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MANAGING PROJECTS WITH STRONG TECHNOLOGICAL RUPTURE

Case of High-Speed Ground Transportation Systems

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Lausanne, EPFL
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PRÉSENTÉE AU DÉPARTEMENT DE GÉNIE CIVIL

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

PAR

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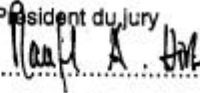
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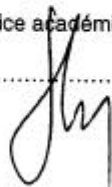
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EXECUTIVE SUMMARY

Managing the launch of new technological trajectories is a complex task, especially in the case of High-Speed Ground Transportation (HSGT) Systems. For instance, Maglev systems are now developed since 40 years, and none of these technologies has been implemented until the first Transrapid contract for Shanghai (which could lead to a 1250 km track between Beijing and Shanghai).

What are the future challenges for cutting-edge technologies such as Swissmetro or the Japanese MLX-01? Behind such a question stands the problem of managing technological rupture. This brings us beyond the engineering field since it implies leading change and innovation through organizations, institutions and policy.

HSGT innovations with strong technological rupture are complex to manage, involving industry, operators, institutions and politicians. The structure of public/private investments and the long lead-life of such projects (much longer than many industrial ones) require from decision-makers a good understanding of the management of complex systems. This presupposes a good technology assessment, in order to identify technological lock-ins, performances and benefits. However only assessing the intrinsic and extrinsic projects' value without the ability to introduce change wouldn't be enough: The ability to lead changes in cultures, organizations, and processes is a determinant of the successful development and diffusion of such technologies.

Therefore, the aim of this research is to examine the role of industry, operators and institutions in the implementation of innovative transportation networks and in the diffusion of innovations. Depending on the national context, experiences have been different depending on the countries. Innovative projects have sometimes been successful; other times they have failed, with millions of dollars wasted. Decision-making is a hard task, especially when it concerns R&D investments in projects that imply strong technological rupture. The assessment of risks and uncertainties is not an easy task, as decision-making unfolds in design, construction and operation phases. Therefore, the importance of integrating structural and organizational factors into the analysis seems to be necessary to provide pertinent recommendations for the management of such projects.

For this purpose, this research provides a methodological approach with a view to understanding the impact of the technological rupture on project management, leading to a set of recommendations. Those ones are based on case studies, as well as the elaboration of Two HSGT Innovation Models, whose understanding is also enlightened by the development of several conceptual Models. The methodology can be described as follow:

1. Case studies: identification of critical factors of success/failure:
 - Related to the structure of the market and its evolution
 - Related to the notion of innovation and rupture

2. Elaboration of innovation models for HSGT technologies:
 - Modeling innovation processes: main existing models
 - Modeling diffusion processes of innovations, and decision-making
 - Elaboration of 2 HSGT innovation models - Putting into perspective the critical factors identified

3. Modeling the influence of institutional & organizational factors
4. Developing an approach centered on the notion of risk/opportunity
 - Defining a methodological approach in order to identify the risks related to the rupture
 - Identifying the impacts of the technological rupture on risks and uncertainties
5. Providing recommendations on project management
 - Recommendations related to the critical factors underlined by the case studies and the conceptual models.

This constitutes the important steps of this research, leading to a better understanding of innovation processes and how to manage them. The identification of critical factors in the management of such projects as well as recommendations are embodied in a Project Management Assessment Tool (PMAS), which is presented in annex.

The originality of this research is to analyze, in a multi-perspective approach, innovation processes in the development of new technological trajectories characterized by strong technological rupture. The value of this research also resides in the international perspective of experiences through the case studies: This led to better take into account market and political contexts for recommendations on how to manage the rupture.

This being said, this approach also provides a good basis for analyzing innovations in large technical systems in general, the nature of which go beyond private interests and are by nature dependent on public and political interests.

VERSION ABRÉGÉE

Gérer le lancement d'une nouvelle trajectoire technologique est une tâche compliquée, surtout dans le cas des systèmes de transport terrestre à grande vitesse. C'est le cas des systèmes Maglev, maintenant développés depuis plus de 40 ans et dont la première implémentation commerciale a été signée en Chine pour la desserte de l'aéroport de Shanghai (avec comme objectif une possible ligne de 1250 km entre Pékin et Shanghai si le système fait ses preuves).

Quels sont les défis pour des technologies avant-gardistes comme le Swissmetro ou le MLX-01 japonais ? Une telle question renvoie à la difficulté de gérer la rupture technologique : Une telle rupture dépasse le domaine de l'ingénierie puisqu'elle implique d'introduire le changement et l'innovation dans les organisations, les institutions et la politique.

De tels projets d'innovation à forte rupture technologique sont d'une grande complexité à gérer, impliquant l'industrie, les opérateurs, les institutions et les politiques. La structure des investissements publics-privés et la longue durée de vie de tels projets (bien plus long que les projets industriels classiques) nécessitent de la part des décideurs une bonne compréhension du management des systèmes complexes. Cela présuppose une bonne évaluation de la technologie, afin d'identifier les verrous technologiques et de marché, ainsi que ses performances et bénéfices. Cependant, l'évaluation intrinsèque ou extrinsèque du projet de rupture technologique sans prendre en compte la capacité de conduire le changement n'est pas suffisante : Introduire le changement dans les cultures, les organisations et les processus chez les acteurs clé est un élément déterminant pour la réussite du lancement et du développement de telles technologies.

L'objectif de cette recherche est donc d'examiner le rôle de l'industrie, des opérateurs et des institutions dans le cas des réseaux de transports innovants et la diffusion des innovations. Suivant le contexte national, les expériences ont été différentes selon les pays. Ces projets de rupture technologiques ont parfois été réussis ; d'autres ont échoué engloutissant des millions de dollars. La prise de décision dans de tels projets de rupture est une tâche difficile, surtout lorsqu'il s'agit des investissements de R&D et du passage au stade de développement : L'évaluation des risques et des incertitudes n'est pas aisée, puisque la prise de décision concerne non seulement la phase de développement, mais aussi les phases de construction (implémentation) et d'opération. L'importance d'intégrer les facteurs structurels et organisationnels dans l'analyse semble donc nécessaire afin de fournir des recommandations pertinentes pour le management de tels projets.

Dans ce but, cette recherche fournit une approche méthodologique permettant de mieux comprendre l'impact de la rupture technologique sur le management de projet et conduisant à un ensemble de recommandations. Celles-ci sont basées sur des études de cas ainsi que sur l'élaboration de deux modèles d'innovation pour ces technologies, dont la compréhension est aussi éclairée par plusieurs autres modèles conceptuels. La méthodologie peut être décrite comme suit:

1. Etudes de cas: identification des facteurs critiques de réussite/échec:
 - Liés à la structure du marché et de son évolution
 - Liés à la notion d'innovation et de rupture

2. Élaboration un/des modèle(s) d'innovation pour les technologies HSGT
 - Modéliser les processus d'innovation: principaux modèles existants
 - Modéliser les processus de diffusion de l'innovation, et de prise de décision
 - Élaboration de 2 modèles d'innovation HSGT. Mise en perspective avec les facteurs critiques identifiés

3. Modélisation de l'influence des facteurs institutionnels & organisationnels
4. Développement d'une approche centrée sur la notion de risque/opportunité
 - Définition d'une approche méthodologique pour l'identification des risques liés à la rupture
 - Identification des impacts de la rupture technologique sur les risques et les incertitudes
5. Fournir des recommandations de gestion de projet
 - Recommandations par rapport aux facteurs critiques soulignés par les différents modèles et les études de cas.

Ceci constitue les étapes importantes de cette recherche, qui permettront de mieux comprendre les processus d'innovation ainsi que la manière de les gérer. Ils ont aussi permis d'identifier un certain nombre de facteurs critiques pour le management de tels projets. Ceux-ci ont été intégrés dans un outil d'évaluation du management de projet (PMAS) qui est présenté en annexe.

L'originalité de cette recherche est d'analyser, avec une approche multi-perspective, les processus d'innovation dans le développement de nouvelles trajectoires technologiques caractérisées par une forte rupture technologique. La valeur ajoutée de cette recherche réside aussi dans l'intégration d'expériences internationales à travers les études de cas, permettant de mieux prendre en compte les contextes politiques et institutionnels.

Ceci dit, cette recherche fournit une bonne base d'analyse pour les innovations dans les grands systèmes techniques en général, dont la nature dépasse les seuls intérêts privés, dépendants d'intérêts publics et politiques.

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6. Impact of the technological rupture on Risk &
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8. Conclusion

ANNEX: Project Management Assessment System

1. INTRODUCTION

1.1. Stakes and importance of the subject

High-Speed Ground Transportation (HSGT) technologies constitute a very interesting case of the analysis of innovation with strong technological rupture. Diffusion of such innovations is also linked to the characteristics of networks, which have a strong impact in the development of new technological trajectories. The failure of all HSGT innovations with strong technological ruptures since 40 years leads to the question of how managing such projects, and what are the conditions of their success.

High-Speed Ground Transportation (HSGT) Systems are usually implemented after a long planning and decision-making process. More than one or two decades are often required to go through feasibility studies, financing schemes and political agreements. Behind these procedures, industry develops new systems or improves existing ones. The dilemma between Incrementalism and rupture is also driven by market share forecasts, as the risk of innovation can be seen as future opportunities.

Strong investments have been made since the 60's to develop alternatives such as Maglev systems. But up to the first contract signed by Transrapid international with Shanghai, none of these technologies has been implemented despite 1.5 to 3 billions US\$ spent by the Japanese Government and 1 billion US\$ by the German Transrapid Consortium.¹

Concerning other R&D programs focusing on HSGT Maglev concepts, the US Maglev Initiative, supported by the Department of Transportation (FDOT), was finally abandoned in 2001: the US Government thus gave up its intention to develop an all-American Maglev technology and the Transrapid was selected as an alternative to HSR systems.

The latest concept waiting for more R&D support and development is SWISSMETRO. The question is whether this is a futuristic concept or merely an Ersatz for the 70's HSGT concept, coming 20 years too late?

What challenges are hidden behind the technological rupture induced by such a concept and what recommendations can be made to manage the development of such cutting-edge technologies?

Apprehending risks and opportunities is a crucial stake and requires understanding the system, whose building blocks are industry, operator, institutions and politics. Innovation in HSGT systems can be associated with three themes:

- Large-scale projects - complex engineering systems
- Transportation projects - planning
- Innovation - change management

No research has up to now been made to underline the impact of innovation on the whole system with international overviews of experiences and focusing on innovation processes.² Usually research is more focused on construction management, transportation planning or innovation management separately or only on a combination of two of them. Innovation was analyzed in the work of Garrison (1996, 2000) and

¹ Source: Transrapid International, *Transrapid: Contract from China*, Berlin 23 January 2001; *Transrapid Project Shanghai*, Berlin 21 January 2001.

² This purpose has been developed within the PREDIT research project, which provided a strong basis for this thesis. The PREDIT reports have been published in 2000 (with the following contributions: Foray & Perret 1998, Foray 2000, Hulten 1999, Llerena et al. 2000, de Tilière & Perret 2000).

Sahal (1981). Simply taking examples in each field shows what difficulties can be handled in project management:

Large-scale construction projects bring inherent complexity and thus increase risks. Examples concerning the difficulties encountered in construction of transportation infrastructures leading to huge cost overruns are numerous: from the new innovative offshore-airport of Osaka³ to the TGV project in Korea or the TGV project in Taiwan.⁴

Moreover, innovation with strong technological rupture can imply a rupture in the demand, leading to higher uncertainties in relation to the demand-forecasts (market opportunities). One famous example is the strategies of Airbus and Boeing concerning supersonic jets versus super-jumbos. Whereas the Franco-British consortium opted for the technological rupture in the 70's with Concorde, Boeing chose Incrementalism with the 747; conversely, in the 90's, Airbus launched the A380 Program whereas Boeing has worked since 1994 on the Supersonic Transportation Program (HSCT).⁵ This⁶ difference between rupture and incremental strategies was based on the differences in market-forecasts.

This being said, Innovation is also associated with risk when the development of new technologies of rupture requires organizational changes and knowledge acquisition. Understanding which kind of organizations are in place in the HSGT market, as well as their link to institutions, is therefore very important. Examples of failures, such as Bœing-Vertol for light rail vehicles⁷ or Grumman for buses (Petroski 1985), show that even for large defense contractors, used to manage complexity, managing new product developments in new markets is more difficult than expected.

Therefore, HSGT projects with strong technological rupture, such as SWISSMETRO, constitute a challenge for industry and operators: This new technological trajectory combines an underground Maglev technology with a large-scale vacuum system, allowing speeds around 500 km/h. If such project implies technological challenges, impacts of the rupture go far beyond the engineering fields: It combines not only technological complexity, but organizational difficulties and strong uncertainties concerning market-forecasts. The rupture is more than purely technological and affects the position of operators (lead-users) and therefore industry, whose roles are crucial for the emergence of such technologies.

This research aims to provide a methodological approach and a set of recommendations for managing projects with strong technological rupture. Its purpose is to underline the link between technological complexity, organizational and institutional patterns, market structure and risk.

1.2. State of research

Very few studies have looked at the question of managing innovation in projects with strong technological rupture, with an emphasis on innovation building blocks (Garrison 2000). Most research on innovation is focused on diffusion patterns of technologies at a macro level, or look at managing innovation processes focusing on one actor (Midler 1993, Weil 1999).

Moreover, if influences of organizational structures have been analyzed at a strategic level (Mintzberg 1995), recent reorganization in the rail market reshapes the organization of projects relating to design and

³ The costs of which increased from 0.75 to 1.5 billion US\$ since 1994 (Interview with Dr M. Takabayeshi, department of Civil Engineering - Osaka University, May 8, 2001).

⁴ More than 100% cost overrun for TGV project in Korea and 50% increase of cost-forecasts for the TGV project in Taiwan, finally attributed to the Japanese Shinkansen consortium, but ending into lawsuit (Source: Erik Rail News).

⁵ The HSCT program included NASA, Boeing and McDonnell Douglas (successor of the SST program in the 70's): 1 billion US\$ has been spent since 1990 before its cancellation in July 2000. Another 15-20 billion were planned for the completion of the project until 2015.

⁶ Results of Super-Jumbo market-forecasts in the 1990's were 1200 units for Airbus and 320 for Boeing, with a profitability threshold of around 500 units (Source: Aviation Week).

⁷ Interview with Prof. E. Beimborn, Institute of Transportation Studies, University of Wisconsin, April 26 2001.

development (see also Van de Ven 1999), especially for large transportation or civil-engineering projects. This implies new challenges for researchers in terms of understanding the impacts on Innovation Models and processes.

Innovation is a topic mostly analyzed in relation to mass-consumption products industry. Innovation Models have been mainly developed at a macro level (Sahal 1981), in order to understand diffusion patterns (Rogers 1995). Moreover, little work has been achieved to analyze this type of projects under the angle of economic analysis (Foray 1998).

Studies have up to now been achieved to evaluate public policies in centralized procedures and concentration of resource allocation for research activities (Ergas 1988; Cohen & Noll 1991). However, there is a lack of integrating and connecting public and private strategies into a common framework of analysis in order to better understand innovation processes and predict technological trajectories.

Concerning the management of innovation and projects related to new technologies, few analyzes look at large infrastructure projects. Existing studies are more retrospective in nature (generally relating to the aerospace or nuclear fields) and tend to the formalization of methods of management and decision-making.

If few researches have been achieved on related topics through national research programs on Swissmetro, the lack of international perspectives occults strategies or behavior of the HSGT actors, now acting globally since the reorganization of the European rail market and recent mergers of manufacturers. Rossel (1998) proposed a methodology for the assessment of disruptive HSGT technologies (with an emphasis on Swissmetro), but this research focuses on public decision-making. Gentinetta (1997) looked at the financial aspects of the project, but with more focus on the implementation phase.

Understanding innovation processes and the impact of the technological rupture (Teece 2000, Mowery 1979) requires to look at risk management theories (Bea 2001) and underlines risks related to organizational and human factors as well as factors shaping success and failure in project management.

1.3. Objectives of the thesis

The main objective of this thesis is to provide a set of recommendation for the management of HSGT innovation with strong technological rupture: How managing the sustainable development of new technological trajectories leads to answer the question: "What are the impacts of the technological rupture and the critical factors in the management of HSGT innovations; and how does one deal with them?"

For this purpose, the elaboration of an HSGT Innovation Model will be an important step, underlying the main processes of development as the key roles of the actors. Such a model will be based on case studies through the elaboration of Specific Innovation Models and on theoretical developments through the elaboration of Generic Innovation Models and Generic Decision-making Models.

The development of such Models will allow the elaboration of management principles to deal with the impacts of the technological rupture. Finally this research will provide a methodology for the assessment of innovations with strong technological rupture, embodied in a Project Management Assessment System (PMAS).

1.4. Methodological approach

1.4.1. Theoretical aspects for case study research

This research will be based on case studies (Yin 1990, Midler 1993, Hlady-Rispal 2000), using phenomenology and historical analysis of High Speed Ground Transportation (HSGT) systems:

Four strategies can be identified for research in management science. The two first ones are the "logical-

formal” and “empirical-formal” ones (AIMS 1996), based either on a theoretical construction or on deductive hypothesis tests. The two other are based on empirical approaches (Savall & Zardet 1996) which are composed, on the one hand, by a contemplative analysis without interference (Figure 1 [1&2], where inductive thinking is dominant) and, on the other hand, by “research-intervention” (Figure 1 [3&4], where the researcher is also an actor in charge of studying and solving an identified problem).

The present research will combine the “empirical-formal” with the “contemplative analysis” approaches (interviews and bibliographical research), and this for all case studies except SWISSMETRO, where a more “research-intervention” approach will be used (Figure 1 [1,2&3]).

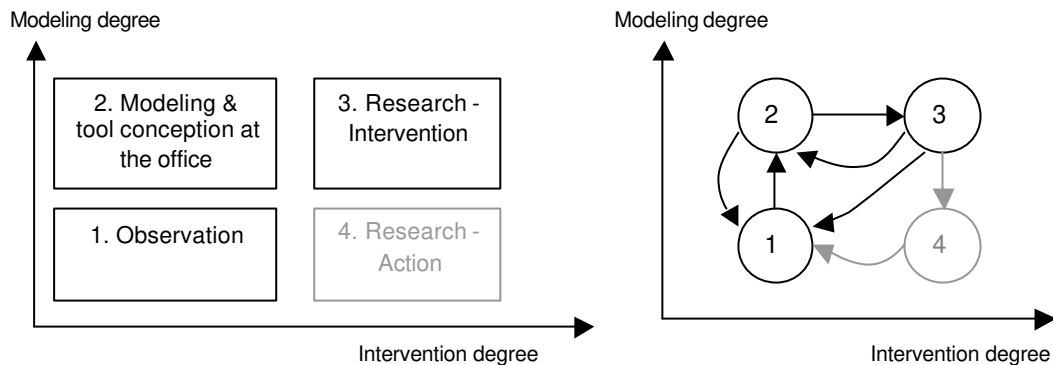


Figure 1: Research Methodology, between theory and practice.

This research intends to lead to theoretical and operational results. It will therefore proceed by constantly confronting theory and case studies, based on the analysis of relevant projects.

1.4.2. From case studies to management concepts

As the present research is focusing on the HSGT market, only a few cases are available. Moreover data are not very rich and records are very fragmented⁹ (and usually not reliable).⁸ This being said, data is probably not the best way to observe past failures⁹. Thus, techniques used in this research are mainly interviews and case studies, which are analyzed through theoretical perspectives. The main purpose is to define a methodological approach in order to apprehend innovation and rupture, and recommend risk mitigation measures as well as best management practices.

A significant part of this work will concentrate on case studies (Figure 2), benefiting from a wide array of interviews, which provide diverse experiences in HSGT project management. The study will concentrate on recent projects, but also look at past developments (1960-1990); other examples taken from other industry branches will enrich this research.

The main case studies have been selected in order to underline the impact of the rupture on management as well as in project success. For this purpose two types of projects were chosen:

- The ones from High-Speed Rail technologies: Underlying technological improvement on a continuous technological trajectory, symbolizing incremental innovations.
- The others from Maglev technologies: Underlying a radical technological rupture, giving birth to a new technological trajectory and symbolizing innovations with strong technological rupture.

These case studies, described in tables 1 & 2, will allow determining the impacts of the technological rupture: They will allow identifying the characteristics of such projects' organization and their management

⁸ Interview with Prof. W. Garrison, 02.2001, Institute of Transportation Studies, UC-Berkeley.

⁹ This has been already observed by Wellington for the management of new railway technologies and projects in 1906 (Wellington 1906)

structures regarding to technological rupture (Figure 3). They will also highlight the complexity of project management in the context of high uncertainty (public policy, technologies, economy and markets).

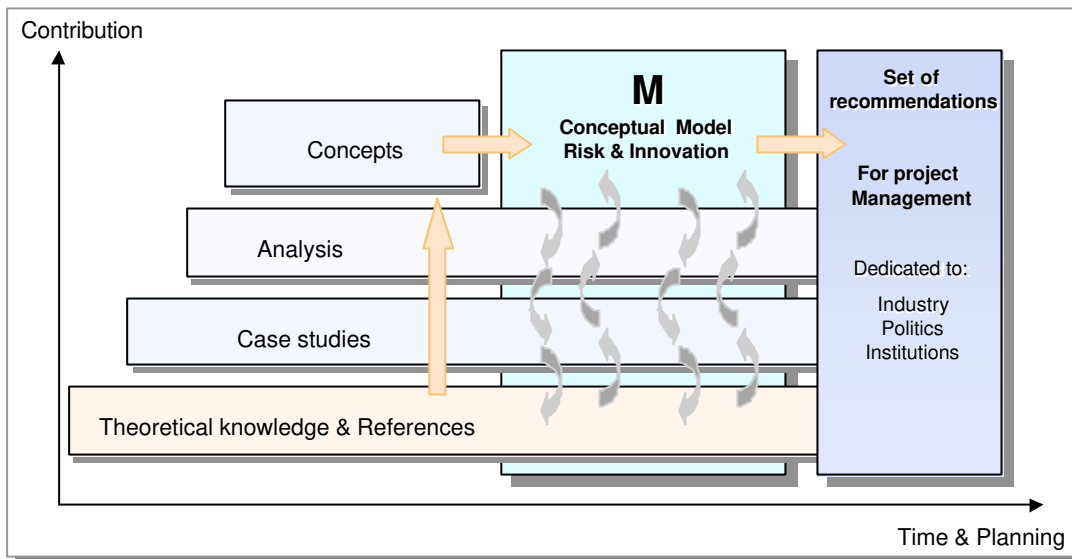


Figure 2: Methodology: from case studies to recommendations

HSGT Innovations with strong technological rupture:

Technology/Programs	Country	Infrastructure	Bibliographical research	Interviews
SWISSMETRO	Switzerland	Maglev	Yes	Yes
TRANSRAPID (*)	Germany	Maglev	Yes	Yes
MLX-01	Japan	Maglev	Yes	Yes
AEROTRAIN	France	TACV	Yes	No
HSGT Act	USA	Rail, Maglev	Yes	Yes
National Maglev Initiative	USA	Maglev	Yes	Yes

Case studies worked out through the PREDIT program. (*) Cooperation IMRI, ITEP, BETA

Table 1: Case studies of HSGT systems (1998-2000).

HSGT Technologies resulting from Incremental Innovations

Technology/Programs	Country/State	Infrastructure	Bibliographical research	Interviews
Shinkansen	Japan	Rail	Yes	Yes
TGV	France	Rail	Yes	Yes
Tilting TGV (*)	France	Rail	Yes	No
X-2000 (*)	Sweden	Rail	Yes	No
Acela-Express	USA	Rail	Yes	No
Turbotrain	France	Rail	Yes	No
Turbotrain	USA-Canada	Rail	Yes	No
HSR projects	Texas, Florida, California	Rail	Yes	Yes

Case studies worked out through the PREDIT program. (*) Cooperation IMRI, ITEP, BETA

Table 2: Case studies of HSGT systems (2000-2001).

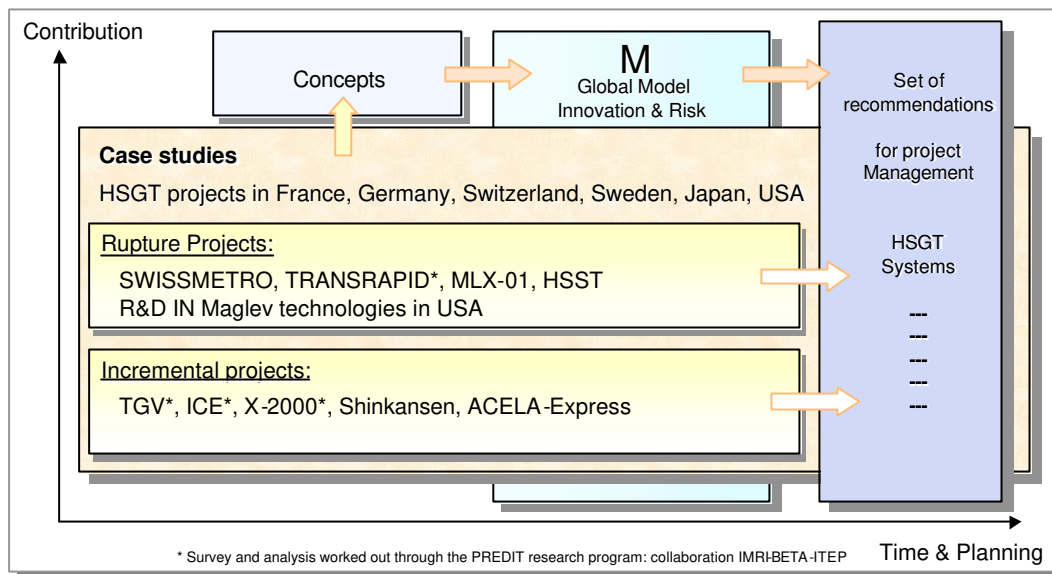


Figure 3: Methodology for identifying the impact of rupture on project management

1.5. Structure of the report

With the purpose to develop HSGT Innovation Models and define the best practices for managing the technological rupture, the research was subdivided in several phases (figure 4), leading to the structuring of this report into six steps:

1. A key issue will be to understand the specific HSGT market and its context of change, in particular how its actors are interacting and motivated in the development and the implementation of technologies with strong technological rupture versus incremental technologies (Chapter 2).
2. This background will provide the basis for understanding the innovation processes, as well as differences between Incrementalism and rupture (Chapter 3). An emphasize will be put on the definition of a typology of innovation, as well as a typology of ruptures. Finally it will lead to stress the link between technological innovations and corporate strategy.
3. The understanding of innovation processes and strategies will lead to the elaboration of two HSGT Innovation Models (Chapter 4). These models will be based on the development of Generic Innovation Models as well as Generic Decision-making Models: Generic Models will be used as tools to analyze the case studies (resulting in the development of an Innovation Model for each case), leading to the definition of the two main HSGT Innovation Models.
4. If Innovation Models emphasize on innovation processes, the role of the main building blocks of these Models will be deeper analyzed in Chapter 5, stressing out the influence of organizational factors as well as the role of paradigms¹⁰ and epistemic communities¹¹, also underlined in case studies: Introducing technological ruptures requires changes, whose consequences not only have an impact on industry and the public sector, but also on institutions.

¹⁰ The notion of Paradigm has been defined by Kuhn (1970) as a set of belief, assumptions relatively spread among an organization and thought as to be true. The notion of technological Paradigm was defined by Constant (1973). See Glossary page 309

¹¹ Epistemic communities are the communities constituted around a shared paradigm (Holzner & Marx 1979 and Haas 1992). See glossary page 309 for definitions

5. The technological rupture is often seen as a tool to produce market ruptures, referring to the concept of risk-opportunity. However, assessing risks and uncertainties are a critical step, not only to demonstrate the opportunity of a technological rupture, but also to manage the project successfully. The elaboration of a methodology (Chapter 6) will be developed with the aim to identifying impacts of innovation and rupture in the assessment of risk and uncertainties. A Conceptual Model of risk will be worked out describing how risks are spread among actors in the development of HSGT technologies. The link with innovation and risk perception will be analyzed. Finally a Global Innovation and Risk Model will try to describe the interrelations between innovation, rupture and risk.
6. Recommendations will be worked out (Chapter 7) from the conclusions of each theme, with a view to elaborating a list of critical factors affecting management of project with strong technological rupture. They will be integrated in the Project Management Assessment System (PMAS). PMAS will be aimed at defining the accuracy of project management structures in the light of the various project patterns (degree of innovation and rupture) and lead to the proposition of mitigation measures as well as best practices.

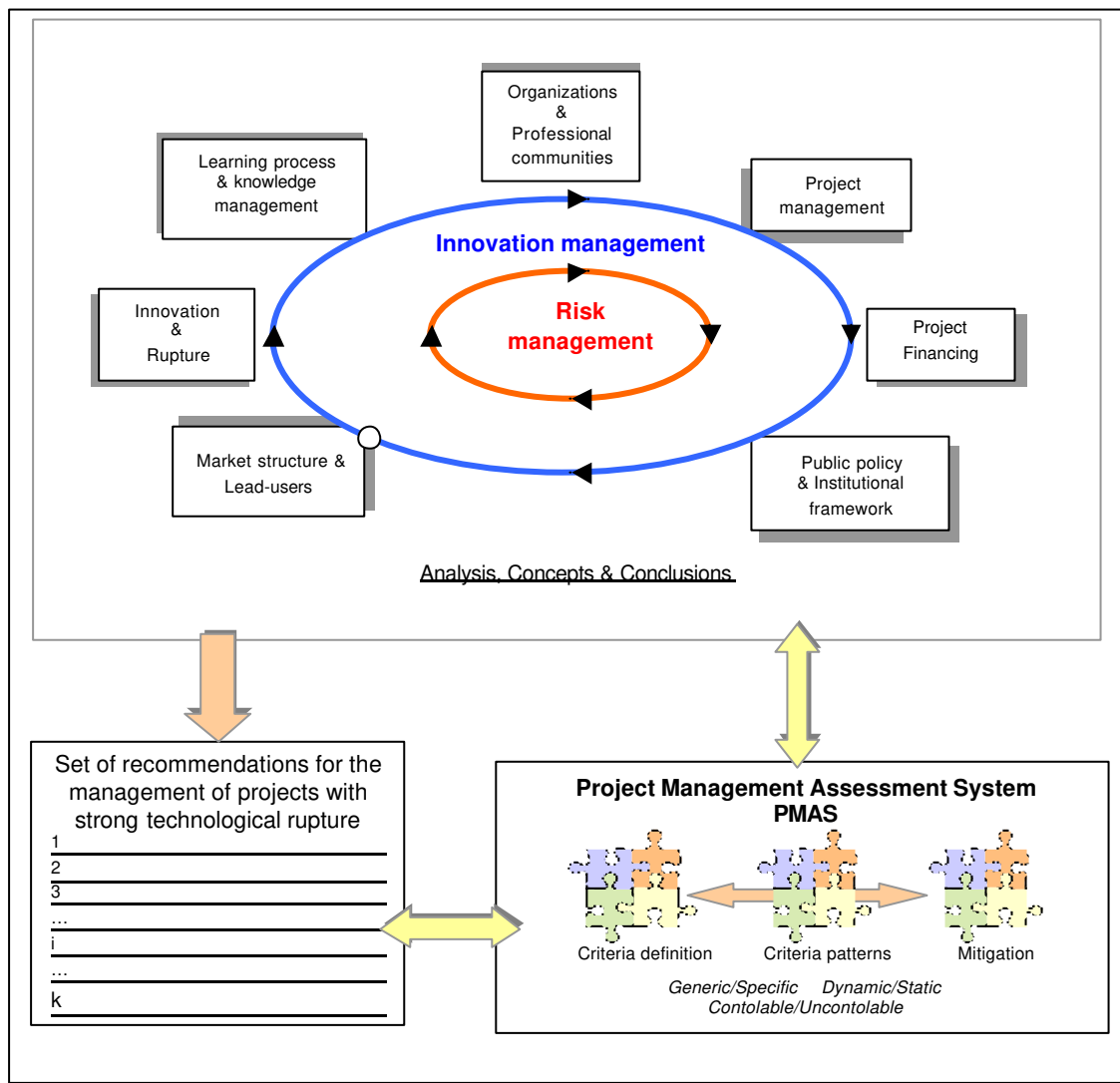


Figure 4: Structure of the thesis; a conceptual model of risk & innovation for project management recommendation

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	1. Introduction
▶	2. The case of high-speed ground transportation projects
	3. Innovation and rupture
	4. Towards an Innovation Model for HSGT systems
	5. How organizational and Institutional factors influence Innovation Models
	6. Impact of the technological rupture on Risk & Uncertainties
	7. Managing the Development of New Technological Trajectories
	8. Conclusion
	ANNEX: Project Management Assessment System

“The end of the high-speed paradigm or the limit of the Keynesian approach...”

2. The case of high-speed ground transportation projects

2.1. Introduction

The management of HSGT projects with strong technological rupture requires a good understanding of the HSGT market. Moreover, being able to identify the impacts of the rupture is critical for the definition of the objectives of the project as well as of the reengineering processes. The complexity of the HSGT environment needs to be analyzed through a systemic approach. Before going deeper into innovation processes and the analysis of rupture (chapter 3) it will be important to provide a background overview of this specific market.

As all large-scale projects, High-Speed Ground Transportation (HSGT) systems involve complex decision-making processes, as well as a lot of technologies and processes that are combined from the design to the implementation phases (Figure 5).

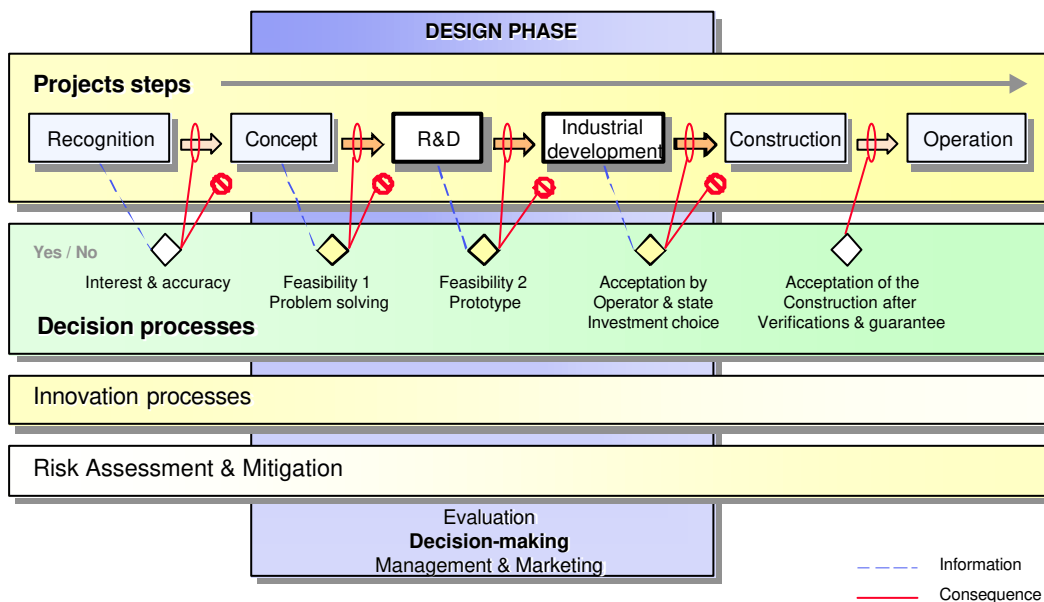


Figure 5: Typical project phases and decision-making processes.

In order to work out pertinent recommendations for the management of such projects, defining what is success or failure becomes the first step. In fact, identifying failure in projects requires special

investigations of each special case: “errors which, even if they are committed are not likely to be discovered, are rarely much feared, and at least the consciousness that there is a danger of error becomes dulled” (Wellington 1906). For this reason, one will have to undertake case studies and interviews in order to identify the root causes of typical failures in innovation projects and to provide possible mitigation measures.

For this purpose, innovation processes will be modeled through the sequence below and using the same background as described in Figure 5. This framework will provide the basis for the case studies analysis that will be described in chapter 4.3 and in order to understand the role of the main actors in HSGT innovation processes.

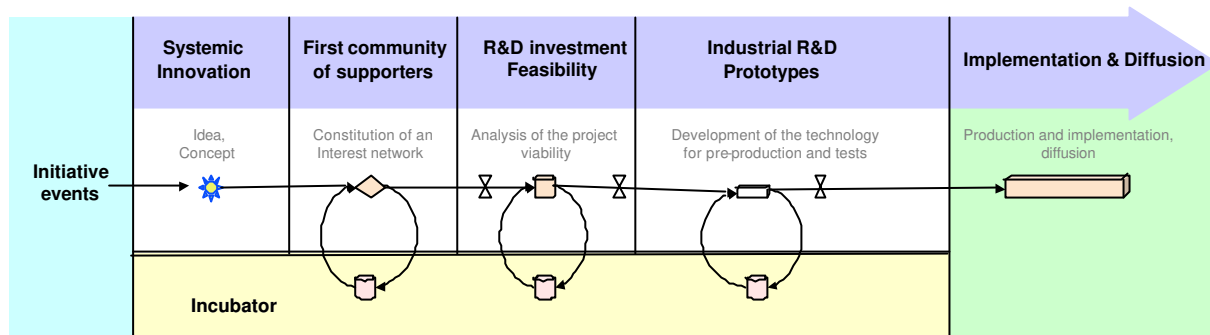


Figure 6: Framework for the analysis of Innovation process

But before going deeper into innovation processes, one will have to analyze the particularities of the HSGT market and to describe the emergence of HSGT technologies and their context, as well as the current developments and trends.

2.2. Characteristics of high-speed ground transportation (HSGT) Systems

2.2.1. Definition

High-speed ground transportation (HSGT) systems are self-guided intercity passenger ground transportation means that are competitive with air and road transport modes, on a door to door basis for trips in an approximate range of 150 to 800 km. HSGT is a family of technology ranging from upgraded steel-wheel-on-rail railroads to magnetically levitated (Maglev) vehicles, capable of sustaining operating speeds of over 200 km/h (Lynch 1998). Other definitions propose the denomination HSGT for vehicles with a maximum speed of more than 200 km/h and capable of an average speed of more than 150 km/h (Hulten 1997). Such systems can be ranged into the following three categories (technologies available for implementation):

- Upgraded high-speed rail (HSR) systems: Using existing rail infrastructures with some modifications of the track and using tilting train technologies, these systems allow for commercial speeds up to 200 km/h (example of the Swedish X2000, the Italian Pendolino or the Franco-Canadian Acela-Express).
- Dedicated HSR systems: Using dedicated high-speed rail infrastructures, these systems allow for commercial speeds of over 250 km/h (certified for a maximum of 350 km/h). Such systems have mainly been developed in Japan (Shinkansen) and France (TGV).

- **Maglev Systems:** Using magnetic levitation on special tracks, such systems avoid contacts between the vehicle and the guide-way and increase aerodynamic properties with the absence of catenaries. Two systems have been tested at full-scale: one in Germany (Transrapid) and one in Japan (MLX-01), with speed ranges of up to 550 km/h. There has however been no commercial application until 2000: the first contract has been signed for a 30 km Transrapid system in January 2001 in China.

Such systems can be subdivided into three elements (Figure 7): infrastructures, equipments and vehicles. Infrastructures such as railroads, Maglev tracks and civil-engineering works such as bridges and tunnels imply the active role of the public sector (institutions) in the decision making-processes, due in particular to the impact on land-use. The role of the private sector is also dominant concerning vehicles and equipment, but it is more focused on the definition of standards rather than being oriented towards project-implementation.

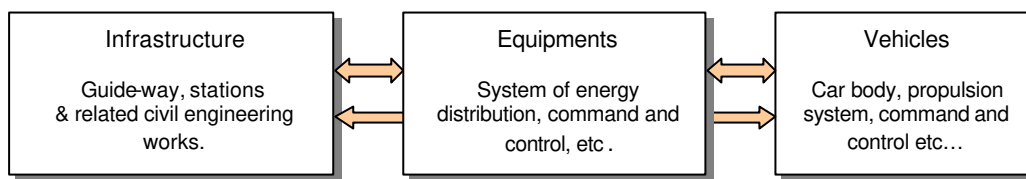


Figure 7: Three components of HSGT systems

2.2.2. HSGT technologies in the transportation supply

The HSGT market is part of the transportation system and is focused on medium and long haul transportation. Its services are in competition with air and road transportation modes. Like airports and freeways, HSGT networks have, in most countries, been developed with the strong support of governments. But this support has also been accompanied by regulation measures, in order to influence the demand and optimize the resources of the transportation networks. Gas taxes, highway tolls and other measures contribute to regulating the competition between transportation modes.

For distances longer than 500 km, air and HSGT modes are more competitive than road transport. Both air and HSGT are competing in terms of travel time and prices. Many HSGT projects are offered with the argument of airport congestion (HSR San Francisco-Los Angeles, Transrapid Pittsburgh, Transrapid Shanghai, Swissmetro Basel-Zurich and Geneva-Lyon etc.). The problem of HSGT systems is the high investment costs and the lack of flexibility when compared with aircraft. Moreover, the problem of tariff competition between both modes can lead to strong demand shifts: for the three main US HSR corridors, a decrease of 10% in the price of air travel can lead to a decrease in the demand for rail transportation by 40% (US-FDOT 1998).

2.2.3. Structure of the HSGT market

- *Building blocks of the HSGT market structure*

Understanding the development of HSGT technologies requires that one understands the structure of its market (which is dependant on the rail market). A generic scheme is given in Figure 8, and all configurations can be derived from it. Depending on the country and the period, this structure evolves through the relation between these main actors (degree of vertical integration).

