape arenas, in Geels and Schot 2007, to which Robinson 2009 refers as arenas-of-action) combining it with Pavitt revised taxonomy of innovation.

From this exercise it became evident that the AGV and ICE-350E were developed in a period of emergence of strategic reports where technology actors aligned their perspectives. Each reflected the technological arena of the commissioning stakeholders; they were mainly produced at regime level; and feeding on each other reports. Less covered in this alignment of perspectives where societal actors at landscape. During this particular period those societal actors were mainly non-governmental organizations and specific interest groups.

It is relevant to note that two main typologies of reports were observed: dominant techno-centric visions produced at regime level (e.g. endogenous to the AGV and the ICE-350E supply chain), and policy foresight reports covering perspectives of actors produced at landscape level (e.g. exogenous to the AGV and the ICE-350E supply chain). Such indicates a discontinuity in the alignment of perspectives between actors at regime level and landscape which were further deepened when studding railway futures formulations.

Robinson and Propp (2011) adapted classification methods proved to be a good tool to classify railways future assessment reports addressing the high-speed train technology system and diagnose the extension of societal embedding within the formulation of the collective socio-technical scenarios.

It was found that visions, roadmaps and other forms of future strategic formulations were relevant in contributing to the revitalization of railways since 2001. However the methodological gap found between railway endogenous techno-centric visions and policy exogenous visions signal that railways future formulations might risk to miss their function if overpassing the emergent new societal challenges occurring at landscape from digitalisation producing social innovations.

Notorious was the case of ERRAC visions and road maps. They provide a pre-competitive forum (inclusive and dynamic), aiming and allowing for multi-level perspective alignments in the liberalized market conditions. 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 triggered and stimulated collaborative research projects, of which the first wave has been to a certain extent embedded in AGV and ICE-350E trains becoming part of the dominant designs and voluntary norms.

However, there is still a long way to go. The need for forums such as ERRAC to move beyond the dominance of endogenous roadmaps (highlighted in this paper) to a mix of endogenous and exogenous roadmaps and other forms of future strategic formulations (such as the STOA type activities) is becoming a pressing issue. SHIFT2RAIL recently launched will inevitably have to address it. This call for more exogenous future strategic formulations is further amplified by other shifts in the socio-technical system of high-speed railways. For example, as I have shown initially the railway operators and their manufacturers once held a strategically important position of being knowledgeable of the whole supply chain. However today they are no longer knowledgeable about the whole technology system. They moved from in-house production by the major manufacturers to outsourcing, pressed by 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.

The survey conducted to the breadth of the technological stakeholders confirms that societal embedding through technology assessment fits the strategic innovation management of the high-speed train technological network as found individually for Alstom and Siemens. Overall respondents have proved that railways are an R&D intensive industry, with the majority of them stating that reported to strategic intelligence guidelines (Q14) informed by formal channels of technology surveillance (Q15), mainly positioned in industry networks (Q16).

The survey also confirmed that railways main purpose for undertaking technological developments is to survive in open market conditions by anticipating societal changes, policies and market constraints and then to make the final product attractive to the end-user (Q17). Manufacturers, however contrasting, mainly pursue technology development for product and design improvements, manufacturing optimization and cost reduction (Q17). The industry is dominated by incremental innovations, reflecting the monopolistic and incumbent nature of their stakeholders (Q18).

The industry is split however in their openness for collaborative research (Q19) with manufacturers and research centers expressing preferences for R&D in consortia while for component suppliers is in-house. User engagement in the technology development is however quite low across all the stakeholders enquired (Q20), with research centers expressing the highest interest to involve them while preferences go to collaborative research performed with specialized knowledge providers as research centers and universities (Q20).

All stakeholders consider societal challenges, policies and market constraints the main factors leading for collaborative research with technical problems left to be solved by in-house research (Q21). At collaborative level manufacturers are aligned with the general trend (this did not occur in Q17).

Significant was to find from the survey that in terms of societal embedding the broad of high-speed train industry attributes high levels of relevance to the societal environment, above policy & regulations. Yet business & engineering dominates (Q22). Societal requirements are relevant at the initial stage (Q23) of technology development process (TRL1) when basic principles are observed and data collected. Then their relevance progressively declines to its minimum (TRL4) when the technology is validated. Latter they regain momentum when the new technology has matured, ready to market (TRL8 & TRL9). Different from manufacturing, component suppliers tend to consider societal requirements in all stages of development, which places them in line with the arguments presented by CTA.

Alignment with societal actors are considered by a great majority of respondents a way of risk mitigation of technology failure (Q26). Manufacturing and researcher centers showing the highest of support but also of concerns. The benefits of shared technological paths are the least considered by manufacturing, confirming the tendency for social embedding for the purpose of promotion and control and the evident division of labour between the technology initiator and the impactee.

Societal embedding is dominated by informal practices (Q27) with a great percentage of respondents stating openness for interaction with societal actors and their recognition as a stakeholder in the technology development. Only a few, mainly coming from research centers, however referred employing someone responsible for societal alignment. Even fewer, as a minority of component suppliers, consultancies and railway associations, mentioned technology assessment gates to address societal constraints.

Mapping and monitoring societal environment (Q28) is relevant for the industry. However, the articulation of scenarios allowing for societal embedding and stimulation of learning from societal actors is the least referred, except for research centers. The industry rather controls than orchestrates their dialogue with societal actors.

Results from the survey confirm my previous findings showing that the most referred type of future formulations are endogenous to the railways presenting their techno-centric visions to an envisaged future they aim to control (Q30). Exception goes to governments and some consultancies referring the most to external reports more inclusive of the wider society and capable of covering wider collective of stakeholders.

In terms of methods used (Q25) respondents equally considered qualitative and quantitative approaches. Manufacturing however standout from other stakeholders by prioritizing quantitative methods, less appropriated in assessing vague and not-known for the industry societal requirements.

VII. CONCLUSIONS, RECOMMENDATIONS and IMPACTS

- ***In conclusion:***

Looking back, this dissertation reflects and benefits from the turning point in society, becoming digital and hyper-connected; the inevitable shift in the strategic direction of high-speed rail innovation in Europe; and Technology Assessment (TA) entry in a new period of ferment.

Society gained an active role in technological innovation from its digitalisation and hyper-connectivity. It shifted from prescriptive, such as Green Peace NGO awareness campaigns on Environment, to interventive, capable of producing innovations that impact high-speed trains, as intuitive apps creating share communities of travellers looking for cheaper and seamless transport solutions.

The railway industry became aware of the relevance to enter this new emergent "socialware" era (Rachel Pacard 2015); while the European Union policies on transport and research prioritise societal demands, with the Forth Railway Package (agreed in April 2016[151]) and Horizons 2020 (framing the period between 2014 to 2020[152]). Railways also institutionalise R&D collective governance structure in SHIFT2RAIL Joint Technology Undertaking pushing technology developments closer to the market.

In its turn Technology Assessment, addressing technological advancements in society, is in a ferment period and consolidating its position across Europe as a theoretical current within the governance of science and technology. It accounts with an increased number of scholars and practitioners jointly reflecting, studying and publishing about it. The often evoked, PACITA[153] project (2012-2015) is impressive in terms of number of attendants to their conferences and number of published papers. TA tools have gained a solid critical-mass and are becoming an institutionalised practice across a wider number of European parliaments and industries, and being exported to emergent economies such as China.

The implementation moment for the recommendations here presented is now. This is to, if railways do not want to miss socialware train, raise their market share in Europe that has been

[151] Link http://ec.europa.eu/transport/modes/rail/news/2016-04-20-fourth-railway-package_en.htm. Retrieved May 2016.

[152] Link https://ec.europa.eu/programmes/horizon2020/en/h2020-section/smart-green-and-integrated-transport. Retrieved May 2016.

[153] Link http://www.pacitaproject.eu/. Retrieved May 2016.

flat if not declining[154] and go beyond the sole commercial purpose of market uptake of their technologies.

With this dissertation I hope I have planted the seeds for the effective leveraging of social innovations from digitalisation into the high-speed train vehicles while informing on the constructive strand of TA as provider of the necessary tools and mediation agents that enable those seeds to grow.

The impact of this dissertation can be even greater if the railway industry commits and wants to take action in addressing societal actors as technological actors; be capable of mapping their capabilities and expectations in ways that can be usable and constructive to their business; converge in pre-engagements and mutual learnings experiences; including societal actors in the construction of their joint social-technical scenarios; and ultimately shape and integrate societal contributions in ways that can be embedded from early stage in the technology development process of the trains (either full system, components or even materials).

In my study on Alstom and Siemens technology development process of their high-speed trains AGV and ICE-350E, their technology transitions, multi-level alignments and future technology formulations, I demonstrate that the high-speed train, but also any other rail vehicle, for its complexity is a collective developed product, subject of different levels of technology interactions, which exchanges are however yet limited to the level of the railway regime (as demonstrated landscape and niche have little if none interactions).

As recommended, societal embedding implementation should be lead by SHIFT2RAIL Joint Technology Undertaking, because it is the product of this collective of actors and its R&D mission is strongly market oriented. SHIFT2RAIL has both arms in the strategic and operational. Strategic from its future agenda setting mandate; operational from its rules setting capability to which research and development projects they fund have to comply. There is also room for implementation by ERRAC and individually by governments, manufacturers and component suppliers.