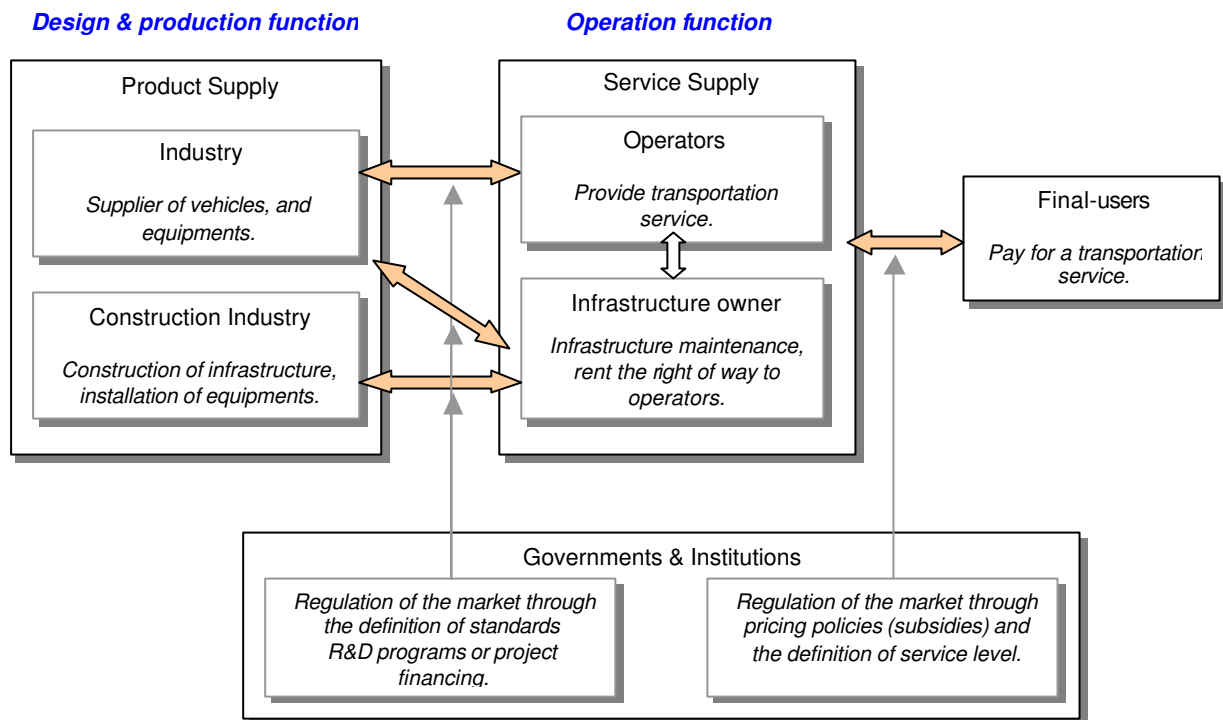


Figure 8: The structure of the HSGT market.

Four main actors are presented: (1) Industry (product supplier), which designs and develops technologies or builds infrastructures. (2) Operators and infrastructure owner (service suppliers), which deliver transportation services to (3) the final users (demand of transportation services). Institutions and governments (4) play the role of regulators, through the definition of standards or in the transportation planning processes (European/Federal, State or Local level).

This generic case shows the links between actors through their specific roles as defined by the European Directive 91/440 (July 1991) concerning the separation between operations and infrastructure. Other configurations can be explained by the same model, but with different relations between actors:

- **Separation between operations and infrastructure:** Some countries have both activities merged into the same organization (USA, Japan); others have separated them or tend to do so (Europe).
- **Vertical integration:** The quasi integration between operators, infrastructure owners and institutions has been the norm until recently in centralized countries such as France or Japan. It sometimes also applies, on the national level, to the relation operator-industry, as it was the case of SNCF-Alstom in the initial phase of the TGV (see also Quinet 1999).
- **Horizontal disintegration:** This concerns the structure of the decision-making process concerning the development of transportation networks, which is more complex and multi-layered in federal States such as the US or the Federal Republic of Germany.

The differences in market structures have a strong influence on the development of innovations (Garrison 2000, de Tilière 2001), in the shaping of organizations, in the decision-making processes and regarding incentives, as we shall see in chapters 4 and 5.

- *The influence of rail actors in the HSGT technologies*

HSGT technologies have over the years been developed by the same industry that has been building and improving railways. Rail technologies range from Light Rail Vehicles (LRV's) and Metros to High-speed Rail Systems (HSR). They include conventional trains for passengers and freight, trailers and other traction vehicles. HSGT technologies are therefore highly dependant on the railway market in terms of spillover and core competences. This contributes to maximizing the economies of scale and scope for these industries. It also remains the main barrier for the introduction of Maglev technologies.

2.2.4. Scale and complexity of HSGT projects

Large infrastructure projects usually refer to transportation, telecommunication, energy or water management systems. Planning, design and construction of such engineering systems can be associated with a challenge in project management. Scale and complexity characterize the difficulties encountered in project management as well as in decision-making processes. Scale refers to time, cost, and project size. The increase of scale requires the mobilization of more resources and leads to more planning difficulties. Complexity is related to the level of interaction between components, which renders the understanding and the apprehension of the system more or less difficult.

High-speed transportation projects involve public and private actors. The role of public entities is justified by the impact of transportation systems on regional and national development as well as regarding social, environmental and economical issues. Politicians, institutions and industry are all involved in the complex decision-making process surrounding HSGT projects; from the technology assessment phase to their successful implementation (or their cancellation during the development phase). The scale of such projects involves different levels of policy-makers or institutions (local, regional and national/federal), thus increasing the complexity of such processes. This complexity is also accentuated by the importance of the social debate surrounding such projects, which are moreover of a very high visibility when for instance compared to defense or aerospace projects.

Transportation infrastructures are large projects with much longer life cycles than ordinary industrial projects; amortization amount to around 25 years for vehicles (rail or Maglev systems) and 40 years and more for infrastructures (Figure 9).

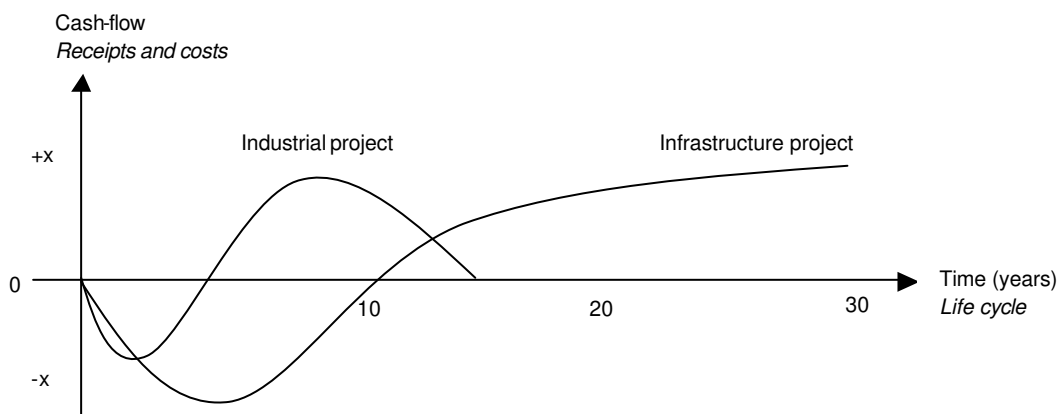


Figure 9: Industrial and infrastructure projects, temporal horizon.

This time scale renders demand-forecasts difficult, in particular since changes in the future of the market or in users behavior are difficult to predict. Moreover, the problem of the social acceptability (Bauer 1995)

of innovations is a critical element for such expensive technologies. HSGT projects are characterized by their high investment costs, between US\$ 10 to 20 million/km for HSR systems, US\$ 15 to 30 million/km for Maglev systems¹² and US\$ 20 to 50 million/km for Swissmetro¹³. As such investments are achieved for the long-term, the notion of irreversibility becomes crucial for decision-making.

Four main properties characterize the inflexibility of a technology (Collingridge 1989) such as HSGT systems:

- A long conception or realization phase.
- A high capitalistic intensity (few investments can be recuperated if the project is cancelled).
- The importance of the infrastructure of the technology.
- An important scale unit.

Both scale and complexity influence the risk in large projects (see also Williams 1999), and require a management based on an accurate risk assessment and mitigation. In the case of HSGT innovations, one should also mention the difficulty of managing change (Gaudin 1978)¹⁴ and of solving technical problems or lock-ins in such complex and large system¹⁵ (Figure 10).

Three points of views can summarize the notion of complexity¹⁶: the system's environment, the technical system, and the organization (Figure 11).

- *The environment* for HSGT technologies is defined by the structure of the market, the planning and decision-making processes and the transportation policies. Social acceptability constitutes a second level of this environment, usually embodied in the policy. The environment complexity may be defined as the market complexity of the product. This environment is often very complex when compared with defense or aerospace projects, which are less visible to public opinion and whose decision-making is more centralized (local-regional-national/federal actors). The complexity may concern the environment in which the technology has to be designed and developed (1), implemented and operated (2). Innovation and rupture therefore require that one understands which changes may affect these two environments.

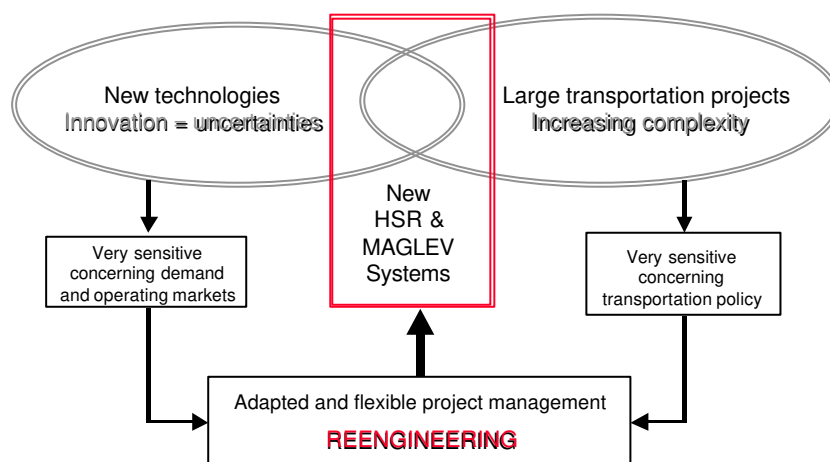


Figure 10: The combination of the development of innovation and HSGT project as a challenge for management.

¹² Source: US Federal Department of Transportation FDOT, estimations 1998 for TGV, US Maglev concepts and Transrapid.

¹³ Source: Swissmetro report for the concession demand 1998, Interview with R. Nieth (project initiator) April 1999. The Swissmetro project is described and analyzed in de Tilière 2000 (a).

¹⁴ Gaudin underlines the role of institutions in innovation and stresses the difficulty in managing change in such organizations (implication for technology assessment and the definition of national R&D programs).

¹⁵ Managing change in organizations: industry, operator but also institutions with the problem of social acceptability in background (Is the cost of the technology acceptable for the service it offers, and does it fit to political priorities?).

¹⁶ Notion of multiple complexity, see also Gareil & Midler 1993.

- *The technical system* is defined by all the technologies involved, and is structured in three elements: system, components and interfaces. This *technological complexity* relates to the use of new and sophisticated technologies in the system. The level of interconnection or interdependence between components in the system defines the *combinatorial complexity*. It underlines the difficulties related to integration constraints of each component: the performance of the system is defined by the performance of both individual components and their interfaces.
- *The organization, including also coordination and logistics* therefore becomes a critical issue when the development of large-scale systems implies a lot of actors from different fields. Moreover, these actors are often geographically dispersed, increasing the management complexity. The development of HSGT systems involves more and more international consortia. These complex partnerships increase complexity, especially when alliances are reconfigured for new projects.¹⁷

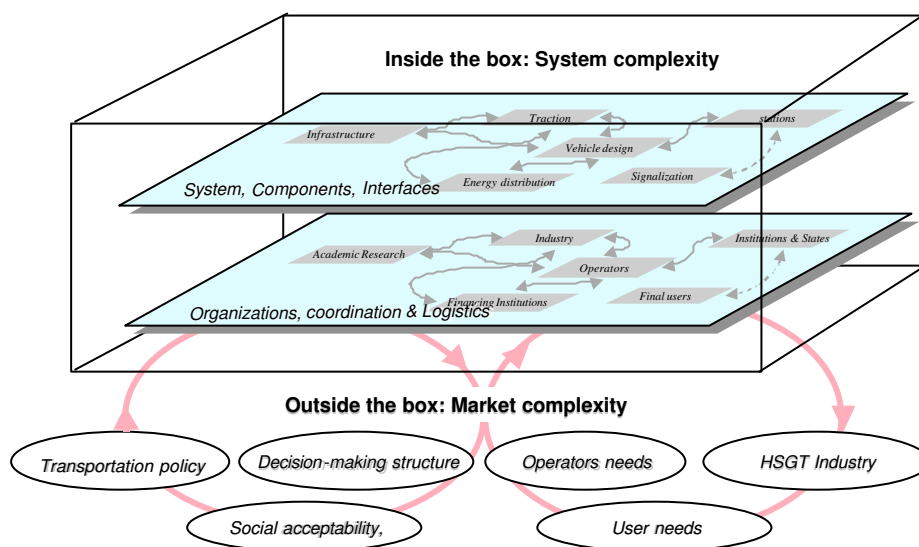


Figure 11: The complexity in the development of large-scale technological systems

Thus the impact of innovation and rupture on risk has to be well apprehended in order to manage the internal environment of the project and the interfaces with the external environment. Before going deeper into the notion of innovation/rupture, risk/uncertainties and their relation, the analysis of the emergence of such systems and of the relevant market structure will provide some guidelines.

2.3. The emergence of high-speed ground transportation systems

2.3.1. High-speed as a paradigm

In the post World War II history of railways, speed has been one of the key issues in the competition with other transportation modes: automobile, buses, and aircraft (Table 3). The first HSGT system was the Japanese Shinkansen, which has been put into operation in 1964 between Tokyo and Osaka (Tokaido line). Two conferences given in 1965 by a delegation of the Japanese National Railways (JNR), one in Washington and another one in Vienna, contributed to the enthusiasm for high-speed networks (Hulten

¹⁷ In international markets, exporting a technology usually means to work with local firms and transfer a part of the technology, which increases complexity and risks (case for the Acela-express in the USA, see de Tilière 2001 (a)).

1997). Soon after, government-sponsored R&D programs, aimed at the development of HSGT technologies, were launched, for instance in the UK, France, Germany, Canada and the USA¹⁸.

After Japan, the first near high-speed services (180 km/h) were implemented in the USA with the Metroliner in 1969 (see also de Tilière 2001, a, p.14), followed by the UK in 1975 with the Intercity 125 trains (Brackman 2000). In 1974, the French decision to build the TGV between Paris-Lyon marked the launching of the second dedicated high-speed network; it was put into operation in 1981.

Year	Record	Country	Traction
1903	210 km/h	Germany	Electric train set
1931	231 km/h	Germany	Rail coach with petrol driven propeller
1953	240 km/h	France	Electric locomotive
1955	331 km/h	France	Electric locomotive
1981	381 km/h	France	Electric train set
1988	407 km/h	Germany	Electric train set
1989	482 km/h	France	Electric train set
1990	515 km/h	France	Electric train set

Table 3: Speed records of High-Speed Rail systems (over 200 km/h)

The main purpose of the development of such networks was the revitalization of the rail sector, which suffered from a long decline of its market shares in most countries. But politicians also strongly supported the HSGT network development in the belief that it was as a strong factor in boosting the economical development of their countries (see also Hulten 1999).

Thus the paradigm was relayed at two levels:

- The first level was the HSGT market, with the competition between transportation modes and between HSGT concepts (technological options); it included both operators and industry.
- The second level was political and related to transportation policy and to the external benefits of such projects on regional and national economies (Keynesian approach).

2.3.2. Looking for new alternatives

In the 1960's the development of the aerospace industry and the increasing impact of technologies through large R&D programs marked the beginning of a period where decision-making was strongly technology driven. Recognizing that the development of the economy was strongly related to the development of technologies embodied in infrastructures, one saw the beginning of a new interest in applying new technologies which produced a large spectrum of options that have been studied through national R&D programs.

The emergence of new HSGT industrial concepts began to flourish in the 60's: air-cushion technologies¹⁹, Maglev technologies²⁰ and turbo-jet propulsion applications. Some of these technologies combined various concepts: for instance the combination of air-cushion and turbo-jet-propulsion for the Aerotrains. Idem for the Grumman concept involving Maglev propulsion after reaching the cruise speed. But some innovations were more adapted to the constraints of the existing network; one example is the concept,

¹⁸ See de Tilière 2001 (a) for more details concerning R&D programs in the USA.

¹⁹ French Aerotrains developed by Bertin Co. (1963-1974) supported with 12 Million 1968 US\$ by the French government. The British Tracked Hovercraft Development Ltd. also received a 5 Million 1968 US\$ from the British government for a prototype demonstration. In the USA R&D on this concept was conducted by General Electric and Grumman Co., but no full-scale demonstration project was build (Yaffee 1968).

²⁰ New interest in Maglev R&D in 1962 in Germany with the Transrapid concept, 1962 in Japan (JNR) and 1963 in the USA at the Brookhaven National Lab. Full-scale demonstration projects were build only in Japan and Germany for High-Speed Maglev systems.

developed by Garret (USA), of a turbine-driven alternator coupled with a linear induction motor and with a vehicle using ordinary railroad tracks. The competition between HSGT technologies was mainly driven by the wish to prove their speed performance advantage against rail technologies (Table 4).

These radical innovations have been developed by newcomers in the transportation market, most of the time without the support of operators, except in Japan. Politicians and institutions were supporting these alternatives as an incentive for the improvement in ground transportation systems. One of the most interesting cases is the example of the aerospace industry in the USA, which provided the majority of contractors under the HSGT Act (1965-1974). The HSGT Office (HSGTO), created for this federal program, was very interested in attracting aerospace contractors to the ground transportation market. By proving their ability to manage innovation in complex aerospace systems, these contractors saw an opportunity for a profitable technological transfer (de Tilière 2001 (a), p.30, 32).

Year	Record	Country	Traction
1967	345 km/h	France	Aerotrain (jet propulsion -air cushion)
1971	164 km/h	Germany	Maglev Transrapid-02
1973	253 km/h	Germany	Maglev Transrapid-04
1986	352 km/h	Japan	Maglev MLU-01
1987	400 km/h	Japan	Maglev MLU-02
1991	412 km/h	Germany	Maglev Transrapid-07
1995	431 km/h	Japan	Maglev MLU-02N
1997	531 km/h	Japan	Maglev MLX-01
1999	552 km/h	Japan	Maglev MLX-01

Table 4: Speed tests of innovative systems (non HSR)

2.3.3. The difficulty for the emergence of alternative technologies

First HSGT R&D programs (1965-1975) explored a wide range of alternatives, but only a few were selected for full-scale demonstration: such examples are the French Aerotrain and the German or Japanese Maglev systems. However none of these systems have up to now been successfully implemented.

The French Aerotrain was cancelled in 1974 to the benefit of the TGV project, after ten years of full-scale development. Aircushion technologies have since then been abandoned: They mainly used jet propulsion and the oil crisis was fatal to their development. Maglev technology tests were not conclusive for high-speed at that time, and couldn't have been transferred to the Aerotrain concept (Frybourg 1987 p.41).

Maglev technologies have been developed since 40 years now (Figure 12) but their successful implementation is still unclear. Three high-speed Maglev technologies have been developed and tested in demonstration sites:

- The German Transrapid, developed since 1962, will be implemented over the length of 30 km in Shanghai: a contract has been signed in January 2001 with the strong support of the German Government (US\$ 227-455 million), whose aim seems less to have been achieving commercial success rather than minimizing losses and investing in the first commercial operation of the system (the development of this technology cost around US\$ 1 billion).
- The Japanese MLX-01 is a Maglev system, which has been developed by the Japanese Railways (JNR) since 1972. The development of successive prototypes and the construction of the demonstration site cost at least US\$ 1.5 billion; but no decision has been taken regarding its implementation.
- The Japanese HSST is a Maglev system, which was initially designed for low-speed applications, but some versions are planed to run at 200-300 km/h. Although numerous demonstration sites have

been opened to the public - a test track in Nagoya, and a 8 month commercial operation at the Yokohama Exhibition in 1989 – the implementation of the system is still uncertain.

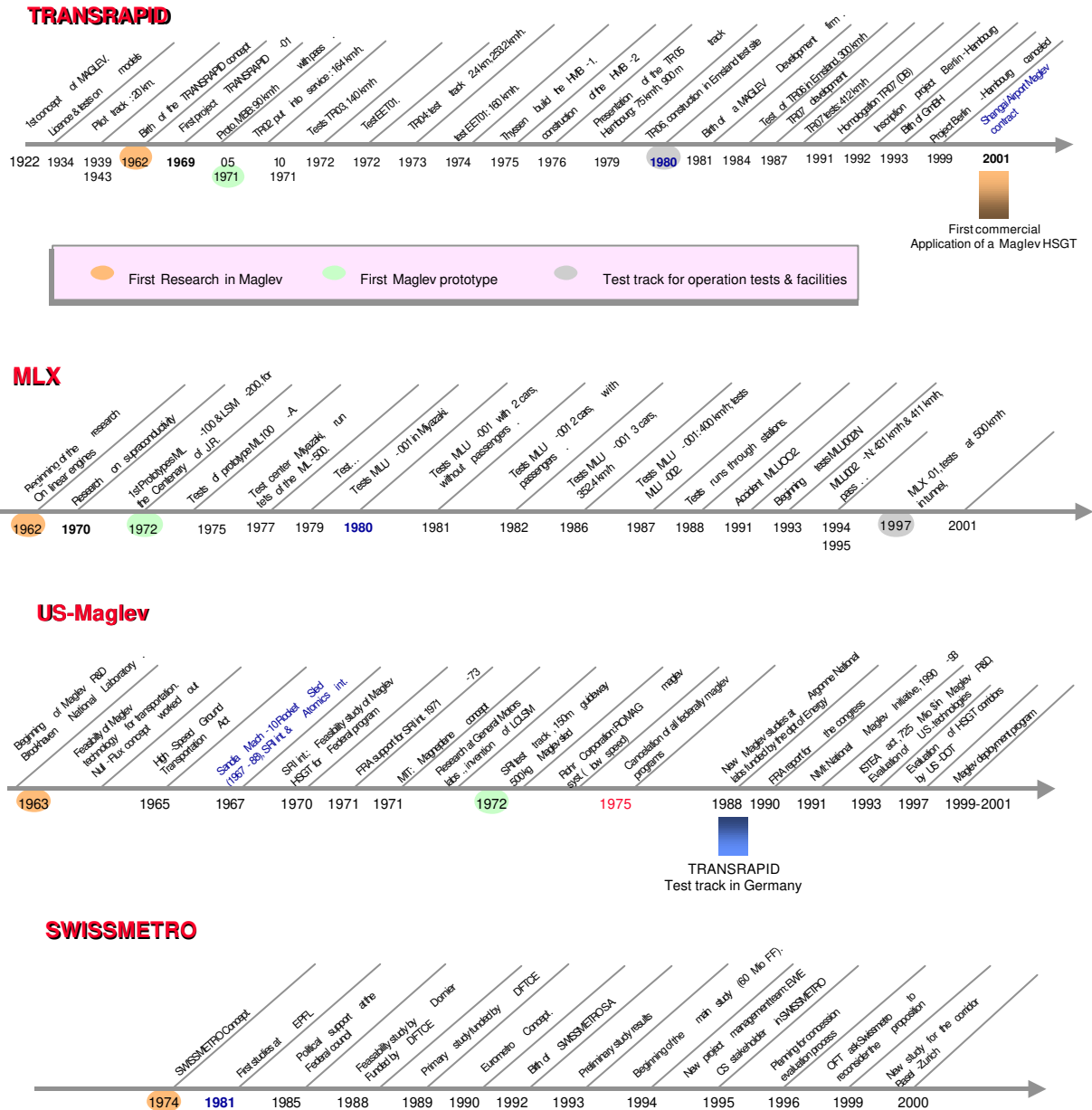


Figure 12: Main events in the development of the main HSGT Maglev technologies.

Despite intensive R&D programs and demonstration tests over 30 years, the Maglev systems have never become commercially operational. The same can be said with regard to low-speed Maglev technologies, except in the case of Japan. Two Maglev metros have been commercially operated in Europe, one in Birmingham and another one in Berlin in the 80's, but both have been dropped in the early 90's; these two

failures underlining the main reasons which constitute an obstacle to the commercial development of Maglev systems²¹:

- *Infrastructure incompatibility.* The AEG M-Bahn was put into operation in 1987 in Berlin, but after a few years of operation, the fall of the Berlin wall again allowed for the use of the former underground system: the M-Bahn operation was dropped in order to decrease operation costs (economies of scales).
- *Problem of standards:* The Maglev people mover at Birmingham Airport was operated during 11 years since 1984. But finally, when some components should have been replaced, they were not available on the market (the technology was not updated by the initial manufacturer - prototype system). As the cost of reengineering the system proved to be too high, services were shut down in 1995 and replaced by a shuttle service.

These case studies have revealed how difficult it is to introduce successful innovative systems; the reasons are cost competition, problem solving, standards, compatibility, and an insufficient market size to enable further technological improvements. But before analyzing innovation processes and the impacts of rupture, it is crucial to understand the actual HSGT market and its context in order to anticipate future changes in the transportation framework and provide accurate recommendations.

2.4. The current HSGT market and its evolution

Why did Maglev technologies not succeed in finding their niches in the past and what are their opportunities for the future? In order to answer these questions, one has to understand what are the main trends for operators and industry. Leaders of HSR technologies are European countries and Japan; other challengers, such as Russia and China, try to develop their own technologies, with incremental HSR solutions. Meanwhile, the Maglev systems leaders are still Japan and Germany; failing to introduce their technologies in their own countries, they try to export them.

Since 1980, Maglev technologies increased their performances by 50% when compared with 25% for rail technologies. With higher performances in terms of speed and energy consumption, Maglev systems are 25 to 30% more expensive than HSR in terms of investments. But their performances in speed, curves and slopes make them interesting by reducing construction costs through more flexibility in the route implementation.

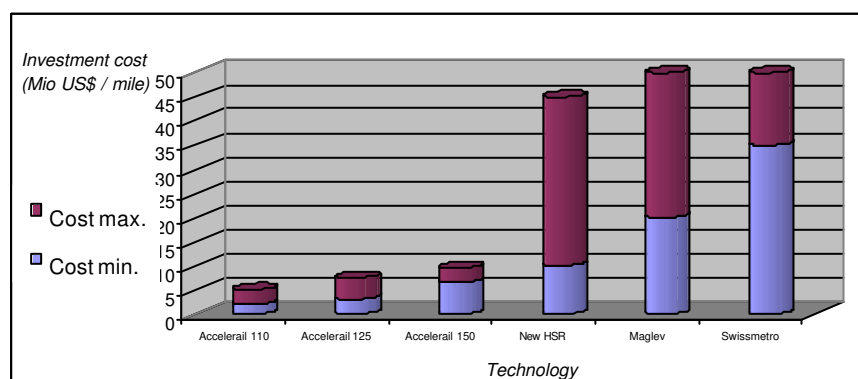


Figure 13: Investment costs for each technology (without R&D costs for Swissmetro)²²

²¹ IEEE; *Proceedings of the International Conference on Maglev and Linear drives*, Las-Vegas 1987 p.113; Eastham 1996 p.41.

²² Sources: US-FDOT 1997 and Swissmetro S.A.

2.4.1. The development and completion of HSGT networks

- *The development and completion of HSR networks*

HSR network in Japan and France presently provide more than 4000 km of services across the European Continent, and 1836 km in Japan²³ (Figure 14 to Figure 19, pages 39 to 41). The more profitable projects have been completed both in Europe and in Japan, but other projects are planned in order to complete these networks.

In Europe, the Trans European Networks (TEN) have been under consideration since 1985, and a package of 11 projects has been designated as a priority in 1994²⁴; these projects are estimated at Euro 84.5 billion and concern rail technologies. The European HSR network has already represented an investment of US\$ 60 billion up to 1995, and an additional US\$ 40 to 65 billion has been budgeted for its completion between 1995 and 2005; moreover, the enlargement of the European Union could lead to additional US\$ 120 billion investments in HSR infrastructures by the year 2010.

The consolidation of these HSR networks and the upgrading of other links, such as the Northeast corridor in the USA, or the new projects in Taiwan, Korea, Turkey, may lead to the increase of the market lock-in for Maglev technologies through the increase of scale economies and technological improvements of rail systems.

- *HSR dedicated networks and Near HSR networks*

Only few countries have implemented HSR dedicated networks (Speed over 200-250 km/h), which are Japan, France and Germany and Spain. Taiwan and Korea are joining the group with new HSR projects, and China is planning too. Technologies used are Shinkansen, TGV or ICE²⁵.

Another group of countries operate Near HSR Systems, with few short segments between 200-225 km/h; among those are UK, Italy, Sweden, USA. Technologies used are mainly Electric Multi Unit (EMU) train-sets such as X2000, ETR 460/480 (Pendolino) or ICN. Those are mainly using tilting technologies to maximize the use of existing networks.

- *The dilemma between Maglev and HSR systems*

In Germany, the introduction of ICE network early in 1991 and its development have reduced Transrapid opportunities in the country for the moment, underlying the importance of the timing in innovation. Since a few years, compatibility and interoperability have become the Leitmotiv for both operators and institutions: Behind rail networks stand organizations, whose role is crucial for the development of innovation (chapter 5.3). But the hope of the Transrapid consortium is currently focused on China.

A contract was signed with Shanghai for a 30 km track Maglev system. This project will be part of a demonstration for the HSGT project between Beijing and Shanghai (1300 km), which will be in operation around 2010. At the same time, China is developing its own HSR technology based on the Swedish X2000 concept (simple and double deck train-sets have been tested at 220 km/h in 1999). The Chinese Minister of transportation declared in May 2001 that the chance of the Transrapid system is currently 50% (against HSR)²⁶, and the results of the Shanghai project will be decisive. Thus the future HSGT network in China could switch to Maglev technology in a near future.

In Japan, the completion of the Shinkansen network and the high cost of introduction of the Maglev MLX-01 technology led the Government to differ the implementation of this new concept. Even the support of the Japanese National Railways in this project didn't help to overcome the political reserve after the economical crisis in Asia²⁷.

²³ Lynch Th. 1998, *High-Speed Rail in the US*, Gordon and Breach science publisher, pp.xiii, 106,110.

²⁴ Proposed at the Corfu summit in 1993 and adopted in the CEMT meeting in Essen in 1994 (Rossel 1998 p.52).

²⁵ Figures page 39 to 41 illustrating the diffusion of networks and technologies are based on the gathering of data from the main manufacturers, railways operators and national transportation departments.

²⁶ Source: *les Echos* May 20, 2001.

²⁷ Interview with M. Takebayashi, Department of civil Engineering, Osaka University, 8.05.2001.

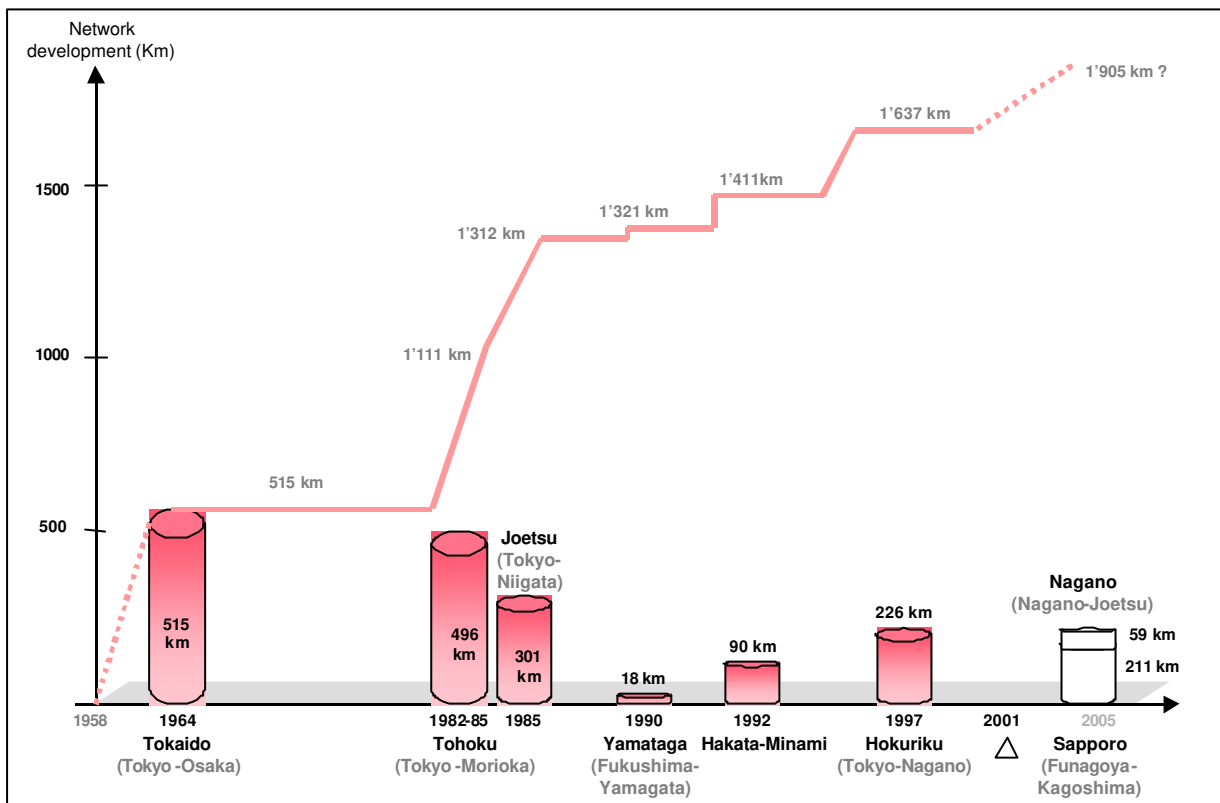


Figure 14: Development of the Shinkansen Network in Japan, 1962-2006

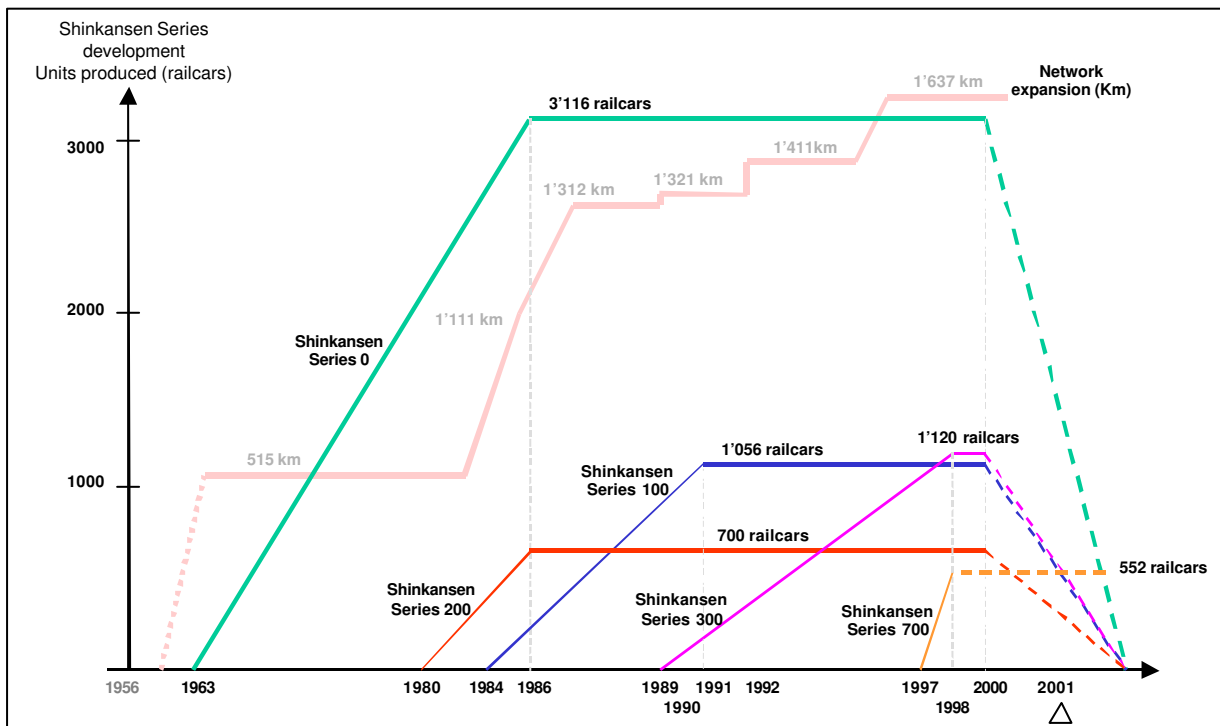


Figure 15: Development of the Shinkansen railcar technology, 1962-2001 (Series > 500 railcars)

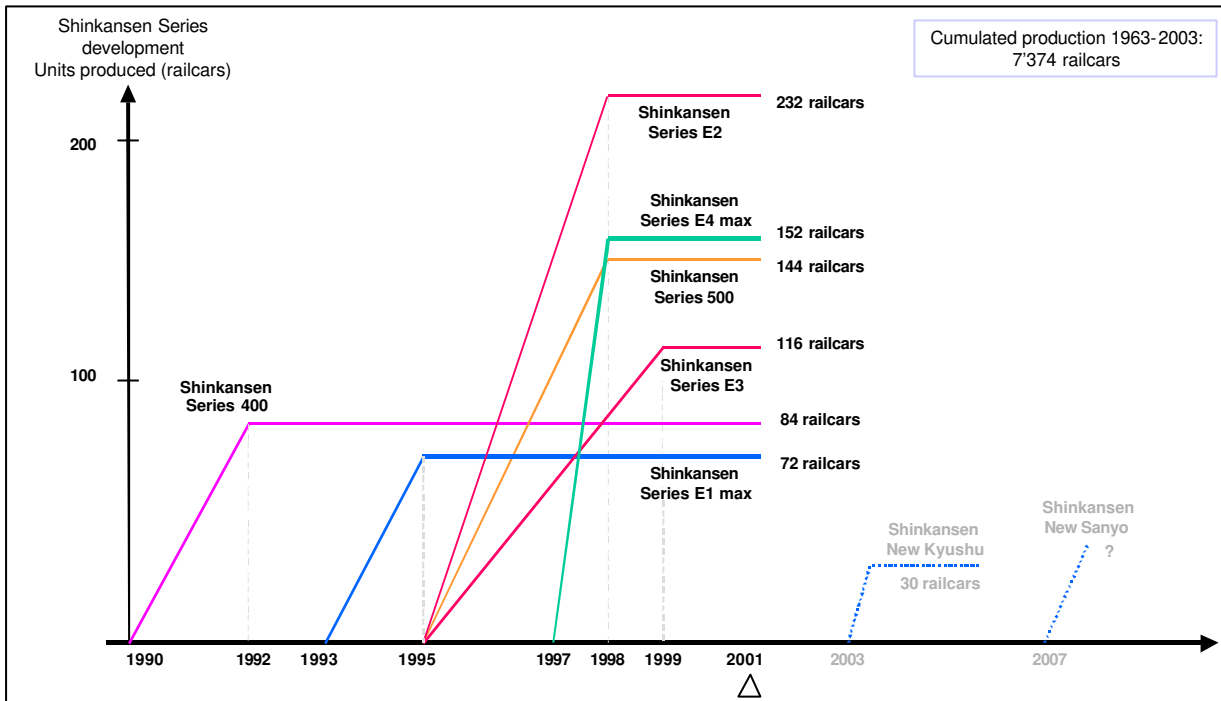


Figure 16: Development of the Shinkansen technology, (Special series & prototypes, production < 500 railcars)

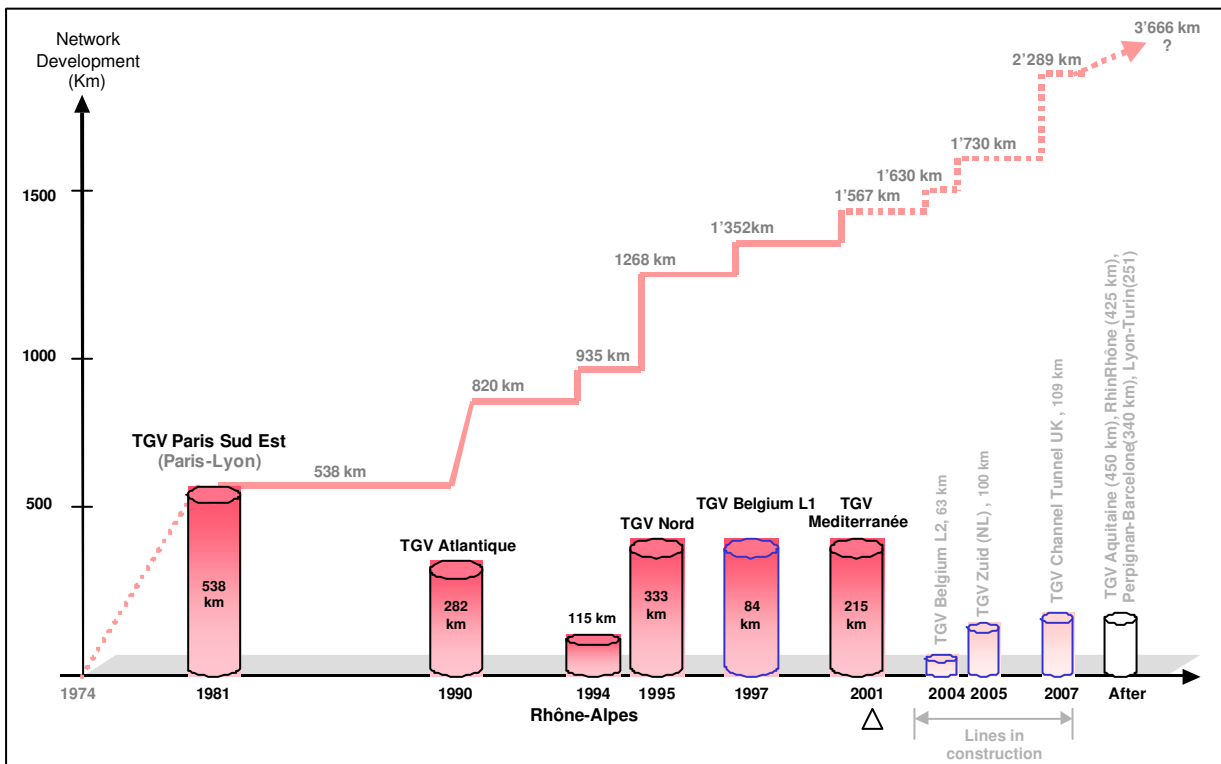


Figure 17: Development of the TGV network, 1974-2010 (lines connected to the French rail network)

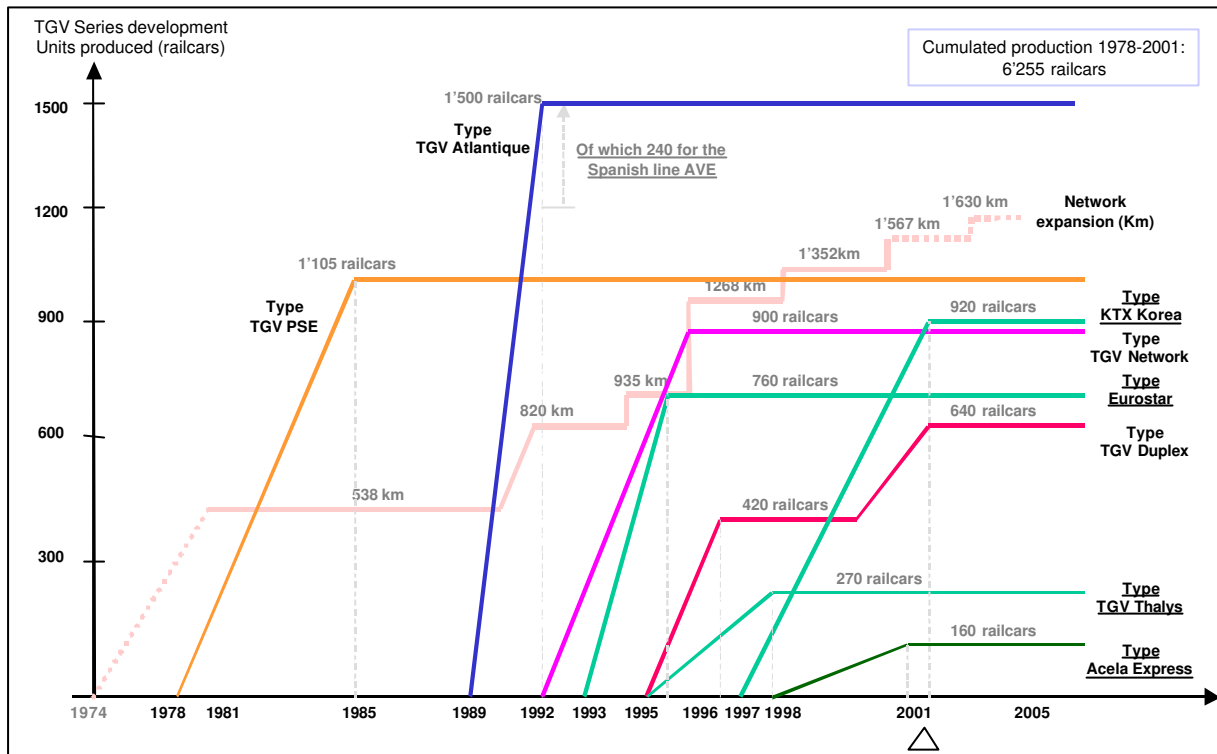


Figure 18: Development of the TGV railcar technology, industrial production 1978-2001 (ALSTOM Group)

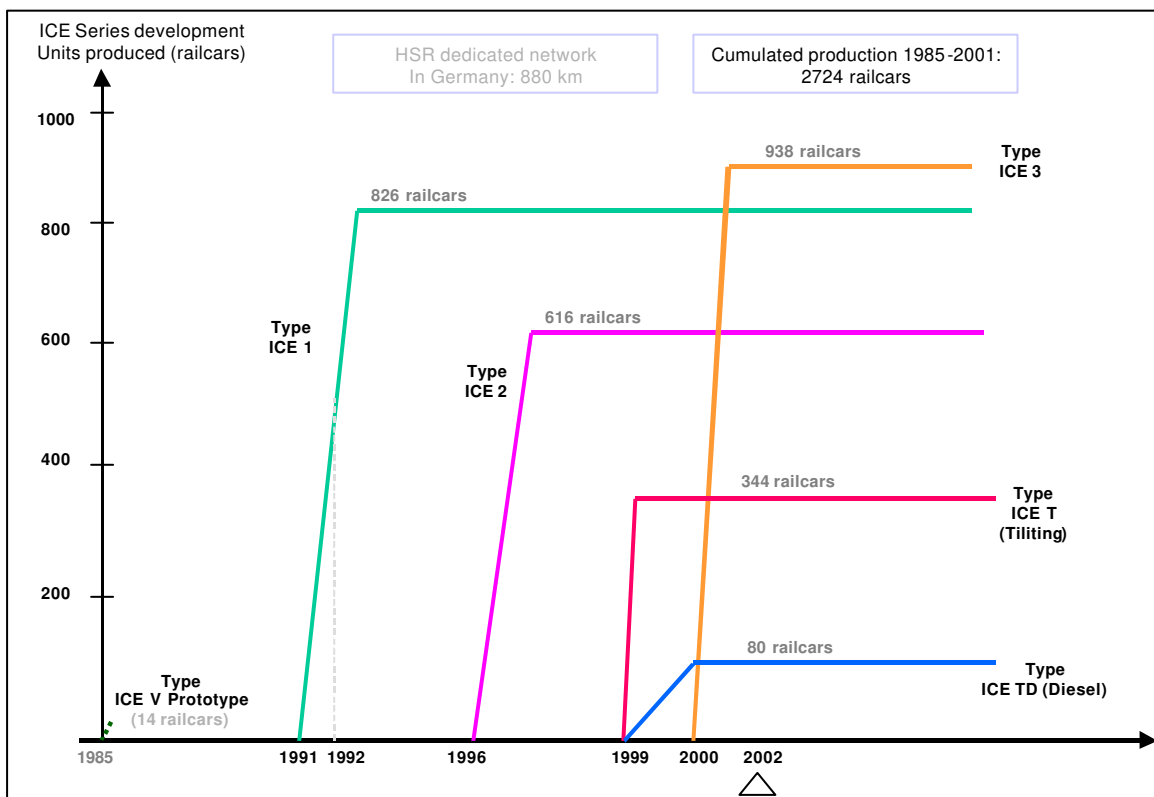


Figure 19: Development of the ICE railcar technology, industrial production 1978-2001 (Siemens)

In the USA, the National Maglev Initiative (NMI 1993-97) was also looking for an opportunity to develop a US Maglev technology in order to introduce new HSGT technologies. But the selection of an incremental solution using tilting technology for the Northeast corridor reduced the chances of Maglev candidates. In 2001, only the Transrapid technology is still taken into consideration by the US Department of Transportation (US-DOT), putting aside four other concepts - Bechtel, Grumman, Foster-Miller and Magneplane (de Tilière 2001 a, p.35, 40).

- *The challenge for Maglev systems*

Does the strengthening of HSR networks constitute an entry barrier for Maglev technologies, even for niche markets? Can these entry barriers be overcome by the performances of technologies such as Swissmetro, Transrapid or the MLX-01? This problem will be analyzed in two steps: the innovation dilemma (chapter 3) and the assessment of risk/opportunity (chapter 6), with an emphasis on project management.

- *Consolidation of the HSGT market*

However, if the development of HSGT networks remains a priority for several countries, one can also observe a consolidation of this market. If new services at 300 and 350 km/h are planned, the race to develop new high-speed trains is slowing down, as railways in Europe and the Far East concentrate on management and service quality. The following table ranks the countries with rail-speeds over 120 km/h:

	Country	Train	From	To	Distance km	Time min	Speed km/h
1	Japan	12 x Nozomi 500	Kokura	Okayama *	192.0	44	261.8
2	France	7 x TGV	St Pierre des Corps	Massy TGV *	206.9	49	253.3
3	International	Thalys 9342	Brussels Midi	Paris Nord	313.4	83	226.5
4	Spain	5 x AVE	Madrid P Atocha	Sevilla *	470.5	135	209.1
5	Germany	2 trains	Karlsruhe	Mannheim	71.0	22	193.8
6	Great Britain	1 x IC225	London Kings Cross	York	303.4	101	180.2
7	Sweden	3 x X2000	Skövde	Södertälje	277.0	97	171.3
8	Italy	ES9325	Piacenza	Parma	57.0	20	171.0
9	USA	1 x NE Direct	North Philadelphia	Newark Penn	122.4	48	153.0
10	Finland	4 x S220	Karjaa	Salo *	53.1	21	151.7
11	China	9 x Fex G	Guangzhou Dong	Shenzhen *	139.0	55	151.6
12	Denmark	Lyntog 6	Odense	Høje Tåstrup	145.0	60	145.0
13	Canada	Metropolis	Dorval	Toronto	519.5	221	141.0
14	Russia	Blue Arrow	Moskva	St Petersburg *	649.9	280	139.3
15	Hungary	3 x Eurocity	Hegyeshalom	Győr	47.0	21	134.3
16	Israel	3 trains	Hof Ha-Carmel	Tel Aviv Merkaz	84.4	40	126.6
17	Poland	10 trains	Warszawa C	Zawiercie	253.2	121	125.6
18	Saudi Arabia	Trains 1/3	Al Hufuf	Ar Riyad	310.0	150	124.0
19	Switzerland	3 x Cisalpino	Montreux	Sion *	68.0	33	123.6
20	Ireland	2 trains	Dublin Heuston	Limerick Junction	172.2	84	123.0
21	Morocco	Al Quaraouyine	Mohammedia	Rabat Agdal	63.0	31	121.9

Table 1: The top 21 fastest start-to-stop trains in all countries with timetabled runs over 120 km/h

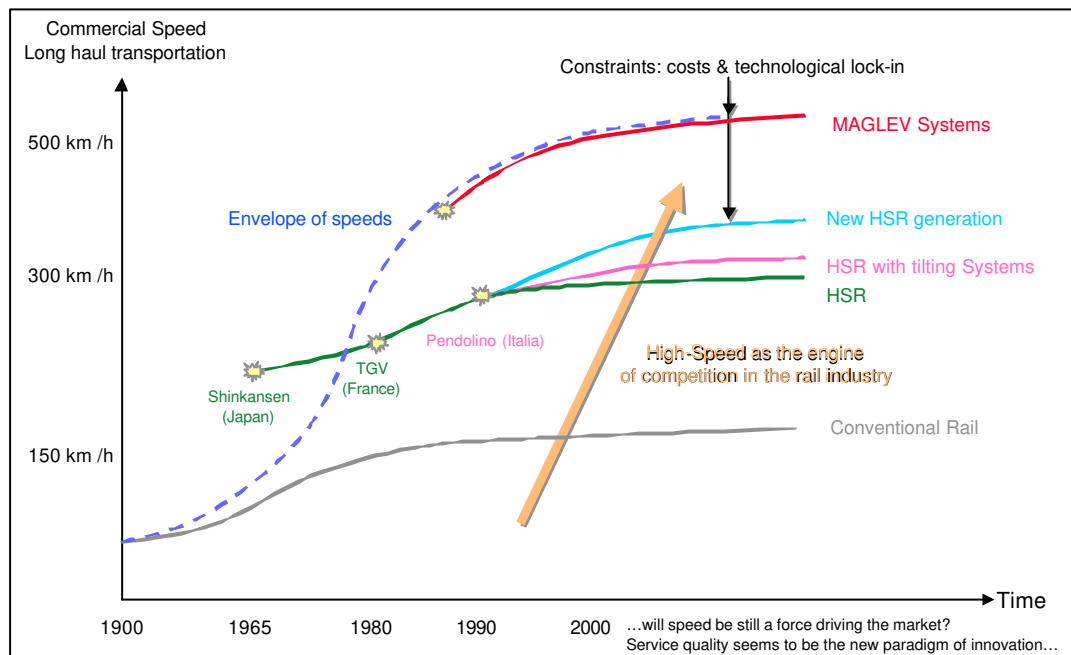


Figure 20: S-curves and product life cycle / technological envelopes and velocities

2.4.2. The internationalization of the HSGT market, relations between constructors

- *HSR technologies*

Since the 80's, Shinkansen and TGV consortia try to sell their technologies in the USA and Asia in order to maximize their benefits and scale economies. But this competition has become stronger in the 90's with the introduction of the Swedish X2000, the German ICE, and the Spanish new Talgo generations. These technologies were competing with each other in the USA (between 1993-1996)²⁸, in Australia, Taiwan, Korea and now China. Most of these technologies are now certified for commercial operation at 350 km/h. Moreover, new HSR technologies are also being developed in China and Russia in order to compete in their national markets.²⁹

This being said, the reorganization of the HSGT market has become very intense in the last decade; this proved necessary in order to face the increasing competition at the international level³⁰ and in the light of the structural changes in European rail markets.

The first reason for these reorganizations is related to the mastering of technologies and to the competences of the industry. But the difficulties in the rail sector and the increase in competition also lay behind all these changes. Strategies to become generalist constructor, such as Bombardier or Alstom, or to focus on niche-market, such as FIAT Ferroviaria, lead to different rearrangements, ranging from alliances to mergers³¹. Alliances are illustrated by examples such as the prototype developed by Talgo and Adtranz for the Spanish HSR market in 1999, Talgo/Klauss-Maffrei for the Talgo XXI, Siemens/Fiat/Adtranz for the Alfa-pendular, Alstom/Siemens for the AVG, or Adtranz/Fiat for the ICN. One of the most important stakes driving industrial strategies since 1995 has been the tilting technology. Mergers such as the acquisition of FIAT Ferroviaria by Alstom in 2000, or the cooperation between Alstom and Bombardier for the Acela-express show the importance of this technology in the HSGT market.

²⁸ In the USA, X2000, Talgo and ICE train-sets have been tested on the Northeast Corridor by the FDOT in 1993.

²⁹ Russia, with the Sokol prototype certified for 280 km/h, and China which first prototype ran at 200 km/h in 1999.

³⁰ Carrière B. 2000, pp.43-50 ; Saubesty & Vernimmen 1999, pp.133-138.

³¹ Merger Bombardier-Adtranz in April 2001, Alstom swallowed 51% of Fiat rail division in June 2000.

A second reason for such alliances is related to national market penetration. The development of the AVG for the Taiwanese market (Alstom/Siemens) or the Acela-Express for the USA (Bombardier/Alstom) shows how alliances can be used in order to share risks or to make good use of a local partner (submissions).

Recent trends towards concentrations³² have underlined the increasing importance manufacturers have granted to these integrations - a trend which has also manifested itself in the increasing number of co-operations noticeable since a decade:

Co-operations HSR:

- Shinkansen E2³³, Partnership Toshiba-Siemens (Siemens provides traction equipments)
- ICE 3: Siemens-Adtranz
- Acela Express: Alstom Bombardier

Co-operations EMU:

- Alaris tilting trains: Alstom-Fiat based on ETR 460
- Alfa pendular: FIAT (derived from ETR 460) and Siemens (Traction)
- Virgin tilting trains: Alstom - Adtranz (ex BRELL)

Other contracts without cooperation

- Alaris tilting trains: Alstom-Fiat based on ETR 460
- ICN, IC2000, X2000 & Swedish EMU: Adtranz
- Alaris, ETR 460, 480: Alstom-Fiat

All the reorganizations concerning rail constructors have followed the same trend than the one, which has taken place in the automobile industry. The increase of competition, embodied in the opening of networks to international competition, has led to an adaptation of strategies. The answer to the growing importance of flexibility, as well as to the reduction in R&D and production costs, is the increased cooperation between firms, partners or competitors. Standardization and economies of scale are now the key words.

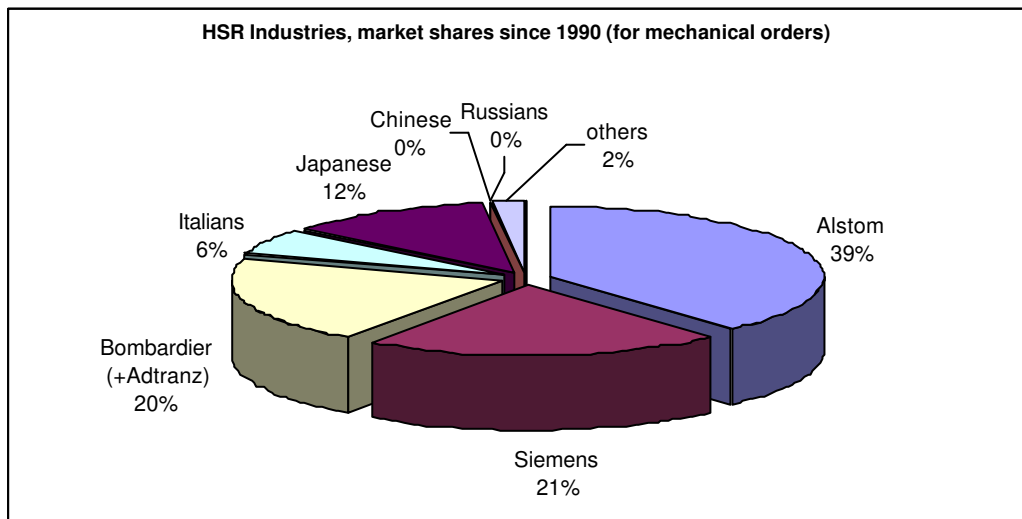


Figure 21: HSR Market shares for mechanical orders 1990-2001 (source: Railway Gazette International 08.2001)

³² Merger AEG-ABB in 1996 (Adtranz), Alstom-FIAT ferroviaria in 2000 and Bombardier-Adtranz in 2001.

³³ Shinkansen consortium: Mitsui & Co., Ltd. acted as a leader in forming the consortium of seven companies with Mitsubishi Heavy Industries, Ltd., Toshiba Corporation, Kawasaki Heavy Industries, Ltd., Mitsubishi Corporation, Marubeni Corporation, and Sumitomo.

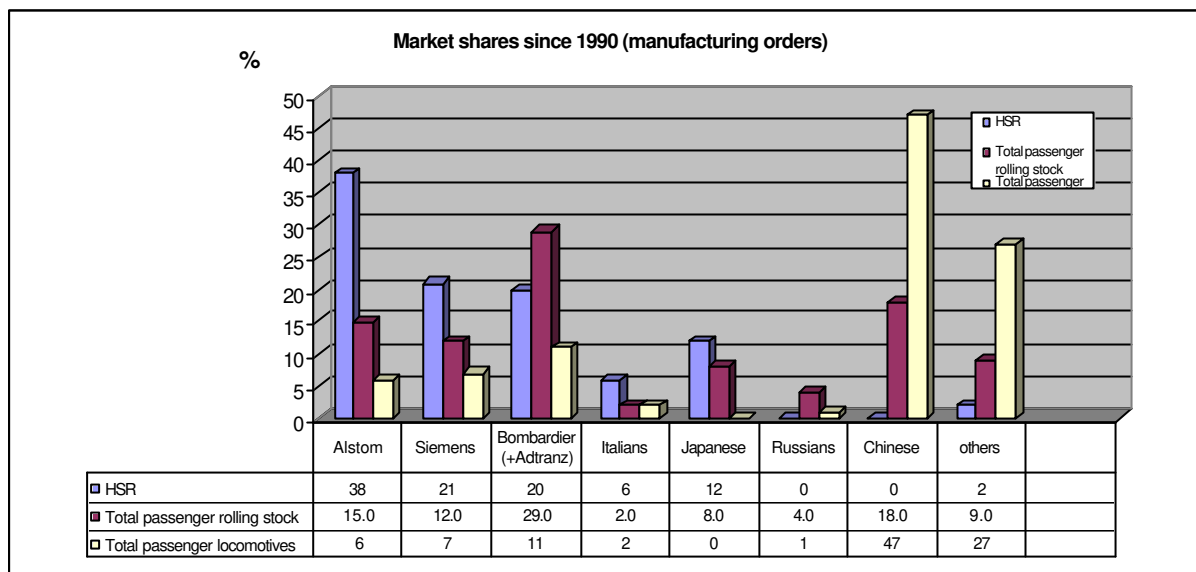


Figure 22: Comparison between market shares, HSR market and Global rail passenger market (locomotives/rolling stock – mechanical orders 1990-2001)

International management consortia appear to offer the best way for rail services to present an attractive and cost-effective alternative (generalization of tilting solutions) to the new generation of low-cost airlines.³⁴

- *Maglev technologies*

Contrary to the increasing globalization of the HSR industry, the Maglev industry is still a very uncertain market-niche. Projects are mainly developed by national consortia, such as the German Transrapid (Siemens, Thyssen, Adtranz), the Japanese MLX-01 (Japanese National Railways JNR and RTRI), the HSST (Japanese Air Lines JAL and Nagoya prefecture), and the US Maglev consortia (four concepts led by Grumman, Bechtel, Foster-Miller and Magneplane). Only the Swissmetro project - still in an embryonic stage - gathers foreign industrial sponsors: Swiss, French (Alstom) and German (Adtranz); however, the foreign interest is mainly aimed at gathering insight into the future HSGT technologies in Switzerland.

The difficulty of implementing these technologies - added to the difference of standards - led to a strong dependence of the Maglev technological development on national policies. Examples are the strong support of corresponding R&D programs with more than US\$ 1.5 billion in Japan and with US\$ 1 billion in Germany. In Switzerland and in the USA, most research subsidies have been provided by federal programs. However, the market doesn't seem ready yet to handle the development of this technology on its own. Nevertheless, the first Transrapid contract signed in China between the consortium lead by Siemens, the German Transportation Minister and the Chinese Finance Minister can change the situation. The commercial operation of the system, expected after 2003, will possibly lead to a further reduction in the costs of the technology and to an improvement in its reliability.

- *What consequences on innovation?*

The change of the structure of the HSGT constructor market will also have an important impact on innovation. Alliance and mergers strategies, aimed at benefiting from scale economies and sharing R&D

³⁴ Pettitt G., 1999; "Consolidated designs to serve high-speed partnerships", *Railway Gazette International* July 1999.

costs between partners, will lead to an increasing standardization within the HSR industry. Meanwhile, the fragmented market of Maglev faces serious difficulties in increasing cooperation between consortia, because of the important standard differences still competing for a niche with the support of national governments.

2.4.3. Changes in the operators market

Understanding HSGT innovation developments also requires understanding the role of operators and the possible influences on them by changes in the market. In Europe, the introduction of the Directive 91/440 in 1990 led to major changes in the operators' landscape. The background of these reforms is to be seen in the willingness to harmonize the rail European network, and thus increase the interoperability and free access for operators. The main objective is the extension of the high-speed network across Europe and its integration into a global market.

- *Relation Operator-Infrastructure owner*

The notion of a global European market in the rail sector was embodied in the Directive 91/440 (art.6-8), which separates between operations and infrastructure. For this purpose, infrastructure companies were created, for example in France³⁵ or in Germany, who bought the operators debts. Such companies are mainly owned by States and their role is to attribute and manage operation contracts (definition of service level, evaluation and selection of operators).

The main consequence is that there will be a trend to split R&D between infrastructure (responsibility of the infrastructure owner) and rolling stock (responsibility of the operator/constructor), with a greater fragmentation of the decision-making in terms of responsibility and focus.

But the problem of infrastructure profitability implies taking into account freight as well as passengers, since the use of the same infrastructure helps to reduce costs. This could, in return, constitute a problem for Maglev systems, which are only designed for passengers and light freight (see also Rossel 1998 p.60).

- *Independence of operators management*

The first consequence is the progressive vertical disintegration between governments/institutions and operators.³⁶ This means a modification of the decision-making structure, the vertical integration of which has produced large engineering systems such as the Shinkansen or the TGV. The progressive opening of national markets means privatization of the operation functions.

In the past, innovations in infrastructure and rolling-stock were discussed at two levels: the operator (also infrastructure owner) and institutions. Now operators will be more independent in their relations with constructors, and the role of institutions for technological choices will be more centered on infrastructure. The relation between institutions and operators will be more focused on service rather than on technical specifications.

The actual trend towards reorganization through alliances and mergers also concerns the operator market, whose is looking for economies of scale. The increasing competition in this sector and the actual focus on cost efficiency leaves little place for the adoption of more risky technological solutions, the benefits of which are difficult to assess³⁷. The structure of the operator market and the backup by governments therefore play a key role in the development of innovation, until the maturity of the technology. These relations will however need to be analyzed more deeply through the definition of Innovation Models (chapters 3).

³⁵ For the relation between SNCF and RFF and its implications, see Saubesty & Vernimmen 1999, pp.128-131.

³⁶ Directive EU 91/440, art.4 and 5, see also Rossel 1998 pp.41-43.

³⁷ See also the conclusion of Garud & Rappa (1994) saying that markets are unlikely to select out complex technologies that are difficult to evaluate.

- *Relation Operator -Constructor*

The relation between operator and constructor is also evolving. The internationalization of the HSR market, as well as institutional changes concerning the operation market, leads to a redefinition of their role. In the past, national markets favored the integration between both actors, sometimes inciting operators to play a role in both functional and technical specifications³⁸. The trend is therefore a shift of the role of operators from technical specifications to functional specifications. At the same time, the relation operator-constructor evolves from one of partnership to one of greater competition. These changes in decision-making have an impact on innovation processes. As a next step, one will now have to analyze more in depth these mechanisms and their implications for project management.

2.4.4. Understanding innovation's difficulties in the HSGT market

- *Innovation failures*

HSGT technologies suffered the same rate of innovation failures than the ones encountered in the other industries. Failures are much more common than successes: how many advanced technological concepts have had to be given up with millions of dollars wasted? Have engineers pushed the envelope too far? Did they understand that the consequences of technological rupture go beyond the engineering field and that the main challenge is managing systemic change rather than solving technological lock-ins?

Managing such projects needs a very good understanding of the project environment and the great complexity of transportation systems. The first recommendation may therefore be to provide a structured methodology for assessing such projects and the underlying links between innovation, risk, organization, policy, project financing and finally project management.

As Schumpeter (1942) refers to "destructive innovation", one should also underline that innovation is a political game where the power of influence of actors is critical for the sustainability of rail versus Maglev systems, especially in the case of a narrow market window.

- *The HSGT market as a part of the rail market*

Since more than 30 years, over-capacity of plants for rolling-stock manufacturers has globally been a problem. It led to a high level of concentration in the last decade, in order to rationalize and reduce the risks related to the strong irregularity of orders. To face the consequences of these demand patterns, manufacturers have developed activities ranging from metro to HSR systems, allowing for them benefiting from greater spills-over as well as from economies of scope and scale.³⁹

This being said, HSGT technologies are an important but a relatively small market window in the rail sector, (worldwide).⁴⁰ R&D as well as manufacturing activities is therefore developed with a view to maximizing transfers between all rail segments activities. Moreover, the market of HSGT rolling-stock renewal takes an increasing importance as first generations of Shinkansen and TGV's come to the end of their life cycle.

This remains a main problem for the development of Maglev systems, Maglev being far from being the core competencies of these industries (Bombardier, Alstom). Only Siemens and Japanese manufacturers have been involved in such developments, but their original activities were more focused on electrical equipments (and not rolling-stock).

In order to benefit from scale economies and synergies, Maglev leaders should promote technologies for low-speed and intercity passenger systems as well as metros. Creating a full range of Maglev systems

³⁸ For example the quasi integration between GEC-Alstom and SNCF (Henry & Quinet 1999).

³⁹ Siemens bought Matra MTI, Alstom bought FIAT Ferroviaria and Bombardier bought Adtranz to take advantage from those benefits and be able to face the increasing competition in the rail sector.

⁴⁰ Recent orders of SNCF (leading operator for HSR behind JNR) are representative of the HSGT market shares, with an order of 60 TGV to Alstom (2000-2003; €1.2 bn) and 500 regional trains to Bombardier (2001-2004; € 2.5 bn).

can lead to a decrease of R&D and production costs, which is essential for the viability of their technological trajectory. However, only Japan is working in this direction with a full range of products:

- HSGT Maglev: MLX-01 (speed>400 km/h), still in test at Yamanashi.
- Intercity Maglev: HSST (one version for 100 km/h, another for 200 km/h; project for a 300 km/h version. A first project is in planning in Nagoya, operation due to 2005).
- Metro Maglev: Osaka line 7, setting new standards for other prefectures' projects in Japan. Operated since 1998. Other lines are in construction in Osaka.

China, Looking for the rapid development of its transportation system as well as for future leadership in the high-tech field, could also follow this strategy. Shanghai acquired the Transrapid system in 2001, and its operation in 2003 will define the choice of the system (HSR/Maglev) for a 1250 km track between Shanghai and Beijing. Behind such decisions stands the will to develop internationally competitive technological and industrial capabilities.

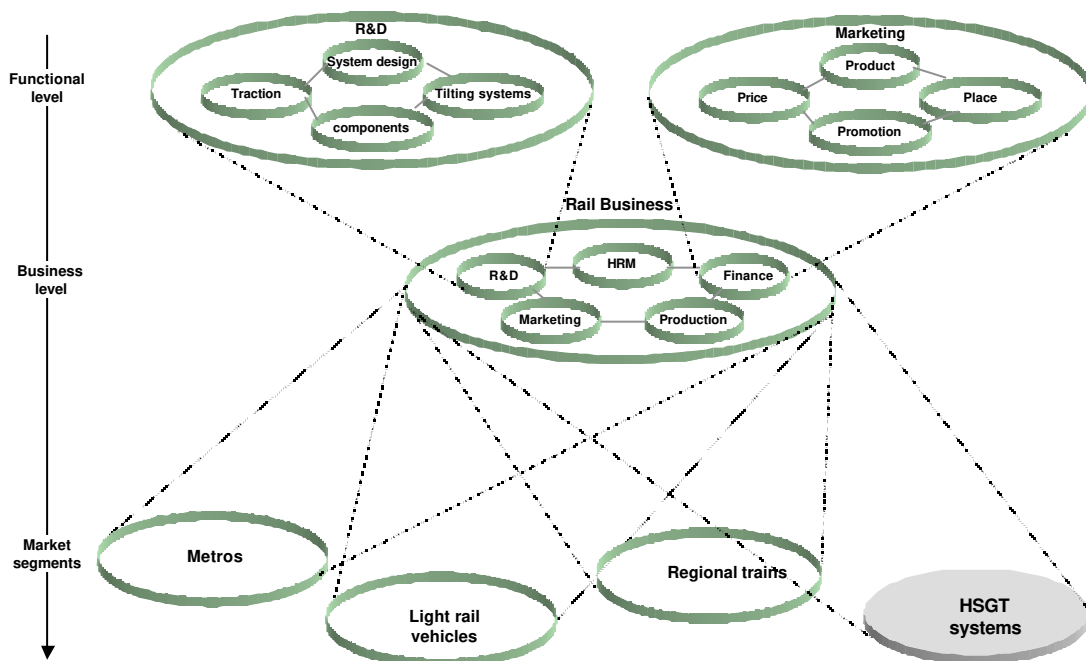


Figure 23: HSGT business as part of the market of ground transportation systems

- *Patterns of rail networks and the notion of over-supply*

Varian (2000)⁴¹ underlines the problem of inflexibility of guided ground transportation systems and introduces the notion of oversupply. His comparison with IT networks highlights the fact that in optic cables infrastructures, all type of information can circulate (music, video, telephone, fax, e-mail etc), which is not the case of guided ground transportation infrastructures.

Such inflexibility, coupled with cutting-edge and costly technology, leads to the problem of oversupply in a market, which has always been difficult (all successful systems have always been strongly supported by governments and institutions).

⁴¹ Varian H.; *Miles and miles of flexible track*, Forbes, Febr. 2000.

The risk of oversupply⁴² relates to providing new infrastructure capacity, whereas existing ones can be used and improved at lower costs. Two factors stand behind such arguments:

- First, the market structure leads to “winner take-all” structures, because of the strong networks effects.
- Second, users (operators) face large costs for switching suppliers: The actual debate in Taiwan in order to force the Japanese consortium to provide a Shinkansen with standards compatible with European ones aims at maintaining the competition for maintenance service and further contracts.

For these reasons, managing the emergence of disruptive systems such as Maglev technologies is a headache-puzzle, and the need to provide a good methodology for apprehending such challenges is important.

2.5. Conclusion

In the competition to set standards in HSGT technologies in the 70's, HSR concepts won market shares because Maglev technologies were not ready for operation at that time. Then, after the expansion of HSR networks in Japan, Europe and recently in the USA, economies of scale and scope achieved by this industry (operators and manufacturers) constituted an important barrier for a new systemic innovation such as Maglev technology. But implementation of Maglev metros already failed in Germany and UK in the 90's; and in Japan, MLX, HSST and Osaka systems have been too different to fully benefit from scale economies.⁴³

If the main change or rupture will come from China - the first country to implement the Transrapid system for commercial operation -, the possible construction of a 1250 km track between Shanghai and Beijing may brake this barrier: such a new network will possibly allow creating sufficient economies of scale to set the Transrapid concept as a new technological standard for the operation of High-Speed Intercity corridors.

Behind such a shift, stand the combined strategies of manufacturers, operators, politics and institutions. The purpose of this research is to try to understand and model the core-process (Figure 24), which influences the types of HSGT innovations, as well as to provide recommendations on the management of such projects.

Matching core competences and identifying market needs for the definition of R&D strategies require a good understanding of innovation processes. But the management of innovation is not only based on technological feasibility and market analysis: The challenge⁴⁴ also implies the management of knowledge, organizational skills and certainly political far-sight and will.

If one of the biggest challenges for systemic HSGT innovation is their acceptance by operators, the political context is also crucial. The recent changes in the market structure for operators in Europe, and for manufacturers worldwide, lead to the necessity to develop adequate Innovation Models and to clarify the roles of the various actors in the innovation processes.

⁴² Oversupply relates to the fact that too much investments may result in economical problems, as no new activities may be created in the future to increase the value of past investments (unlike telecommunication networks). Over-supply may be considered as a disproportion in the supply (performance of the engineering system), which leads to an economical failure if its relative use is (far) under the system capacity. It usually comes from a misevaluation (over-evaluation) of the market.

⁴³ HSST uses Linear Induction Motors (LIM) for sustentation and propulsion, the Osaka new metro uses rail tracks and LIM as propulsion and the MLX uses the Linear Superconductivity Motor technology.

⁴⁴ Ability to negotiate and influence outcomes through networking.

The following chapters provide a methodology for understanding the critical factors that have to be managed by means of decision-making and Innovation Model, and for setting up a list of critical factors affecting successes and failures of projects with strong technological rupture.

As Rossel (1998) presented a cluster approach for the assessment of such projects, this research proposes a transversal approach, centered on processes: HSGT technologies are the products of different Innovation Models, from the incremental X2000 to the Swissmetro, including the Shinkansen or the TGV systems. These models are characterized by decision-making structures and innovation processes, which take place in the system operator-industry-institution/government.⁴⁵ The typology of these models is important to define because they imply different management strategies.

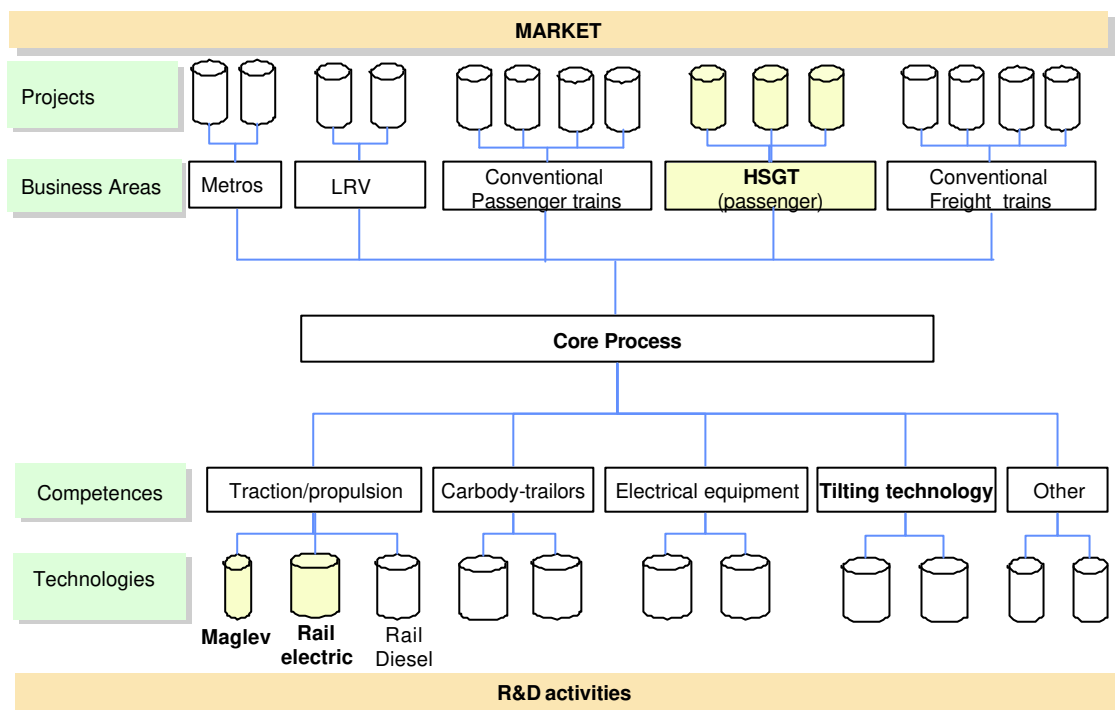


Figure 24: Core process, from the core competences to the definition of business projects: the place of HSGT technologies (adapted from Prahalad & Hamel 1994).

⁴⁵ In this system, social acceptability and user needs are included in the role of operators (service provider) and policy (regulation by institution and governments).

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	1. Introduction
	2. The case of high-speed ground transportation projects
	3. Innovation and rupture
	4. Towards an Innovation Model for HSGT systems
	5. How organizational and Institutional factors influence Innovation Models
	6. Impact of the technological rupture on Risk & Uncertainties
	7. Managing the Development of New Technological Trajectories
	8. Conclusion
	ANNEX: Project Management Assessment System

Between radical innovation and Incrementalism, the performance dilemma.

But what is performance?

3. Innovation and rupture

3.1. Introduction, learning from previous technological challenges

Behind innovations strategies leading to rupture or Incrementalism stands the notion of performance: perspectives are different from the perspective of scientists, manufacturers, operators or politics. Whereas innovation may mean completely new components or architectures for scientists, it may mean new architectures while maintaining existing components for manufacturers.⁴⁶

In order to better understand how innovation occurs and is managed in complex engineering systems, it may be useful to look back into the past (Olsson 2000). Learning from failures or successes in innovation development can help enrich the theoretical basis on innovation management. Case studies worked out for HSGT systems, as well as other works such as Cowan (1999)⁴⁷ or Bell (1998)⁴⁸, provide an interesting background. Concerning innovation with strong technological rupture in complex systems, other experiences such as Superphenix, Concorde⁴⁹ or the SST (HSCT) program, also provide some interesting hind-sights on technological wonders, on the over-evaluation of innovation benefits and on innovation processes. Concerning transportation technologies, ARAMIS, Transrapid, the TGV, the Aerotrain, the Shinkansen or the MLX-01 also provide, among others, a good basis for defining innovation processes and models.

HSGT systems are part of innovations that move forwards transportation networks. As other transportation, communication or energy systems, the challenge of innovation is not only embodied in technological complexity but also in its environmental complexity. This increases difficulties in market analysis, knowledge management, learning abilities and project management.

But before going into the complexity of the HSGT Innovation Models, one has to analyze the innovation typologies, in order to map out the main ruptures of a technology. Understanding what are the differences between rupture and Incrementalism, as well as their consequences, will lead to establishing the link between the main innovation strategies: to what extent can the creative destruction be applied to HSGT technologies; and which barriers can be overcome and which ones not?

⁴⁶ Interview with the Path Program director (March 2001, Richmond-USA): requirements from GM and Toyota to finance research on self guided cars.

⁴⁷ Cowan 1999 *Learning from disasters & learning by doing*, MERIT working paper.

⁴⁸ Bell R. 1998, *Les sept péchés capitaux de la technologie*; éditions du Seuil.

⁴⁹ Meunier p286-92: Design & construction of 20 Concorde: FF.35 Bn (1981 currency) which represent 4 time the TGV PSE costs.

3.2. Anatomy of innovation

3.2.1. Mastering product and process innovations

- *Innovation as the process of bringing inventions into the market*

An innovation “is a useful combination of prior arts” (Garrison 1996). In another words, innovation is defined as the introduction and application of a process, a product or a procedure considered to be new in a group, organization or society. New is related to the adopting unit/group, which expects a benefit from this innovation.

Thus, innovation implies not only an invention or a creation, but also the process, which allows its implementation into a market or an organization. Innovation management may be defined as managing this process starting from an idea and bringing it into the market. That’s why new and useful combinations describe innovations in engineering systems, underlying the importance of current/future market needs. If invention is a creation of a new device, innovation also entails a commercial and practical application (Sahal 1981 p.41).