This dissertation is not limited to envisaged impacts in the railway industry, it is also impacting TA, in particular, the constructivist strand (CTA). With my study on societal embedding in the technology development of high-speed trains I bring CTA application from niche technologies and open ended futures, to a very clear field of application with much more stable futures. In

[154] According to FOSTER-RAIL project railways market share growth in Europe has been flat at about 6% for years. Link http://www.errac.org/wp-content/uploads/2016/04/CER_FosterRail_publication_2016_DEF.pdf. Retrieved May 2016.

this way this dissertation contributes to broaden societal reflexive CTA into demonstration CTA.

I am confident that very soon railways and TA will be able to collect the fruits from this dissertation, taken from the positive feedback and acceptance I have had in the various presentations and publications I made at each advancement of my research.

From what was here said I can only finalise by saying that my PhD is just the starting point framing the necessary next step in collectively making the high-speed train and railways a societal success.

- ***Recommendations and impacts:***

For societal success of railways to happen the following recommendations could apply and related impacts could be expected:

Recommendation 1: There is potential for adding value to the technology development process by enlarging the business network to include social actors, capable themselves of innovating, when elaborating collective visions and undergoing collaborative R&D.

Impact 1: This way one could expect broadening stakeholder involvement and extend environments of technology selection beyond customers and user to include the wider society. This would be from the early stage of product development.

Recommendation 2: The above recommendation requires treating society not only as a technological impactee but also impactor, opening new markets and itself capable of bringing innovating from its digitalization and hyper connectivity. Technological interactions should be tailored to suit the TRL development stage of the R&D project, as to optimize the value from mutual interactions to occur.

Impact 2: Such would lead to a coherent application of societal embedding, by adapting the structure of the relations to the research project maturity.

Recommendation 3: It also requires drawing on third parties to orchestrate such interactions. A number of types of third parties are possible, but must be chosen with care as it is more than marketing and requires targeted and informed orchestration.

Impact 3: This way it can be assured impartiality, reduction of inherent complexities, reflexivity of actors' roles, allow for mutual interactions and learning.

Recommendations 4: Railways have to move towards stabilizing design trajectories (reducing uncertainty and risk) by reviewing societal requirements and capabilities at early stages of the R&D projects.

Impact 4: Increase attractiveness to passengers and wider society; allow for constructive pre-engagements from societal actors; early identification of unknown-unknowns.

Recommendations 5: It can also be suggested to draw on expertise in linking societal engagement to technology design processes.

Impact 5: Railways can learn from others success, overcome techno-centric agendas and research and development projects.

Recommendations 6: The collective R&D strategic platforms as ERRAC and operational organisations as SHIFT2RAIL (S2R) offers good grounds to embed societal actors in the collective technology development process of high-speed trains (and not limited to). This can also happen at individual level, mainly by railways technological initiators as manufacturers, component suppliers and also railway operators. Below I will further detail this recommendation.

Impact 6: Extending railway research to society meets the EU research policy objectives as stated in HORIZONS 2020[155] prioritizing research that meets fast emergent societal demands, which became guiding principles followed by ERRAC and the Rail Joint Undertaking SHIFT2RAIL and individual stakeholders if envisaging collaborative research under EU funding.

By further detailing *Recommendation 6* my approach is not to be prescriptive but rather open the debate on how the above listed recommendation could be applied to high-speed trains (and beyond).

SHIFT2RAIL Joint Technology Undertaking stands as railways first collective strategic step in the direction of socialware offering therefore a good ground for the formalisation of the practices of societal embedding in the technology development process.

For example the regulation[156] establishing SHIFT2RAIL heightens an objective already pursued in ERRAC by adding the adjective *radical* to the need of "enhance the attractiveness

---

[155] Regulation of the European Parliament and of the Council establishing Horizon 2020-The Framework Programme for Research and Innovation (2014-2020), SEC(2011) 1427-Volume 1 and SEC(2011) 1428-Volume 1.

[156] Council Regulation (EU) No 642/2014 of 16 June 2014 establishing the Shift2Rail Joint Undertaking. See also SHIFT2RAIL open call day link https://webcast.ec.europa.eu/shift2rail-joint-undertaking-open-call-day . Retrieved in May 2016.

and competitiveness of the European railway system to ensure a modal shift towards rail". Moreover its Multiannual Annual Action Plan[157] features "extended stakeholders network", while its first issued Annual Action Plan, in 2015[158], introduces in its open call a cross-cutting activity (CCA) on the "long term needs of different actors in the railway sector" (S2R-OC-CCA-01-2015)[159].

Despite that the Multiannual Annual Action Plan it is yet missing a reference to how cross cutting activities actually link and are embedded in the technology innovation programmes (IP) as could well be the "IP4 - IT Solutions for Attractive Railway Services" introducing the "semantic web for transportation" and "IP1 - Cost Effective and Reliable Trains (including high capacity trains and high-speed trains)" from which are expected projects tackling digitalization, big data and prospective market studies.

A first step could be therefore ensuring that a resulting CCA project would actually be a third party study representative of the extended network of actors to society. It should build on ERRAC extensive work yet limited to the railways regime by extending it to the societal actors from landscape. As a result, a map of societal expectations and capabilities should be proposed.

This should feed SHIFT2RAIL Annual Work Plan call for a cross cutting activity establishing railways socio-technical scenarios extended to society and a road map defining specific technological areas for experimenting identified societal innovations.

The CCA call should then leverage to technological large scale demonstrator projects under the innovation programmes of SHIFT2RAIL Annual Work Plan. One way could be for example introducing a work-package or a project task in a large demonstrator project where railway actors and relevant societal actors could be called to experiment their innovations in relation the specific technology being demonstrated. The technology readiness level (TRL) of the technology demonstrated would set the 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 road maps. Actual development and testing would have to be covered by the calls in HORIZONS 2020, in the same terms as suggested for SHIFT2RAIL. The added value of ERRAC is the possibility to interlink with other transport modes technological

[157] Link http://shift2rail.org/wp-content/uploads/2013/07/MAAP-final_final.pdf . Consulted in May 2016

[158] Link http://shift2rail.org/wp-content/uploads/2013/07/MAAP-final_final.pdf . Consulted in May 2016

[159] This cross-cutting activity, granting 400 thousand Euros, could well be the continuing of ERRAC funding rather than the commission of this task to a third party. By the time I write this paragraph (June 2016) the call is closed but the results of the evaluation are not yet known.

platforms, as with aeronautics, waterborne and road. This is also a fertile ground for societal embedding in future technologies that target intermodal bottle necks. Also ERRAC would allow to have societal embedding on the science side of developments as SHIFT2RAIL is mainly focusing on the one of technology.

In terms of individual stakeholders, as governments, manufacturers, component suppliers and train operators, societal embedding should be implemented by their strategic intelligence in ways that it would leave room for mutual learnings relations to happen with societal actors. This means allowing for strategic consultations with societal actors that lead to joint technology paths and mutual engagements (not only promotion or legitimacy on technology options being promoted); for governments for example establish an observatory for technology assessment; while for industry include in their organisational structures someone responsible for societal alignments, maybe by creating cross functional research teams and distinguish in project evaluation gates societal constraints. This in a way that its implementation should be adjusted to the technology readiness level of the technology being addressed and by mediation of a third part.

BIBLIOGRAPHY

Agogué, M., Le Masson, P., & Robinson, D. K. (2012). "*Orphan innovation, or when path-creation goes stale: a design framework to characterise path-dependence in real time*". Technology Analysis & Strategic Management, 24(6), 603-616.

Abernathy, W. J. & Clark, K. B (1985) "*Innovation: Mapping the Winds of Creative Destruction*". Research Policy.

Argyris, C., & Schöln, D., (1978) "*Organizational Learning: A theory of action perspective*". Reading, MA, Addison-Wesley Publishing Co. 1978.

Armstrong, J., Preston, J. (2011) "*Alternative railway futures: growth and/or specialization?*". J. Transp. Geogr. (2011), doi: 10.1016/j.trangeo.2011.03.12.

Baron, L (2015) "*The permanent adaptation of trains to operators and users*". Parallel Session on Technology Rolling Stock (B) – Performance, 7 July 2015. 9th UIC World Congress on High-Speed Rail, 7-9 July 2015, Tokyo.

BCG Boston Consulting Group (2010) "*Worldwide Rail Market Study – status quo and outlook 2020*". Study Commissioned by the European Rail Industry Association (UNIFE).

BCG Boston Consulting Group (2008) "*World Rail Market Study. Status quo and outlook 2020*". Study Commissioned by the European Rail Industry Association (UNIFE).

Becker, P. (2002) "*Corporate Foresight in Europe: A First Overview*". Working Paper European Commission: 31. Brussels: European Commission.

Beyazit, E., Givoni, M. (2013) "*Technology Development of High-Speed Rail*". In Transportation Technologies for Sustainability, Ehsani, M., Wand, F. Y., Brosch, G. L., editors, pp 537-553, Springer New York. Doi 10.1007/978-1-4614-5844-9_902

Bimber, B., & Guston, D. H. (1997). "*Introduction: The end of OTA and the future of technology assessment*". Technological Forecasting and Social Change, 54(2), 125-130.

Boavida, N., Cabrita, N., Moretto, S. (2010) "*Análise do processo de participação pública no projecto da Alta Velocidade Ferroviária*". IET Working Papers Series, WPS06/2010:25. Universidade Nova de Lisboa, IET- Research Center on Enterprise and Work Innovation, Faculty of Science and Technology.