- *Process versus product innovation*

Distinction between process and product innovation is useful in order to understand the emergence of innovations and their diffusion. An innovative product can be manufactured without innovation on the production processes; likewise a common product can be manufactured using innovative processes. Cost reduction and quality improvement are the drivers of product and process innovation. Their evolutions are interacting, but with a time difference because of the learning curve (Figure 25):

- Learning about failures and improvements in the product/process (detection).
- Learning through problems solving (mitigation/correction).

Manufacturing an innovative system, such as Swissmetro vehicles⁵⁰, will require innovation in production processes aiming at responding to technological problem solving, cost efficiency and quality improvement objectives. Innovation in complex engineering systems increases the probability to innovate in both subsystems products and processes: forecasting the impacts of innovation in the system is a difficult venture, because of the level of interconnections between components.

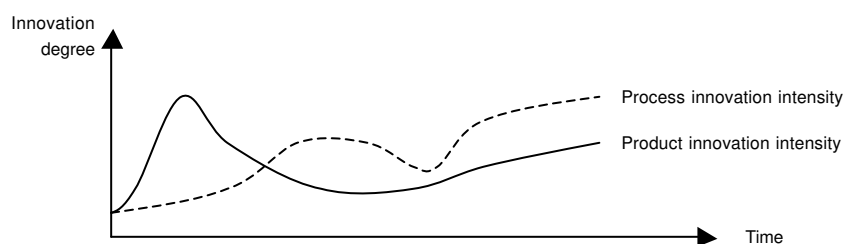


Figure 25: Example of innovation intensity (product/process) for the production of a new device

- *The innovation management dilemma*

Management refers to organizing and planning, and the notion of management science implies the formulation of determined procedures and of analytical and systematic programs (Mintzberg 1998, p.31).

⁵⁰ See de Tilière 2001 (a): those Maglev vehicles involve not only Maglev but also aeronautic know-how to deal with pressurized fuselage design. This new product will imply the development of adapted manufacturing processes.

But innovation is related to creation and invention, occurring in chaotic cycles, and to revolutions. Schumpeter qualifies innovation as a process or a cycle of creative destruction, which “incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one”. Pointing out to the dynamic and dis-equilibrium of such processes, this idea underlines the difficulty of managing innovation, that is to say also of managing chaos. Thus innovation management can be qualified as “controlled disorder” or “calculated chaos”⁵¹.

Therefore, the dilemma of innovation management in fact resides in finding the right balance between creativity and efficiency (Trott 1998, p.35). Efficiency can be improved through learning processes, but also requires a certain continuity or stability. Creativity is needed to keep a competitive advantage in a given market: it aims at significant improvements of processes, products or services. Competitiveness is linked to all three elements, combined in a cycle of innovation and improvements. Managing innovation is managing these cycles, requiring a good understanding of the market, the scientific and technological bases and the organization abilities (Figure 26).

- *Knowledge, Science & Technology*

Understanding innovation strategies in the HSGT industry for both manufacturers and operators requires looking at the root of technological changes. Knowledge, science and technology are the basis of technological innovations and are embodied in human or material resources belonging to organizations.

Technology involves processes in addition to knowledge and tools and may be defined as applied science or a productive derivation of science. Technology is the systematic study of techniques for making and doing things; science is the systematic attempt to understand and interpret the world. While technology is concerned with the fabrication and use of artifacts, science is devoted to the more conceptual enterprise of understanding the environment, and it depends upon the comparatively sophisticated skills.

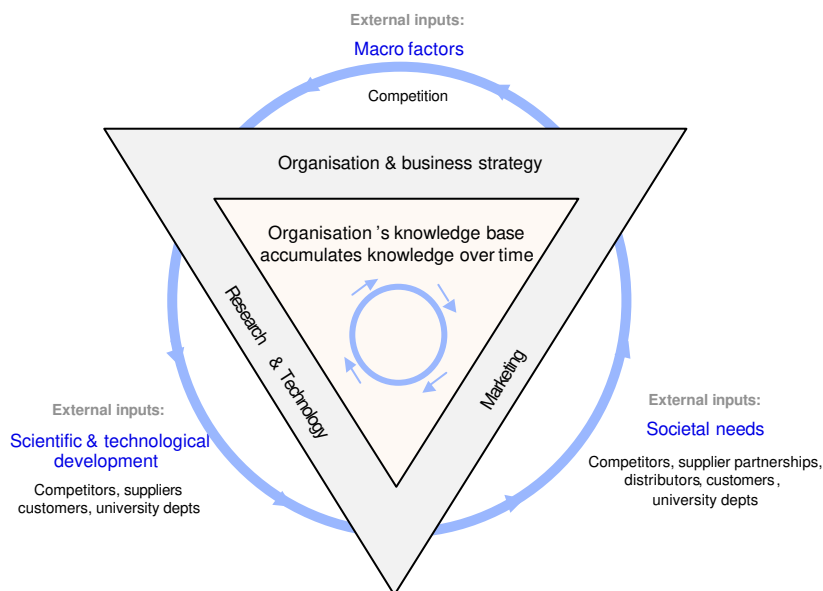


Figure 26: Processes of Innovation management (source: Trott 1998)

⁵¹ *New York Times*, 29 October 1976; article and comments about Mintzberg’s research on the work of the manager. Mintzberg qualifies his work on managers as a “celebration of intuition”, underlying the dilemma of innovation.

Technology⁵² can be divided in three levels, depending on its function as experimentation tool (fundamental/applied science), production tool or component of the resultant technological system (product):

- Infratechnology: Instrumental basis for R&D activities, which requires supplying scientific data for measures, tests and controls. It also includes methods, know-how and knowledge associated with the research (Tassey 1995, Foray 2001).
- Generic technology: Concepts of products or concepts from which commercial applications are developed through applied R&D programs. This includes concepts demonstrated in laboratories but not products and processes finally developed (Tassey 1995, Foray 2001).
- Resultant technology: Concerns the process or product resulting of the R&D activities, based on infra-technologies and using generic technologies.

Technologies can be classified into three categories, depending on their diffusion/codified level: Basic technologies (codified and diffused), key technologies (codified and non diffused) and emerging technologies (non codified and non diffused). The strategies associated with technology portfolio will be analyzed in section 3.2.5.

- *Link between Knowledge, Science & technology*⁵³

Both science and technology are based on knowledge, which enables individuals or organizations to improve the output of their work. Science is the basis for the improvement in infra-technologies and generic technologies, which allows for the development of innovations. The development of Maglev technologies or new components that enable the development of HSR systems has been achieved through both development of sciences and technologies, embodied in tangible and intangible assets (this last includes knowledge).

- *The nature of Knowledge*

Knowledge is related to experience and acquaintance (understanding), and has the propriety to be “sticky” (von Hippel 1994): the transfer or acquisition of knowledge is a key issue in the mastering of technologies and drive firm’s strategies⁵⁴. Therefore, understanding knowledge management in organizations and knowledge transfer becomes crucial, especially for the development of innovation.

The nature of knowledge can be described by means of some of its proprieties, such as codification/tacitness, observable/non observable, positive/negative or autonomous/systemic (Teece 2000 pp.13,14,97). These proprieties influence its replicability, imitability and appropriability, which are part of the reflection for strategies and decision-making related to innovation.

• *The link between innovation and development*

Understanding innovation in high-speed transportation systems requires understanding how technological change is associated with economical growth, by improving transportation services. The development of HSGT networks is the result of the belief that these infrastructures can influence economical growth (Keynesian approach). Economic development and competitiveness are related to the provision of infrastructure according to the works of Biehl 1986, 1991, Munnell 1990, and also in the EU White Paper of 1993. But this evidence is temporized by Vickerman (in Banister 1998) and de Brucker et alii (WCTR 1995), because of the limits of social cost-benefits analysis.

⁵² For more details on the epistemology and concepts of technology, see Sahal 1981, chapters 1.4 and 2.

⁵³ For this relation between knowledge, science and technology and the link with R&D (Schumpeterian hypothesis) we refer to Teece 2000, *Managing intellectual capital*, Oxford Univ. press.

⁵⁴ Case for alliances and mergers concerning tilting technologies in the rail industry (see Saubesty & Virnemen 1999, and de Tilière 2001); US defense contractors push for the development of a US Maglev HSGT industry (1989-98) and the development of Maglev rocket sleds for aerospace applications since 1994 (see de Tilière 2001).

As the development of such infrastructures has been one of the strong interests of governments in most developed countries, technological change has been a key driver to enhance HSGT systems performances and take market shares.

- *Technological change and Economic Growth*

Technological change is seen as inducing economic growth and therefore pushing public government to finance large R&D programs to support and coordinate the efforts of industry (Guinet & Pilat 1999).

The emergence of HSGT systems in the 60's occurred in a period characterized by a strong interest in the application of new technologies in every sector of the industry. Governments were looking for both infrastructure development and technological innovation, and large R&D projects were launched in Japan, France, USA, UK, Germany and Canada, aiming at new concepts enabling high-speed transportation.

Since the 90's, mainly two countries are still very technology driven concerning HSGT application: Japan, with the systematic development of low, medium and high-speed Maglev systems⁵⁵, and more recently China, with its development of HSR technology and interested in the technological transfer of the Transrapid technology.

- *Technological change and competitiveness*

Public R&D programs for alternative technologies in the 70's (as Maglev, air-cushion systems) were seen as an aggression by automobile and rail industry (Frybourg 1987 p.32). The introduction of new technologies changes the configuration of the market and modifies the competitive advantage of the firms present in the market. The introduction of new technologies, such as air-cushion technologies in the 60-70's and Maglev systems or tilting technologies more recently, induced changes in R&D strategies through changes of competitive advantages between actors. This relation between competitiveness (market state and configuration) and technological change has led to different types of innovations.

3.2.2. Typology of innovations

Managing innovation requires finding which patterns may characterize the innovation, in order to adopt accurate strategies or measures. Three axes are defined for the classification of innovations: the first is related to complexity and interconnections between the innovation and its system (Autonomous/systemic). The second is associated with the level of transition between the new and the old system (transition/rupture). The third concerns the core of innovation: product/service.

- *Autonomous and Systemic Innovations*

The distinction between autonomous and systemic innovations (Henderson & Clark 1990) is probably the most important one. An autonomous innovation is located in a component or sub-system, the change of which has no (or a relative) impact on other components or on the system as such. At the opposite side, an architectural innovation concerns a large part of the system, underlying the degree of interdependence between technologies or subsystems. The essence of an architectural innovation is the reconfiguration of an established system to link together existing components in a new way.

Implication of autonomous/systemic for innovation management is crucial and is a driving element for cooperation or alliance strategies, based on the knowledge and the capabilities of firms (Teece 2000 p.63, 64). Architectural innovation usually requires more partnership or outsourcing, as a large part of the system components have to be adapted. In systemic innovations, other components can be found more easily on the market, and innovation can be managed by the firm itself.

⁵⁵ Maglev metro network in Osaka into implementation since 1997, HSST-01 (Chubu Development Corporation) and the MLX-01 (Japanese National Railways).

- *Degree of Innovation: transition/rupture*

The notion of rupture/transition is related to the degree of discontinuity or change in the evolution of a product, such as a train in our case. Transition is associated with Incrementalism, underlying an improvement step-by-step and maximizing the advantages acquired beforehand, by following the same path (strategy, technology etc). At the opposite side, rupture is associated with discontinuity, underlying radical changes. This notion of transition/rupture has an impact on knowledge management, by valorizing or destroying acquired competences (Schumpeter 1941, p41).

The idea of discontinuity concerns both products and processes. The distinction has therefore to be achieved between a disruptive innovation (product), which is the result of a continuous process, and a product (transition), which is the result of a disruptive process. As Midler (1993) points out, evolutions in project management have redefined the boundaries between incremental and radical innovations.

In this research, the focus will be on the management of projects with strong technological rupture, that is to say on the degree of innovation in products.

- *Innovation product/service*

Discontinuity can be measured in relation to the product/technology or to the market/service⁵⁶. Innovation strategies can be described by the Johnson & Jones Matrix (1957) for the technology development (Trott 1998 p.178). The product objectives are defined by two axes: the technological innovation degree (from no change to new technology) and the market newness (from an existing to a new market).

Both dimensions are extremely important, and innovation in HSGT systems has been driven by both service improvement (reduction in travel time, increase of accessibility) and technology improvement (industrial strategies in a competitive environment). The main discussion concerns the relation between products and services in the assessment of innovation, underlying the innovation trap (Millier 1999). The misevaluation of this relation leads to the myth of the big market or the notion of oversupply. The real service improvement generated by new technologies needs the combination of techniques and marketing.

- *Core concepts and linkages*

A core design concept is associated with each component (physically distinct portion of the product), which performs a well-defined function. The product or system implies the mastering of the linkages between core concepts, which means the combination of core designs associated with different defined functions that makes the system work.

Innovation can therefore require two kinds of knowledge (Henderson & Clark 1990): component knowledge, related to core designs, and architectural knowledge, related to the integration and the linkages between components into a coherent whole. This leads to the innovation matrix.

		Core concepts	
		Reinforced	Overtured
Linkages between core concepts & components	Unchanged	Incremental Innovation	Modular Innovation
	Changed	Architectural Innovation	Radical Innovation

Figure 27: Typology of innovations

- *The case of HSGT systems*

In the HSGT projects analyzed in this research, all systems are the result of systemic innovations. Maglev technologies imply an innovation extended to both vehicles and infrastructure (guide and energy transfer equipments) and represent the most systemic innovation in these systems.

⁵⁶ See also Saubesty & Virnemen 1999, pp.5-6.

HSR and tilting technologies are also systemic innovations, but to a lesser degree, since only train-sets and not rail infrastructures are concerned. HSR systems were incremental solutions; maximizing the use of network infrastructures and knowledge as well as production tools of rail industry. Maglev technologies, on the other hand, can be qualified as a rupture for the industry involved and the infrastructure non-compatibility. Because of its higher commercial speed, it can also be seen as a rupture in terms of demand.

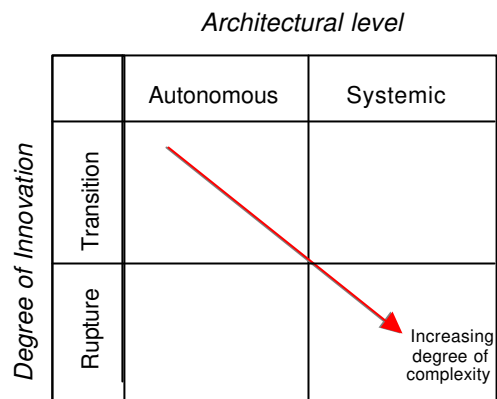


Figure 28: Typology of innovations and complexity

3.2.3. Innovation and product life cycle

The emergence of innovation and problems encountered in project management are related to the notion of product life cycle.

The innovation context can be better understood through the notions of substitution curves and competition phases, which are relevant for the definition of R&D strategies. For each phase of a product-cycle, the following factors vary in terms of importance: management, scientific and engineering know-how, unskilled labor, external economies and capital.⁵⁷

- *Innovation phases and S-curves*

The life cycle of technologies can be represented by S-curves describing technological envelopes. For HSGT technologies, the emergence of new concepts was based on the notion of speed performances. Speaking of substitution curve wouldn't be appropriate in the case of Maglev or HSR technologies, as the market is structured in niches.

However, since the 60's, the increase of new technologies and competitors in the HSGT market has led to a shortening or acceleration of product-cycles, especially since the beginning of the 90's.

In the 1960's, the development of the aerospace industry and the increasing impact of technologies through large R&D programs has led to a period where decision-making has been strongly technology driven. Recognizing that the development of the economy was closely related to the development of technologies embodied in infrastructures, a new interest arose in applying new technologies and produced a large spectrum of options that have been studied through national R&D programs. This period (1960-1989) produced some interesting innovative and complex systems - the Concorde, Ariane, Superphenix, the Transrapid or the MLX-01, among the most emblematic ones. These new technological developments were also strongly supported by institutions, which considered them as an opportunity to improve the performances and the competitiveness of the related sectors (Bell 1998).

- *Exploration Phase: Learning through diversity*

In the HSGT industry, the emergence of new rupture concepts flourished with the development of the air-cushion technologies⁵⁸, Maglev technologies⁵⁹ and turbo-jet propulsion applications. Some of these

⁵⁷ See Freeman & Soete 1997 p.279 for more details about those variations and p.358 for another description of product life cycles.
⁵⁸ French Aerotrains developed by Bertin Co. (1963-1974) supported with US\$ 12 Million 1968 by the French government. The British Tracked Hovercraft Development Ltd. also received a US\$ 5 Million 1968 from the British government for a prototype

technologies combined various concepts: for instance, air-cushion and turbo-jet-propulsion, as in the case of the Aerotrains or the Grumman concept (which also involves Maglev propulsion after the cruise speed has been reached). But some innovations have been more adapted to the existing constraints of the network, such as the concept developed by Garret (USA): a turbine-driven alternator coupled with a linear induction motor, with the vehicle using ordinary railroad tracks.

These radical innovations were developed by newcomers in the transportation market. Politicians and institutions have supported these alternatives as an incentive for the improvement in ground transportation systems. One of the most interesting cases is the example of the aerospace industry in the USA, which provided the majority of contractors under the HSGT Act (1965-1974). The HSGT Office (HSGTO), created for this Federal Program, was very interested in attracting aerospace contractors for the ground transportation market. These contractors having proved their ability to manage innovation in complex aerospace systems, it was considered to be an opportunity for a profitable technological transfer. But as will be developed further, the structure of this market and the prevailing organizational and institutional characteristics lead to a series of failures.

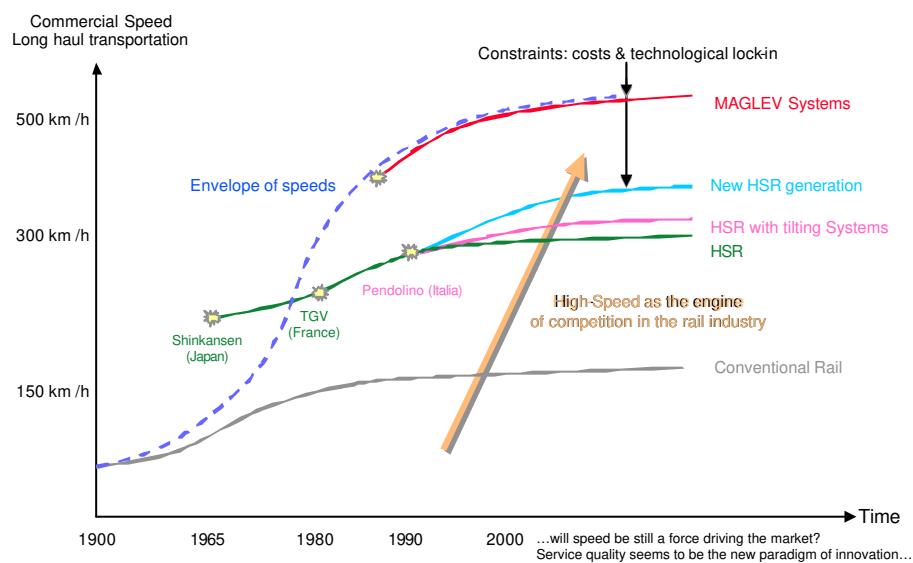


Figure 29: S-curves and product life cycle / technological envelopes and velocities

- Tension between transition & rupture: the innovation dilemma

Many national R&D programs have assessed a large spectrum of technology, and this exploration phase was characterized by a tension between transition and rupture. In this context, rupture is also associated with the non-compatibility with rail infrastructures. Rupture is usually understood as overcoming presumed technological lock-ins in a current system, in order to respond to a future market adaptation or a special market niche. In contrast, Incrementalism development allows an improvement in performance without a fundamental discontinuity in the learning curve. An innovation linked to a technological rupture implies, in the early stage of the development (prototype), a decrease of the product performance because of the lack of experience concerning both product and processes. One way to overcome this handicap is through a “learning by doing” strategy during the development and the operating phases (learning by using).

demonstration. In the USA R&D on this concept was conducted by General Electric and Grumman Co., but no full-scale demonstration project was built (Yaffee 1968).

⁵⁹ New interest in Maglev R&D in 1962 in Germany with the Transrapid concept, 1962 in Japan (JNR) and 1963 in the USA at the Brookhaven National Lab. Full-scale demonstration projects were built only in Japan and Germany for High-Speed Maglev systems.

In most countries where HSGT systems have been developed, R&D programs were undertaken for both incremental and radical innovations. High-speed rail (HSR) solutions were more incremental whereas Maglev concepts or Track Air-cushion technologies were more radical. They involved higher commercial speed (rupture in the supply) and non-compatibility with the existing rail network.

R&D-based development of high-speed wheel-rail technologies was a priority for many rail operators/industry involved in this market. The Shinkansen technology and the emergence of new alternatives (rupture) was an incentive to enhance the performances of the current rail systems in many countries. Japan chose to develop two options in parallel: the Shinkansen; and Maglev systems for the longer term (the Maglev options have been preserved until now).

The same dilemma arose in Germany with the Transrapid Maglev technology. In the USA, Japan and Europe, the dilemma between transition and rupture arose around the notion of performance/compatibility, and alternatives were tested until the mid 70's.

The concept of evolution / compatibility versus revolution/performance is the basis for discussions on innovation. Different models of innovations⁶⁰ were shaped depending on the industry's position in this market, its type of organization and the institutional context.

The different kind of possible innovations can be classified according to their degree of innovation, that is to say from transition/incremental to rupture/radical (Figures 28 a & b).

But complexity in engineering systems also emerges at the architectural level. An innovation can be located at a component, subsystem or system level. The innovation can be defined as autonomous or systemic (architectural)⁶¹. This relates to the innovation's interdependences in the system. In an architectural or systemic innovation, a large part of the system needs to be modified or adapted. This new configuration therefore requires some autonomous innovations, so as to allow new recombination.

- Selection Phase: Learning through the standardization of the dominant concept

After a decade of investigations in new HSGT concepts and interesting evolutionary developments, a large part of these alternative options have been abandoned in the mid 70's: the French Aerotrain in 1974 and all US technologies, except the Metroliner and the Turbotrain. Institutions ended this extensive R&D phase by focusing on wheel/rail technologies, working with current operators. Only rail options were implemented, whereas two Maglev technologies were maintained as an option in Japan and Germany.

The selection phase is a way to concentrate resources on a technology and to learn more rapidly, through an early adoption of the system for operation (learning by using). The main difficulty is the timing of these phases and of the selection process for both industry and institutions. An early adoption can result in a failure if the technology has not been sufficiently developed in order to allow its accurate validation. One example is the Japanese Maglev system (MLX-01), for which a test track was built in 1991. Full costs of development have until now amounted to about US\$ 1.5 billion, but the operation costs of the cryogenic cooling system seems too high for eventual commercial implementation.

Since the 80's, the concept of High-Speed Rail (HSR) has emerged. After the dominant concept selection, competition was based on incremental innovations along this path (technological system as a dominant design). If institutions are mainly involved in the selection of system infrastructure concepts, their role is also very important for the technological choice of components (through the definition of safety standards etc). Industry is innovating within this framework on a technological path, which is partially defined. In the 90's, options were focused on the development of tilting technologies and double-deck train-sets. Innovations were mainly oriented on cost efficiency, materials life cycle, comfort etc.

Since the implementation of HSR networks in Europe, rail industry has competed by means of different standards⁶². One can analyze co-evolution or cohabitation of standards for such infrastructure through the notion of national markets. The harmonization of the European rail market, which started in 1990, has affected the innovation processes. Operators and institutions have had to reposition themselves and the

⁶⁰ Innovation models: push (technology driven), pull (market driven) and interactive (see also Trott 1998).

⁶¹ Henderson & Clark 1990.

⁶² Standards concern Infrastructure, Energy, Rolling stocks, Maintenance and Inspection/control.

industry therefore sees its environment changing (restructuring of the structure of decision-making processes).

An interesting tool for decision-making analysis is the option choice theory, which can help in understanding the selection process of new technologies. This analysis has to be achieved by the private industry, as regard the definition of its R&D strategy, and also by institutions, which have to support or evaluate emerging technologies for future implementation (attribution of concessions, public participation in infrastructure investments etc.). This assessment takes into account economical and financial criteria, but other critical factors also have to be considered in order to explain the real decision-making process in both industry (suppliers and operators) and institutions.

3.2.4. Competition phases and “the habits of highly effective revolutions”

One of the main difficulties in the emergence of innovations is related to the question of the competition phase of the market. The competitive advantage of an innovation is associated with one or several performance criteria. Three phases can describe the product-life cycle in the market environment (competition steps presented in Figure 30). Varian (2000) analyzes the competition process in more detail, saying that the technological innovation passes through experimentation, capitalization, management, hyper-competition and consolidation, as it undergoes industrial development. Entry costs are lower at the beginning, and rise progressively.

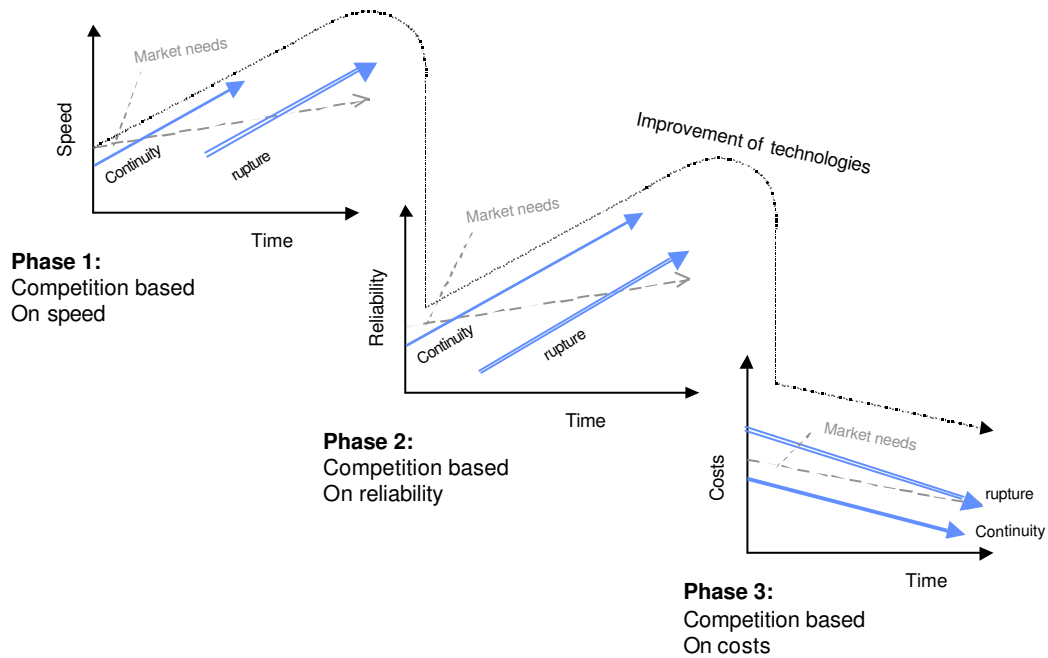


Figure 30: Sequences of the HSGT competition phases by objectives, relation with the product/design life cycle.

To be more precise, two phases can describe innovation over the product/industry life cycle: the first one is represented by a higher innovative rate in the product (design), in order to build a competitive advantage in the market in terms of product performance, whereas the second phase puts a stronger emphasis on cost reduction, through a higher rate of process innovation.

This underlines the difficulty for new technologies to compete with more proven ones, which benefit from an accumulation of experience on the product (learning by using, feed-back from operators for example) and on processes (the efficiency of which already has been improved).

This fact also highlights one of the dilemmas for the adoption of Maglev systems: these systems were ready for market applications in the 90's, but the HSR industry was competing for cost reduction. The competitive advantage of Maglev, which is mainly its commercial speed, was hidden by higher costs and a lack of reliability because of the newness of the system.

3.2.5. Innovation and R&D strategies

Before going further in the analysis of incremental or radical innovations, one will have to present some notions of R&D strategies, as they will provide the basis for decision-making.

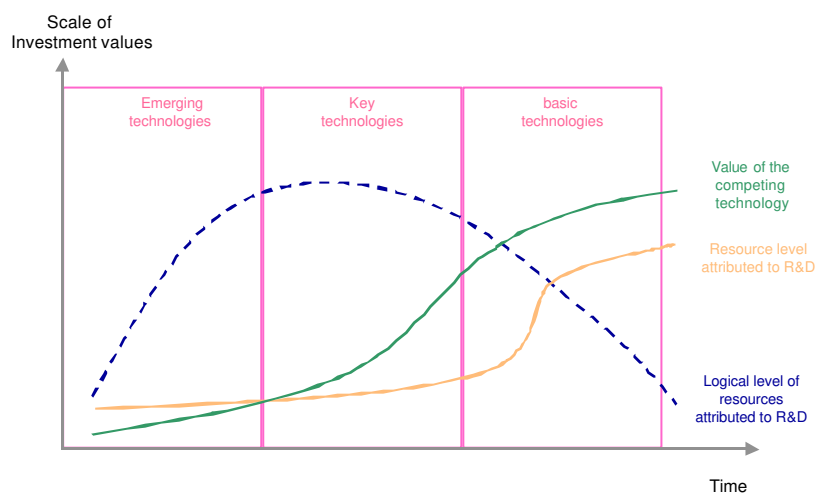


Figure 31: Attribution of R&D resources for basic, key and emerging technologies

Managing innovation and developing new technologies is a question of strategy, which has to be based on resource allocation (Figure 31) and capabilities (know-how and flexibility embodied in both production tools and organizations). This background will be very important for the recommendations concerning project management, since they define the basic drivers of decision-making in the industry: R&D horizons, learning strategies, spillover, R&D strategies, access modes to technology as well as know-how and several concepts of innovation strategies.

- *R&D Horizons*

Three R&D horizons can be defined, based on short, middle or long-term strategies:

- The first horizon H1 is a business as usual strategy, focusing on short-term actions and benefits and which requires less R&D investments. In the HSGT industry, for example, it means improving the current generation of technologies such as TGV, Shinkansen series 300, ICE etc.
- The second horizon H2 is a strategy of new product development, focusing on middle-term action and benefits. It requires more R&D investments than H1, but much less than H3. Concerning the HSGT industry, it relates to the development of a new generation of technology, which is however based on the current one (the French AVG program and TGV duplex, the Japanese Shinkansen series 500 to 900, the new German ICES and Tilting technologies).

- The third horizon H3 is a strategy based on radical innovation, focusing on long-term action and benefits. It requires much more R&D investments, because of the need of problem solving and of developing infra-technologies. This horizon can for instance be illustrated by the R&D in Maglev technologies, which exists since 40 years now: the German Transrapid, the Japanese MLX-01 or Swissmetro.

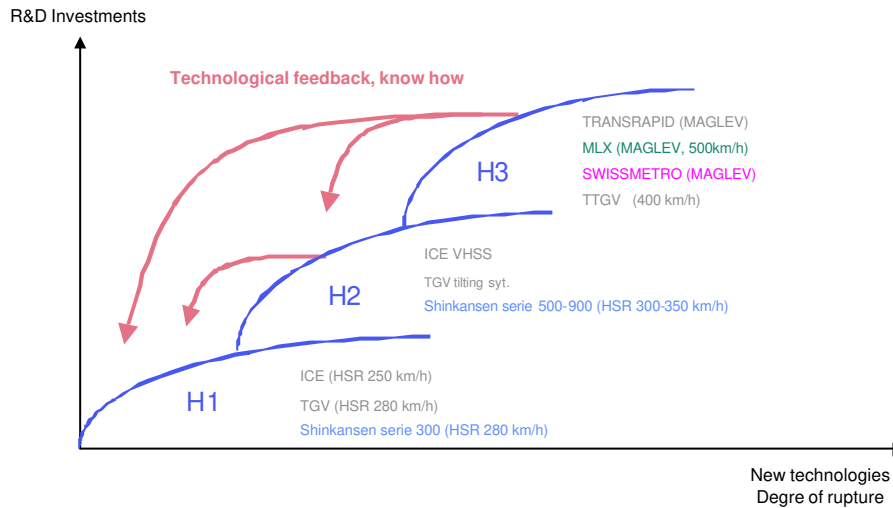


Figure 32: Strategic Horizons, R&D investments in the development of technologies

The notion of horizons and the typology of technology (basic/key and emerging technologies)⁶³ define the competitive position of respective products and processes. This position is stronger for key technologies and less decisive for basic technologies, which are easier to be appropriated. Emerging technologies are more susceptible to modify the future bases of competition (structure of the market, creation of new niches etc).

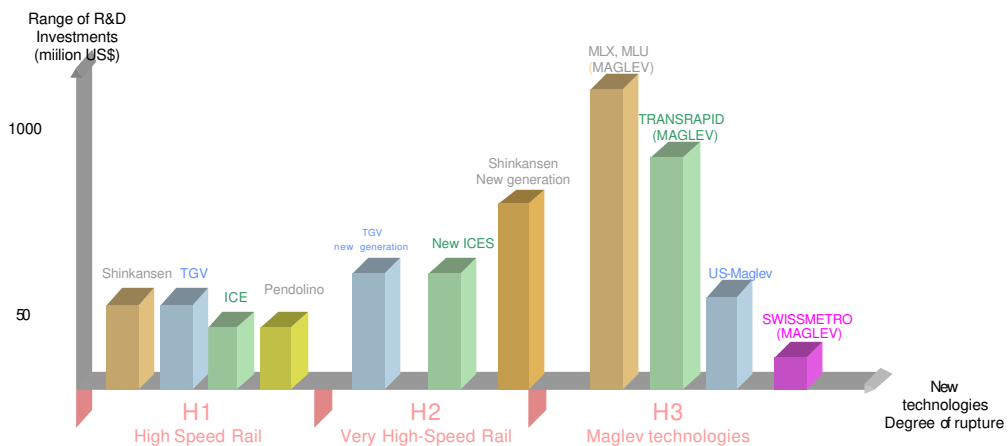


Figure 33: Global investments for the development of HSGT technologies since 1990

⁶³ A.D.Little typology, also developed by Frybourg 1987 p.36 for the transportation sector.

Investments in HSGT technologies can range from US\$ 50-100 million, for the development of a new HSR system,⁶⁴ to US\$ 1 billion for the development of a new Maglev technology, which requires the building of test tracks and special installations (full-scale development).⁶⁵

- *The notion of learning curve, learning methods*

The notion of learning curve is important in the context of the development of innovations since the articulation of R&D strategies is based on knowledge management (acquisition, appropriation or retention). Learning refers to scientific and technologic knowledge achieved through research and experimentation, embodied in organizations and production/experimentation tools.

Five types of strategies⁶⁶ can be used in the development of innovation: learning without doing, learning before doing, learning by doing and serial and parallel learning. These strategies are based on balancing the maximization of knowledge and experience acquisition and minimizing costs, taking into account irreversibility problems. The context of learning can be ranged from simulation to commercial production/operation (Pisano 1996), with a link between the level of representation and the cost.

Concerning Maglev technologies, for example, Transrapid, MLX and HSST technologies have been developed on a full-scale, in the hope of a possible commercial application and in order to set standards. Learning by doing and using is more expensive and implies the problem of irreversibility (when compared with US concepts or Swissmet ro).

- *Mastering technologies and know-how, access modes*

Understanding strategies of HSGT industry and the evolution of the structure of consortia, partnerships or recent concentrations lead to the notion of mastering of technologies. If access modes to technologies do not form the main subject of the present research, they remain a critical element for the definition of innovation strategies.

The degree of appropriation or exclusivity of a technology (Figure 34) shapes the degree of liberty to introduce systemic innovation and influences the degree of internal or external R&D. This has an impact on partnership or cooperation strategies (Tables p.70-71), and therefore on the type of innovation. The choice of R&D strategies must be adapted to the type of innovation (shaped by Innovation Models, §4.1.1), but decision-making is mainly based on a cost/opportunity analysis, where opportunities are counterbalanced with costs, risks and delays in the access to the technology (Table 6 p.71).

If partnership and cooperation allow reducing risks in costly R&D programs, success also hinges on building competence networks supporting a systemic innovation.

- *R&D Strategies in HSGT systems*

Looking at HSGT systems, first incremental innovations (the Japanese Shinkansen and the French TGV) were achieved through research and cooperation between national operators (JNR/SNCF) and national manufacturers. But developments of the technologies were mainly based on applied R&D, which have been realized in less than 4 years until the first pre-production. Acceding to such technologies was easier and less costly than developing alternative technologies (TACV or Maglev concepts), since the basic technologies were well mastered and were proven in operation for lower speed.

⁶⁴ US\$ 50 million for the development of a new HSR gas-turbine locomotive (ISTEA program 2000-2002, collaboration FDOT-Bombardier). US\$ 120 million for the development of HSR designed for 350 km/h (partnership Alstom-SNCF).

⁶⁵ Investments for Maglev technologies including full-scale tests are over US\$ 1 billion for Germany and US\$ 1.5 billion for Japan.

⁶⁶ See von Hippel & Tyre 1993, Pisano 1996, Boisot & Mack 1995, Foray 2000 pp.37-40, Saubesty & Virnemmen 1999 pp.113-118, Alter 1995 p.84.

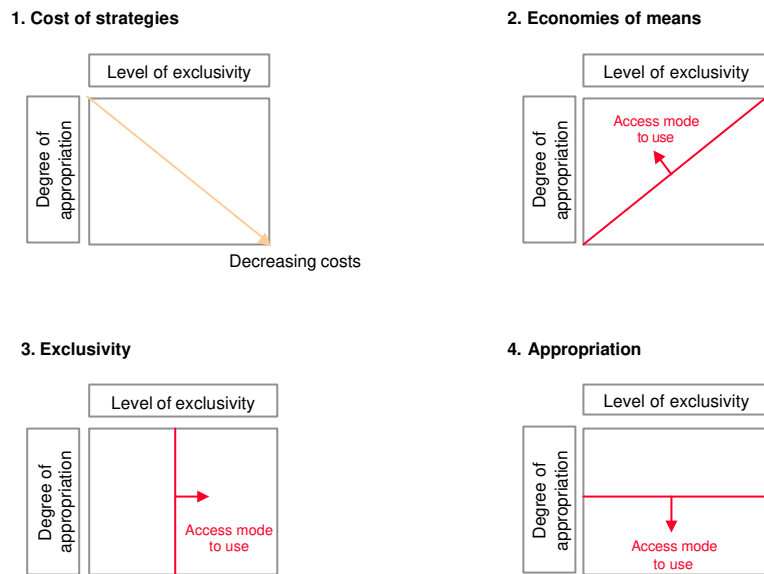


Figure 34: Main access modes depending on exclusivity and appropriation modes

Types of access	Elements of the technology accessible		
	Knowledge	Means	Know-how
1. Purchase of the system	Weak	Excellent	Usage & specification
2. Purchase of a technology	Null	Null	Usage only
3. Outsourcing of a competence	Weak	Null	Progressive
4. Active watching	Variable	Null	Variable -
5. Engagement of specialists	Variable	Null	Variable +
6. Technological transfer	Sufficient	Weak	Sufficient
7. Joint-venture	Good	Good	Excellent
8. Participation	Good	Excellent	Excellent
9. Formation	Excellent	Null	Average
10. Strategic alliance	Good	To define	Good
11. R&D cooperation	Very Good	Good	Good
12. Large programs	Good	Variable	Good
13. Research with universities	Excellent	Variable	Weak
14. Research under contract.	Excellent	To define	Excellent
15. Internal R&D	Very Good	Excellent	Excellent

Table 5: Elements of a technology accessible, knowledge, means and know-how.

Types of access	Criteria of strategic choices			Criteria of tactic choices			
	Appropriation	Exclusivity	Master-ship	Cost	Opportunity	Risk	Delays
1. Purchase of a system	--	--	--	++	+	++	++
2. Purchase of a technology	--	++	0	++	+	++	++
3. Outsourcing of operations	-	-	-	++	+	++	++
4. Minor participation	+	++	+	+	-	-	++
5. Major participation	-	-	-	--	--	-	++
6. Joint-venture	+	0	0	-	+	0	0
7. Partnership	++	0	+	-	-	0	0
8. Alliances	++	0	+	-	+	0	0
9. Networking	++	0	+	-	0	0	0
10. Patent acquisition	0	++	+	-	0	++	++
11. Capital risk	-	++	0	--	--	-	+
13. Research with university	+	-	0	0	++	0	--
14. Reverse engineering	++	+	+	0	-	+	+
15. Active technology watch	+	+	+	+	++	+	+
16. Engagement of specialists	++	++	++	+	0	+	++
17. Out-sourced R&D	++	+	+	--	++	-	-
18. Internal R&D	++	++	++	--	++	-	-
19. Formation	++	--	0	0	-	+	+

Table 6: Evaluation of access modes of technologies through strategic and tactic criteria.

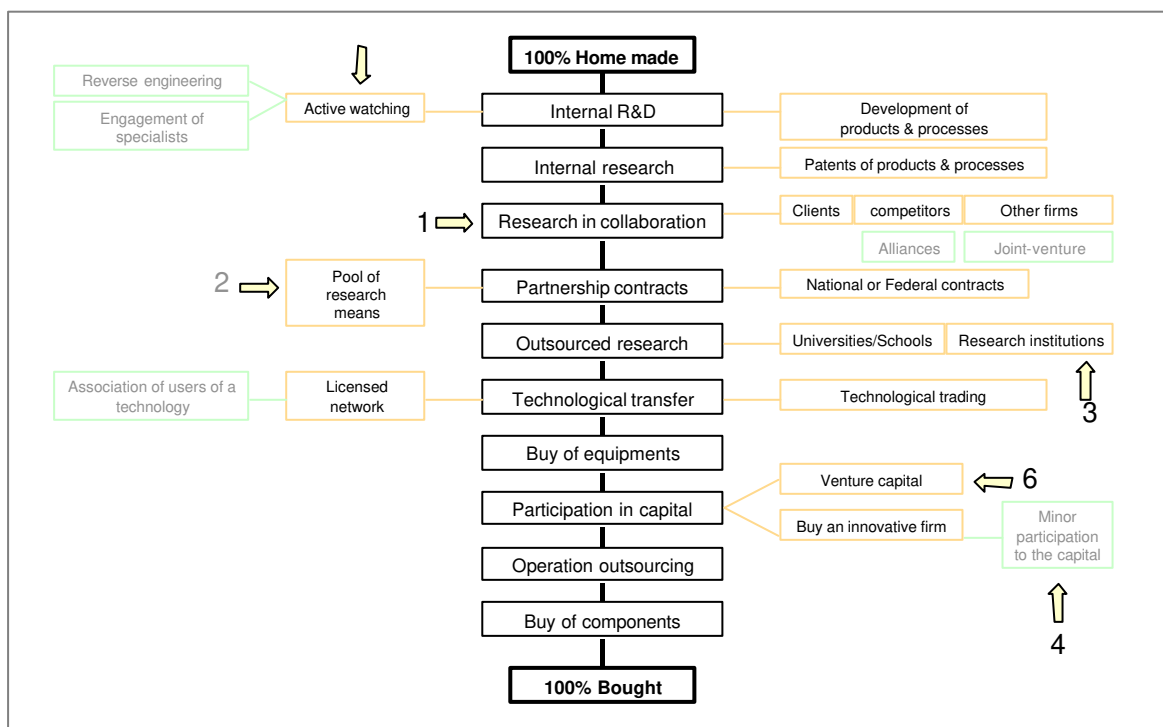


Figure 35: Putting access modes of technologies into figure

In the case of Maglev systems, the innovations requiring strong technological rupture proved to be very costly in terms of R&D and had to be strongly supported by governments through national programs. “Champion programs” were adopted in Germany (1962-1979) and in the USA (1990-2001) and put into competition several national industrial consortia. In Japan, the Maglev program was supported through R&D budgets allocated to JNR and its new research institute RTRI.

If R&D focusing on one program only can be very hazardous, there is, in some cases, such as young companies or specific projects, no other solution. For instance, the development of Maglev technologies has required a very high concentration of resources in order to develop the scientific basis, knowledge and experience (the MLX-01 was developed through internal R&D, led by R&D departments of JNR and heavily subsidized by the Japanese Government). The Transrapid program was achieved through a consortium under a German-federal R&D program. Swissmetro studies were also supported by public research-programs, but since Swissmetro S.A. didn’t have internal R&D resources, studies had to be achieved under contract Figure 36, [S1]); however, the current challenge for Swissmetro is to find industrial partners for the development phase and in order to set up a new consortium [S2].

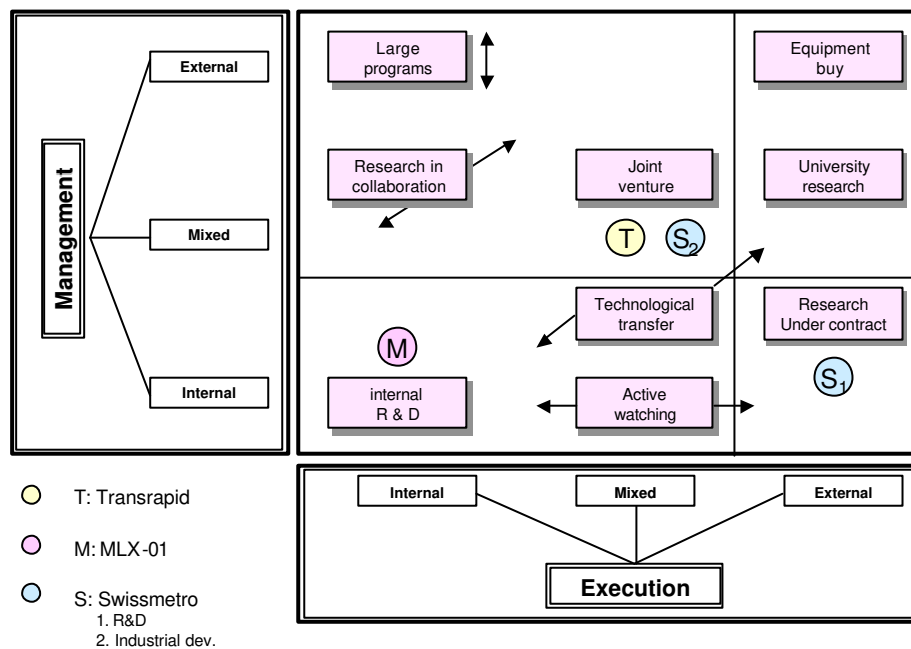


Figure 36: R&D Strategies in Maglev HSGT systems: outsourcing levels of management & execution

Without the support of national or federal R&D programs, more performing firms in the HSGT market rather focus on optimizing their approach through the use of access modes which are less costly and more practical to implement.

Radical changes in the HSGT manufacturing sector have leading to increasing co-operations and mergers to succeed in international contracts. Therefore the growing importance of co-design and partnership implies a higher difficulty in managing systemic ruptures. It rather encourages improvements along the same technological trajectory and focus innovations on components of the system.

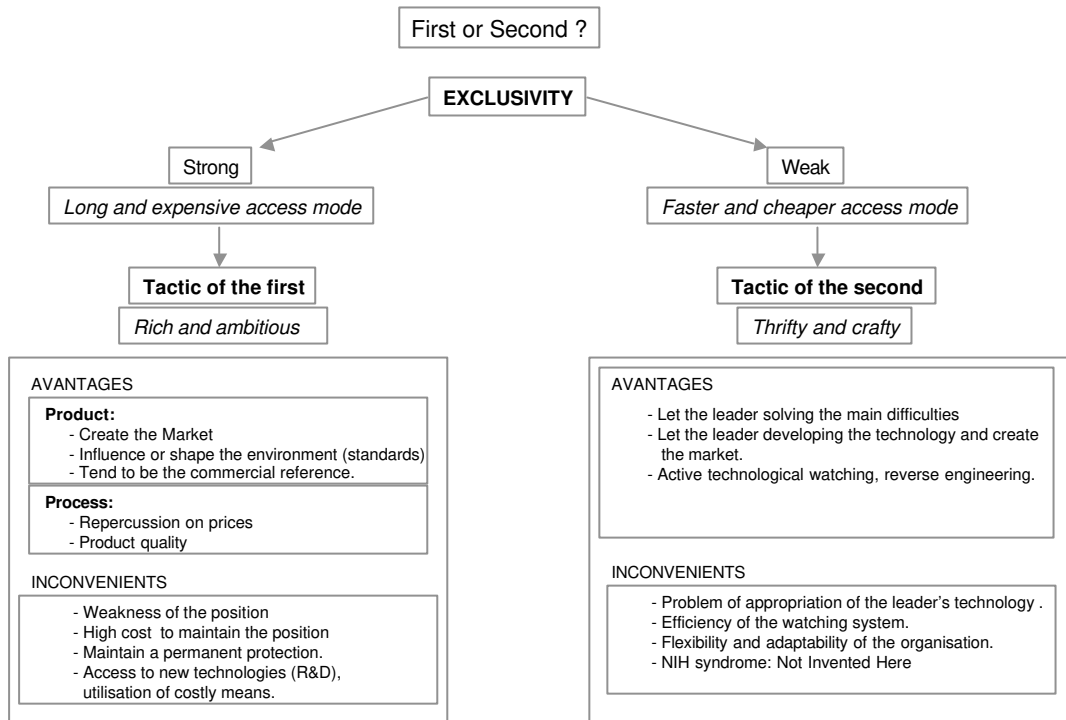


Figure 37: R&D Strategy; advantage and inconvenient in the race to set new technological standards.

3.3. Mapping out the Rupture

3.3.1. Notion of multiple perspectives

Schumpeter (1942) describes innovation as a *destructive creation*, underlying the notion of rupture and discontinuity. But as innovation refers to both product and market, a distinction has to be made between discontinuity in R&D and discontinuities in use. If apprehending the rupture and assessing its impacts are crucial for decision-making and management, the difficulty remains in the understanding of multiple perspectives concerning innovation in complex systems (Figure 38). This notion, introduced by Lindstone (1974), is important in order to understand how innovations can succeed or fail, and this approach has been used for the case studies analysis summarized in chapter 4.3.

But before trying to understand the approach, as set out above, one will have to analyze in more details the notion of rupture. In chapter 4, one will integrate the notion of multiple perspective in the elaboration of Innovation Models.

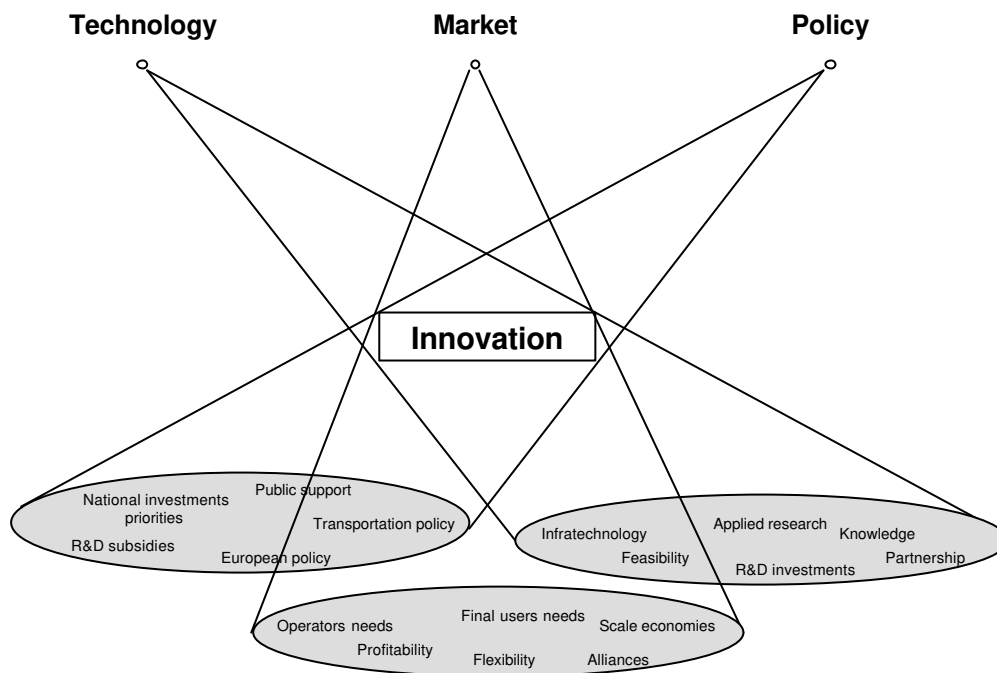


Figure 38: Notion of multiple perspectives, impacts of innovation with strong technological rupture

3.3.2. Typology of ruptures

Innovation can lead to different kinds of ruptures. These ruptures can be described under the angle of their impacts, which can be technological, economical, organizational, social, political or institutional. But the timing of their discovery is also important, as some ruptures could not be foreseen and can therefore be observed only ex-post.

- *Ex-ante rupture*

A rupture can be part of the purpose of an innovation and therefore be described as an ex-ante rupture. One can take as an example the emergence of a new demand for commuting trips, after the introduction of a HSGT service, in order to reduce the travel time (for example from 3h30 to 50 min with the Swissmetro between Zurich and Geneva).

- *Ex-post rupture*

Other effects cannot be foreseen, but occur after the introduction of the innovation: they can be described as ex-post rupture. In transportation systems, such non-apprehended consequences can be induced effects, such as changes in users' behaviors, land-use patterns, etc.

- *Rupture based innovations*

Some innovations are based on rupture and lead to innovative products or processes, which can be deliberate or fortuitous. As this research is focusing on technologically based innovations, the next paragraph will develop the concept of technological rupture.

3.3.3. The technological rupture

- *Technological rupture and Innovation*

The technological rupture does not correspond to innovation in the literally sense; it is rather a process, which leads to innovation.

The purpose of a technological rupture can be to provide better, faster and cheaper transportation services (performance improvement) or to create a new niche of services (market innovation).

Maglev systems, for example, constitute an innovation with technological rupture since they provide both a change in the vehicle propulsion and the track concept:

- Rupture of the propulsion concept: substitution of steam by diesel and electric traction.
- Rupture in the track concept: Maglev systems are monorail vehicles and non-compatible with current rail systems.

The purpose of these systems is to provide faster services with less energy consumption thanks to linear magnetic motors and better aerodynamic performances (no wheel-rail contact, no bogie and catenaries, which represent 50% of the air resistance at high speed).

- *The rupture and the filiations of innovation*

The notion of rupture is also linked to the use by consumers of a product. From a broader perspective, innovations are continuously spreading into various engineering disciplines. Innovations appear to be recombination or new combinations of existing technologies. Thus rupture must be defined for a specific range of product or services and associated with a precise function (for example, the candle and the lamp, or the plough and the tractor).

- *Rupture as a discontinuity in R&D*

Rupture implies discontinuity and is associated with a breakthrough. Technological rupture implies a radical change in a new technology when compared to existing ones, whereby this change is not the simple result of an extrapolation of the current technology (available for the same type of use). The degree of change has to be high enough so as not to be associated with mere Incrementalism.

Technological rupture is achieved through specific R&D aimed at recombining generic technologies and improved by new scientific results (figures 39 & 40).⁶⁷

The technological rupture implies the development of infra-technologies required to support the applied R&D. Swissmetro, which involves both Maglev technology and the large-scale vacuum in the tunnel imply new simulation tools for the studies concerning aerodynamics, concrete porosity etc, that have to be tailored for the project.

- *Technological rupture, impact on performances*

Two phases can be identified in the emergence of an innovative system with regard to performances: childhood, and adolescence. The first phase is the result of a technological rupture, which implies a

⁶⁷ Source Foray 2000, p13.

decrease of performances, when compared with mature systems (HSR in our case), because of the need of problem solving. This requires a long process of technology improvement (learning phase), which leads to better performances (Figure 41).

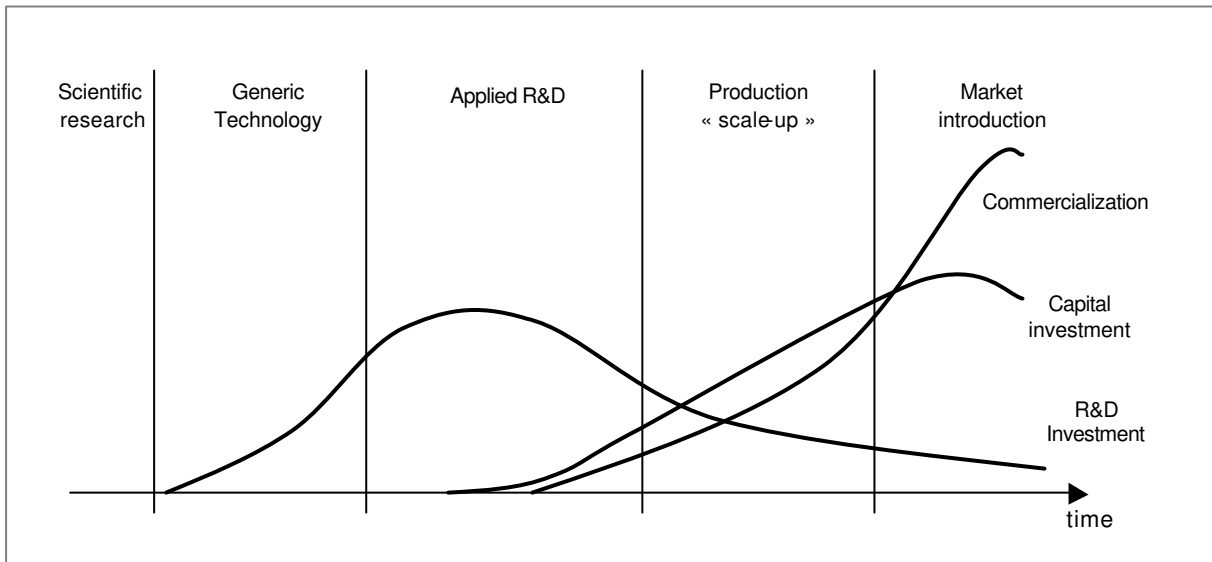


Figure 39: Investment cycle for an incremental technological change (Source: Foray 2000 p. 13)

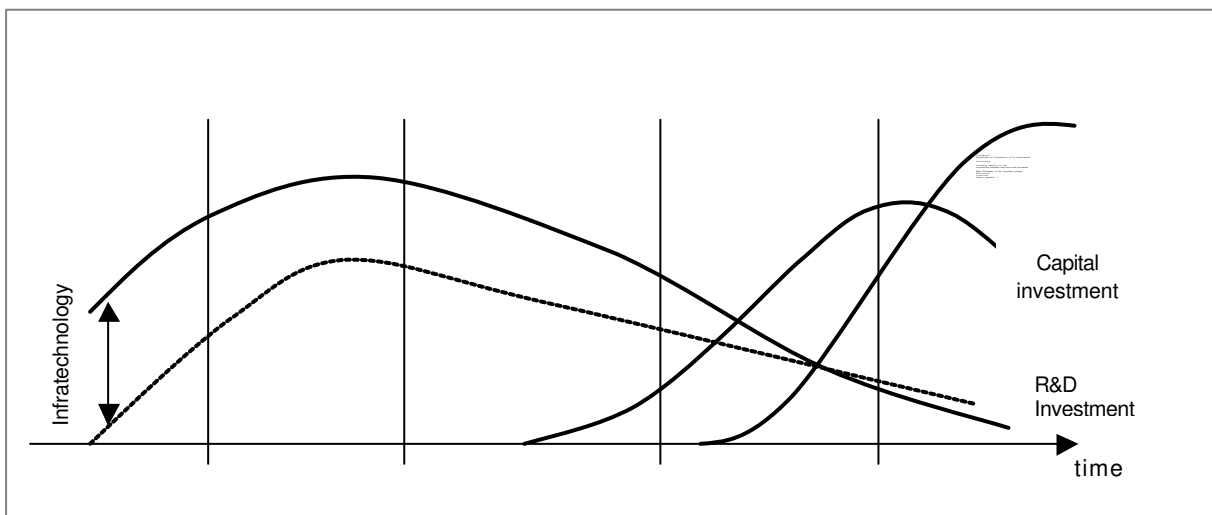


Figure 40: Investment cycle for a technological rupture (Source: Foray 2000 p. 13)

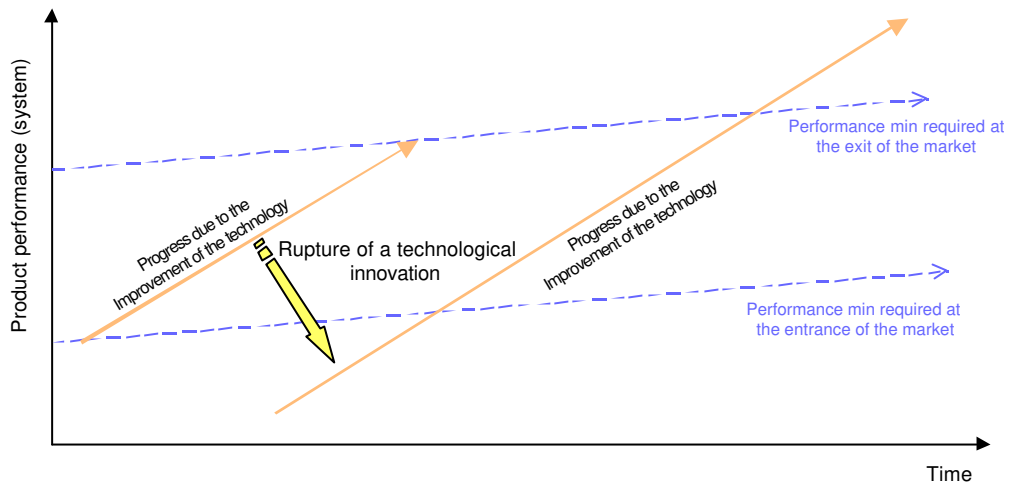


Figure 41: effects of the technological rupture & the continuing improvement in a technology

Concerning Maglev systems, the rupture implied large R&D investments, since the 60's, in order to allow such technologies to reach the service performance required for the entry into the HSGT market. They reached maturity at the end of the 80's, in the case of the Transrapid, and the 90's, for the MLX-01. However, all processes aimed at decreasing the costs for the full-scale production still have to be developed. The experience that will be acquired during the first commercial production and operation (learning by using), together with the feedbacks from operators, will be of prime importance. The road for Swissmetro is still long and the project is only at its very beginning.

The Swissmetro technology should be able to benefit from the successes or failures of the German and Japanese experiences regarding the Maglev technology. It will, however, be a pioneer in several fields related to the vacuum: pressurized Maglev vehicles, tunnel, large-scale vacuum systems, pressurization/de-pressurization of the stations etc (Figure 42).

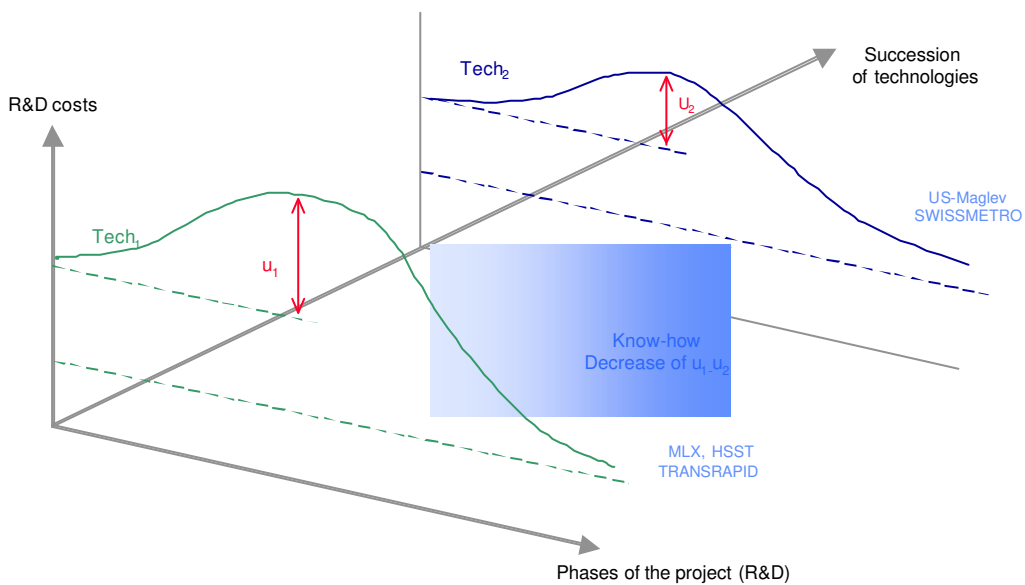


Figure 42: the impact of technological rupture on R&D and the effect of knowledge and know-how accumulation

Considering that the R&D cost (u_1) required to developing the Maglev technology for HSGT systems for the Transrapid and the MLX-01 has been expensive for leaders, other following competitors will be able to develop their technology by learning from the experiences (successes and failures) of the first entrants in the market ($u_2 < u_1$). This strategy was used in the USA to develop a national Maglev technology⁶⁸, with the competition of four main consortia (Bechtel, Magneplane, Grumman and Foster-Miller), and should be used by Swissmetro for its propulsion technology if the project will go on.

However, with regard to other projects, other generic technologies or adaptations of combined technologies may require important R&D investments, higher than the input of other project experiences ($u_2 > u_1$). This is the case of Swissmetro regarding aspects related to the large-scale vacuum system: The R&D cost u_2 required for the development of this project will be mainly focused on the current technological lock-ins related to the large-scale vacuum and its implication on the design of vehicles and stations.

- *Impact on the market, radical versus pseudo innovations*

A technological rupture can have strong or little impact on the market. Therefore, the distinction between radical innovations and pseudo innovations is useful to apprehend technological ruptures, defining two extremes based on the impact of innovation:

- A pseudo innovation (Mensch 1979) leads to little consequences on the market.
- A radical innovation combines the technological rupture with a strong impact on the market.

Concerning transportation services, the market can be divided into two layers: operators and final users; and classification of innovations may be done for both of them, as impacts of the rupture may be different on the market of operators than on the market of final users.

3.3.4. The notion of Transition Barrier

- *The cost of rupture*

Innovations and ruptures in HSGT technologies aim at the improvement of transportation services and at the increase of performances, which are a function combining speed, investment, operation and maintenance costs (plus other factors such as safety, comfort etc.). To do so, the focus can be on infrastructures (tracks) or/and vehicles. The degree of rupture has an impact on resources and means necessary to reach performances required at the entrance of the market (Figure 41).

Resources and means to develop the disruptive technology and the associated processes and to overcome the transition barrier are higher than in the case of incremental innovations:

- R&D investments for the development of infra-technologies, problem solving, and development.
- Costs of building new networks and partnerships required for successful development.
- Cost of marketing the new system and building new networks for the innovation diffusion.

Incremental HSGT technologies, such as HSR systems and tilting technologies, are based on proven technologies, which are improved constantly through R&D programs, coupled with operators' feedbacks. R&D networks and links between manufacturing consortia, operators, influent associations or institutions (UIC, DG VII of the European Commission, ERRAC etc) have already been constituted. The general direction and the means for R&D can be shared and fine-tuned, thus allowing to maximize efforts (know-how, experience and knowledge).

⁶⁸ See de Tilière (2001), pp.35-38.

Maglev technologies remain a radical rupture, even if such technologies are evolving since the 80's as incremental developments. The incompatibility with traditional rail networks limits to a large extent the possibility of using the rail epistemic communities for the diffusion of Maglev systems (resistance to change). This underlines the fact that transition barriers can be of two orders:

- First order: Resource availability, technological lock-in, development or access to Infratechnology, market penetration (operators and infrastructure owners).
- Second order: Organizational changes, social changes (resistance to change, uses and behaviors).

- *Transition barrier related to technological development*

The cost of developing new HSR vehicles, such as the new diesel HSR developed by Bombardier and the US Federal Railroad Administration, is estimated at US\$ 50 million. Infra-technologies are already in place and test centers for experimental runs also exist. Numerous test centers of Alstom, Bombardier, JNR are dedicated to rail technologies and can be used to test regional trains, HSR systems or freight locomotives. Developing disruptive technologies, such as the Swissmetro vehicles, is much more expensive (US\$ 400-500 Million): the following requirements increase costs and constitute a technological transition barrier:

- Constitution of a new R&D network, managing new partnerships.
- Constitution and improvement of the necessary infra-technologies.
- Construction of test facilities: new tracks and tools.
- Constitution of know-how and experience through full-scale experimentation and demonstrations.

Developing new technological trajectories has been very costly for every Maglev consortium (development of full-scale facilities and years of problem solving and tuning). More than US\$ 3 billion have been spent in Japan, for the MLX-01, and US\$ 1.5 billion in Germany, for the Transrapid. Both technologies have had to pay for the cost of the transition barrier, but without the advantage of any visible successes.

A large part of these costs (u_1 ; transition barrier) are due to the lack of analogical links and compacity (see also Foray 2000 p.12). Maglev systems have been developed without the strong spillovers from other mature systems.

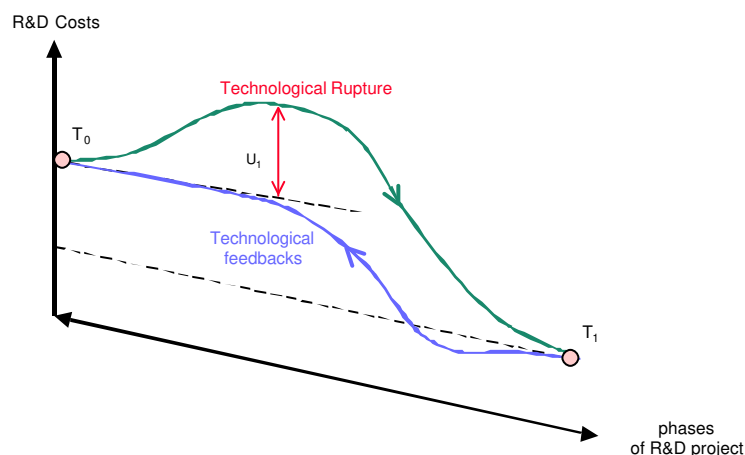


Figure 43: The cost of overcoming the transition barrier related to the technological rupture

On a same technological trajectory, most components are available on the market or can be tailored in a timely manner, which in turn helps to decrease the cost of development (standardization, whose importance has increased in the past decade). HSR systems strongly benefit from the maturity of rail technologies. Analogical links allow to benefit from knowledge, know-how and experience and to solve problems in a faster and cheaper manner. The compacity of the problem, which describes the number of problems to solve and their degree of difficulty, decreases in the case of incremental technologies.

- *The risks of technological lock-in*

In the challenge of overcoming transition barriers and developing disruptive technologies, the main risk is the technological lock-in. This is the impossibility to solve a technical problem with the current knowledge and tools.

Such problems can be of a purely technical nature, which made it for instance impossible for Bertin & Cie to develop a Maglev version of the Aerotrain in a short-term horizon, leading to abandoning the project in 1974 (paragraph 4.3.4).

However, such technological lock-in can be caused by other constraints, such as costs, standards etc. Costs are for example the actual problem of the Japanese MLX-01; the impossibility to decrease costs related to the cryogenic cooling system currently represents a technological lock-in, which may cause the death of the project if the problem is not solved in the near future.

- *The market as a major transition Barrier*

If technological developments, including the development of infra-technologies and the improvement in related processes, represent a very important challenge, the transition barrier of an innovation is finally also influenced by the market reaction.

For the introduction of any product, marketing and setting-up distribution networks represent a significant part of investments or efforts required for success.

HSGT technologies can be classified depending on market opportunities, the degree of technological complexity and entry barriers (Figure 44). For HSGT technologies, the main criterion for assessing the market barriers is the general compatibility with existing standards or networks from the operators' point of view (or the fact that the technology has already been tested successfully in commercial operation).

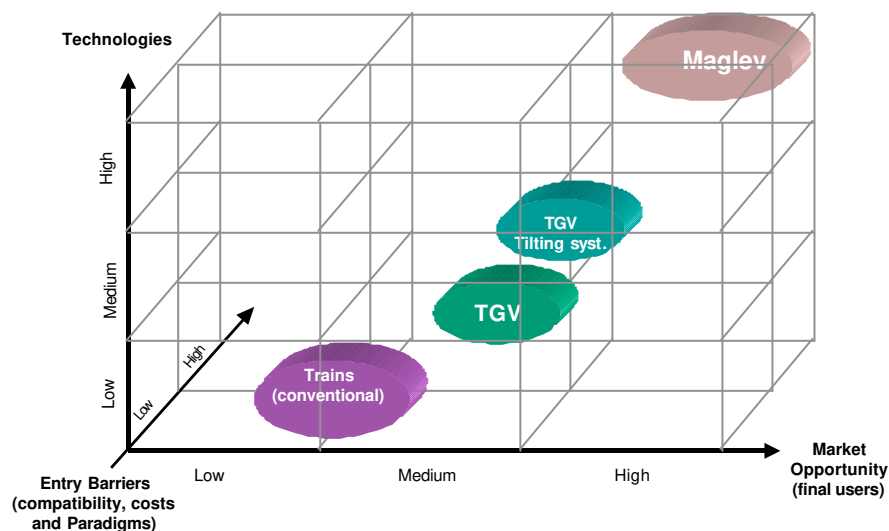


Figure 44: Technological performances, market opportunities and entry barriers.

Promoters of HSGT systems with strong technological rupture usually mainly analyze aspects linked with the system performances and associated market opportunities (increase of demand, final users). However, they usually concentrate less on the analysis of entry barriers toward the innovation and the rupture induced.

Introducing new innovations with strong technological rupture, such as Swissmetro, implies much more far-reaching consequences (for example, a technology concerning pressurized vehicles is closer to aerospace technologies than current HSR systems). The rupture for manufacturers, as well for operators and infrastructure owners, is evident. Managing such innovations is therefore subordinated to managing and leading change within the industry, operators and institutions. In the end, the main barrier appears to be resistance to change (the low returns of the innovations lead to programs largely supported at national or federal levels).

Therefore, the aim of incremental strategies is to reduce the cost of new generations of HSGT systems and to avoid risks linked to transition barriers (technological lock-ins, market acceptance).

3.4. Incrementalism and path dependency

3.4.1. Incrementalism as an alternative to the rational deductive approach

- *Limitation of the strategies of rupture based on rational deductive approach*

The concept of innovation with strong technological rupture refers to the deductive rational approach. According to the main authors on Incrementalism (Lindblom 1963; Quinn 1978 and Johnson 1988), this approach has two main backdrops:

- Separation between objectives and means:⁶⁹

It considers objectives as defined ex-ante and automatically leading to the selection of the most efficient means. This leads to a separation between objectives and means, which can cause severe difficulties if means are underestimated or inadequate, or if objectives are overestimated.

- Limited rationality:

In the rational deductive approach, one assumes that decision-makers have a full understanding of a problem; but this bears the risk that they underestimate the difficulty of understanding the whole complexity of a problem. In addition, if information is expected from various experts, the difficulty of managing communication flows becomes even more critical: collection and selection, relevancy, understanding.

- *The incremental approach*

The incremental approach was developed by Lindblom (1963) as an alternative to the rational approach, which was based on the political model of decision-making (see paragraph 4.2.6).

- Linking objectives and means:

The incremental approach makes a less clear separation between objectives and means, thus leading to a more realistic view of strategies. This approach reduces risks by maximizing existing resources and experiences. Objectives are set and adapted step by step, thus allowing higher flexibility and minimizing ruptures.

⁶⁹This limitation is also underlined by Mintzberg as a detachment error, leading to the failure of strategic planning. Limitations of the detachment between action and thought stand in the fact that thought may emerge from actions, and that thought must be applicable to the firm's actions. (in Mintzberg 1994, *Grandeur et décadence de la planification stratégique*, Paris, Dunod)

- Emerging strategies as means of minimizing the effects of limited rationality:

The incremental approach is also based on the assumption that the real view of things results from the combination of partial or limited views of people or of parts of an organization (depending on their position within the firm and their expertise). Thus, according to the incremental approach, emerging strategies are considered as based on resources as well as on upstream information flowing from all components of the organization.

Incrementalism is therefore based on the coupling between objectives and means as well as on the concept that the formulation of decisions is a learning process, where thought is embedded in action.

3.4.2. Disjointed, logical and cognitive Incrementalisms

- *Disjointed incrementalism (Lindblom 1963)*

Lindblom (1963) introduced this approach as a model of decision-making, proposing a new mode of analysis and evaluation of alternatives. Its main characteristics are the following:

- Fragmentation of the entities of analysis and evaluation:
Incrementalism is defined as disjointed, because numerous actors are implicated in the decision-making process, and there is no formal or apparent coordination between themselves.
- Analysis of the marginal value:
Alternatives are based on a reference situation, which differs from the status quo by an incremental change. This implies that decision-makers can only understand the changes related to the variables concerned by the incremental change and not all other ones (reducing risks linked to information and complexity). Moreover, the selection of the best alternative is based on differences between policies (strategies).
- Adjustments of objectives and means:
Objectives are readjusted depending on their feasibility and their costs all along the process, thus allowing implementing the Kaizen approach for continuous improvement.
- A reconstructive processing of data:
During investigations of an alternative, problems are emerging constantly. Incrementalism allows a constant reformulation and reconstruction of data all along the project.
- Several analysis and evaluations:
Analysis and evaluations are coupled and evolve with the appearance of new problems.
- A corrective orientation of analysis and evaluation:
The purpose of Incrementalism is not to move towards a final objective, but to move away from the initial situation. The approach therefore consists in improving this initial situation through corrective actions.

In their analysis of the development of the Tilting Technology in France, Saubesty & Vernimmen (1999, p104) associated the elaboration of decisions and the management between SNCF and Alstom with disjointed Incrementalism. In order to decrease the degree of complexity, the project was split into subprojects, fragmenting the decision-making entities. Thus decisions were the result of consensus, leading to mutual adjustments between the various partners (the operator, the manufacturer and the State). This approach also allowed to describe incremental innovations that have been achieved in the following countries:

- Italy (Pendolino, ex-FIAT Ferroviaria)

- Sweden (X-2000, ABB)⁷⁰
- US (Acela Express, Alstom-Bombardier)

In fact, the disjointed Incrementalism is well adapted for defining strategies involving more than one actor in the HSGT market: operator and manufacturer, operator and State or the three of them. This mainly applies to cases where a technology has to be developed in the national interest and where a consensus between these actors is needed.

- *Logical Incrementalism (Quinn 1978)*

If the disjointed Incrementalism aims at a realistic description of the decision-making processes and proposes to explain emerging strategies, Quinn redefines Incrementalism as a deliberate strategy leading to the notion of logical Incrementalism.

Quinn characterizes this approach through five points:

- The strategy emerges from a series of “strategic subsystems”. Managers must ensure the coherence of the firm’s strategy.
- Each subsystem has its own logic.
- Incrementalism in strategic subsystems must allow to:
 - ? Deal with both cognitive limits and processes for each important decision.
 - ? Build the analytical framework required for such decisions.
 - ? Create the consciousness, understanding, acceptance and engagement of both people and organizations, which are required for the efficient implementation of strategies.
- The global firm’s strategy, confronted with the subsystems interactions, is drawn into the logics of those subsystems.
- Logical Incrementalism is therefore not only an opportunistic way to sort things out, but also an efficient and proactive management technique. It allows to improve and to integrate analytical and behavioral aspects required for the formulation of a strategy.

Quinn adds two elements to the disjointed Incrementalism of Lindblom: the existence of subsystems logics within organizations; and the existence of a competent manager, who plays the role of integrator and finally selects the best options.

This form of Incrementalism is best suited for the definition of strategies by rail manufacturers and operator at the firm’s level.

- *Cognitive Incrementalism (Johnson 1988)*

Johnson uses the socio-cognitive approach to explain incremental strategies and considers that the key to the strategic process lays in the mind of the managers. This approach mainly focuses on information transactions, as well as on understanding complex processes of changes within organizational, cultural and temporal dimensions.

In his approach, Johnson places in the center of what he calls the essence of cultural networks the notion of paradigm: myths, symbols, structures of power, organizational structures, control systems and routines.

⁷⁰ see Hulten 1999

The notion of cognitive Incrementalism appears to be adapted to this concept of decision-making process since it also reflects political and symbolic realities, rather than logical and rational solutions only.

The notion helps to understand several strategies, especially when projects are recoded, such as the tilting technology in France for the TGV or for interregional trains, as underlined by Saubesty & Vernimmen (1999, p.107): the paradigm of the all TGV strategy in France finally leads to a difficulty in positioning and justifying the tilting technology for HSR systems.

3.4.3. Incrementalism and path dependency

- *Infrastructure and technological path dependency*

The notion of technological path dependency can be best explained by the notion of increasing returns of adoption associated with rail networks and the incompatibility of Maglev systems. As underlined by Frybourg (1987, p49), existing infrastructures unavoidably have to be taken into account as long as the demand is not sufficient in order to justify new infrastructures, as in the case of Maglev tracks.

However, if this is true for countries in which rail networks have been well developed, the situation is different in countries where new infrastructures still have to be built. Launching new technological trajectories therefore appears easier, although industrialists must obtain advantageous returns in innovations, which has never been the case in the HSGT sector (without the support of governments).

Incrementalism allows learning by using since operators can easily proceed, before any order, to technical and commercial tests of new train-sets on their present networks, which is not possible in the case of disruptive technologies.⁷¹

Economies of scale achieved by industry combined with economies of scope achieved by networks (Braeutigam 1999) benefit both operators and industry and constitute a market lock-in in terms of increasing returns (de Tilière 2001, p8).

- *Incrementalism: learning through standardization*

After the emergence of HSR technologies and the completion of national HSR networks in France and Japan, international standards for HSGT systems were set-up, which also defined a technological trajectory for European countries (only Germany is also involved in Maglev technology). The main world leaders in the rail manufacturing market are now using the logical Incrementalism defined above.

The increasing trend of standardization in this sector is the result of a deliberate strategy aiming at maximizing the benefits of infra-technologies and R&D networks developed for all ranges of rail technologies.

Concerning Maglev technologies, the industries involved in the Transrapid program are working since a decade in order to improve the system, thus coming closer to logical Incrementalism. The first Chinese contract will allow this technology to benefit from further incremental improvements through the learning by using process.

The logical Incrementalism approach is a way to focus on component innovations and to thus implement the Kaizen approach of improving products and processes through standardization.

⁷¹ CFF in Switzerland with the ICN trainset, FRA in the USA for the selection of their system: X2000, Talgo.

- *Incrementalism and organizational path-dependency*

The notion of cognitive Incrementalism defined by Johnson also prefigures the idea that organizations are subject to path-dependencies, which Foray (2000, p44) described as the “organizational memory”. This notion can therefore also influence strategies towards innovation (incremental/rupture), since technological strategies are the result of strategies of operators (lead-users) and manufacturers. These influences will be analyzed in chapter 5.

Organizational memory concerns both operators and manufacturers, whose experience and knowledge in product and processes can be maximized through economies of scope.

Moreover, the organizational path-dependency also concerns the organization of R&D programs. These programs are defined in close cooperation between manufacturers and operators, by means of fragmented R&D subprograms, which decrease the need of ruptures and changes of a systemic order.

3.5. Conclusion: Rupture and Incrementalism as governance modes

Technological innovations, which can be characterized as incremental or rupture, are in fact the result of more general strategies involving governance modes. Emerging strategies lead to incremental innovations, focusing on subsystems, whereas deliberate strategies may lead to strong technological rupture.