Boavida, N., Moretto, S. (2011) "*Innovation Assessment of a Portuguese railway branch of a foreign multinational: A case study*", Proceedings of the XIV Congreso Latino-Iberoamericano de Gestión Tecnológica – ALTEC 2011 (19-21 October 2011), Lima, Perú, Asociación Latino-Iberoamericana de Gestión Tecnológica, Pontificada Universidad Católica del Perú, Pages 339-587, 2011. ISBN 978-612-4057-48-9.

Böhle, K., Moniz, A. (2015) "*No Countries for Old Technology Assessment? Sketching the Efforts and Opportunities to Establish Parliamentary TA in Spain and Portugal*", *TATuP - Journal by ITAS on Technology Assessment*, 2015.

Brandes, J. (2015) "*The next 50 years for high-speed rail*", Siemens key-note speech, round table, at UIC World Congress on High Speed Rail, Tokyo, 7-9 July 2015.

Cadet, D. (2011) "*Industry Vision*", Presentation at the First Doctoral Conference on Technology Assessment, Panel Railways, 9 July 2011, PhD Programme on Technology Assessment, IET- Research Center on Enterprise and Work Innovation. Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, 2011.

Callon, M. (1991) "*Techno-economic Networks and Irreversibility*". In John Law (ed.) A Sociology of Monsters? Essays on Power, Technology and Domination, pp. 132-61, London: Routledge.

Callon, M. (1986). "*The sociology of an actor-network: The case of the electric vehicle*". In Mapping the dynamics of science and technology (pp. 19-34). Palgrave Macmillan UK.

Callon, M., Laredo, P., Rabeharisoa, V., Gonard, T., & Leray, T. (1992). "*The management and evaluation of technological programs and the dynamics of techno-economic networks: The case of the AFME*". Research policy, 21(3), 215-236.

Callon, M. & Latour, B. (1981) "*Unscrewing the big Leviathan or how do actors macrostructure reality and how sociologists help them to do so*". In K. Knorr-Cetina and A.V. Cicourel, Advances in Social Theory and Methodology: Toward an Integration of Micro and Macro Sociologies, London, Routledge & Kegan Paul, pp. 277-303.

Campus, J., de Rus, G., Barrón, I. (2006) "*Some stylized facts about high speed rail around the world: an empirical approach*". Proceedings 4th Annual Conference on Railroad Industry Structure, Competition and Investment, Universidad Carlos III de Madrid, October 19-21, 2006.

Casprini, E., Paraboschi, A., & Di Minin, A. (2015) “*Web 2.0 enabled business models: An empirical investigation on the BlaBlaCar case*”. In Academy of Management Proceedings (Vol. 2015, No. 1, p. 18509). Academy of Management.

Castellacci, F. (2008) "*Technological paradigms, regimes and trajectories: Manufacturing and service industries in a new taxonomy of sectoral patterns of innovation*", *Research Policy* 37 (6-7): 978–994, 2008. doi:10.1016/j.respol.2008.03.011.

Chen, L. (2015) “*Meet Europe's Newest Unicorn: BlaBlaCar Raises $200 Million At $1.6 Billion Valuation*”. Forbes 16 September 2015. Link http://www.forbes.com/sites/liyanchen/2015/09/16/meet-europes-newest-unicorn-blablacar-raises-200-million-at-1-4-billion-valuation/#7bd930fa158a

Coates, J.F. (1976) “*The role of formal models in technology assessment*”, Technology Forecast and Social Change Vol 9 (Issues 1–2) 139–190.

Collingridge, D., (1980) “*The Social Control of Technology*”. Printer London.

Comtois, C., Loo, B. P. Y. (2015) “*Sustainable Railway Futures: Issues and Challenges*”, Transport and Mobility Series, London: Ashgate.

Constant, O. (2006) “*TGV*”. Éditions E.P.A. ISBN 2851206435.

Cooper, R. G. (1990) “*Stage-gate systems: a new tool for managing new products*”. Business horizons, 33(3), 44-54.

David, P.A. (1985) “*Clio and the economics of QWERTY*”. In American Economic Review 75: 332-337.

Deuten, J. Jasper and Rip, Arie and Jelsma, Jaap (1997) “*Societal embedding and product creation management*”. Technology Analysis & Strategic Management, 9 (2). pp. 131-148. ISSN 0953-7325

Dosi, G. (1982) “*Technical paradigms and technological trajectories – a suggested interpretation of the determinants and directions of technological change*”. Research Policy, 11 (3), 147-162.

Ebeling, K. (2005) “*High Speed rail in Germany*”. Japan Railway & Transport Review nr.40. March 2005.

Elwyn, G., Hardisty, A. R., Peirce, S. C., May, C., Evans, R., Robinson, D. K.R., Gray, W. A. (2012). “*Detecting deterioration in patients with chronic disease using telemonitoring:*

navigating the 'trough of disillusionment". Journal of evaluation in clinical practice, 18(4), 896-903.

Elzen, B., Geels F. W., Hofman P. S., Green K. (2005) "*Sociotechnical scenarios as a tool for transition policy: an example from the traffic and transport domain*", in Boelie Elzen, Frank W. Geels and Ken Green (eds.), System Innovation and the Transition to Sustainability, Cheltenham: Edward Elgar Publishing Ltd., pp.251-281.

European Commission (2001) "*White Paper - European Transport Policy for 2010: Time to Decide*". COM(2001) 370 final. Brussels, 12.9.2001.

European Commission (2002) "*Land transport and marine technologies. RTD activities supported under the Growth Programme*". ISBN: 92-894-2077-4

European Commission (2006a) "*Sustainable Surface Transport Research Technological Development and Integration: 2002-2006 Projects Synopses*". ISBN: 92-79-04584-9.

European Commission (2006b) "*Communication from the Commission to the Council and the European Parliament. Keep Europe moving. Sustainable mobility for our continent. Mid-term review of the European Commission's 2001 Transport White paper*" {SEC(2006)768} COM(2006)314 final.

European Commission (2009) "*Communication from the Commission. A sustainable future for transport: Towards an integrated, technology-led and user*". COM(2009)279/4.

European Commission (2010) "*High-speed Europe. A sustainable link between citizens*", Luxembourg: Publications Office of the European Union, 2010. doi: 10.2768/17821.

European Commission (2011) "*White paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*". COM(2011) 144 final.

European Commission (2013) "*European Commission Staff Working Document. Impact Assessment - Accompanying the document proposal for a Council Regulation establishing the Shift2Rail Joint Undertaking*" (COM(2013) 922 final).

European Council (1996) "*Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system*". Retrieved 7 March 2012, Link http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0048:EN:HTML.

European Rail Research Advisory Council (2012) "*Roadmaps on WP01 Greening of Surface Transport, WP02 Encouraging Modal Shift and decongestion of transport corridors, WP03 Ensuring sustainable urban transport, WP04 Improving safety and security, WP05*

Strengthening Competition". Published by ERRAC Roadmaps, The FP7 project ERRAC. Link http://errac.uic.org/spip.php?article13#outil_sommaire_2

European Rail Research Advisory Council (2011) "*Rail Route 2050: the sustainable backbone of the single European Transport Area*". Published by ERRAC Roadmaps, The FP7 project ERRAC. Update of the ERRAC vision (2001).

European Rail Research Advisory Council (2007) "*Strategic Rail Research Agenda 2020*". Published by the FP7 project ERRAC. May 2007.

European Rail Research Advisory Council (2002) "*SRRA Strategic Rail Research Agenda 2020: A turning point for European railway research*". First report of ERRAC. Published by ERRAC. September 2002.

European Rail Research Advisory Council (2001) "*A joint strategy for European rail research 2020: Towards a single European railway system*". Published by UNIFE, UIC, CER, UITP.

Garud, R., & Ahlstrom, D. (1997) "*Technology assessment: a socio-cognitive perspective*". Journal of Engineering and Technology Management, 14(1), 25-48.

Garud, R., Rappa, M. A. (1994) "*A socio-cognitive model of technology evolution: The case of cochlear implants*". Organization Science, 5(3), 344-362.

Geels, F. W. (2002a) "*Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study*". Research Policy, Vol. 31, No. 8/9, pp. 1257-1274.

Geels, F.W. (2002b) "*Understanding the dynamics of technological transitions: a co-evolutionary and socio-technical analysis*". Doctoral dissertation, Universiteit Twente, 1-426. Enschede: Twente University Press.

Geels, F.W., Kemp, R., Dudley, G., Lyons, G. (2012). "*Automobility in transition: A socio-technical analysis of sustainable transport*". In Routedge. ISBN13:98-0-415-88505-8(hbk).

Geels, F. W., Schot, J. (2007) "*Typology of sociotechnical transition pathways*". Research Policy 36 399–417. doi 10.1016/j.respol.2007.01.003.

Giannakouris, K., Smihily, M. (2013) "*Businesses raise their internet profile by using social media*", Statistics in focus 28/2013, Eurostat, ISSN: 2314-9647, Catalogue number: KS-SF-13-028-EN-N.

Giuntini, A. (2011) "*Will railways save Europe? Past and present of high-speed trains the old continent*". Proceedings Coloquio Internacional 150 anos de cominho de ferro no Barreiro.

Historia, Patrimonio e Perspectivas Actuais e Futuras do Caminho de Ferro. 4-5 Fevereiro de 2011. Barreiro Portugal.