The impact on governance modes is underlined by the strong difference between Incrementalism and rupture. Rupture induces the following patterns, which lead to the need for substantially increased resources and means:

- The lack of infra-technologies, necessitating drastically increased R&D efforts.
- The lack of knowledge (rupture as a creative destruction).
- The increasing complexity, as the rupture concerns the whole system architecture.
- Building new networks (partners) for sharing R&D efforts, industrial development as well as the diffusion of the technology
- Marketing the rupture in order to influence paradigms.

If innovation may be the result of incremental or synoptic processes, technological ruptures leading to systemic innovations are the result of synoptic processes only, as underlined in the table next page.

The main difficulty in the Synoptic Approach lays in the fact that preferences are defined a-priori (when the strategy is defined), whereas in the Incrementalism approach goals are constantly redefined or readapted in relation to the means involved.

Therefore, in managing the rupture, or in Synoptic approaches more generally, alternatives for the future can be multiple, instable and fluid. This constitutes the main problem for HSGT innovations, which are characterized by strong inflexibilities. For this reason, Weiss & Woodhouse (1992) prefer incremental approaches, like Collingridge (1989, 1990), who underlines the importance of introducing a degree of flexibility into inflexible technologies.

To conclude on innovation, rupture and Incrementalism, one has to underline the fact that technological choices (rupture or Incrementalism) are the result of global strategies. They are made by firms and

shaped by organizational structures, paradigms and policies. Understanding the emergence of such products or technologies requires understanding what are the links between organizations, management, strategies, technology and knowledge.

Characteristics	Synoptic process (rupture)	Incremental process
Start of the process	Problem or opportunity occurred and perceived during the watching phase.	Problem or dissatisfaction of the current state.
Role of objectives	The process is oriented to reach a specific goal or a future desired state.	The process is curative, oriented to obtain a modification of the actual state.
Relation End/Means	Goals are defined first, independently from the study of alternatives. The decision is an end/means process.	The curative change is considered at the same time as the analysis of means to be engaged. Processes are simultaneous.
Selection phase	The final choice of an alternative is function of its contribution to reach the goal.	The final choice is achieved by combining considered alternatives with their possible consequences and by selecting the combination that, in most cases, leads to the wanted result.
Degree of the process completion	The process is exhaustive in the identification of goals and means.	Few solutions and consequences are considered.
Degree of integration	Efforts are achieved to integrate decisions of the strategy and ensure that they strengthen it.	Few integration efforts. The strategy is a set of decisions weakly linked.

Table 7: Differences between the Synoptic Approach (rupture) and the Incremental Approach (source: Fredrickson)⁷²

The following chapter will describe how such mechanisms work, by means of several Basic Innovation Models, Decision-Making Models, and Innovation Diffusion Models. This will lead to the elaboration of an Innovation Model for HSGT technologies, which will be coupled with Institutional and Organizational Models later on.

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⁷² Fredrickson 1983; "Strategic process: questions and recommendations", *Academy of Management Review* pp.565-575.

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	1. Introduction
	2. The case of high-speed ground transportation projects
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▶	4. Towards an Innovation Model for HSGT systems
	5. How organizational and Institutional factors influence Innovation Models
	6. Impact of the technological rupture on Risk & Uncertainties
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	ANNEX: Project Management Assessment System

Source and emergence of innovation,

the leading roles and actors in the innovation ballet.

4. Towards an Innovation Model for HSGT systems

Critical factors for the emergence of innovations will be discussed in this chapter, including their main impacts on innovation processes. This will allow for the elaboration of an Innovation Model on the basis of case studies as well as theoretical considerations.

Before introducing the HSGT Innovation Model, one will begin by describing and developing general diffusion models of innovation (§ 4.1.5). A particular attention will have to be paid to the specific environment of the HSGT market and to recent changes in Europe, which will then have to be integrated into the HSGT Innovation Model.

4.1. Innovation and diffusion Models

This chapter examines different innovation and diffusion models, the aim being to describe the HSGT innovations and the emergence of strong technological rupture.

Understanding the adoption and the diffusion of such innovations will require looking further into the mechanisms and factors underlying the decisions of the main actors. One will then have to translate the notions of barrier-breakthrough, discrete choice and increasing returns of adoption into proto Innovation Models. Finally, these proto models will allow to analyze the role of the main actors in the HSGT sector.

4.1.1. Basic Innovation Models

Since innovation plays a key role in modern economic development, it is important to understand the factors, which both stimulate innovation and maintain a high level of knowledge generation and diffusion in a given setting. This topic was the subject of much investigation at both firm and national levels. Beginning from Schumpeter (1934, 1942), analysts from the 1960s, such as Schmookler (1966), Freeman (1974), Nelson & Winter (1982), Mensch (1979), Mowery & Rosenberg (1979), Roobeek (1987) and others, have sought to clearly define innovation processes. Conceptual advances over this period have also been directed towards a more informed public policy in this arena (Kline & Rosenberg, 1986).

The development of new technologies can be seen as the result of a process focused on finding new market applications for technological or scientific spillover, a process resulting from a market need or a combined approach.

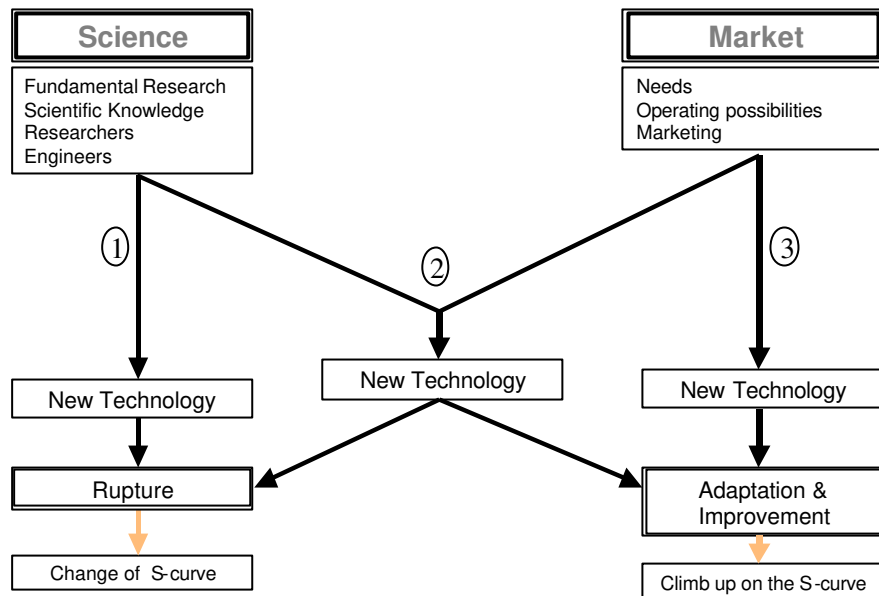


Figure 45: The emergence of new technologies, source and nature of innovations⁷³

The three cases in the figure above can be described as follows:

- ① The technological demand is by far superior to the capacity of science. A voluntary effort allows for the birth of new technologies. This is the case for HSGT systems with regard to national R&D programs for HSR, Maglev and other alternatives during the 60's and 70's in the USA, Japan, France etc.
- ② The most frequent case where the demand for a new technology meets the technical possibilities, or vice-versa.
- ③ The technological supply is by far superior to the absorption capacity of the market. The market makes the selection. This is presently the case of HSR technologies (dedicated networks, tilting technologies, duplex train-sets and the Transrapid Maglev technology, now entering into the HSGT market in China).

These three kinds of Innovation Models can be redefined by considering four steps: R&D, manufacturing, marketing and market penetration:

- *The five generations of the innovation process*

The conceptualization of the innovation process has changed over various generations. Moreover, the understanding of these processes also reflects industrial strategies and management paradigms. As described in Rothwell 1992, the following five generations of Innovation Models can summarize this evolution:

First Generation: *Technology Push*: Simple linear sequential process, emphasis on R&D. The market is at the receiving end of the fruits of R&D.

⁷³ Source: Martinet B., Lebidois D. & Ribaut J.M., 1991; *Le management des technologies*; ed. d'organisations.

- Second Generation: *Need Pull*: Simple linear sequential process, emphasis on marketing. The market is the source of ideas for directing R&D. R&D has a reactive role.
- Third Generation: *Coupling Model*: Sequential, but with feedback loops. Push or pull or push/pull combinations. R&D and marketing more in balance. Emphasis on integration at the R&D/marketing interface.
- Fourth Generation: *Integrated Model*: Parallel development with integrated development teams. Strong upstream supplier linkages. Close coupling with leading edge customers. Emphasis on integration between R&D and manufacturing (design for marketability). Horizontal co-operation, (joint ventures, etc.)
- Fifth Generation: *Systems Integration and Networking Model (SIN)*: Fully integrated parallel development. Use of expert systems and simulation modeling in R&D. Strong linkages with leading edge customers ('customer focus' at the forefront of strategy). Strategic integration with primary suppliers including co-development of new products and linked CAD systems. Horizontal linkages: joint ventures; collaborative research groupings; collaborative marketing arrangements, etc. Emphasis on corporate flexibility and speed of development (time-based strategy). Increased focus on quality and other non-price factors.

- *The science-push approach, linear model:*

The first, prevalent during the 1950s and 1960s, was the *science-push approach*. This approach assumed that innovation was a linear process, beginning with a scientific discovery, passing through invention, engineering and manufacturing activities and ending with the marketing of a new product or process. Until the early 1980s, many policy makers and managers accepted the view that a new product or process is the result of discoveries in basic science, brought to the attention of parent organization for possible commercial applications by its research staff.⁷⁴

In this model, there are no forms of feedback. It very quickly appeared that this model only applied to relatively simple forms of products, such as petrochemicals, and has been largely superseded by new models. It also sometimes still appears to be the model underlying public policy making in the fields of research and innovation.

This *science-push approach* has also been very visible in the transportation sector, where both firm managers and policy-makers have been pushing for technology transfers from the aerospace industry to the HSGT industry. National R&D programs to this effect started in France, UK, USA⁷⁵, Germany and Canada in the mid-60's, focusing on disruptive technologies for ground transportation systems.

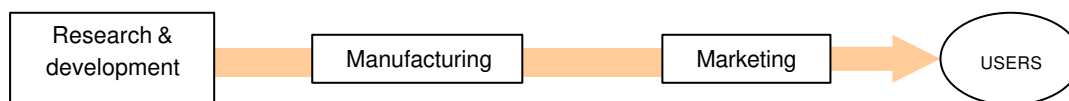


Figure 46: Push model, looking for a market to sell a new technology

- *The pull approach, linear model:*

From the early to mid-1960s, a second linear model of innovation was adopted by public policy makers in advanced capitalist economies. This was the demand-pull model. In this model, innovations are viewed as derived from a perceived market demand, which then influences the direction and the rate of technology

⁷⁴ Dodgson M., 1999; *Systemic integration of the innovation process within the firm*, WP Australia Asia Management Centre, Australian National University, p.1.

⁷⁵ See de Tilière G., 2001 p.30 and Frybourg M., 1987 chapters 1&2.

developments. In this model, innovations are induced by the departments, which deal directly with their customers, who in turn indicate design problems or suggest possible new areas for investigation (Kamien and Schwartz 1982: 35). This concept is also highlighted by the research of von Hippel (1988) on the role of *lead-users as functional source of innovation*. In this approach, the solutions to any problem (raised by the marketing department and the customer service) are provided by the research staff.

Maglev technologies can be seen as the result of push logic, if we consider operators as lead-users. But promoters of these technologies now argue that because of changes in the environmental priorities, these technologies correspond to an environmental push. This environmental push is increasing through the trend to internalize external costs in the evaluation of such projects.

The pull model can more or less be applied to Maglev systems, from the final-users point of view (depending on the social acceptability face to cost/benefits); however, none of the current rail operators is presently considering Maglev projects in the short or medium term.

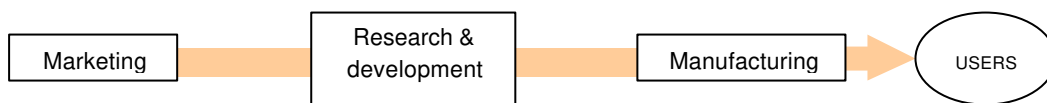


Figure 47: Pull model, developing a new technology for an existing demand

Many commentators presently consider both linear models of innovations as oversimplified (e.g. Stienmueller, 1994; Rothwell, 1992). For example, they use the case of the biotechnology industry to show that not only does the development of several products conform to science-push models, but also that at an industry-wide level, the importance of science-push and demand-pull may vary during the different phases of the innovation process.

- *Simultaneous coupling model*

The third model, the "coupling" model, was centered around an interaction process in which innovation was regarded as logically sequential, though not necessarily continuous (Rothwell & Zegveld, 1985 p.50). The emphasis, in this model, is on the feedback effects between the downstream and upstream phases of the earlier linear models. The stages in the process are seen as separate but interactive.

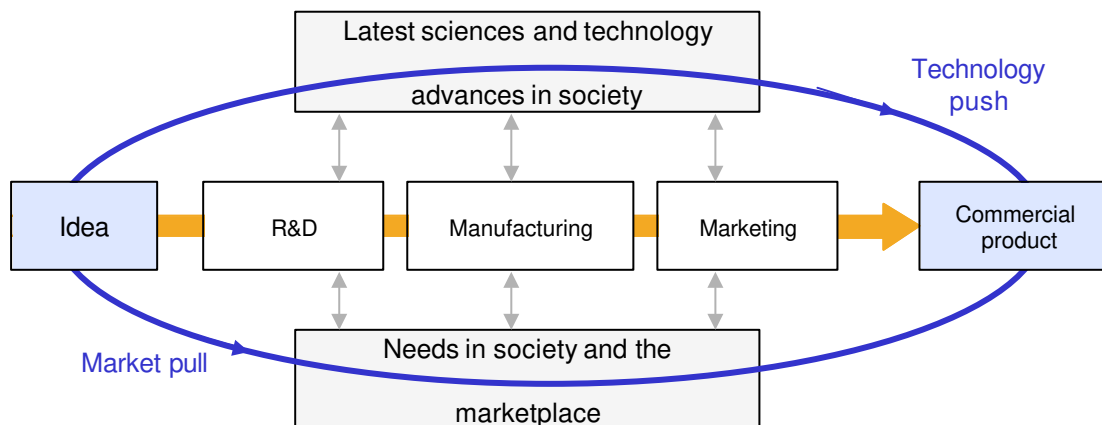


Figure 48: Simultaneous coupling model, an improvement in linear approaches push/pull.

This model is therefore applied in strategies for innovation that can be characterized by linear models. For example, the Swissmetro project, which originated in a push approach, must find ways to emerge and find

connections in the R&D, manufacturing and marketing fields if it wants to avoid falling into the pitfall of being forgotten like all futuristic or unrealistic projects.

- *Interactive Model, and Systems Integration and Networking Model*

New models (the "fourth and fifth generation" Innovation Models, as Rothwell calls them) have incorporated the feedback processes operating within and between firms. The high level of integration between various elements of the firm in innovation is captured in the 'chain-linked model' of Kline & Rosenberg (1986), which shows the complex iterations, feedbacks and interrelationships between marketing, R&D, manufacturing and distribution in the innovation processes.

The fifth generation Innovation Model includes considerations of the growing strategic integration between different organizations inside and outside the firm. They also include the ways those considerations are being enhanced by the 'electronification' of the innovation process and the use of new organizational techniques, such as parallel rather than sequential developments. They allow to move away from the 'silos' of functional structures towards an organization better corresponding to business processes.

Within firms, there is an increasing awareness of the need to introduce organizational forms, practices and skill balances, which allow for the maximum of flexibility and responsiveness to deal with unpredictable and turbulent markets. The value-creating activities of the firms are linked with the ones of suppliers and customers, and all their technological activities are guided by increasingly coherent and effective technological strategies. The important feature of the 5th generation innovation process is the increasing extent of the strategic and technological integration.

The strategic integration between firms is increasingly global and occurs across technological, market and financial areas (Dodgson 1999 p.3). Dodgson illustrates this fact with the example of Boeing and the design of its 777 jet. From the outset, Boeing involved its customers and suppliers very closely. It created what came to be known as the Gang of Eight, comprising 8 international airlines, which met over 12 months to help specify the needs for the new aircraft. Reflecting its decision to purchase 34 of the new planes before they had even been designed, one of those clients, United Airlines, was intimately involved in its configuration (see also Sabbagh, 1996). Boeing also involved very closely its suppliers in the design of the 777. Important components, such as major parts of the fuselage and the rudder, were subcontracted to Australian and Japanese firms. Engine manufacturers, such as Pratt & Whitney, designed their engines in close conjunction with Boeing. Four firms have developed new electronic 'toolkits' in order to assist their innovation and new product development processes. Boeing's 777 jet was entirely designed by computer; the Company distributed 2,200 computer terminals amongst the 777 design team, both inside and outside the firm, all of which were connected to the world's largest grouping of IBM mainframe computers. The computer system allowed the electronic prototyping and the testing of parts, avoiding the lengthy and costly process of effective testing.

The aim of this increased strategic and technological integration often is better competitiveness through the shortening of the time the goods and services come to the market.

- *Innovation Models and the reengineering approach*

Latest models underline the importance of good management and reengineering in complex systems, whereby all functions, from R&D to marketing, have to be integrated simultaneously. This requires the ability to redefine, at each step, strategies and means by ways of a reengineering approach (see Hammer & Champy 1993). Corrective actions can be initiated by different departments of a given firm (marketing, customer management, manufacturing or R&D).

- *The notion of ex-post & ex-ante rupture*

The notion of ex-ante and ex-post is important in order to describe the rupture in general, and the

technological rupture in particular. It can be applied to the aims of the rupture, related to strategies; or to its consequences:

Whereas the rupture ex-ante is the result of a deliberate strategy, which is at the core of its objective (case of Maglev technologies), the rupture ex-post is rather a consequence of a strategy. The rupture ex-post can be the prerequisite for the success of an incremental strategy, which has to face unattended lock-ins (for example, several technological ruptures in subsystems and components were required in order to allow speeds of over 350-400 km/h for HSR technologies).

This notion ex-ante/ex-post is also interesting with a view to describing the consequences of the rupture: a technological rupture defined ex-ante can produce other ruptures after its introduction (ex-post), the consequences of which can be very significant and even more important than the rupture initially foreseen. An ex-post rupture can be social, technical, political or related to market shifts etc.

4.1.2. The Barrier-Breakthrough Model of Innovation (Ayres)

- *The role of perceived technological barriers and the notion of Technological Breakthrough*

Ayres 1987 and Sahal 1981 have provided interesting researches on substitution and diffusion models of innovations, which have underlined the patterns of such processes in the case of infrastructure networks (such as the energy and rail sectors).

The most important pattern is the strong irreversibility of infrastructure investments, which is also an important driver in the choices related to implementation of HSGT technologies. In order to better understand the influence of such patterns on innovation processes, the following points develop a specific Innovation Model, which allows to analyze in an accurate manner HSGT projects with strong technological rupture.

- *The childhood phase: 1960-2000*

The first phase of the industrial life cycle, following a breakthrough, is characterized by a tremendous proliferation of new entries, offering alternative configurations, variations and improvements. Technological progress is rapid and standardization of products is difficult. The childhood phase ends when the subsequent technological trajectories are well defined.

- *The adolescent phase: a premature step forward?*

The adolescent phase, usually called “growth phase”, is characterized by the product standardization as well as by the improvement of production processes. This phase can be interrupted by significant technological changes or in the case of technological substitution.

- *Extension of the notion of Breakthrough: transition barriers*

How does the Barrier-Breakthrough Model apply to the case of HSGT technologies? The problem of HSGT systems, such as Maglev technologies, is that such architectural innovations are linked to networks characteristics. Awaiting their commercial operation, and for reasons of caution, the product life cycle of Maglev technologies was achieved through an “in vitro” development.

This Model fits into the “in vitro” development of these Maglev technologies, which have been protected from the competition of the more mature HSR technologies: The next step, or the passing into the adolescent phase of those technologies, is their market breakthrough and their commercial diffusion.

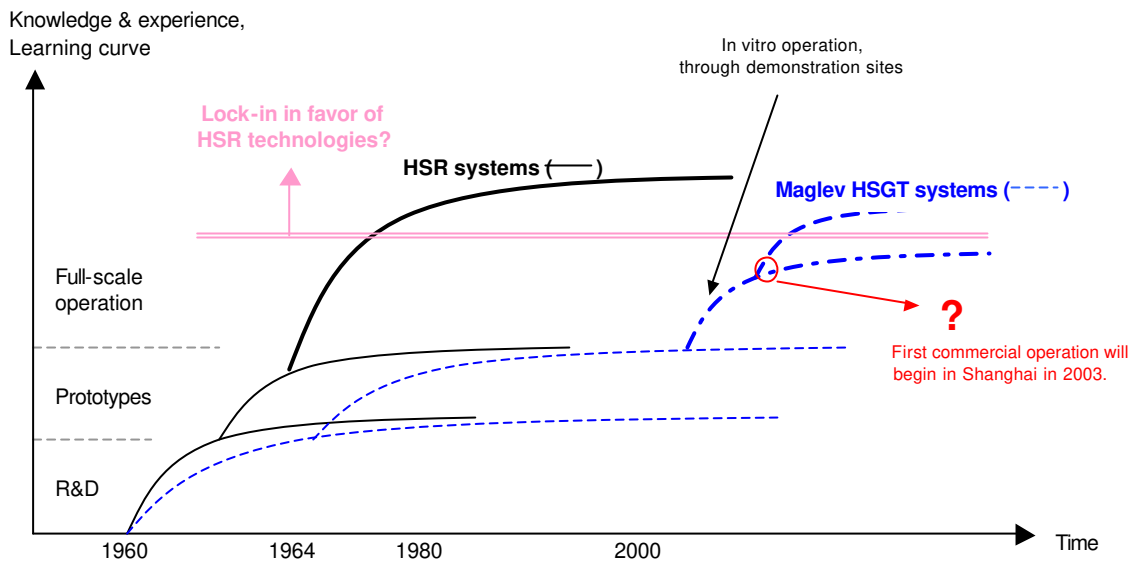


Figure 49: Concept of learning curve, learning before doing, by doing and by operating

4.1.3. The Innovation Model with increasing returns of Adoption (Arthur 1989)

This Model⁷⁶ describes the problem of adoption of a new technology when network externalities and standardization are critical factors for the emergence and diffusion of an innovation. This approach fits very well into the case of HSGT systems, that is to say when a decision has to be taken to upgrade or extend a rail system for higher speeds.

This Model is based on the principle of random walk, with discrete choices and absorbent frontiers:

Taking into account two technologies: A and B, (for example A for Maglev -Transrapid, MLX-01 or Swisshmetro- and B for HSR technologies);

One can consider two types of agents: R or S depending on their preferences. They can be operators, institutions for HSGT systems (decision-makers related to system adoption).

The number of adoption n_A and n_B is the number of links/projects that are/will be implemented and commercially operated.

Associated returns of adoption are defined for each agent and for each technology by:

	Technology R	Technology M
Agent R	$a_R + r n_A$	$b_R + r n_A$
Agent S	$a_S + s n_A$	$b_S + s n_A$

Associated returns of adoption, with r and s two positive parameters

⁷⁶ Arthur W.B. 1989; Competing technologies, increasing returns and lock-in by small historical events, Economic Journal, 1999, pp.116-131.

Assuming $a_R > b_R$ and $b_S > a_S$ which means Agents R prefer the technology A and Agents B prefer technology B, but their choices may change according to increasing returns of adoption (economies of scale, achieved through standardization and described in paragraph 3.4 as path-dependency).

Choices are discrete and for the adoption of a technology on a link, the difference $n_A - n_B$ decreases by a unit. The notion of irreversibility or increasing returns of adoption is taken into account by the cumulative effect of adoption (n_A and n_B), and the notion of lock-in, which is achieved for a technology when an absorbent barrier is reached (figure 50).

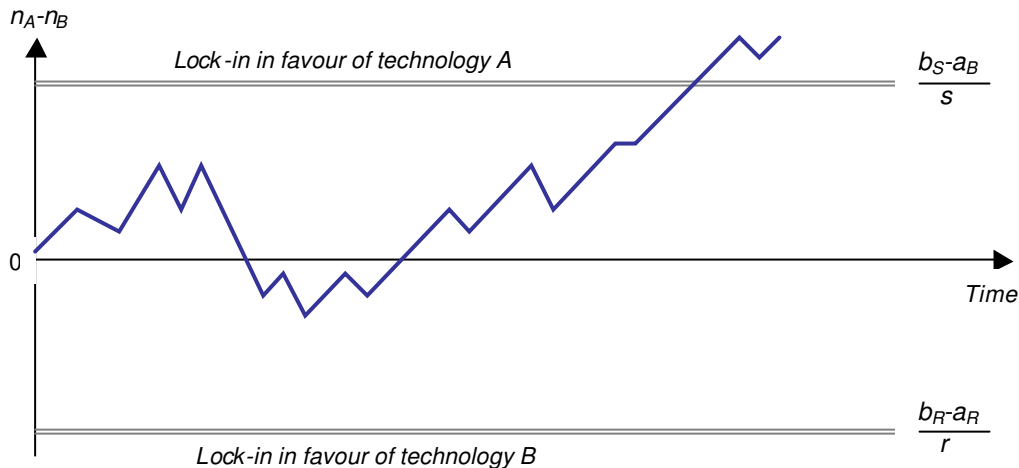


Figure 50: Innovation Model with random walk and absorbent barriers (Arthur 1989)

This model needs some discussion before being applied to HSGT technologies. Timing of the introduction of the competing technologies and the problem of spatial characteristics don't fit into the HSR/Maglev case⁷⁷. Firstly, the HSR market has been established since a long time, thus leading to the lock-in for HSR systems. Secondly, the nature of the HSGT market has to be seen as international, because of the small market window for Maglev HSGT technologies (if we combine constraints of both economical and political factors plus the weight of existing operators in decision-making). In all countries where Maglev was seen as a potential alternative, HSR was finally implemented. The emergence of technological alternatives has been problematic since the 60's despite large R&D programs (de Tilière 2001).

4.1.4. The break-through Innovation Model for HSGT systems

HSGT systems were first developed at national levels, such as Japan (Shinkansen/MLX-01), France (TGV/Aerotrain) and Germany (ICE/Transrapid). The competition between national consortia aimed at setting de facto standards to win international market shares.

The assumption that the Maglev HSGT technology was introduced in competition with the HSR technology has not been completely included in the Model presented above (since Maglev technologies have only been operated on demonstration sites). Thus HSR technologies have in fact only been competing between themselves. The "in vitro" development of Maglev HSGT technologies can be

⁷⁷ Llerena P., Danner Ptey S. & Shenk E., 2000; *Choix d'investissement dans les projets de rupture technologique, éléments d'analyse à partir du cas allemand*, PREDIT report n°98 MT07 DT3.

described by drawing a curve, which takes into account the maturation of the in vitro technology (the barrier breakthrough is easier if the technology is as developed as the one of its competitors).

At the beginning, the model is not set at 0, since rail systems were already well developed, with national operators and HSR networks already well extended. This competitive advantage sets a higher probability for the adoption of HSR systems since it maximizes network effects.

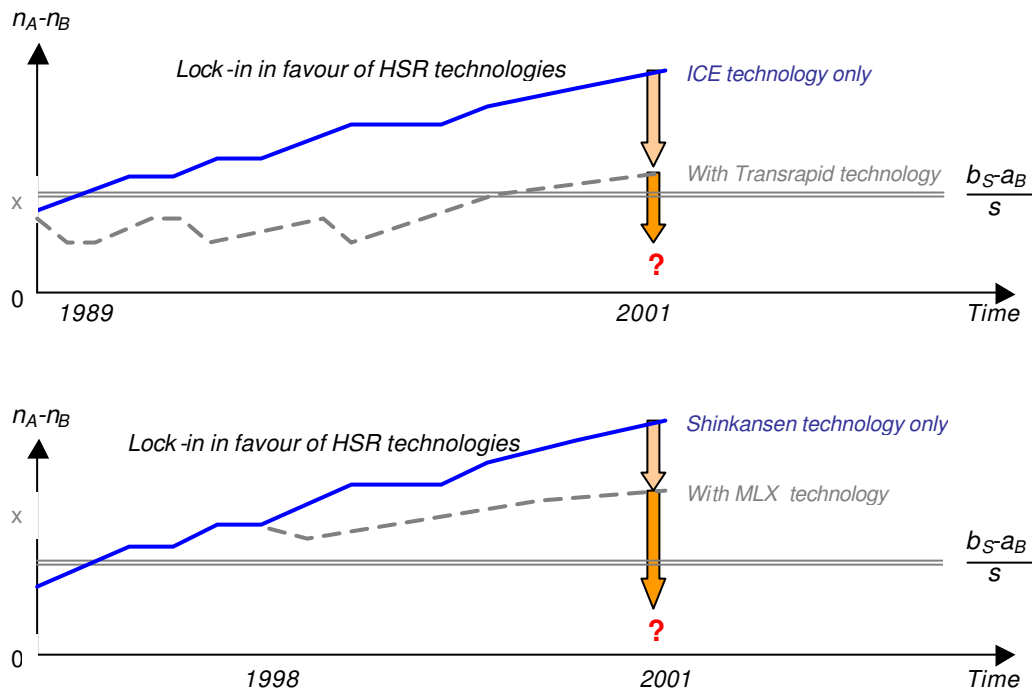


Figure 51: The barrier breakthrough model for HSGT technologies

In Germany and Japan, the maturity of alternative technologies has been achieved through the intensive “in vitro development”. This development has been massively supported by governments, with the wish to protect the emerging technology from mature ones. It was decided to develop these R&D programs because of the promising performances of Maglev technologies. Which means, for the HSGT niche market, that the benefits of the Maglev development were seen as higher than its development costs plus the cancellation value of future HSR technologies. However, in both Germany and Japan, HSR technologies were also developed in parallel: Maglev technologies were thus developed as an option.

What is the cost of the barrier breakthrough V_{bb} ?

For the actor supporting the innovation (development or adoption): $V_{bb} = I + C + V_a - R$

- I Investments
- C_c Cost of change
- V_a Abandonment value of the old technology (if incompatibility)
- R Revenues (sell of the system)

The cost of change C_c includes the cost of knowledge acquisition, all hidden costs linked to the organizational changes required for the new system development or implementation, as well as the abandonment value of the old technology V_a .

A remaining problem is to understand the decision-making process of the various actors, in order to understand how they define their strategies regarding to innovation. These relations and mechanisms are described in the following paragraphs.

4.1.5. The Innovation Diffusion Model (Rogers 1995)

- *The Centralized and Decentralized Diffusion Systems*

Innovation diffusion processes can be described by means of two basic models (Rogers 1995)⁷⁸. The way innovations occur and are adopted depends on the source of these innovations and the structure of their Diffusion Systems. The components of the diffusion model are the lead-users, the decision unit structures and the agents of change.

A Centralized Diffusion System (Figure 52) corresponds to the “Push” Innovation Model (top-down direction of diffusion). In this Model, needs are created by the availability of the innovation, and the decision-making processes in R&D investments are centralized.

The decisions regarding the diffusion of innovations are taken by top administrators and technical experts.

The degree of adaptation and of re-invention of the innovation is lower than in the Decentralized System described below.

In the Decentralized Diffusion System, innovations are spread through horizontal networks among near-peers and in a relatively spontaneous fashion. This corresponds to the “Pull” Innovation Model. Innovations are created by certain local users and can be re-invented by other adopters (high degree of local adaptation).

This implies that in the decentralized system, innovations are geared closely to the users needs.

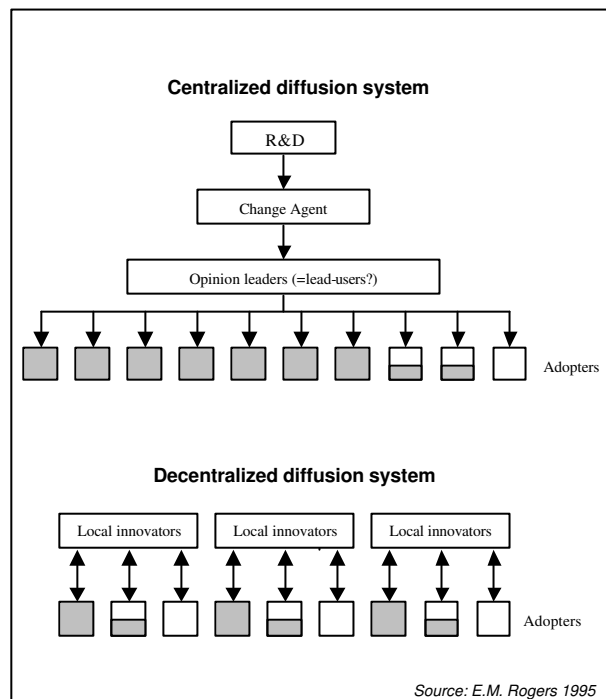


Figure 52: Innovation Diffusion System

Going beyond those two concepts, there is a third Diffusion System, which corresponds to the “Interactive” Innovation Model. It is based on a Centralized Diffusion System, but with an interactive loop between R&D definition and adopters (which goes beyond marketing studies only, because of the active participation of users in the R&D process).

These three Diffusion Systems constitute a basis for understanding innovation processes in the case of ordinary goods/markets. But HSGT technologies mainly depend on the rail transportation market, whose nature and recent evolutions require the specific adaptation and development of these Diffusion Systems.

⁷⁸ E.M. Rogers 1995, *Diffusion of Innovations*, 4th Edition, The Free Press, p. 367.

- *Variables determining the rate of adoption of innovation*

In order to explain the rate of adoption in the innovation diffusion process, Rogers (1995) has defined five groups of variables:

- I. Perceived attributes of innovations
 - a. Relative advantage
 - b. Compatibility
 - c. Complexity
 - d. Triability
 - e. Observability
- II. Types of innovation-decision
 - a. Optional
 - b. Collective
 - c. Authority
- III. Communication channels
- IV. Nature of social system
- V. Extent of promotion efforts of change agents

According to these variables, innovations with strong technological rupture imply, at first, a smaller rate of adoption, or at least a longer time of adoption. The notion of critical mass (percentage of adopters in the beginning of the S-curve) can determine the future success or failure of the innovation (notion which is also behind the “Barrier-Breakthrough” and the “Increasing Return of Adoption” Models, developed above § 4.1.2 & 4.1.3).

In the case of Maglev technologies, this can be illustrated by two endeavors to develop and introduce low speed transits systems: One in Birmingham (U.K., developed by General Electric) and the other in Berlin (Germany, developed by AEG). Both systems were very competitive in terms of investment and operation costs and were operated during around a decade.⁷⁹ But the lack of further diffusion of the technology led to the dismantlement of both systems, because of increasing maintenance costs and, in the end, of a very high cost of system reengineering.

Introducing a new technology is therefore not enough: It is of prime importance to plan its diffusion through a network or further projects if one wants to avoid its failure (risk of non-profitability due to increasing costs of maintenance of “prototype products”).

- *The problem of decision-making and strategies*

The macro Innovation Models presented above underline some critical factors conditioning the success or failure of innovations. They are interesting and stress some points that have to be considered within a rational decision-making process. However, they don't take into account nor fully explain actor's strategies and their issues.

Therefore, the Innovation Model we want to develop must integrate the decision-making process. This new dimension, called by Allison the “Essence of Decision”⁸⁰, allows to better understand the innovation process and as well as to elaborate adequate recommendations for project management.

⁷⁹ For more details, see Dreinmann K.; 1987, pp. 113-128 & Eastiam T. 1996 pp.40-43.

⁸⁰ Allison G.T., 1971; *Essence of Decision, explaining the Cuban missile Crisis*, Harper Collins Publishers.

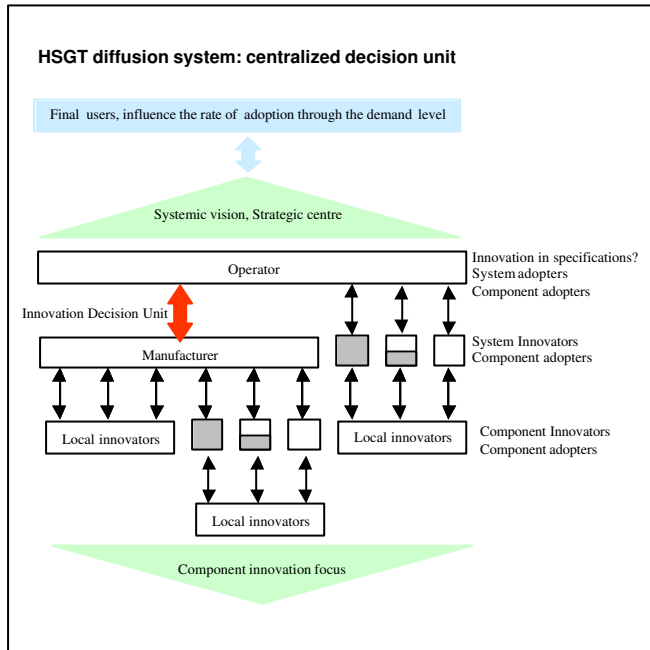


Figure 53: HSGT Diffusion System of Innovation & its decision unit.

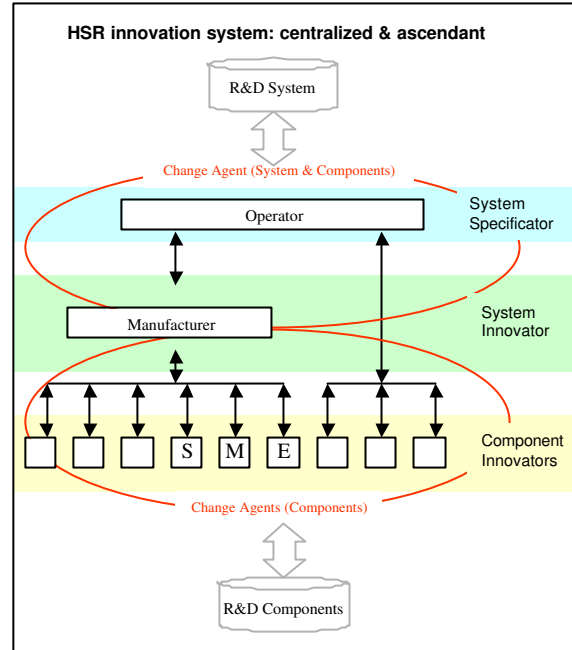


Figure 54: The role of change agents in HSGT Innovation

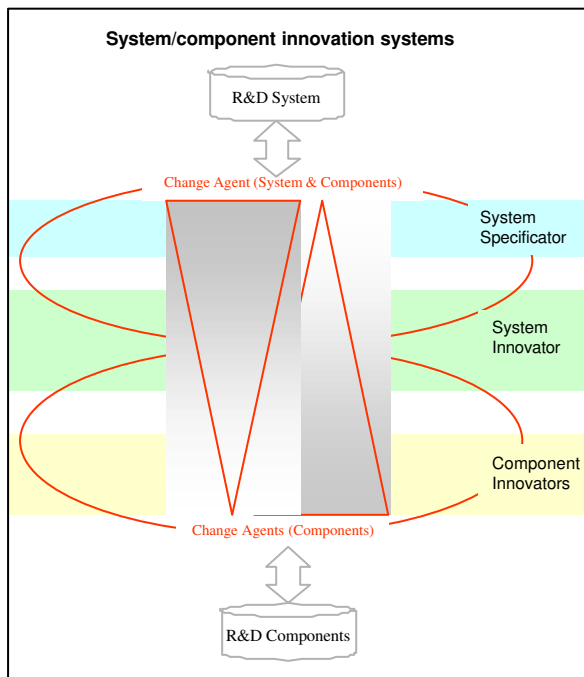


Figure 55: HSGT Diffusion System of Innovation

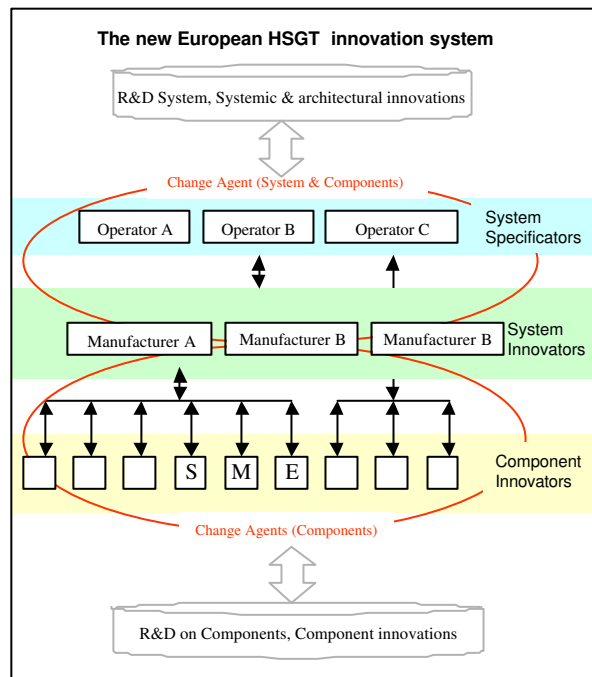


Figure 56: Globalization of the market, HSGT Innovation System

- *Recent changes in the decision model in Europe*

The diffusion of HSGT technologies is like a scrabble game, where each technology has to find a place in the market. Only HSR innovations have been diffused through the support of rail operators, arising in Japan (1964), France (1981), and followed by near HSR in UK (1984), Sweden (1990) and Germany (1991).

Figures page 104 describe the HSGT Innovation Diffusion System, as well as the evolution of this one from the centralized one (figure 54) towards a more decentralized – the “new European System” (figure 56). Innovations can be the result of two processes:

1. The strategy can consist in the integration of component innovation within existing HSR systems. These innovations are the result of SME initiatives or a response to innovative specifications from the manufacturer (Alstom, Siemens ect) or the operator (SNCF, DB, CFF etc). Concept of incremental innovations characterized by an ascendant Diffusion System.
2. Some innovations may come from specifications from the operator/manufacturer requiring innovative solutions.

The change agents for the system architecture are the duo operator-manufacturer, which take into account the following constraints or enablers:

- Economic factors.
- Industrial policies (suppliers, partners).
- Transportation policy
- The role of institutions towards change.

Concerning innovations on components, change actors are usually small and medium enterprises (SME), leading to more aggressive R&D strategies than large manufacturers (which are more focused on systemic innovations and system architecture).

The difference with the model of national tandems operator-manufacturer, is that the internationalization of both operation and manufacturing markets put more pressure on standardization. For example, the Taiwanese consortium of this new HSR project is fighting with the Japanese Shinkansen consortium to implement a compatible technology to both Japanese and European technologies. The purpose is to put into competition the maximum of manufacturers for the long-term.

4.2. Innovation Model: Decision models & Innovation process

4.2.1. Modeling HSGT innovation processes

If basic Innovation Models described in the previous paragraph (§ 4.1) underline some major characteristics in the innovation process, this is not enough to constitute a basis for recommendations on project management. These models are more macro and don't focus on decision-making and innovation processes (§ 4.3).

In fact the complexity lies in the HSGT market configuration and in the strategies of actors - which will be analyzed as potential sources of innovations (§ 5.2). Part of this complexity is also related to organizations, which shape strategies and therefore the type of innovation that are produced (§ 5.3). The importance of public policies as well as the role of institutions will also be analyzed (§ 5.4).

These aspects will be illustrated through the results of the HSGT case studies, summarizing projects' milestones and underlining critical factors in the innovation process leading to implementation success or failure. These elements will constitute the basis for the elaboration of the HSGT Innovation Models.

The development of systemic innovations requires an integrated methodology for Risk Assessment focused on innovation processes. Case studies enlightened that successful project development requires a global understanding of the transportation system as well as the management of new product development. The impact of the technological rupture deals with all processes from the product development to the market forecasts (operator and final users). In order to identify the impact of innovation and rupture on these actors and on the project, a conceptual model has been built, providing the basis for the analysis of case studies:

Four layers are defined in order to draw recommendations for the management of such projects with strong technological rupture: (1) the actors and organizations, (2) the project processes, (3) innovation processes and (4) risk assessment.

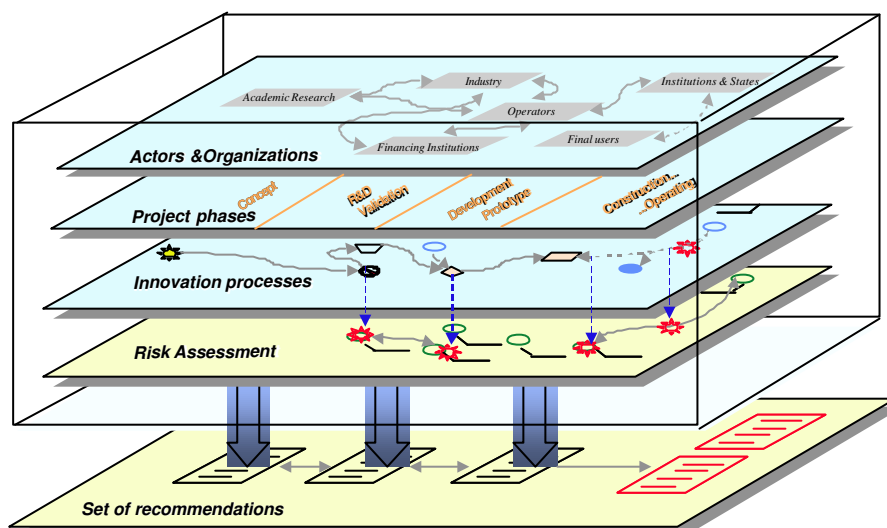


Figure 57: Methodology for working out recommendations through the case studies

4.2.2. Modeling Innovation Decision-making Processes

- *Decision-making process: Insight on organizational and behavioral complexity*

The decision-making process embedded into the innovation process can be conceptualized in a linear and sequential approach as developed by Rogers 1995 (Figure 58). The development of innovations is in reality much more chaotic and complex: A lot of feedback loops have to be added in this model and this for the different organizational units or actors concerned.

Managing innovation requires to deeply understand how the decision-making process works, how major R&D choices are achieved within the industry as well as how decisions of project implementation are achieved (which influence industrial choices and conversely).

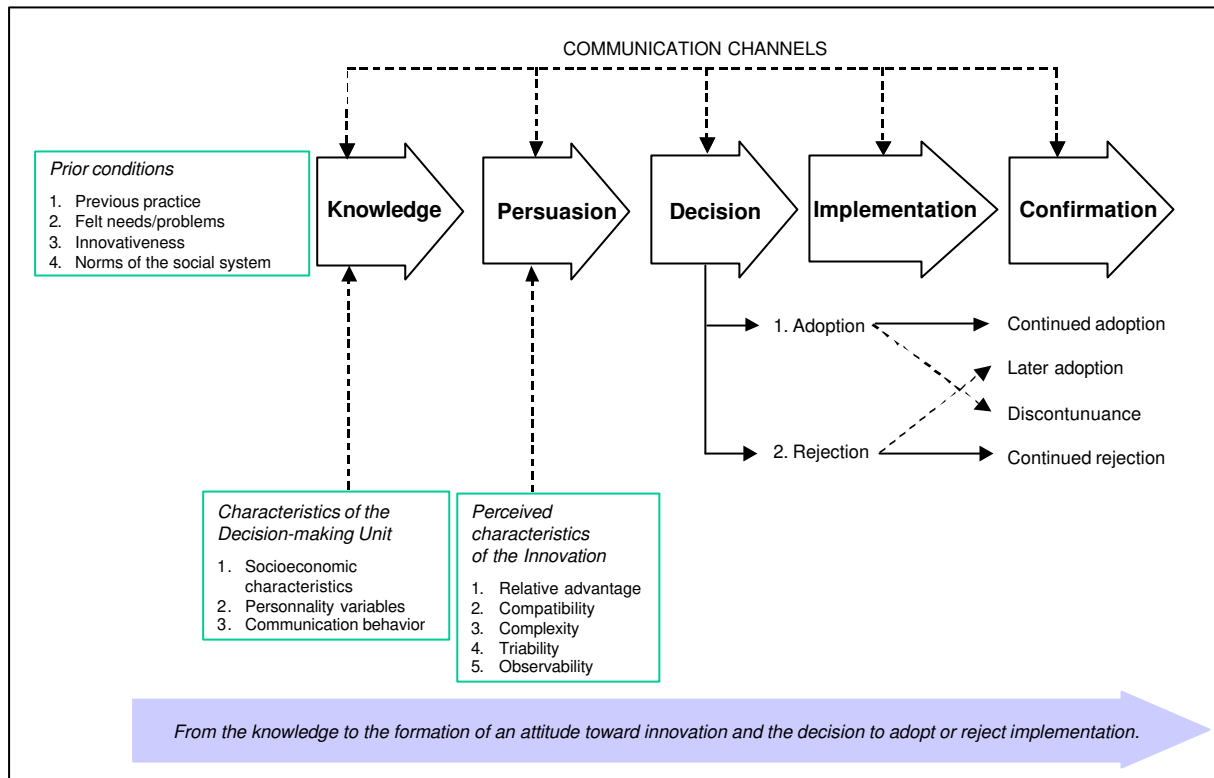


Figure 58: Model of Innovation-decision process (source: E.M Rogers 1995 p163)

- Toward the elaboration of Decision-making models

The notion of "limited rationality" of decision-makers introduced by Simon 1957⁸¹ underlines the role of organizational and behavioral factors rather than rationality only, in order to explain decisions and strategies. Cyert & March 1963⁸² also underlined this role in their "Behavioral theory of the firm" as well as Allison 1971⁸³, refuting the monopoly of rationality as explaining factor of decision. Observing that organizations usually take satisfying decisions rather than optimal solutions⁸⁴, Allison developed three models considered as a decision-model typology based on case studies (among which the Cuban missile crisis was the main).

These models supposed that decisions are not only based on one paradigm, but three:

- Rational decision-making
- Organizational processes
- Political processes

⁸¹ Simon H, 1957; *Model of Man, Social and Rational*, John Wiley & sons inc. New York.

⁸² Cyert R.M. & March J.G., 1963; *A Behavioural theory of the firm*, Englewood Cliffs, New Jersey: Prentice-Hall.

⁸³ Allison G.T., 1971; *Essence of decision: explaining the Cuban missile Crisis*, Harper Collins publisher.

⁸⁴ "Organizations are happy to find a needle in the haystack rather than searching for the sharpest needle in the haystack" (Allison 1971 p72)

4.2.3. A Generic Model of decision-making process

The phase of decision-making is part of a sequence involving the concept of Preference, Causality and Certainty Models (March 1988)⁸⁵:

- The Preference Model (PM) influences the identification of objectives (definition of the set of goals and objectives).
- The Causality Model (CaM) influences the identification of scenarios (definition of accurate and efficient means to achieve the goals).

These two first models are upstream to the decision phase.

- The Certainty Model (CeM) accompanies the decision phase and describes the evaluation a priori of the scenarios: This model defines the degree of certitude of the decision-maker concerning the consequence of his choice and influences the outcome of the decision-process.

A Generic decision-making model can be elaborated (Figure 59), based on the following concepts:

- Rationality decision-makers (Simon 1957)
- Organizational and Political Paradigms (Allison 1971)

Depending on the importance of the paradigms between themselves, three main models can emerge:

- The Rational Decision Model.
- The Organizational Decision Model.
- The Political Decision Model.

The Generic Decision Model underlines the fact that organizational or political factors may influence, either the Preference Model, the Causality Model or the Certainty Model (Figure 59). They may also influence directly the set of objectives, the scenarios or the evaluation, if organizational and political pressures modify outcomes without changes in Preference, Causality and Certainty Models. An influence between Preference, Causality and Certainty Models can also be noticed.

Depending on the weight of the three paradigms or the predominance of one of them (Organizational - Political - Rational), in the global decision-making process, the configuration of this Generic Model evolves toward the three models described in the sections below.

If one may summarize the Generic Decision Model into a function: a decision process D can be seen as a function f of decision processes based on a rational process P_R , which may be influenced by organizational processes P_O or political processes P_P functions:

$$D = f(P_R; P_O; P_P)$$

In order to explain the transition between the Generic Decision Model and the three specific Decision Models (Rational, Organizational and Political), the formulation of D can be defined by the decomposition of the function f into three functions, f_R , f_O , f_P , related to the three paradigms:

$$D = \alpha \cdot f_R(P_R) \circ \beta \cdot f_O(P_O) \circ \lambda \cdot f_P(P_P)$$

- With "o" an operator symbol defined by the theory of functions.

⁸⁵ March J.G., 1988; *Decisions and Organizations*, Oxford: Basil Blackwell.

- Where α , β and λ are the weight of the paradigms, with the value 1 if very strong, and 0 if negligible:

- α : weight of the Rational Paradigm; $0 = \alpha = 1$
- β : weight of the Organizational Paradigm; $0 = \beta = 1$
- λ : weight of the Political Paradigm; $0 = \lambda = 1$

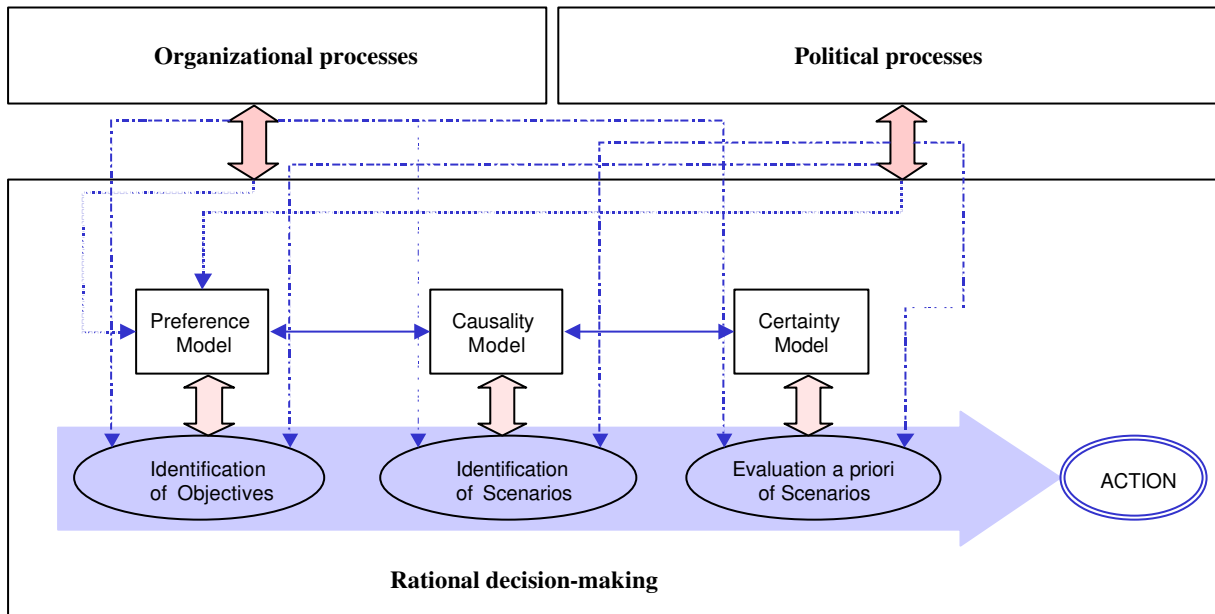


Figure 59: Toward a Generic Decision-making Model

4.2.4. The Rational Decision-making Model

If organizational and political factors can be neglected: the weight of the Rational Paradigm leads to:

$$\begin{aligned} \beta &\sim 0 \\ \lambda &\sim 0 \\ \alpha &= 1 \end{aligned}$$

Therefore, the Decision Process can be described by $D \sim f_R(P_R)$

The Generic Model takes the form of the Rational Decision Model (Figure 60), where the rational decision-making process primes.

The notion of “bounded rationality” (Simon 1957), is integrated in this first module (Rational Decision Model) of the Generic Decision Model. In this module only the characteristics of the product, the internal competencies of the firm/consortium and the market are balanced: this is a “rational decision-making” process.⁸⁶

⁸⁶ This module is close to the “model I” of Allison 1971 considering the case for a single decision-maker: when more actors contribute to this process, political factors influence the outcomes (model III of Allison 1971).

In a rational process, several models can explain the “bounded rationality” described by Simon 1957. Such models are based on the three concepts used by March 1988 (Preference – Causality – Certitude):

- The *Preference Model (PM)* shapes the set of objectives that are defined by the decision-maker (influence of its education, culture, experience and available information: The function that shapes the definition of the set of objectives and expresses the notion of “bounded rationality” is defined by Φ_{PM}).
- The *Causality Model (CaM)* is also based on the same parameters, but define causality relations and schemes between possible actions and outcomes (cognitive maps): this model influences the identification of the set of scenarios. The function that shapes the definition of the set of scenarios and expresses the notion of “bounded rationality” is defined by Φ_{CaM} .
- The *Certainty Model (CeM)* is related to the perception of the future and how the future interaction and evolution between the environment/market and the scenarios may influence outcomes (degree and direction). This model depends mainly on the pertinence of the information used as well as on the knowledge on the reliability of the definition process of objectives and scenarios. The function that shapes the scenarios evaluation and expresses the notion of “bounded rationality” is defined by Φ_{CeM} .

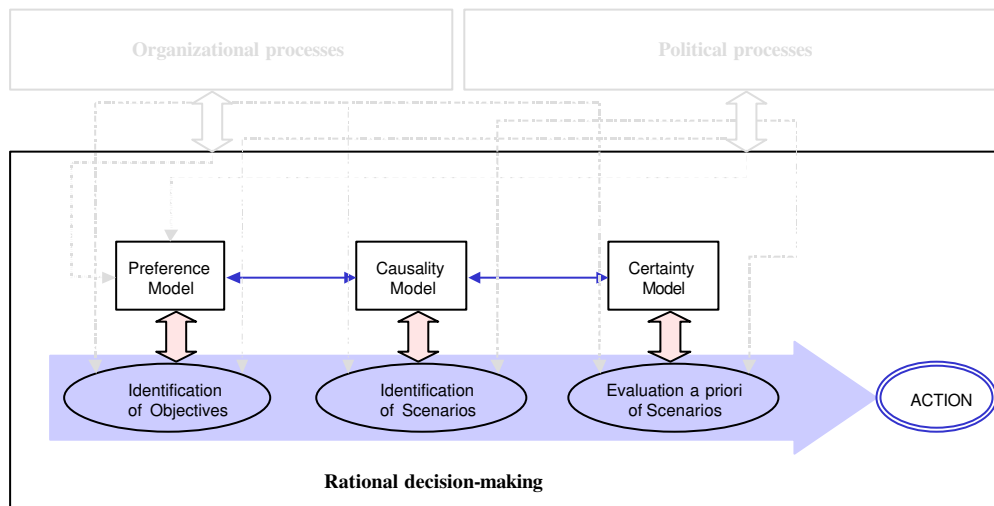


Figure 60: The Rational Decision-making Model

The rational decision process P_R is defined by the functions Φ_i :

$$P_R = \Phi_{PM}(\text{Set of Objectives}) \circ \Phi_{CaM}(\text{Definition of scenarios}) \circ \Phi_{CeM}(\text{Assessment})$$

In this Rational Decision Model, the “rational decision” can be conceptualized by the following expression:

$$D = f(P_R) = f[\Phi_{PM}(\text{Set of Objectives}) \circ \Phi_{CaM}(\text{Definition of scenarios}) \circ \Phi_{CeM}(\text{Assessment})]$$

This model aims at being more realistic than the Allison’s Model I, with the acceptance of organizational and political influences (that can’t be avoided in firms or consortia), but which influence is still minimized in an effort of rationality in order to find optimal solutions rather than only “satisfying ones”.

4.2.5. The Organizational Decision-making Model

When organizational processes primes and constitutes the main influence factor in the decision-making process (reference to the Allison's Model II), the configuration takes the shape of the Organizational Decision-making Model (Figure 61).

Hypothesis: $\lambda \sim 0$

Therefore: $D = \alpha \cdot f_R(P_R) \circ \beta \cdot f_O(P_O)$

Organizational processes shape the decision-making process directly through the definition of the set of objectives, or scenarios; or indirectly through the Preference, Causality and Certainty Models (organizational culture, knowledge management, etc have an impact on information flows).

These influences are well described by Mintzberg 1989⁸⁷ and Allison 1971, who also notice that since organizations are afraid of uncertainties, short-term corrections are usually preferred rather than optimal or long-term corrections.

This idea behind this model was also analyzed by Cyert & March 1963,⁸² and confirmed by the research of Chandler⁸⁸ since the 70's on the structure of organizations and its role in the decision-making process. The way organizations are structured can influence significantly outcomes of decision-processes. For example decisions concerning the same problem issued from a tight consortium (Alstom-SNCF for the development of the TGV or the Shinkansen consortium for instance), or a loose one (such as Swissmetro).

According to this model, the organizational typology influences the governance modes and therefore the type of innovation, which are produced by the organizations. Conversely when radical innovations are planned through a new strategic action, the organization evolves⁸⁹ to succeed in this innovation process.

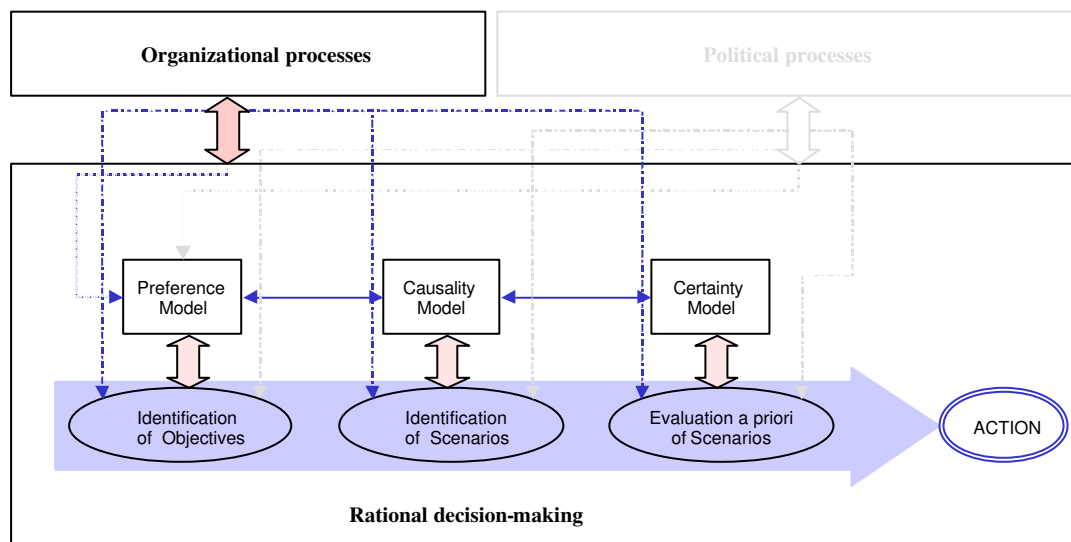


Figure 61: The Organizational Decision Model

⁸⁷ Mintzberg H., 1989 ;*Inside our strange world of Organizations*, The Free Press, New York (chapters 6-14).

⁸⁸ Chandler A., 1977; *The visible hand, the managerial revolution in American Business*, Harvard University Press, Cambridge.

⁸⁹ The evolution could be achieved through continuous improvements (Kaizen) or more radical changes (reengineering theory, Hammer & Champy).

4.2.6. The Political Decision-making Model

When political processes prime and constitute the main factor of influence in the decision-making process (reference to the Allison's Model III), the configuration takes the shape of the Political Decision-making Model (Figure 62). Here, "political" has to be understood in a large meaning.

Political processes constitute the play of actors (innovation building blocks) in the decision-making process, for instance within a consortium, or between the manufacturer and its suppliers for the case of a systemic innovation. It also concerns political interferences, when governments and institutions are involved or influence the strategies of industry.

Hypothesis: $\beta \sim 0$

Therefore: $D = \alpha \cdot f_R (P_R) \circ \lambda \cdot f_P (P_P)$

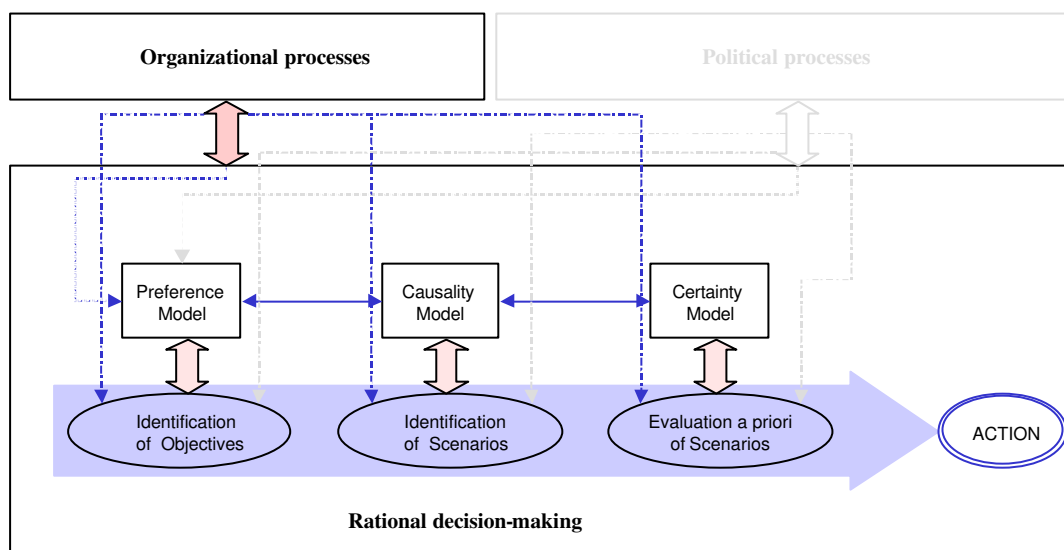


Figure 62: The Political Decision Model

Political processes influence the decision-making process directly through the definition of the set of objectives, or scenarios through the following sequence:

Pressure => Negotiation => Compromise

Indirect influences are also operated through the Preference, Causality and Certainty Models (organizational culture, knowledge management, information flows etc).

In this model, preferences, political positions of each actors and their relations between each other are sometime more important than the rational evaluation of choices (Allison 1971 p.145).

4.2.7. Decision-making Models and the formulation of Incremental/Rupture Strategies

- *Comparison between the Rational, Organizational and Political Decision-making Models*

These decision-making models underline different side of the management and strategic complexity (Generic Decision-making Model). In some cases decision processes can be managed through some

rationality, which is close to the search of an optimum (Rational Decision-making Model). When Organizational or political factors shape decision-making processes, those ones move to the search of an optimum towards satisfying solutions: the look is no more in the system Firm abilities/outcome/performance but in a system which also considers political forces and broader organizational factors.

The main characteristics of these three Specific Decision-making Models can be described through the following approach, based on the work of Allison 1971 (table below):

	Rational Decision Model	Organizational Decision Model	Political Decision Model
Unity of analysis	Action as a choice	Action as the result of organizational process	Action as a political process
Concept	The organization as a rational actor: Choice based on the following sequence: Objectives, Options, Consequences	The organizational structure and its fragmentation/division imply more complex decision-making procedures. The problem is subdivided depending on this structure and can imply information/solution retention.	Political players in the arena, situations, deadlines, nature of stakes, networks and rules.
Dominant Causality	Objectives explain actions.	Procedures explain actions in the short-term and the objectives of organizational units explain actions in the long-term.	Action as a result of political negotiation.
Impact of Decision Models on action	Substitution effect	Problematic of the implementation, Incremental change, Administrative feasibility.	The negotiation rules are decisive.

Table 8: Decision Model characteristics, adapted from Allison 1971

- *Contribution of the Generic Decision-making Model*

The Generic Decision-making Model as well as its relation with the three Specific Decision Models, brings more realism into the evolution or change of paradigms and its impact on Decision-making Models. As decision-making processes are spread over a long period in the case of large infrastructure projects and HSGT technologies, change of paradigms can induce modifications in Decision-making Models (associated to a project, an organization etc.). Such mechanisms are now well explained through the sections 4.2.3 to 4.2.6, whereas Allison and March were more focused on explaining specific models without more emphasis on changes of configurations.

- *Influence on the formulation of Incrementalism/Rupture Strategies*

Rational Decision-making Models mainly favor deliberate strategies, whereas organizational and political Decision-making Models, which result from compromises and negotiations, rather favor emerging approaches.

- Strategies of rupture are merely the result of deliberate approaches, corresponding to the Rational Decision-making Model. However, emerging strategies can sometimes lead to rupture if a strong

consensus is reached among the key actors. In this case, the Organizational or Political Decision Models can produce ruptures, but mainly in centralized systems, as we shall see in chapter 5.

The support of the actors as well as their cohesion are strengthened by the cognitive processes defined in paragraph 3.4.2: Paradigms play an important role. For instance, national industrial policies in France, Germany and Japan allow the development of HSGT innovations (see chapter 4.3).

In these cases, synoptic approaches are put in place where objectives are defined first, and the means to reach these objectives are defined afterwards: This constitutes the main challenge of managing radical innovations.

- Incremental strategies are usually the result of emerging strategies, opposed to synoptic approaches, and which are focusing on the improvement of the current state. But within this framework, the degree of innovation will be also a result of Decision-making Models. If Lindblom (1963) defines Incrementalism as a realistic decision-making process, combining Rational and Political Decision Models, Quinn (1978) defines Incrementalism as a management strategy. Therefore Incrementalism can also corresponds to a rational choice (Rational Decision-making Model defined in paragraph 4.2.4).

4.3. From case studies towards an HSGT Innovation Model

4.3.1. Framework

If innovation can be defined as the process of bringing a new idea into the market, the concept evolves through the different steps of the “product definition”. Feedback loops and the notion of incubator⁹⁰ are part of this process, where each step is the result of a decision or of the game of actors.

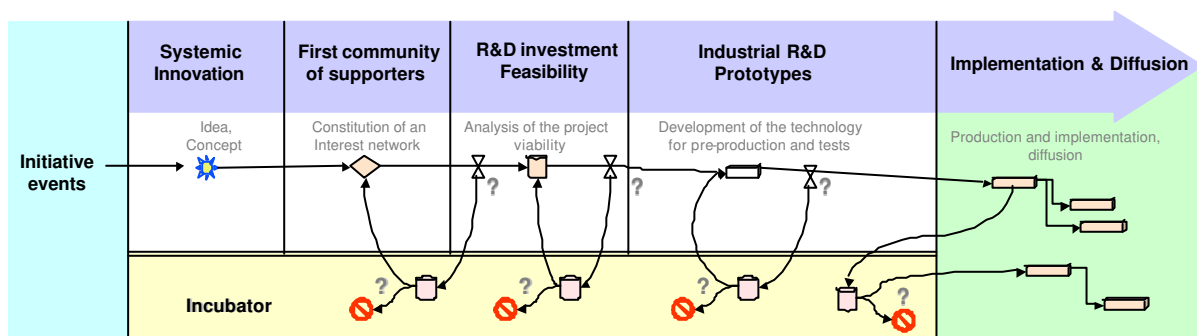


Figure 63: Framework for the analysis of HSGT Innovation processes

This framework will be the basis for the analysis of the following case studies. Decision-making models will be discussed for each case in order to understand the main drivers of innovation processes.

However, if the elaboration of Innovation Models for each case study will be based on this framework (sequence), lessons from case studies will underline the “multiple perspective” of such innovation

⁹⁰ Incubator: place in the Innovation Model where ideas or innovations which are not developed or implemented stay, waiting for new opportunities or new applications.

processes (see also the approach of Lindstone 1984). In this way, each case study will bring different enlightenments on managerial challenges, which will be afterwards summarized through a common framework (Figure 63).

4.3.2. Case of the Shinkansen and MLX-01: the Japanese fascination for innovation

- *Birth of the Shinkansen, role of the lead-user*

Facing the concurrence of air and auto transportation modes in the 50's, the Japanese National Railways (JNR) planned to build a high-speed line between Tokyo and Osaka. This rail link was saturated, carrying more than 20% of all Japanese rail passengers (and 23% of the rail freight) with an annual traffic growth over 7%.

The strong will of politics and industry to develop national technologies (former rolling-stock and traction vehicles were imported from the USA), was also a main concern during this period⁹¹. The need to double the capacity of the Tokyo-Osaka line opened the space to introduce a new high-speed line: the Tokaido Shinkansen called by many people the "dream super-express".

The source of this innovation came from the JNR following by the industry, which innovation was more problem solving rather than a radical change in strategy.

- *Political support & risk of legislature changes*

The main actor of change was the JNR president, Shinji Sogo. Convinced that the problems encountered by JNR could only be solved by the Shinkansen, he established a review and an investigative agency called the *Tokaido Line Augmentation Survey Board* within the JNR in May 1956. Hideo Shima, later to be called the father of the Shinkansen, was appointed as Technical Chief, and the issue of the Shinkansen was handled as a state project. After the final choice of the JNR cabinet, its president (S. Sogo) worked hard to convince the government as well as influent politicians for backing-up the innovative project.

It was achieved in 1958, backing this 194.8 Billion Yen project with the approval of the finance minister M. E. Sato. It is interesting to notice that Sato was previously a manager in the ministry of railways. However, if the networking was favored by several key contacts, Sato was aware of the danger of political changes: such infrastructure projects take longer time to plan and implement than a legislature.

- *World bank fund as a guarantee of a sustainable political trajectory*

Sato proposed to the JNR to use funds from the World Bank. This strategy requires from the government a completion guarantee of the project. This means that it cannot break its promise even if the Cabinet changes. This strategy provided an insurance for a political long term commitment in the development of the Shinkansen network.

- *The World Bank conditions on technological choices*

JNR decided to ask a US\$ 80 million loan, and had to demonstrate its good financial conditions as well as the profitability of the Shinkansen project. However even technical issues were discussed, such as the choice of the gauge and other technological characteristics of the system: One of the World Bank criterion excluded experimental technologies from loans.

The loan was attributed after the JNR has proven that no experimental factors were included in this bullet train concept.

⁹¹ Hideo S., 2000; *Birth of the Shinkansen, a memoir*, RTRI Journal.

- *The Tokaido Shinkansen, a successful project?*

If the completion of the project planned for 1964 was achieved in time for the Tokyo Olympic games, costs overruns were the principal concerns of politicians.⁹¹ While public budgets have been cut by the government, the Tokaido line project saw two successive cost increases, going up to 380 billion Yen (95% cost overruns). Consequently, both JNR president and the project Chief engineer had to resign just before the completion of the Shinkansen. Even if the concept finally was known as a success in terms of supply quality and demand trends, this was first a big financial failure.⁹² This underlines the fact that assessing project is really difficult from outside, and the notion of “success” has to be defined carefully and according to precise criteria.

- *Development of the Shinkansen network: a political choice to promote rail.*

The introduction of the Shinkansen technology was accompanied by a strong choice concerning the Japanese transportation policy: The high-speed rail system was planned to be the inland transportation mode, in detriment to the inland air transportation system. Airports and airline companies had to focus on international flights, and very little was achieved to promote substantially this transportation mode until now, neither through industrial support nor academic R&D.

For this point, Japan and the USA constitute the two opposite extreme concerning the modal choice and its support for industrial R&D (national transportation and industrial policy).

The national transportation system has been closely linked to the development of the Shinkansen network since 1964, with actually more than 1600 km of dedicated high-speed lines, which are operated. This network should be expended to 1900 km for 2007 (see Figure 14 page 39).

This choice concerning industrial strategies is also linked to the post war context, explaining the focus on rail rather than air transportation systems: Restriction about military activities – The aerospace industry was mainly based on military contracts for R&D, and civil applications followed through technological transfer and spill over effects (as in the USA with the main defense contractors, or in Europe with British Aerospace or Dassault, Aerospaciale etc.).

Therefore, the Japanese heavy industry focused on rail technologies matching the political will to build a new national ground transportation system.

- *The Japanese system: a centralized decision-making process*

The Japanese political system as well as its society is very centralized. It can be compared to some extent with the French system. Centralized decision-making processes, as well as the quasi-vertical integration of the JNR with the Japanese Government contributed to the quick development of the Shinkansen network (easier convergence of paradigms).

- *The Japanese culture towards technological innovation*

Is Japan unique concerning its attitude towards technological innovation? The rhythm of innovation is very high and this sentiment is reinforced by the Japanese society: this can be verified in the customer behavior of the automobile or computer markets. This is also the case in the HSGT industry and moreover in the ground transportation industry, including HSGT systems, mass transit technologies etc.

When JNR launched the Shinkansen program, it also negotiated with the government to keep relatively high fares in order to finance HSGT R&D programs. Among them, was the Maglev R&D program supported by JNR as the future generation of HSGT systems started in 1962.

⁹² It must be added that this cost overrun took place while no difficulties in corridor planning had been encountered: all the corridor was kept secured since WWII for rail project development. This factor constitutes now the main planning trouble in many countries.

- *Maglev technology as an option, excellence of a national industry*

The first full-scale prototype (ML100) was tested in 1972. Since, new prototypes were developed and tested, with an average of every three years, until the last version (MLX-01) introduced in 1996. Two test tracks were built for tests, one in Miyasaki (7 km, 1977-1995), and the Yamanashi test track (42.8 km) opened in 1996. Since 1972, eight concepts and full-scale prototypes have been developed, and R&D investments are estimated to US\$ 1.5 billion (up to 3 billion according to several experts)⁹³.

The parallel development of HSR and Maglev technologies was achieved with the purpose to keep a leading position in the HSGT market for potential international contracts (in order to set de facto standards). But the MLX-01 is still waiting for implementation because of the high cost of this technology, as well as the Japanese economic crisis, which arose just before its implementation was planned.

- *Cost as a market barrier for international sales*

If the Shinkansen was a success story in Japan, it encountered a lot of difficulties in competing for international contracts. Since the 80's the Japanese HSR technology is competing with the French TGV. If the competition for leadership was first based on performances and reliability (1960-1985), since the late of the 80's costs became the main paradigm driven by two parallel phenomena:

- Cost efficiency driven by liberalization and reorganization of railways in Europe and Japan. Difficulties of other private railways (USA for example, because of the lack of public support)⁹⁴: Pressure of the lead-users' market.
- Cost efficiency driven by the increasing competition between manufacturers: internationalization of market. This led to the concentrations that took place in this sector since the last decade in a crisis background in rail technologies in the 90's. Pressure of the manufacturing market.

This being said, the problem of the Shinkansen technology, 50% more expensive than TGV's is obvious. International sales in the HSR market have, since more than a decade, been won by the TGV consortium led by Alstom (Korea, Spain, USA). The first opportunity, which is still contested, is the Taiwanese⁹⁵ contract concerning a 350 km distance connection from Taipei to Kaohsiung (firstly awarded to the European consortium Alstom-Siemens). According to some Japanese sources⁹³, the Japanese government provided a backup of 50% to win the contract.

Concerning the MLX technology, costs are at the moment 50% more than Shinkansen! According to RTRI⁹⁶ actual objectives (2001-2005) are to reduce these costs by 20 to 30%, which will be still 20-30% more expensive than the Shinkansen, and much more than TGV's.

- *Taking advantages of failures, the importance of spill over*

One of the Leitmotiv in the Japanese industry⁹³ is that even if an innovation doesn't succeed, spill-over can be applied in other solutions and it finally creates a dynamic based on innovation processes. If the Maglev HSGT technology is not yet implemented, Maglev technologies have also been developed in Japan for medium speed (HSST project, in full-scale demonstration since 1985) and for low speed (low

⁹³ Interview with Dr. M. Takabayeshi, Institute of Transportation studies, Osaka University, 3 March 2001.

⁹⁴ Since the 80's, HSGT technologies such as Shinkansen or TGV are in competition on several US potential corridors. Only one as been partially achieved in 2001 between Boston and Washington (Northeast Corridor) based on tilting TGV technology manufactured by Alstom-Bombardier.

⁹⁵ Japanese Alliance was awarded a contract for building a high-speed railway in Taiwan valued at a total of approximately ¥332 billion. Mitsui & Co., Ltd. acted as a leader in forming the consortium of seven companies with Mitsubishi Heavy Industries, Ltd., Toshiba Corporation, Kawasaki Heavy Industries, Ltd., Mitsubishi Corporation, Marubeni Corporation, and Sumitomo Corporation (source: Toshiba activity report 2001).

⁹⁶ RTRI : Japanese Railway Technology Research Institute.

speed technology has been implemented for metros in Osaka prefecture - rail system using Maglev propulsion - and was set as reference standard for other prefectures in Japan).

The size of industrial activities is important and must be sufficient in order to allow enough recuperation of spills-over: This favors innovation activities through a reduction of risks.

But to possible, this “Innovation Leitmotiv” has to be shared by the industrial community (manufacturers and their suppliers), by the market and by the political community (national R&D programs, transportation and industrial policy). It therefore becomes a shared paradigm in the society based on a culture, which sets technological innovation as a standard.

However, with the economical crisis, a fracture appears in this belief: “Cost-blinded innovation processes” are pointed out. This could ring the death of the MLX project if cost-killing efforts are not sufficient.

- *Conclusion on Innovation and Decision Models*

The case of the Shinkansen development by the JNR is very close to the Rational Decision-making Model. The structure of decision-making as well as the political system, both very centralized at that time, allowed through the agreement of the JNR’s CEO and of the government to implement the new strategy very rapidly before the opening of the Olympic games in 1964.

If the Shinkansen was a revolution in the rail sector, as the first HSGT technology, it was more a radical innovation concerning the transportation market, whereas from the technological point of view this was an incremental innovation: If it was a conceptual revolution to challenge high-speed, this was closer from the new product development perspective than from a radical technological rupture.

After the constitution of the Shinkansen team in 1956, 6 years only were needed to deliver the first prototype (series 1000), which was a dominant design and can be considered as a pre-production series (Figure 64).

In fact infra-technologies were mainly developed: Scientific research and generic technologies were sufficient to focus on applied R&D and production scale-up. This allowed to shorten the innovation processes and the time to market introduction (see details as well as figures page 76).

In the case of Maglev technologies, JNR also started its research in 1962. But working on the Infratechnology was necessary, and 10 years of scientific research were required to “master” the generic technology for the two first LSM prototypes in 1972. However prototypes are now developed since 30 years, and the new version, the MLX01, tested since 1996 show that costs are not mastered yet.⁹⁷ Mastering a technology therefore requires to master both technical and economical aspects.

Maglev technologies were a radical innovation from the market and the technological perspective, and this was probably too much to be manageable for a market introduction until now.

4.3.3. Case of the US HSGT innovations

- *Decision-making structure & institutional context*

The US case study (de Tilière 2001 (a)) shows how different conditions may be from a country to another. If the Japanese and French systems were very centralized (governance mode) with a public national operator, the US case rather illustrates the difficulties encountered in federation systems: The US Federal Department of Transportation (FDOT) is in relation with each state’s DOT and its role is mainly to coordinate R&D programs⁹⁸ depending on FDOT’s choices and priorities. Moreover, the main role of the FDOT is focused on safety standards and resource allocation among states.

⁹⁷ 50% more expensive than the Shinkansen in 2001, the next challenge is to reduce them by 20-30% in a 5 years horizon.

⁹⁸ R&D programs were simpler to manage because the decision-making was at the federal level (HSGT program 1965-74, NMI 1990-93). But project implementation and therefore the diffusion of a technology remains the main problem.

As a result, decision-making in the implementation of ground transportation system is very complex⁹⁹, which, added to the “visibility” and political risks of such projects, slow down large project implementation.

At the inverse, activities based on military & air-space business benefit from a much more centralized decision-making system, depending directly on the US-Congress and the military department (less visibility and less complex process than in ground transportation projects). As a result the main US manufacturing industries are engaged in such activities, and all US railcar manufacturers went out of this market before the 80's.