Given, L. M. (2008) "*The SAGE encyclopaedia of qualitative research methods*". Vol. 1&2. Sage Publications. ISBN 978-1-4129-4163-1.

Givoni, M. (2006) "*Development and Impact of the Modern High-speed Train: A Review*". Transport Reviews, Vol. 26, No. 5, 593–611, September 2006.

Grin, J., Grunwald, A. (2000) (eds): "*Vision assessment: shaping technology in 21st century society*". Berlin, Heidelberg, New York: Springer 2000. 190 pp.

Grin, J., van de Graaf, H. (1996) "*Implementation as communicative action. An interpretive understanding of interactions between policy actors and target groups*". Policy Sciences, 29, p. 291-319.

Grin, J., van de Graaf, H., Hoppe R. (1997) "*Technology Assessment through Interaction. A guide*". With a contribution from P. Groenewegen. Den Haag: Rathenau Institute.

Grunwald, A. (2011) "*Energy futures; Diversity and the need for assessment*", Futures 43, 2011, p.820-830.

Guston, D. H. (1999) "*Evaluating the first US consensus conference: The impact of the citizens' panel on telecommunications and the future of democracy*". Science, Technology & Human Values, 24(4), 451-482.

Guston, D.H. and D. Sarewitz (2002) "*Real-Time Technology Assessment*". Technology in Culture, v. 24, pp. 93-109.

Hastbacka, M. A., Greenwald, C. G. (1994) "*Technology Assessment – Are you doing it right?*" Arthur D. Little – PRISM (Fourth Quarter): 35-45.

Henn, M., Weinstein, M., Foard, N. (2009) "*A critical Introduction to Social Research*". Second edition. London. Sage. ISBN 9781848601796

International Union of Railways (2015) "*High-speed rail facts and figures*", High-speed department, UIC, Paris, May 2015.

International Union of Railways (2013) "*Data of high-speed trains 2013*", UIC High-Speed.

International Union of Railways (2010a) "*Necessities for future high speed rolling stock*". Report of the International Union of Railways (UIC), 2010.

International Union of Railways (2010b) "*High speed rail. Fast track to sustainable mobility*". Brochure of the International Union of Railways (UIC). 2010. ISBN 978-2-7461-1887-4.

International Union of Railways, CER, EIM (2013) "*Challenge 2050, The rail sector Vision*". Date: February 2013.

Joss, S., & Durant, J. (1995) "*Public participation in science: The role of consensus conferences in Europe*". NMSI Trading Ltd.

Justen, A., Schippl, J., Lenz, B., & Fleischer, T. (2014) "*Assessment of policies and detection of unintended effects: Guiding principles for the consideration of methods and tools in policy-packaging*". Transportation Research Part A: Policy and Practice, 60, 19-30.

Keseljevic, C. (2015) "*The cross fertilization of French and Japanese high-speed models trough mutual technical influence in the past 50 years*". Presentation at the panel Culture & Society – Rail Policy, Congress UIC HIGHSPEED 2015, Tokyo, 7-10 July 2015.

Kliiver, L. (1995) "*Consensus conferences at the Danish Board of Technology. In Public participation in science: The role of consensus conferences in Europe*". London: Science Museum.

Krabbenborg, L. (2013) "*Involvement of civil society actors in nanotechnology: creating productive spaces for interaction*". Groningen: PhD Thesis RU Groningen.

Kuhlmann, S., (2001) "*Distributed Techno-Economic Intelligence for Policymaking*". *Science and Technology*, 2001.

Kuhlmann, S., et al. (1999) "*Improving Distributed Intelligence in Complex Innovation Systems*", Brussels/Luxembourg, Office for Official Publications of the European Commission, 1999. http://ideas.repec.org/p/pra/mprapa/6426.html.

Lente, H. V. (1993) "*Promising technology: the dynamics of expectations in technological developments*". Doctoral dissertation, Universiteit Twente. Enschede: Twente University Press.

Lichtenthaler, E. (2004) "*Coordination of Technology Intelligence Processes: A Study in Technology Intensive Multinationals*", *Technology Analysis & Strategic Management*, 16(2), 197-221, 2004. doi:10.1080/0953732041000l682892.

Mazzucato, M. and Robinson, D.K.R. (2015) "*NASA's changing innovation policy: challenges and opportunities of 'directing' and 'facilitating' a new public-private innovation system in Low Earth Orbit*". Commissioned Report for the Office of the Chief technologist, NASA HQ.

Meunier, J. (2002) “*On the fast track – French Railway Modernisation and the origins of the TGV, 1944-1983*”. Forward by Dukakis, M. S. Praeger. ISBN 0-275-97377

Miles, M. B., Huberman, A. M. (1994) “*An expanded Sourcebook. Qualitative Data Analysis*” Second Edition. Sage Publications. ISBN 0-8039-4653-8 (cl).

Moretto, S., Palma, A. P., Moniz, A. B. (2012) "*Technology Assessment in the High-Speed Train Manufacturing Industry: Evidence from a Case Study*", in J. Pombo, (Editor), Proceedings of the First International Conference on Railway Technology: Research, Development and Maintenance, Civil-Comp Press, Stirlingshire, UK, Paper 167, 2012. doi:10.4203/ccp.98.167.

Moretto, S., Robinson, D.K.R., Moniz A.B. (2014) “*The role of Endogenous and Exogenous Future Oriented Technology Assessment in the European High-Speed Innovation System: Constructive Technology Assessment as the Next step?*”. Proceedings at the 5th International Conference on Future Technology Assessment Analysis (FTA), - Engage Today to Shape Tomorrow. European Joint Research Center (European Commission). 27-28 November, Brussels.

Moretto. S., Pastrana Palma, A., Moniz, A.B (2012) "*Constructive Technology Assessment in Railways: The case of the High-speed Train Industry*", in J. Pombo, (Editor), International Journal of Railways Technology, Volume 1 – Issue 3, Pages 73-95, 2012. Saxe-Coburg Publications. Doi: 10.4203/ijrt.1.3.5 Link journal http://www.ctresources.info/ijrt/

Nelson, R. & Winter, S. (1977) “*Towards a theory of innovation*”. Research Policy 6.

OECD (2013) “*Policy round tables. Recent Developments in Rail Transportation Services 2013*”. OECD Competition Committee report. DAF/COMP(2013)24.

OECD (2009) “*Innovation in firms. A microeconomic perspective*”. OECD innovation strategy. 20 Nov 2009. ISBN 9789264056206 (print). DOI 10.1787/9789264056213-en. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/innovation-in-firms_9789264056213-en;jsessionid=48pbim01tc53r.x-oecd-live-03

Parandian, A. (2013) “*Anticipating Ethical, Legal, and Social Aspects of Emerging Technology Gaps in Innovation Chain: The Case of Body Area Networks”*. Nanotechnology and Human Health, 281.

Parandian, A. (2012) “*Constructive TA of Newly Emerging Technologies. Stimulating learning by anticipation through bridging events*”. PhD thesis, Technical University Delft, defended 12 March 2012.

Parandian, A., & Rip, A. (2013) "*Scenarios to explore the futures of the emerging technology of organic and large area electronics*". European Journal of Futures Research, 1(1), 1-18.

Pavitt, K. (1984) "*Sectoral Patterns of Technical Change: Towards a Taxonomy Model and a Theory*", Research Policy 13, 343-373.

Pereira, M. S. (2011) "*Railway Trends*". Presentation at the First Doctoral Conference on Technology Assessment, Panel Railways, 9 July 2011, PhD Programme on Technology Assessment, IET- Research Center on Enterprise and Work Innovation, Faculdade de Ciência e Tecnologia, Universidade Nova de Lisboa, 2011.

Petersen M.S., Enei R., Hansen C.O., Larrea E., Obisco O., Sessa C., Timms P.M., Ulied A. (2009) "*TRANSvisions - Report on Transport Scenarios with a 20 and 40 year Horizon*". Final report. Funded by DG TREN. Copenhagen, Denmark.

Picard, R. (2015) "*Celebrating the past*", SNCF invited speaker, opening ceremony, UIC World Congress on High Speed Rail, Tokyo. 7-9 July 2015.

Pisano, G. P (2012) "*Creating an R&D strategy*", Executive summary, Working papers, Harvard School, 11 May 2012. Retrieved from link http://hbswk.hbs.edu/item/7014.html

Pisano, G. P (2015) "*You Need an Innovation Strategy*", Harvard Business Review, Issue June 2015.

Preston, J. (2009) "*Trends in European Railways over the last two decades".* Built Environment 35 (1), 11-23.

Rip (2015) "*Training module of managing technology in society*". University of Stellenbosch. South Africa.

Rip, A. (2012) "*The context of innovation journeys*". Creativity and innovation management, 21(2), 158-170.

Rip, A. (2001) "*Technology Assessment*", in Smelser, N. J., Batle, P. B. (eds). International Encyclopaedia of the Social & Behavioural Sciences. Oxford, Vol. 23, pp. 15512-15515.

Rip, A. (2005) "*Technology Assessment as Part of the Co- Evolution of Nanotechnology and Society: the Thrust of the TA Program in NanoNed*". Paper contributed to the Conference on "Nanotechnology in Science, Economy and Society", Marburg, 13-15 January 2005

Rip, A., Kemp, R. (1998) "*Technological change*". S. Rayner & E.L. Malone (Eds), Human choice and climate change (Columbus, Batelle Press, 2).

Rip, A., Misa, T. J., & Schot, J. (Eds.). (1995) "*Managing technology in society. The Approach of Constructive Technology Assessment*". London, New York: Pinter Publishers.

Rip, A., Robinson, D. K. R (2013) "*Constructive technology assessment and the methodology of insertion*". In Early engagement and new technologies: Opening up the laboratory (pp. 37-53). Springer Netherlands.

Rip, A. and Schot, J. W. (2002) "*Identifying Loci for Influencing the Dynamics of Technological Development*". In Williams, R. and Soerensen, K. (ed) Shaping Technology. Guiding Policy; concepts Spaces and Tools. Cheltenham: Edward Elgar.

Rip, A., van Lente, H. (2013). "*Bridging the gap between innovation and ELSA: The TA program in the Dutch Nano-R&D program*". NanoNed. NanoEthics, 7(1), 7-16.

Robinson, D. K. R. (2011) "*Value chains as a linking-pin framework for exploring governance and innovation in nano-involved sectors: illustrated for nanotechnologies and the food packaging sector*". European Journal of Law and Technology, 2(3).

Robinson, D. K. R. (2010) "*Constructive Technology Assessment of Emerging Nanotechnologies. Experiments in Interactions*". PhD thesis, Universiteit Twente, Enschede, The Netherlands, defended 25 November 2010.

Robinson, D. K. R. (2009) "*Co-evolutionary Scenarios: An application to prospecting futures of responsible development of nanotechnology*". Technological Forecasting and Social Change, 76 (2009.07.15) 1222-1239. Doi: 10.1016/j.techfore 2009.07.15.

Robinson, D. K. R. and Boon, W.P.C. (2014) "*Does 3D Bioprinting mean business? Making explicit the assumed industry scenarios for the assessment of business cases for breakthrough technologies*". 5th International Conference on Future-Oriented Technology Analysis (FTA) - Engage today to shape tomorrow Brussels, 27-28 November 2014.

Robinson, D. K. R., Huang, L., Guo, Y., Porter, A. L. (2013). "*Forecasting Innovation Pathways (FIP) for new and emerging science and technologies*". Technological Forecasting and Social Change, 80(2), 267-285.

Robinson, D. K. R., Propp, T. (2011) "*Innovation-Chain+ approach to prospecting technology embedment in society: An Illustration for potential nano-enabled agrifood sector transformations*". Fourth International Seville Conference on Future-Oriented Technology Analysis (FTA). FTA and Grand Societal Challenges – Shaping and Driving Structural and Systemic Transformations Seville 12-13 May 2011, 1-27.

Robinson, D. K. R., Propp, T. (2008) "*Multi-path mapping as a tool for reflexive alignment in emerging science and technologies*". Technological Forecasting and Social Change, 75(4), 517-538.

Robinson, M., Velardi, L., Ulianoz, C. (2011) "*Market impact evaluation – the way to judge the success of completed rail research*", Procedia – Social and Behavioral Sciences. Transport Research Arena – Europe 20112.

Rolland Berger (2014) "*UNIFE World Rail Market Study – Forecast 2014 to 2019*". Commissioned by UNIFE and Conducted by Rolland Berger.

Roland Berger (2012) "*Worldwide Rail Market Study – forecast 2012 – 2017*". Study Commissioned by the European Rail Industry Association (UNIFE).

Roland Berger (2008) "*Worldwide Rail Market Study – status quo and outlook 2016*". Study Commissioned by the European Rail Industry Association (UNIFE).

Rosenberg, N. (1979) "*Technology Interdependence in the American Economy*", Technology and Culture, January 1979, pp.25:50. Reprinted in Rosenberg, N., "Inside the Black Box: The Technology and Economics (Cambridge, Univeristy Press, 1982, pp55:80, at p. 59

Russell, A.W., Vanclay, F.M., & Aslin, H.J. (2010) "*Technology assessment in social context: The case for a new framework for assessing and shaping technological developments*". Impact Assessment and Project Appraisal, 28(2), 109-116.

Saint-Martin, N. C. (2015) "*Alstom view of the next 50 years ahead*", Alstom invited panellist, round table, UIC World Congress on High Speed Rail, Tokyo, 9.07.2015.

Schilling, M. A., (2010) "*Strategic Management of Technological Innovation*" (3rd edition), New York University, McGraw Hill International Edition.

Schippl, J., et al. (2013) "*Eco-efficient Transport, Final report*". STOA Project Eco-efficient Transport, deliverable nr. 5, Karlsruhe, April 2013.

Schippl, J. (2013) "*Participative scenarios on eco-efficient transport: methodological challenges, results and relevance for policy making*". Paper submitted for the IFA Seminar 2013.

Schippl, J. et al. (2008) "*The future of the European long distance transport – Scenario report*". European Parliament, Science and Technology Options Assessment (STOA). IP/A/STOA/FWC-2005-28/SC27.

Schippl, J., Fleischer, T. (2012) "*A problem-oriented categorization of FTA methods for transport planning*", *Foresight*, Vol 14, No. 4, 2012,, pp. 288-293. ISSN 1463-6689.

Schot, J., & Geels, F. W. (2008). "*Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy*". Technology Analysis & Strategic Management, 20(5), 537-554.

Schot, J., Rip, A. (1997) "*The past and the future of Constructive Technology Assessment*". Technology Forecasting and Social Change 54(2), p. 2551:268. PII S0040-1625(96)00180-1.

Siemens (2010) "*Designing the future - How mobility tomorrow is taking shape – complete mobility – facts, trends, stories*". Issue 05 | September 2010. Transportation Systems. Siemens AG. www.siemens.com/mobility.

Siemens (2011) "*Pictures of the future*". Magazine for Research and Innovation / Fall 2011. Siemens. Link www. Siemens.com/proof.

Siemens (2010) "*Designing the future - How mobility tomorrow is taking shape*". Complete Mobility. Facts, trends, stories. Issue 05 | September 2010. Transportation Systems. Siemens AG. www.siemens.com/mobility.

Siemens (2009) "*The future needs the railways for a cleaner environment*". Green Mobility. Transportation Systems. Siemens AG.

Siemens (2006) "*The future needs mobility - Completely in detail*". Complete Mobility Transportation Systems. Siemens AG.

Simon, H. (1962) "*The architecture of Complexity*". Proceedings of the American Philosophical Society 106, pp. 467-82.

Smits, R. E. H. M., Leyten, J. (1991) "*Technology assessment: Waakhond of speurhond: Naar een integraal technologiebeleid*". Zeist: Kerckebosch bv.

Smits, R., van Merkerk, R., Guston, D. H., Sarewitz, D. (2008) "*The Role of Technology Assessment in Systemic Innovation Policy*", Innovation Studies Utrecht -Working Papers Series ISU Working Paper #08.01, University of Utrecht, p.27.

Steinmann, L. (2014) "*Le succès de Blablacar bouscule la SNCF*". LesEchos.fr, 2 July 2014. Link http://www.lesechos.fr/02/07/2014/lesechos.fr/0203613823111_le-succes-de-blablacar-bouscule-la-sncf.htm#Xta83r3ZesumGtfF.99

TAMI (2004) "*Technology Assessment in Europe; Between the Method and Impact*", 9, 1-99, EC-STARA, Brussels, 2004.

Takagi, R. (2005) "*High-speed railways: the last 10 years*". Japan Railway and Transport Review, 2005(48): 22-29.

te Kulve, H. (2011). "*Anticipatory interventions and the co-evolution of nanotechnology and society*". PhD thesis. University of Twente.

te Kulve, H., Rip, A. (2013). "*Economic and societal dimensions of nanotechnology-enabled drug delivery*". Expert opinion on drug delivery, 10(5), 611-622.

te Kulve, H., Rip, A. (2011) "*Constructing Productive Engagement: Pre-engagement Tools for Emerging Technologies*". Science Engineering Ethics (2011) 17:699-714. Doi 10.1007/s11948-011-9304-0.

van de Ven, A., Polley, D. E., Garud, R., Venkataraman, S. (1999). "*The innovation journey*". ISBN-13: 978-0195341003.

van den Belt, H., Rip, A. (1987) "*The Nelson-Winter-Dosi model and the synthetic dye chemistry*". In W.E. Bijker, T.P. Hughes and T.J. Pinch (eds). *The social construction of technological systems: New Directions in the Sociology and History of Technology*, Cambridge Massachusetts: The MIT Press, 1987, 135–58, quotes on 143–44. 6.

van den Ende, J., Mulder, K., Knot, E. M., Vergragt, P. (1998) "*Traditional and Modern Technology Assessment: Toward a Toolkit*". *Technological Forecasting and Social Change* 58, p.5:21. PII S0040-1625(97)0052-8.

van Eijndhoven, J.C.M., (1997) "*Technology assessment: Product or process?*", in Technological Forecasting and Social Change 54 (1997) 269-286.

van Lente, H. (1993) "*Promising Technology - The Dynamics of Expectations in Technological Developments*". Ph.D Thesis, University of Twente. Delft: Eburon Press.

van Merkerk, R. O. (2007) "*Intervening in emerging nanotechnologies: a CTA of Lab on a chip technology*" (Vol. 367) Utrecht University, Royal Dutch Geographical Society.

van Merkerk, R. O., & Robinson, D.K.R. (2006) "*Characterizing the emergence of a technological field: Expectations, agendas and networks in Lab-on-a-chip technologies*". Technology Analysis & Strategic Management, 18(3-4), 411-428.

van de Poel, I. R. (1998) "*Changing technologies: a comparative study of eight processes of transformation of technological regimes*". Twente University Press.

von Schomberg, R. (2013). "*A vision of responsible research and innovation*". Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society, 51-74.

Weil, M., Dura, H., Ziemann, S., Baumann, M., Zimmermann, B., Simon, B., Decker, M. (2014, March). "*Constructive technology assessment (CTA) for nano-enabled technologies*". In abstracts of papers of the American chemical society (vol. 247). 1155 16th ST, NW, Washington, dc 20036 USA: Amer Chemical Soc.

Wood, F. B. (1997) "*Lessons in technology assessment methodology and management at OTA*". Technological Forecasting and Social Change 54:145-62.

Yin, R. K. (2003) "*Case Study Research – Design and Methods*". Third Edition. Editors Leonard Bickman and Debra J. Rog. Applied Social Research Methods Series. Vol 5. Sage Publications. ISBN 978-0-7619-2552-1.

Zhou L., Shen, Z. (2011) "*Progress in high-speed train technology around the world*". Journal of Modern Transportation, Vol. 19, Nr. 1, March 2011, Page 16. doi 10.3969/j.issn.2095-087X.2011.01.01.

ANNEXES

Annex 1. Map of the high-speed train network in Europe

High-Speed Train Network in Europe, retrieved from the presentation of Iñaki Baron de Angoiti, Open Ceremony, UIC HIGHSPEED Congress 2015, Tokyo. Link http://www.uic-highspeed2015.com/

Annex 2. Survey questions

Assessing High-Speed Trains Innovation Management and Societal Alignment

Introduction page

Dear colleague, You are invited to take part in the academic survey on "Assessing High-Speed Trains Innovation Management and Societal Alignment". Your answers are of great relevance to further knowledge about innovation management while identifying societal assessment practices in such a complex technological system of an important high socio-economic impact. Expected results aim at further contribute to the market success of future generations of such vehicles in view of increase dependence of this technology on public acceptance and capacity to cope with fast emerging global challenges. The survey has a total of 30 questions and will take about 15 minutes to reply. Thank you for your cooperation. Susana Moretto PhD candidate on technology assessment applied to the high-speed trains, Faculty of Sciences and Technology, New University of Lisbon, Portugal, also visiting School of Economics and Management, Tongji University, Shanghai, China, E/mail s.moretto@campus.fct.unl.pt

Next

22%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Confidentiality assurance

All information you list is kept confidential. You may which to stay anonymous or protect the identity of your institution by leaving in blank the concern boxes.

Back Next

11%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Correspondent type

1. You reply to this survey in the role of

- ☐ User (you might want to skip questions which not apply)
- ☐ Technological stakeholder
- ☐ Policy Maker
- ☐ Other ________

2. List 3 aspects that you value in your decision to take a high-speed train (ex.: comfort, speed, energy efficiency, ticket-price, etc)

3. Should users have a say in the technology development of the vehicle?

- ☐ Not at all
- ☐ Yes in all aspects
- ☐ Yes but excluding the mechanics of the train
- ☐ Yes but only if the technology directly impacts the riding experience of the train

Comments

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Correspondent identification

4. Your name (optional)

First ______ Surname ______

5. Your job title *

______

6. Your functional area inside your institution *

- Operations
- Engineering
- Sales and Marketing
- Management
- Researcher
- Professor
- PhD Student
- Other ______

7. Your report line

- Don't report
- Headquarters top-management
- Subsidiary top-management
- Headquarters technical director
- Subsidiary technical director
- Headquarters commercial director
- Subsidiary commercial director
- Operations director
- Director of University or Research Center or NGO or governmental agency or department
- Other ______

8. Country where you are currently working *

-- Please Select --

9. Your e-mail

Back Next

33%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Institutional profile

10. Name of your institution (optional)

11. Type of institution you work for

- Manufacturing industry (assembly)
- Component supplier
- Train operator
- Rail infrastructure
- University
- Research Center
- Railway association
- Government
- Certification Body
- End-User
- Other

12. Home base country of your institution

-- Please Select --

13. Which percentage per year of revenue your institution invests in research and development?

- Less then 1%
- Between 1% and 3%
- Between 3% and 5%
- Above 5%

14. Your institution has an explicit research and development strategy

Don't know ◯ No ◯ Yes ◯

15. Does your institution has a technology surveillance structure? (scan for future technology opportunities, external market conditions, as well as to align with the other internal strategies)

Don't know ◯ No ◯ Yes ◯

16. You or a colleague take part in your institution research and technology observation as

- ☐ centralized technical unit at the headquarters
- ☐ local technology observation unit at the subsidiary company
- ☐ headquarter international technology unit
- ☐ technology envoy to a specific supplier or subsidiary company
- ☐ listening post (scientific boards, etc)
- ☐ research centers
- ☐ expert participating in networks
- ☐ lead user or lead supplier
- ☐ not applicable
- ☐ other

Back Next

44%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Technology Development Approach

17. Rank the frequency in the purposes of your technology development activities

	1 Never	2	3	4	5	6	7	8	9	10 Always
Product development and design	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Manufacturing process	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Modeling and planning	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Certification and homologation (make products and methods compliant with regulations and customer requirements)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cost reduction (product, process and operations)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Solve technical problems	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Make the final product attractive to the end users	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Enter in new markets or gain market share from competitors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Anticipate new social challenges, policies and market constraints	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments

18. Existing practices in your technology development projects

- ☐ basic research, applied research
- ☐ concept development and feasibility
- ☐ product development and processing
- ☐ regulations

- ☐ public affairs and public relations
- ☐ societal assessment (formulation of scenarios)
- ☐ market entry
- ☐ Other ______

19. Your research and development work is held as follows

- ☐ in house with my engineering team or colleagues
- ☐ in bilateral collaboration with an external partner
- ☐ in consortium with external partners
- ☐ call upon user-groups
- ☐ Other ______

20. Your research work is done in partnership with

- ☐ colleagues (in-house)
- ☐ train manufacturing industry
- ☐ suppliers from the rail sector
- ☐ direct competitors
- ☐ universities and research centers
- ☐ customer
- ☐ end-user
- ☐ certification bodies
- ☐ railway associations
- ☐ suppliers from other sectors (specify) ______
- ☐ Other ______

21. Collaborative research and development is relevant (collaborative here means doing research with one or more external partners)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Not Applicable

to elaborate new solutions matching customer requirements	◯	◯	◯	◯	◯	◯
to anticipate new social challenges, policies and market constraints	◯	◯	◯	◯	◯	◯
to solve a technical problem in a core technology sub-system	◯	◯	◯	◯	◯	◯
to solve a technical problem in an outsourced technology sub-system	◯	◯	◯	◯	◯	◯
to make the final product compliant and attractive with customer requirements	◯	◯	◯	◯	◯	◯
to transfer technology or absorb technology	◯	◯	◯	◯	◯	◯

Comments

Back Next

56%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Technology Development Contextualization

22. Rate in relevance the factors driving your research and development

	Not relevant 1	2	3	4	5	6	7	8	9	Extremely relevant 10
Policy (European and national policies, regulations, funding)	○	○	○	○	○	○	○	○	○	○
Society (environment, mobility, end-users)	○	○	○	○	○	○	○	○	○	○
Business (direct and indirect competitors, supply chain, customer requirements, costs)	○	○	○	○	○	○	○	○	○	○
Internal drivers to the institution (strategy, resources, operations, etc)	○	○	○	○	○	○	○	○	○	○

Comments

23. When developing a new technological solution for the high-speed train, at which technological readiness levels (TRLs) you consider the listed drivers

	Policy drivers	Business drivers	Societal drivers
TRL 1. Basic principles observed and reported	☐	☐	☐
TRL 2. Technology concept and/or application formulated	☐	☐	☐
TRL 3. Analytical and experimental critical function and/or characteristic proof of concept	☐	☐	☐
TRL 4. Component and/or breadboard validation in laboratory environment	☐	☐	☐
TRL 5. Component and/or breadboard validation in relevant environment	☐	☐	☐

	Policy drivers	Business drivers	Societal drivers
TRL 6. System/subsystem model or prototype demonstration in a relevant environment	☐	☐	☐
TRL 7. System prototype demonstration in its environment	☐	☐	☐
TRL 8. Actual system completed and 'qualified' through test and demonstration	☐	☐	☐
TRL 9. Actual system 'proven' through successful mission operations	☐	☐	☐
Never	☐	☐	☐

Comments

24. Your sources of information on technology drivers, opportunities and constraints are

- ☐ Scientific papers and reports
- ☐ Conferences and workshops
- ☐ Trade shows
- ☐ Training session
- ☐ Virtual networks
- ☐ Technology platforms
- ☐ Collaborative projects
- ☐ Customer or end-user direct inquiry
- ☐ Other

25. You base your technology decisions on

- ☐ Quantitative indicators
- ☐ Qualitative indicators
- ☐ Best practices
- ☐ Informal appraisals
- ☐ Influence from others
- ☐ Other

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Technology Development Societal Alignment

26. In your opinion technological development alignment with societal actors (consumer organizations, user-groups, environmental groups, citizens groups) is

- ☐ a risk at early stage as confidential information can become public or raise premature negative reactions
- ☐ a risk at latter stage as it can increase costs of reengineering product and processes as there might be little room for change
- ☐ beneficial when it is still possible to incorporate their expectations
- ☐ beneficial if the dilemma of unbalances and desalignments are successfully overcome
- ☐ beneficial if creates shared technological paths
- ☐ beneficial as societal actors can provide indications on the degree of public acceptance of new technologies
- ☐ Other

Comments

27. Technology management in your institution considers

	Yes	No	Maybe
Distinguishes separate development lines (gates) for societal alignment?	☐	☐	☐
Includes someone responsible for societal alignment in cross-functional team?	☐	☐	☐
Treats societal actors as stakeholders?	☐	☐	☐
Shows openness and pro-activeness to interact with societal actors?	☐	☐	☐

28. Technology management in your institution pays enough attention to

	Yes	No	Maybe
Articulation of scenarios for societal inclusion?	☐	☐	☐
Mapping and monitoring relevant environment including society?	☐	☐	☐
Stimulating continuous learning during societal inclusion process?	☐	☐	☐

Back Next

78%

Save and continue later

Assessing High-Speed Trains Innovation Management and Societal Alignment

Technology Management and Future Prospective

29. In your research work you consider visioning the future (anticipation of drivers and constraints)

1 Not relevant	2	3	4	5	6	7	8	9	10 Extremely important
○	○	○	○	○	○	○	○	○	○

30. Your sources of information about future emerging drivers and constraints are

- ☐ internal reports
- ☐ external reports from consultants
- ☐ external reports from railway organizations or research centers
- ☐ external reports from technology platforms as the one for rail (ERRAC)
- ☐ Other ____

31. The methods you mostly rely upon to predict the future are

- ☐ don't know
- ☐ delphi
- ☐ forecasting
- ☐ foresight
- ☐ evaluation
- ☐ scenarios
- ☐ road-mapping
- ☐ life-cycle-assessments
- ☐ brain-storming
- ☐ other ____

32. In your opinion future exercises should consider

- ☐ policy and regulatory framework
- ☐ culture (norms, values, opinions)

- [ ] structure of the sector and production chain
- [ ] societal actors relevant for technological development
- [ ] Other ______

33. In your opinion future exercises should result in

- [ ] enlightenment on what the future might be (static futures)
- [ ] enlightenment on the path for the envisaged scenario by providing alignments with supply chain and societal actors
- [ ] alert on emergent constraints
- [ ] orchestrate alignments with wider society (account positions and interests of other actors)
- [ ] actors pre-engagement through socio-technical scenario building
- [ ] Other ______

Back Submit

89%

Annex 3. Dissertation summary chart

Chapter I: Railways are yet struggling with market uptake of their new technologies despite almost two decades of investments in collaborative research. To maintain their dominant position under the new market conditions, manufacturers introduced in railways strategic intelligence to technology management, extended to the supply chain. The result has been an increase institutionalisation of their strategic technological networks in ERRAC and most recent SHIF2RAIL. They aim at "promoting" jointly agreed solutions at pre-competitive stage while "controlling" (steering) future technological developments. The recent digitalisation of society has broadened the notion of technological selection to a wider spectrum of new social actors, themselves capable of creating new market demands and innovating, moving further away manufacturers and their networks from controlling the market uptake of their technological solutions. How can TA support the high-speed train industry embrace this new socialware era?

Ref.	**Question**	**Proposition**	**High-Speed Trains & TA interceptions**	**Method**	**Findings**
RQ.1.	**What is the relation between high-speed trains technology and TA?**				
	P.1. Proposition: Rail and TA intercepts at the level of actors technological decision-making (technology selection). TA refers to "informed decision making" on new technologies as the ones being inclusive of society. Those decisions are made by governments, non-governmental institutions, corporations alone or in networks. Each one is covered by different TA strands. Since 2001 high-speed train manufacturers became fully responsible for designing, manufacturing and commercialising the vehicles in collaboration with their network of suppliers. TA presented different strands which selection depends on the addressee (governments, non-governmental institutions, firms, or their networks) and level of application (policy-making, science and technology, public engagements). This requires literature review on TA as to find the best suit.		TA stands	Literature review on TA theories concepts and models	*Findings from Chapter II:* TA is in a period of ferment of renewed methods. The EU funded project PACITA (2011-2015) reflected that and it was a major source of information. For the purpose of this dissertation CTA - Constructive Technology Assessment - standsout from other strands. This because, inspired in actors-network theory, it is the stand that addresses technology as the construction of networks of actors, which act at the level of science and technology, constraint by different environments of technology selection (business, regulatory and societal). CTA, proposes a strategic intelligence model to extend that network of actors to society from early stage of the development process. CTA has been positioning itself as a way to overcome the institutionalised division of labour between promotion and control of technology referred as the Collingridge dilemma. It deals with the inherent asymmetries between "impactors" (insiders, at the source of the technology) and "impactees" (outsiders , impacted by the technology) with heterogeneous expectations and capabilities (as well as different powers, timings, interests, resources, etc). CTA proposes doing it by bridging events between those heterogeneous actors orchestrated by a third party, to probe each others assessment worlds (supply-chain plus in Robinson & Propp 2008), and ultimately arrive to socio-technological scenarios of aligned visions (Te Kulve & Rip 2011). Those scenarios not only take actors initiatives and interactions into account but also their surroundings. They are not used to extrapolate particular developments into future (control function)

				but rather to enhance the flexibility of stakeholders regarding their strategic decisions (mutual-learnings), which in its turn is what modulates technology developments. As it was seen CTA offers a two-fold application (i) analysis making (e.g. setting the scene: problem identification, phase in which is the technological development, actors involved and mapping on their expectations); and (ii) practice-oriented (e.g. models for interventions allowing for technological future formulations embedding society). CTA methods for analysis range from data collection and interviews allowing placing concerned innovation journey in context (main reference Deuten, Rip & Jelsma 1997), to define multi-level-perspectives (as further developed by Geels 2002) and to determine collective strategy formulations (elaborated by Robinson & Propp 2008). CTA practice-oriented methods refer to socio-technical scenarios (elaborated by Te Kulve & Rip 2011) supported by methods including bridging events (Parandian 2013); third party mediation of pre-engagements (te Kulve and Rip 2012); bridging gaps between technology development and use (Paridian 2012, Robinson 2010); backcasting (Schippl 2008); inclusion of unknown unknowns (Justen et al. 2014). So far, PhD students applying CTA have been on basic research, as in nano-technology, addressing scientific developments. My research contributes extending CTA to mature innovations and further bring its application to the technology domain.
RQ.2.	**How the industry might be falling short in embedding society in their product development? (this requires to verify how technologies are selected)**			
RQ1	*P.2. Proposition:* The case study of AGV and the ICE-350E is addressed. The disappointing commercialisation of those trains after years of collective investments in their development has raised concerns in the railway industry on the market uptake of their new technologies, while fast emergent digitalisation of society is raising new challenges. The object of analysis is therefore the development process. The unit of analysis are their manufacturers, Alstom and Siemens, and collective of stakeholders' part in the technological chain. CTA offers different layers for analysing the industry practices, which unfolds into four sub-research questions (SRQ.2.1, SRQ.2.2, SRQ.2.3, SRQ.2.4)	CTA presents analytical frameworks which intercepts the case study in terms of strategic intelligence formulation (SRQ.2.1), technology transitions (SRQ.2.2), multi-level perspectives (SRQ.2.3) and	Case studies supported by literature review on and unstructured interviews with manufacturers informants.	*Findings in Chapter IV are referred in the sections below.*

			futures assessment (SRQ2.4).		
SRQ.2.1.	**What happens in terms of innovation journey?**	*P.2.1. Proposition:* Once in liberalised market conditions the manufactures Alstom and Siemens relay on strategic intelligence to support decision-making in the technological development of the AGV and the ICE-350E. Strategic intelligence is found in their organisational structure and technological paths. In this part it is relevant to address evidence of societal embedding in those two manufacturers' strategic formulation during the development of the AGV and the ICE-350E.	Strategic function of TA Deuten, Rip, Jelsma (1997) [build on Kuhlmann (1999) Schot and Rip (1997) and later developed in Smits et al. (2008)].	Case studies supported by literature review.	*Findings chapter IV, section 4.1. Strategic intelligence:* *Theory:* Theory places Technology Assessment in strategic intelligence. Kuhlmann (1999) is the first conceptualising it. Smits et al. (2008) further elaborate on its distinctive elements (as focus on decision-making support, problem orientation, intensive interaction with the wide of actors. Schot and Rip (1997) reinforce the element of anticipation from early stage of development. While Deuten et al. (1997) formulate the previous on the new product creation process extended to society. I found however that Deuten et al. (1997) do not detail the optimal organisational structure of firms or its networks to conduct societal embedding. To overcome such theoretical gap I recurred to Lichtenthaler (2004) technology surveillance studies. *Case:* It was found that Alstom and Siemens strategic intelligence broadly aligns with CTA societal embedding recommendation. Both manufacturers filter societal constrains at socio-economic and to some extend policy levels; they have in place surveillance structures of people working mainly at the subsidiaries; they also have people part in external expert networks and in contact with lead users and suppliers; their privileged partner for societal surveillance are universities and component suppliers; and they give preference for societal embedding in non-core-technologies as interiors and telematics. In which Alstom and Siemens did not seem aligned with CTA societal embedding principle was on the technological decision-making trajectory. For both manufacturers it was found societal alignments occurred mainly during the commercial trajectory at the interception with the technical, by the time the technology was matured and ready to commercialise. Constructivists advocate that it should rather occur much earlier in the development process (Deuten et al. 1997). This is an indication that during the development of the AGV and the ICE-350E Alstom and Siemens monitored societal constraints for a purpose of "promotion" and "control" rather than producing alignments (Deuten et al. 1997). Despite the above refreed, evidences were not found at which technological readiness level societal embedding actually occurred. Also missing was the study on other stakeholders part of Alstom and Siemens supply chain. Both aspects were later covered by the survey.

SRQ.2.2.	**What has been the evolution in time?**	*P.2.2. Proposition:* During the technology transitions from one generation of high-speed trains to the other strategic decision-making nor societal constrains have been considered in the same way. It is relevant to understand how decision-making in high-speed trains have evolved by focusing on the societal element.	Technological transitions Geels (2002a), [see also Rip and Kemp (1996, 1998), Constant (1978), Rosenkopft Tushman (1993), Nelson 1994]	Case studies supported by literature review.	*Findings chapter IV 4.2. Technology Transitions:* *Theory:* Technology transition, here covered, and the Multi-Level Perspective (MLP), to be covered in the next section, are core analytical tools as they feed the main function of CTA in the understanding of the co-evolution of socio-technical systems. They were introduced in the 1990's. Technology transition by Aire Rip, Rene Kemp (1998) and Johan Schott (1997) and Multi-Level Perspective by Rip and Kemp (1998). In this section and in the next one were very useful Geels visualisations (2002a and Geels & Schot 2007) further developing both models. *Case:* By using CTA technology transition model it became evident that both trains the French AGV and the German ICE-3050E represented a shift in Alstom and Siemens decision-making. They refer to the transition from hardware to software technological developments as policy and regulatory constraints became the primary trigger for technology change. Alstom and Siemens developed these trains in the race to champion supply to the trans-European high-speed networks and have their standards a reference in interoperability. It was also possible to visualise the first signs in the emergence of a new approach in Alstom and Siemens technology decision-making that most likely will precipitate them to socialware developments driven from the exponential digitalisation of society and social innovations they arise.
SRQ.2.3.	**What happens in terms of multi-level perspective?**	*P.2.3. Proposition:* The AGV and ICE-350E result from the sum of the technological decisions, and their alignment, occurring between different stakeholders. They are produced from the alignment of multi-level perspectives on what the technology direction should be; and those alignments are mainly occurring at regime level.	Multi-level perspective Geels and Schot (2007)	Case studies supported by literature review.	*Findings chapter IV 4.3. Multi-level perspective:* *Theory:* To explore the multi-level perspective between the various actors in terms of technological knowledge exchanges happening during the development process of the AGV and ICE 350E (2001-2008) I further applied Geels levels of analysis (niche, regime, landscape arenas, in Geels and Schot 2007, to which Robinson 2009 refers as arenas-of-action) combining it with Pavitt revised taxonomy of innovation. *Case:* From this exercise it became evident that the AGV and ICE-350E were developed in a period of emergence of strategic reports where technology actors aligned their perspectives. Each reflected the technological arena of the commissioning stakeholders; they were mainly produced at regime level; and feeding on each other reports. Less covered in this alignment of perspectives where societal actors at landscape. During this particular period those societal actors were mainly non-governmental organization and specific interest groups.

					Relevant to note that two main typologies of reports were observed: dominant collective and individual techno-centric visions produced at regime level (e.g. endogenous to the AGV and the ICE-350E supply chain), and policy foresight reports covering perspectives of actors produced at landscape level (e.g. exogenous to the AGV and the ICE-350E supply chain). Such indicates a discontinuity in the alignment of perspectives between actors at regime level and landscape which I further studied and results are presented in the next section.
SRQ.2.4.	**What happens in terms of formulations of future technological paths?**	*P.2.4. Proposition:* The AGV and ICE-350E technologies reflects the industry collective visions and roadmaps. They are simultaneously the result and determinant of the collective technology path in Europe post-2001 (envisaged railway market liberalisation and completion of the trans-European network).	Future strategic formulations Robinson, Propp (2011) [see also Te Kulve, Rip (2011)]	Case studies supported by literature review and unstructured interviews with report commissioners.	*Findings chapter IV 4.4. Formulations on future technology assessment:* *Theory:* Robinson and Propp adapted classification methods (2011, p.23, table 2, of levels of innovation chain+ analysis) was proved to be a good tool to classify railways future assessment reports addressing the high-speed train technology system and diagnose the extension of societal embedding within the formulation of the collective socio-technical scenarios. Case: It was found that if the visions, roadmaps and other forms of future strategic formulations were found relevant in contributing to the revitalization of railways since 2001 they might risk to miss their function if overpassing the emergent new societal challenges occurring at landscape from digitalisation producing social innovations Notorious it was the case of ERRAC visions and road maps. They provide a pre-competitive forum (inclusive and dynamic), aiming and allowing for multi-level perspective alignments in the liberalized market conditions. 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 ICE-350E trains becoming part of the dominant designs and voluntary norms. However, there is still a long way to go. The need for forums such as ERRAC to move beyond the dominance of endogenous roadmaps (highlighted in this paper) to a mix of endogenous and exogenous roadmaps and other forms of future strategic formulations (such as the STOA type activities) is becoming a pressing issue. SHIFT2RAIL recently launched will inevitably have to address it. This call for more exogenous future strategic formulations is further amplified by other shifts in the socio-technical system of high-speed railways. For example, I have shown in this section that initially the railway operators and their manufacturers once held a strategically important position of being

					knowledgeable of the whole supply chain. However today they are no longer knowledgeable about the whole technology system. They moved from in-house production by the major manufacturers to outsourcing, pressed by 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.
RQ.3.	**Who in the R&D process has propensity to address societal embedding?**				
	P.3. Proposition: A survey to the broad of stakeholders apply as not all the actors involved in the AGV and ICE-350E development have the same approached towards societal embedding.		Deuten, Rip, Jelsma (1997), Geels (2002), Robinson and Propp (2008)	Survey	*Findings chapter IV 4.5. Survey:* *A. Strategic innovation Management* The high-speed train industry overall is R&D intensive, lead by component suppliers and research centers spending above 5% of their turnover. Contrasting, manufacturers split their levels of R&D spending between 1%-3% and 3%-5%, which reflects outsourcing. The industry reports to strategic intelligence guidelines (Q14) fed by formal channels of technology surveillance (Q15) mainly positioned in networks (Q16). Their main purpose for undertaking technological developments is to survive in open market conditions mainly by anticipating societal changes, policies and market constraints and then to make the final product attractive to the end-user (Q17). Manufacturers however contrast mainly pursuing technology development for product and deign improvements, manufacturing optimization and cost reduction (Q17). The industry is dominated by incremental innovations, reflecting the monopolistic and incumbent nature of their stakeholders (Q18). The industry is split however in their openness for collaborative research (Q19) with manufacturers and research centers expressing preferences for R&D in consortia while for component suppliers is in-house. User engagement in the technology development is however quite low across all the stakeholders enquired (Q20), with research centers expressing the highest interest to involve them. Preference goes to collaborative research performed with specialized knowledge providers as research centers and universities (Q20). All stakeholders consider societal challenges, policies and market constraints the main factors leading for collaborative research with technical problems left to be solved by in-house research (Q21). At collaborative level manufacturers are aligned with the general trend (this did not occur in Q17). *B. Societal embedding:*

				The high-speed train industry attributes high levels of relevance to the societal environment, above policy & regulations. Yet business & engineering dominates (Q22). Societal requirements are relevant at the initial stage (Q23) of technology development process (TRL1) when basic principles are observed and data collected. Then their relevance progressively declines to its minimum (TRL4) when the technology is validated. Latter they regain momentum when the new technology has matured, ready to market (TRL8 & TRL9). Different from manufacturing, component suppliers tend to consider societal requirements in all stages of development. Alignment with societal actors are considered by a great majority of respondents a way of risk mitigation of technology failure (Q26). Manufacturing and researcher centers showing the highest of support but also of concerns. The benefits of shared technological paths it is the least considered by manufacturing. Societal embedding is dominated by informal practices (Q27) with a great percentage of respondents stating openness for interaction with societal actors and their recognition as a stakeholder in the technology development. Only a few however referred employing someone responsible for societal alignment, mainly coming from research centers. Even fewer mentioned technology assessment gates to address them, such as a minority of component suppliers, consultancies and railway associations. (Q28) Mapping and monitoring societal environment is relevant for the industry. However, the articulation of scenarios allowing for societal embedding and stimulation of learning from societal actors is the least referred, except for research centers. The industry rather controls than orchestrates their dialogue with societal actors. Results here show that the most referred type of Future Technology Assessments are endogenous to the railways presenting their techno-centric visions to an envisaged future they aim to control (Q.30). Exception goes to governments and some consultancies referring the most to external reports more inclusive of the wider society and capable of covering wider collective of stakeholders. In terms of methods used (Q25) respondents equally considered qualitative and quantitative approaches. Manufacturing however standout from other stakeholders by prioritizing quantitative methods, less appropriated in assessing vague and not-known for the industry societal requirements.