- *The culture of self-sufficiency and flexibility*

In the American culture, the notions of self-sufficiency and flexibility are deeply rooted and constitute the main drivers of the transportation policy. In this context, the development of the air transportation mode was less criticized than the public support to rail projects in the main potential HSGT corridors.

This constitutes the main gap between the American and the European/Japanese culture, where the notion of public service and national transportation systems were the root of the development of HSGT networks. Now things have been evolving (deregulation and privatization of rail markets in Europe -1990- and Japan since 1987) but the difference stands now in the concept of internalization of external costs which influences, the structure of public-private partnerships (public investments and subsidies).

- *Political risks*

HSGT programs have always been very sensitive to political risks as the support of governments and institutions is a prerequisite for any large transportation project. For example, political changes in Texas and Florida made TGV projects failed. But in a context of complex political arena (usually the case in decentralized systems¹⁰⁰) the risk is higher, especially for “radical solutions”, as the consensus among numerous decision-units produces usually incremental solutions, except in crisis situations.

- *Epistemic communities*

The role of epistemic communities was the main driver in the two main R&D programs related to US-HSGT technologies. Both HSGT Act (1965-74) and NMI (1990-93) were approved by the congress with the initiation and support of the main defense contractors: Boeing, Gruman, Lockheed-Martin etc. Their purpose was to benefit from the public and political interest in HSGT system (federal programs and public subsidies) in order to enter into a new market (HSGT market). But both initiatives failed because of the lack of implementation facilities.

- *Conclusion*

The US industry is used to the concept of Program Champion for such systemic innovations: this was used for the National Maglev Initiative (1990-93), during the HSGTA (1965-74) in the HSGT sector. This is also how innovations emerge in the US aircraft industry, mainly under public defense contracts. In uncertain markets, where implementation difficulties are mainly due to political reasons and to the lack of institutional facilities, industry asked for federal initiative to launch research programs concerning systemic innovations. Technological risks are too high alone to be added to strong political uncertainties.

The Political Decision-making Model is predominant with the influence of epistemic communities. In the HSGT R&D programs, US defense contractors (looking for new market opportunities and spillover) and the US-corp. of engineers (looking for new fields of competencies – limited for a time to the water/hydrologic domain) were lobbying to the congress for Federal HSGT programs.

⁹⁹ Especially because HSGT corridors are often Interstate Projects.

¹⁰⁰ Mintzberg makes reference to the *balkanization* of an organization when the decentralization leads to a predominance of political games among its components (Mintzberg 1989).

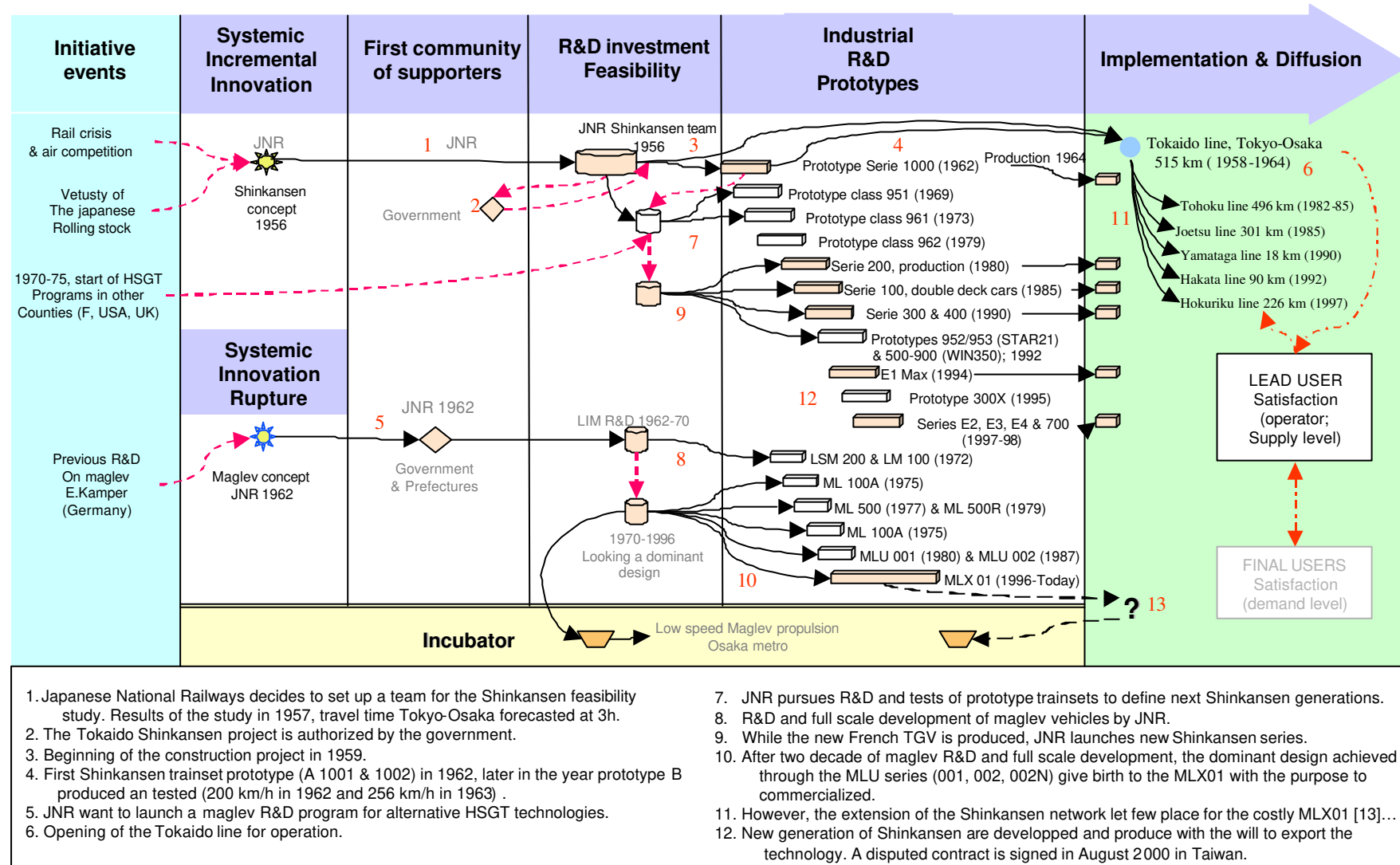


Figure 64: Innovation Model of the Japanese HSGT technologies

But as other federal countries, the institutional and political complexity pushes the Generic Decision-making Model towards its Organizational and Political configuration. This case may be compared to the emergence of the X2000 in Sweden, where Incrementalism was the result of organizational factors within the political and institutional system. At the same time, this supposes political games between actors for the emergence of a consensus on the project concept (and therefore the technological innovation).

4.3.4. Case of the French Aerotrain and TGV

Was the French TGV a logical consequence of decades of R&D in HSGT technologies? The recent enthusiasm for the TGV and HSR technologies hides that the logical evolution from conventional trains to high-speed trains was more than uncertain before the 80's.¹⁰¹

- *The origin of HSGT concepts in France*

The HSGT concept is born in Japan through the impulsion of JNR, its national operator, in order to face its financial and image crisis in a context of hard competition for railways. In France, the high-speed commercial services were first embodied in the Aerotrain of the entrepreneur Jean Bertin: At that time, SNCF only proceeded to running test in order to set speed records with electric locomotives (240 km/h in 1953 and 331 km/h en 1955). The Aerotrain was a track-air cushion vehicle (TACV) propelled with turbo-jet engines (manufactured by SNECMA).

Innovations from the aerospace industry were at that time frequently integrated in HSGT concepts (USA, Canada, U.K.). The aerospace industry was also looking for spillover and new market opportunities, and public institutions were also interested through national R&D programs to modernize rail systems and promote national innovations.¹⁰²

Bertin presented his concept and was rapidly supported by the DATAR (Délégation à l'Aménagement du Territoire et à l'Action Régionale), which considered there an opportunity to better develop regions through a high-speed network. R&D subsidies were provided to support the full-scale development of this technology.

- *Bertin & Cie: an innovative entrepreneurial organization with good marketing skills*

Bertin & Cie, founded in 1956 by Jean Bertin, patented numerous inventions relative to air cushion technologies. This highly innovative organization presented the Aerotrain concept through a model demonstration in 1963.

During a decade, Bertin has rallied through its personal network a large community of supporters, from the engineering and political field (the engineers of Polytechnique Paris certainly constitutes a strong epistemic community). The marketing of his technology was such that the Aerotrain was frequently cited in the medias and became very popular as a new fleuron of the French technology.

- *Role of national R&D programs to promote alternatives*

The French government was looking at the revitalization of its ground transportation system, such as other national HSGT R&D programs in the USA, UK, Canada and Germany. The R&D program was presented to the public, the DATAR and the French Transportation Ministry, and in 1964, it was decided that 50% of R&D costs would be hold by the public budget and 50% by the SNCF itself.

¹⁰¹ This is also the statement of the analysis of Meunier J., 2001 ; *The politics of High-Speed Rail in France, 1944-1983* ; PhD Thesis Brandeis University, Edition UMI 9997732.

¹⁰² French TurboTrain, United Aircraft TurboTrain, US TACV concepts etc. (see also de Tilière 2001, SNSF report page 34)

The *Aerotrain company*, founded in 1965, managed things rapidly to open a 6 km test track (near Gometz), and later a 35 km test track (with the financial support of the DATAR and the national R&D program). After several prototypes, an Aerotrain version was able to operate for demonstration with passengers, and set speed records at 303 km/h in 1966 and 372 km/h in 1968.

The fact that public institutions supported a private alternative underlines the tension that arose between the government and the SNCF (with the critics on the financial situation of the National rail Operator as background).

- *Aerotrain: a systemic innovation based on components available in the market*

The Aerotrain is an innovation, as the industry likes it¹⁰³: A new concept based on current technologies, which are well mastered. The first Aerotrain prototype¹⁰⁴ used a 260 hp Continental aircraft piston engine driving a reversible-pitch propeller. Air-cushion was provided by two 50 hp Renault Gordini engines, driving two centrifugal fans. Later, for the I-80 prototype (250-300 km/h), the vehicle propulsion system used two Turbomeca jet-turbines (1500 hp) as well as two other (400 hp) for the air cushion system. A second version S-44 (180 km/h) was based on a Maglev technology developed by Merlin-Gerin, and the air cushion system used a Chevrolet GM engine V8 525 hp.

This strategy made possible a rapid development of the technology as well as numerous demonstration tests in a short period of time. But this also allowed to benefit from the market prices, since the concept was mainly based on proven technologies.

Thus the Aerotrain innovation consists in the integration of available components, and is therefore by definition an architectural-based innovation without component innovations. The availability of components in the market was a critical factor to speed up the development and to overcome youth defaults of the technology as well as to keep costs as low as possible.

- *The promising future of the Aerotrain and the loss of the SNCF credibility: 1963-1973*

The success of the Aerotrain in the media in France as well as abroad led to an increasing interest in this technology in the USA and UK. In France, it earned a large support among people from the transportation ministry as well as several regions asking for project implementation (Paris-Brussels, Lorient-Rennes, Paris-Orleans, Strasbourg-Mulhouse, Aix en Provence-Marseille etc).

At that time, a strong consensus was for the Aerotrain project, and none believed in the ability of SNCF to propose high-speed rail solutions. The transportation ministry was also supporting this technology, since it was also supporting this French technology abroad.

Looking for an alternative proposition in order to face the threat of the Aerotrain, the SNCF worked out an HSR solution in 1969. It was embodied in the Coquerand reports (1969-70), which gave birth to the C03 project based on the TurboTrain technology (Meunier 2001, pp. 210-250).

In 1970, there was a much greater faith for the Aerotrain due to the mediated project of Bertin and its numerous operation tests. But The SNCF since 1969 was determined to act and began a strong and aggressive media campaign on the development of a cost-efficient High-Speed Rail technology.

- *Resistance towards innovation and the power of lead-users*

The Aerotrain project was on hold in many countries (Mexico, Sweden, Japan, Brazil and Italy) while governments and private investors were waiting for the French to put into operation the first line (Meunier 2001 p 190). All potential foreign adopters were waiting for the first commercial operation planned for Paris-Cergy. Adopters never want to take the risk of being the first adapters and pay additional costs of development for the maturation of the technology: *Wait and see* has been the common attitude among

¹⁰³ Interview of the Path R&D program supported by GM and Toyota at Berkeley-Richmond for self guided vehicle technologies (USA).

¹⁰⁴ Société de l'Aerotrain: "Aerotrain Vehicles", in *Jane's Skimmer Systems 1969-70*, ed. Roy Mc Leavy-London.

operators as regards to this technology as well as the Maglev technology up to now. The main argument against the Aerotrain was that the project was a cutting-edge technology, being *too advanced*, in addition to be supported by Bertin & Cie, an outsider¹⁰⁵ of SNCF.

Even in the mid 60's, at the beginning of the formulation of any strategy at SNCF, most people including managers and engineers didn't believe in HSR (Meunier 2001 p 207). "*The C03 project was much more controversial than many railway historians have acknowledged*" (Meunier p248).

But the national operator had the advantage of its establishment: It still constituted the main (exclusive) distribution channel of HSGT technologies as lead-user with strong connections with administrations and institutions. Finally, SNCF organized a coherent response to Aerotrain in 1968: An aggressive media campaign was initiated based on high-speed services and insisting on minimizing costs.

- *Technological lock-in*

SNCF engineers believed in the 60's that there was a technological lock-in in the commercial operation of trains (wheel-rail technology) at more the 200 km/h as well as a problem of cost efficiency. In the mean time promoters of the Aerotrain didn't foresee the future lock-in related to the use of turbo-jet engine for intercity travel: Environmental sustainability as well as the energy crisis was finally the main drivers of following political decisions (economical paradigm, combined with the choices regarding energy policy – French nuclear program).

The sudden oil crisis occurred in 1973 added to the doubts on the workability (sustainability) of TACV technologies (based on turbo-jet propulsion systems). The enthusiasm and interest for TACV vanished, and with the financial difficulties, R&D programs were cut in UK, USA and Germany. Only Germany and Japan decided to pursue Maglev R&D.

Concerning the future of the Aerotrain, only the S-44 version with a Maglev (LIM) propulsion would have been interesting. But Maglev propulsion was not ready at that time for commercial application, and a Maglev Aerotrain was not ready for implementation when political changes occurred in 1974.

- *Political risks and concerns*

If politicians like Pompidou were supporting the Aerotrain project, Giscard d'Estaing, his finance minister was against any HSGT project. The Aerotrain was supported in 1971 by the transportation ministry and the French President, Pompidou. The government was at that period pushing for the Orly-Roissy proposal arguing that "the essential motivation behind this decision stands in the opportunity to diffuse a remarkable French technology abroad" (Meunier 2001 p.170).

But Giscard d'Estaing, voiced concerns, arguing harmful competition between transportation modes and advocated buses flexibility against any massive investment in new fixed infrastructures. But after the death of Pompidou, Giscard was elected president in 1974 and officially pulled the plug of the Aerotrain: this was the irreversible death of the project.

But things were not going better politically with SNCF. Between 1960-80, most governments were hostile to the TGV because of financial concerns¹⁰⁶ (Meunier p 220). Several times the president (Giscard) put the SNCF CEO on pressure to demise the TGV project manager and stop the R&D project. The TGV was built against the will of the authorities¹⁰⁷ and managed internally by SNCF without public support. The conflict between SNCF and the government was still open, when the TurboTrain project approved in 1971 (6th Plan) was delayed to the 7th Plan because of the urban mass transit priority.

¹⁰⁵ Bazin J.F. wrote from Bertin in *Les défis du TGV*, Paris 1981 p.81: "This amateur genius had the misfortune not to have joined the ranks of the SNCF. Worse, he had the audacity to fly with his own wings over territory that belongs to national railways."

¹⁰⁶ Since the presidency of Pompidou, modernizing industries like SNCF, EDF was a priority in France.

¹⁰⁷ Picard J.F. & Beltran A., "Origines de la grande vitesse", *revue générale des chemins de fer* 8-9 (Aug-Sept. 1994)

The technological development of the SNCF was at that time subordinated to the government agreement. This one was given by Chirac (State Secretary for Economy & Finance), who signed the declaration of public utility in 1968. This allowed SNCF to call for tenders to build TGV prototypes (Meunier p 248). The TGV was finally on the track: Since the TurboTrain experience, politicians and bureaucrats saw there the way for SNCF to reach and maintain its financial equilibrium.

Finally, the decision for the construction of the TGV line Paris-Lyon was planned in 1974, based on the successful experience of the TurboTrain line Paris-Caen-Cherbourg. This profitable project influenced politicians in encouraging the SNCF in more profitable activities. Moreover, SNCF proposed to convert future TGV train-sets to electric propulsion. This was also an important mark, as the French energy policy was to insist on its self-sufficiency with the development of the nuclear program.¹⁰⁸

In this context, the emergence of a technological innovation was highly dependent on the political concerns. Also, the development of the TGV network was strongly supported by Mitterrand (French President in elected 1981), who believed in the increasing role of the public sector and its influence on the national economy: The TGV network was therefore part of a political program.

- *The role of institutions*

The AeroTrain was supported by the DATAR since the beginning (Meunier 2001 p.158) as well as the transportation ministry as a tool to support the regional development. However, other institutions were probably closer to SNCF, especially when implementation and planning processes started: Bertin complained about administrative delays concerning the AeroTrain project, whose purpose was only to make the project abort.

Nonetheless, SNCF also fought in order to convince the Finance Ministry, arguing that no technological innovation was included in the TGV and that it was only an incremental solution (it has been the same for the Shinkansen to obtain a credit from the World Bank).

- *From the C03 project to the TGV implementation: a series of chaotic processes*

The history of the TGV is not a simple linear evolution, but rather a series of chaotic events. First, the AeroTrain shook the SNCF from its lethargy, and gave birth to its High-Speed Rail response: The TGV was since that time an evolution, not linear, but a *series of fits and starts* (Picard & Beltran 1994).

The first concept, The Transport Express, was submitted in Dec. 1965 by R. Geais (C03 project), supported by the SNCF president L. Armand. A project platform was constituted in 1966 to build an experimental vehicle based on the TurboTrain concept. The first prototype ran in April 1967 (238 km/h) and in 1969, two prototypes were ordered¹⁰⁹: the TGV-001 and the TGV-002 (tilting train, abandoned as its technology was qualified as too tricky)¹¹⁰. The TGV-001 reached 300 km/h in 1972. After the political agreement in 1974, the TGV train-sets were converted to electrical propulsion.

- *The TGV: history of an organizational revolution within SNCF*

The birth of the TGV in the mid 60's was the work of a new research department later called the "TGV platform". This project-based adhocracy within SNCF contributed to the strategic reorganization that took place at SNCF: commercial policy, industrial policy, research policy and internal structure were all rethought (Meunier 2001 p.206).

¹⁰⁸ In 1973; the energy represent 4.28% of SNCF costs for traction, 5.24 in 1974 and 5.25 in 1975. So the choice was to avoid gas-turbine locomotive, symbol of France's dependence on other countries' natural resources...while electric trains use a domestic source of energy (nuclear power and the French self sufficiency).

¹⁰⁹ Body car manufactured by Alstom and gas-turbine engine by Jeumont-Sneider.

¹¹⁰ The TGV002, incorporating a tilting technology, was later abandoned as considered as technologically too tricky.

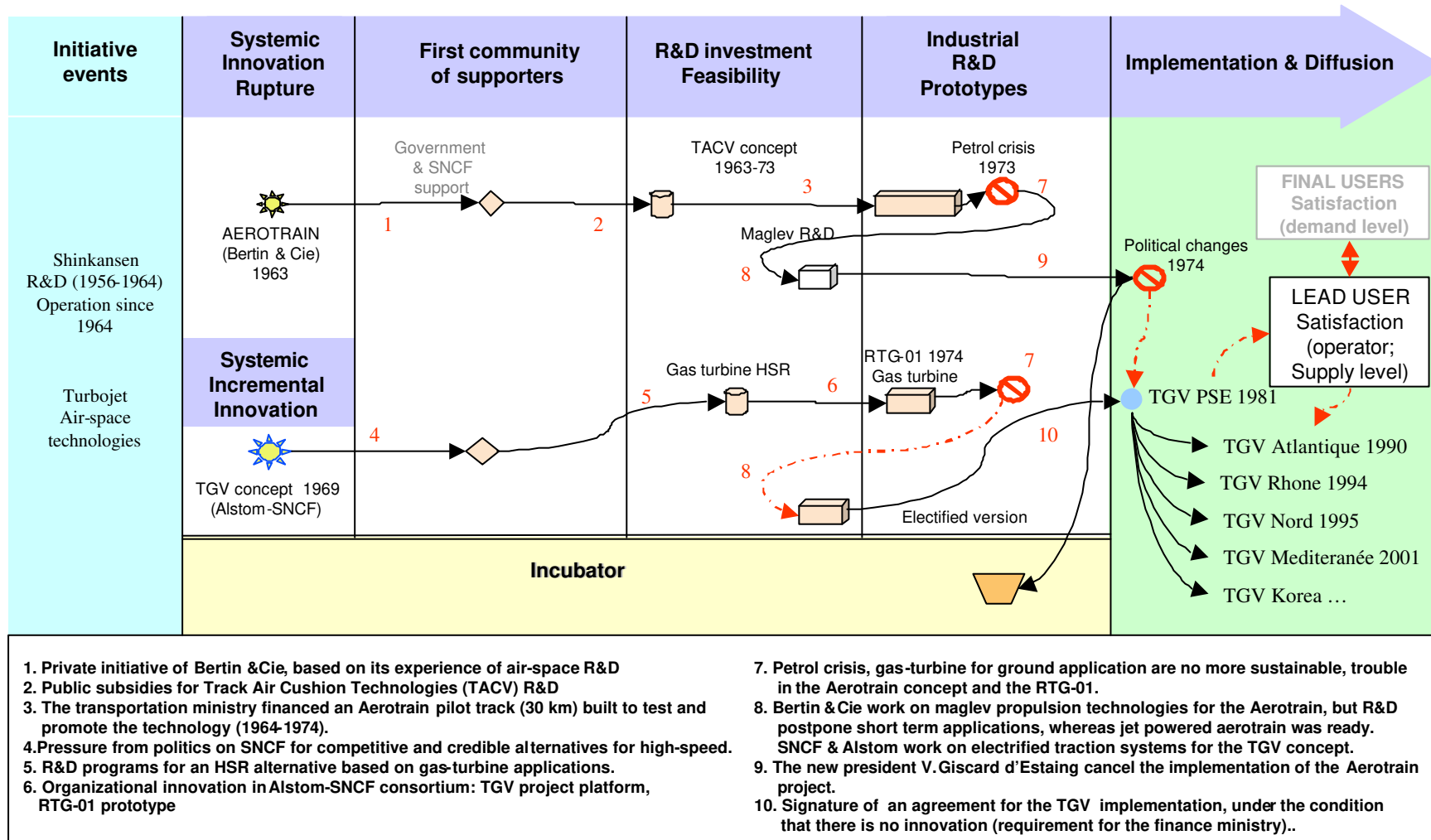


Figure 65: Innovation processes: AEROTRAIN & TGV (France)

If the TGV concept was evolutionary, its birth required an organizational rupture to mobilize quickly enough resource and knowledge within SNCF and its suppliers (Alstom).

- *Conclusion about Innovation and Decision models*

Concerning the Aerotrain and the TGV, both innovations have been at the beginning the result of a Rational Decision Model (see § 4.2.4). But when the step of implementation came, political considerations were crucial for the required “public approbation” (government & administrations).

This is surprising that the project from the SNCF, large administrative organization, was not derived from the organizational decision model. In fact as the Aerotrain shook strongly the SNCF, the reaction has been the creation of an internal adhocatic organization focused on the future TGV project and directly based under the direction of the SNCF CEO L. Armand: This project platform concept used for the TGV was very innovative, mixing engineers from industry and SNCF. This concept was later used for the Twingo project by Renault (Midler 1993)¹¹¹ and constitutes now a reference for the new product development (NPD).

If both Aerotrain and TGV are derived from a Rational Decision Model until the R&D phase (feasibility studies), the importance of networking, epistemic communities as well as interferences of politics rapidly influenced innovation processes in the stage of industrial R&D and prototype development: this makes the rational decision model rapidly shift to the political model.

At the same time, the links between the operator and the manufacturer as well as the institutions have also an impact on the set of technical solutions. But in this case it is relatively hard to say if organizational tensions interfered significantly with outcomes, and this seems to be not as significant as in the German case (see § 4.3.6).

To conclude on Innovation Models, both TGV and Aerotrain innovations are very different: the TGV is based on rail technologies and the Aerotrain on aerospace technologies. But it must be added that for both, the development was extremely rapid because the related infratechnologies were well developed: The work was mainly focused on applied research, aiming at putting existing technologies together. But finally, the Aerotrain lost because of a paradigm shift followed by a technological lock-in: The importance of using of electrical power was a new paradigm, according to the new objectives of energy self-sufficiency after 1974 (national nuclear program). But the Maglev technology was not ready to be implemented on the Aerotrain since the Infratechnology was not ready and the technology not mastered (technologically and economically).

4.3.5. Case of the Tilting Technologies

- *Mastering the Tilting Technology*

The case of the tilting technology is very interesting, underlying the complexity in managing innovation processes. If the TGV-002 prototype was based on this concept in 1972, the complexity of such a system was thought as a barrier for its commercial introduction (problem of reliability). The competitive advantage of this version was not sufficient, especially if the main part of the new Paris-Lyon track was dedicated to high-speed.

The tilting technology was finally exploited at the end of the 80's by FIAT Ferroviaria (ETR 450 called the *Pendolino*) in Italy, and ABB in Sweden (X2000). The purpose of such technologies was to maximize the use of existing infrastructure. They were developed and implemented in countries where the planning process was complex and the implementation of dedicated high-speed line to hard (incremental solutions). The technology was developed under contract from operators, with the agreement and support of politics.¹¹² But later, these incremental development appeared to be much more costly than expected.¹¹³

¹¹¹ Midler Ch. 1993, *L'auto qui n'existait pas, management des projets et transformation d'entreprise*, InterEditions.

¹¹² Such technologies were afterwards tested in the USA in several corridors between 1994-97 and implemented (Talgo-pendular

- *Timing of an introduction*

After the implementation of the tilting technology on several near high-speed rail technologies, other HSR manufacturers worked with FIAT to include it on their train-sets (Alstom, Talgo, Bombardier): After the expansion of HSR dedicated networks, the current step is the consolidation of existing networks, allowing for HSR train-sets to earn time on terminal networks or portions which are not upgraded for high-speed.

The timing of the introduction is therefore crucial for the emergence of an innovation. It must be in phase with the needs of operators or of the transportation policy: When the tilting technology appeared for the first time in the 60's, it didn't correspond to operators needs. But since the introduction of HSR dedicated lines, tilting systems offer an intermediary solution allowing HSR trainsets to also perform in non-upgraded lines.

- *Innovation and decision models*

These technologies may be associated with incremental innovations from the technological point of view, but constitute rather small improvements rather than major change from the market point of view. Concerning innovation processes, their emergence is the result of Organizational and Political Decision Models. In these cases, political systems (more decentralized in Sweden, or the US, when compared with Japan or France) made decision models evolve towards Organizational ones, as the planning process was a driving element of the emergence of innovation in these cases (see also Hulten 1999).¹¹³

4.3.6. Case of the German Transrapid and ICE

The case of Germany is very interesting concerning the development of HSGT technologies.¹¹⁴ As in Japan, both HSR and Maglev technologies have been developed until now (Transrapid kept as an option). But whereas HSR technologies allowed learning by using with the feedbacks of operators, the Transrapid System was developed "in vitro", in special demonstration sites such as in Emsland since 1989.

- *Role and specialization of institutions in the support of industrial efforts*

Increasing nuisances of road transportation modes and the decrease of rail market shares in the mid 60's led to public interest in the development HSGT technologies in Germany. Several industries and the Deutsche-Bahn formed a working-group for this purpose in 1967. Two years later, the government ordered through the Department of Transportation (BMV) the HSB study, aiming at looking for HSGT alternatives.

As a result, two technologies were selected for further investigation in 1971: Maglev and Rail systems. Three main actors have sponsored these investigations as further R&D programs: the Department of Transportation (BMV), the Department of Research & Technology (BMFT) and the Deutsche Bahn (DB).

- The BMFT was involved in both rail and Maglev research aiming at the development of HSGT systems, but its role was mainly focused on innovative technologies: the BMFT has a Synoptic Approach by nature, looking for best performances. It's interest was mainly focused on Maglev development, and after on HSR technologies.

first, and the Acela express in the Northeast corridor in 2000).

¹¹³ Hulten S., 1999; *The quest for affordable High-speed trains, case for Sweden*, PREDIT report n°98 MT07 DT2.

¹¹⁴ For more details on the projects history and a complementary analysis, see Llerena, Shenk & Danner-Petey 2000; PREDIT report n°98 MT07 DT3.

- The BMV and the DB launched, in parallel, a modernization program of rail infrastructures, setting their first objectives in 1970 towards a network able of 300 km/h. Their incremental approach was at this time closer to a Rational Decision Model, setting ambitious objectives (HSR systems were planned to be operated under 200km/h at this period).

Institutions supported completely all R&D projects with strong technological rupture: the BMFT financed DM 1.56 billion for Maglev technologies and DM 0.64 billion for HSR innovations, between 1970 and 1991. Programs Concerning applied R&D, where spillovers were expected in the short-term, innovations were co-financed at 50% by Institutions (BMFT/BMV) and at 50% by Industry.

- *Role of National R&D programs: from Invention to Innovation*

National R&D programs allowed the development of the German Maglev System, the Transrapid, through the high concentration of public resources and the interest of industry (history of the project described in Figure 12 p.36 and innovation processes in Figure 67 p.133).

If the invention of Maglev concepts happened before World-War II (1922-1940), further R&D and development really began in the 1960's with the interest of industry, such as Thyssen, which developed the Transrapid concept in 1962, or MBB in 1966: The Innovation period (1962-1969) concerned research focused on EDS versus EMS propulsion systems.

The beginning of public R&D program through the BMFT support in 1969, launched the third phase: The consolidation of technological alternatives (1969-1979). This happened after the diffusion of the paradigm and the constitution of an epistemic community, based on the belief that Maglev systems were intrinsically superior to HSR technologies. Private and public actors saw there an opportunity for the German industry to set new international standards for HSGT technologies, as well as to respond to the future transportation challenges.

- *The concept of Program Champion adapted to a "winner take-all" market*

The first phase of innovation through R&D allowed to define the main technological dominant designs, of which several Maglev systems emerged before 1969. However the industry didn't have the resource to finance the development of such risky program: Continuing the R&D phase through the full-scale development, while political risks concerning the issues were too high has been possible only through a strong public support (especially in this "winner take-all market").

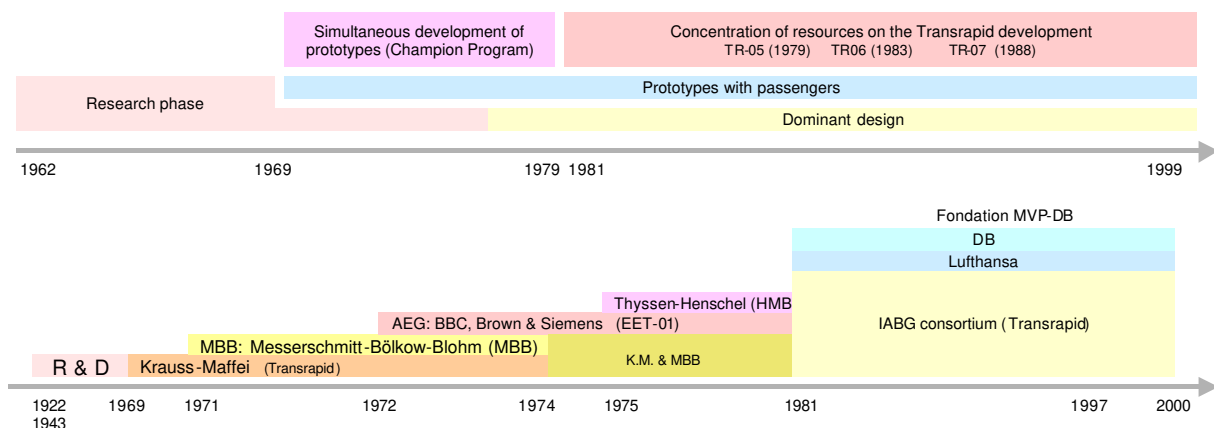


Figure 66: Organization of the Maglev Champion Program (1969-1981) in the Maglev development phases

The BMFT organized the consolidation phase (1969-1979), aiming at the selection of the more pertinent standards among Maglev concepts. This was organized through a Champion Program, based around four consortia (Figure 66). This simultaneous development of Maglev concepts allowed reducing the time to acquire information on the technology. Four concepts were developed through full-scale demonstration tests between 1969-1979, of which the MBB consortium was merged with the Transrapid one (Krauss-Maffrei) in 1974. Thereafter, three consortia competed until the Transrapid concept proved its superiority in 1979.

These two selection phases allowed concentrating resources on the most promising technologies. This finally led to a reconfiguration of the consortia around the Transrapid project, which was selected in 1979 as the dominant design. A consortium was created in 1981 (IABG), aiming at pursuing the full-scale development with the construction of the Emsland demonstration site (still in operation now).

Such Champion Programs were also used in the USA for the National Maglev Initiative Program (1990-93), even if it didn't reach the phase of full-scale development.

One must notice how losers of this Champion Program were integrated into the winning consortium after the selection phases (MBB in 1974, AEG and Thyssen in 1979-81). This strategy emphasized on capitalizing the maximum of experiences, including on failures: The cost of information acquisition has been very expensive.

Building a national Maglev industry requires a high level of resource concentration.¹¹⁵ The role of the BMFT was to bring financial support as well as to coordinate, organize and arbitrate the selection phases (estimating when sufficient level of information was reached).

- *Financing the "in vitro development" of the Transrapid*

The choice of concentrating resources on the winner option (Dominant design) led to the reorganization of consortia around the Transrapid project: Supported by the BMFT, the new consortium aimed at developing the technology to its maturity for future implementation.

Technologies with strong technological rupture are subject to strong disadvantages in terms of lack of maturity in their infancy. These are due of the newness of the product, of its related processes (production, operation, control etc) and of its related infratechnologies. This leads to less reliability and higher costs when compared with incremental innovations. Such innovation must therefore find protected market niches in order to be diffused.

In the case of the Transrapid, the test center in Emsland aimed at providing technical facilities (30 km track) for research and development. Such a center was not available for Maglev technologies earlier, whereas HSR technologies have been benefiting from large test centers set in place by both manufacturers and operators.

This Maglev test center allowed with a strong financial support to bring the Transrapid technology to its maturity during the 1980's (the DB recognized its maturity in 1989).

However, investments costs have been considerably increased by the fact that this development has only been achieved "in vitro" until now. Missing opportunities to be implemented, Transrapid didn't succeed to reach the last stage of learning phase: learning through its use or through interference with operators. It should have allowed:

- Shortening the time of information acquisition.
- Reducing the costs of R&D.
- Improving the system according to the comments of both users and operators, based on a framework of daily operations.

¹¹⁵ As observed also in Japan; and that is also why the USA finally cancelled the full-scale development phase of their Champion Program, to the advantage of the Transrapid (if an eventual implementation should occur).

But operators are reluctant to implement a system, which has not achieved its proofs: They mostly prefer to wait for commercial operating experience before being engaged in a costly adventure.

The strategy of operators engaged in the consortia of Maglev development probably preferred to push for an “in vitro” development, mainly financed through public support, rather than taking the risk on their own to implement the technology earlier.

- *Transrapid: Convergence between an Industrial Paradigm and a Transportation Paradigm?*

The paradigm surrounding the Transrapid resulted from the convergence of two wills from the 1960's-70's:

- Developing a new HSGT network (Transportation Paradigm).
- Building up a related national industry, competing for international leadership (Industrial Paradigm).

This period was strongly technologically driven (as also underlined in other case studies) and the paradigms described above were matching to the Technological Paradigm (prevailing High-Tech and approaches of rupture as well as Rational Decision Models).

This gave birth to the first phase of Research Programs, where Maglev and HSR technologies were integrated into a same global objective.

However, the decision to build the TGV in France, taken in 1974, led the DB and the BMV to bring back into question the higher concentration of resources on Maglev technologies. At the end of the 1970's, their preoccupation therefore emphasized more on incremental technologies. This led to a bifurcation in German HSGT Research Programs: The BMFT has thereafter mostly supported the Maglev Program, whereas the BMV and the DB have rather focused on improving current rail technologies.

- *ICE as a response to the operator needs*

The introduction of the TGV networks in France in 1981 and its rapid development put the DB on pressure: The SNCF was able to win new international corridors with its TGVs (linking Paris), opening future possible competition with DB on its national network.

Germany, which finally had rather invested in the Transrapid, saw the DB and the BMV responding to the TGV threat by the ICE Program, which was launched at the end of the 1970's. The experimental ICE was tested in 1982, and the two first lines to be commercially operated were put into service in 1991 (Hanover-Wurzburg & Mannheim-Stuttgart).

- *The influence of lead-users in the direction of innovations*

Driven by the competition between European operators, the choice of the DB finally let the Transrapid in a lasting development phase. The ICE was developed by Siemens and Adtranz (now Bombardier), for the need of the DB: This incremental technology aimed at “occupying” the German Rail Network, offering a concept equivalent to the TGV in order to:

- Respond to the growing expectations of cities and regions toward the introduction of faster services.
- Respond to the competition of the SNCF on international corridors.

As in the Scrabble game, the best solution is not the one with the best score alone, but the one, which fits the best to the context (constraints) and maximize the score. The European Rail market led the DB to opt for the ICE, which was a technology responding to the following requirements:

- Compatible rail standards to lock the German rail network to TGV's

- Benefit from the support of the European Community concerning Trans-European Networks (Transrapid has never figured on such propositions, since it was not compatible with rail standards).

Moreover, the ICE option led to the following advantages:

- Rapid development phase of prototypes in order to prove the concept viability.
- ICE train-sets allowed to be quickly introduced on the network, even if rail-tracks were not completely upgraded.

- *The cost of flexibility and Incrementalism*

However, if such incremental innovation fitted better into the context (according to the operator), flexibility and compatibility, which have been a main decision criteria, have a cost: The improvement of services in terms of speed has been very expensive. The ICE network has been one of the most expensive worldwide, based on this ratio.¹¹⁶ Clever (1997) for the case of Germany and Hulten (1999) for the case of Sweden, underlined the fact that the step by step implementation and upgrading of rail networks were finally much more expensive than expected, when compared with the implementation to the French TGV's dedicated lines. However, these conclusions concern rather the management of networks' developments rather than the intrinsic potential of technologies. This can be put in relation with national systems of political decision-making (federalism and decentralized countries versus centralized ones).

- *Technologies with strong rupture; Political risks and the timing of introduction*

The emergence of the ICE created a sudden change in the German Industrial policy related to the HSGT market: The national portfolio was therefore enriched of HSR competencies, providing two viable HSGT alternatives, whereas the Transrapid was seen as the only German HSGT technology earlier.

The fact that the Transrapid was declared mature only early in the 1990's, after 30 years of developments, led to a bad timing of its introduction in Germany:

- The ICE was going to be implemented.
- The restructuring of the DB (lead-user) was difficult.
- The change of government brought politics less convinced of the Transrapid pertinence (the Greens – There was also certainly a lack in the marketing strategy of the Transrapid consortium, who didn't anticipate this possible political change).¹¹⁷

Developing highly inflexible technologies, whose period of development is longer than a legislature, increases considerably political risks.

In the case of compatible technologies, such risks are considerably decreased by a reduced development phase (2-5 years for the validation of the first generations of Shinkansen, TGV and ICE). Moreover, if changes in policies occur leading to project cancellation, spills-over may easily be found, and train-sets may be sold to other rail networks.

- *Conclusion, Decision-making and Innovation Models*

Germany disposes now of two HSGT options: The Transrapid was the promising one, but finally didn't fit well to the operator concerns with the changes occurred in the rail market since the 1990's. However several regions (Landers) are interested in its implementation, letting the future of this technology in

¹¹⁶ See the comparative study of HSR investments: Clever R. 1997, *Zeitschrift für Verkehrswissenschaft: Schnelligkeit oder Häufigkeit*, Verkehrs-Verlag J. Fischer-Düsseldorf.

¹¹⁷ Correspondence with B. Lamour, ex-Scientific adviser at the French Embassy in Germany (October 2001).

Germany still open, despite a smaller market niche.¹¹⁸ The ICE, was finally implemented, better corresponding to the challenges faced by the DB since a decade.

These Innovations are different, opposing Incrementalism (ICE) and rupture (Transrapid):

- The Transrapid is typically an innovation produced through the Push Innovation Model (first generation of Innovation Model). It is the result of a Synoptic Approach, embodied in a Rational Decision-making process. The cohesion of an epistemic community (industry, scientists and politics unified by a convergence of paradigms) was enforced by the coordinating role of the BMFT (as well as its financial support). This led to a low influence of the organizational and political factors of the Generic Decision Model, letting place to a Rational Decision Model.

The Transrapid is an innovation with strong technological rupture, whose development has been possible only by the definition of a National R&D Program, allowing a continuous effort over a few decades.

- The ICE is an incremental innovation, referring to the Pull Innovation Model (second generation of innovations Models). The role of the DB, the lead-user, was decisive in the development of this incremental technology fitting to its short and medium term strategy: responding quickly to the challenges of the opening of national rail markets and the increasing competition with the SNCF for international corridors. This corresponds to an HSGT Innovation Model where the operator needs define technological trajectories. The DB chose to maximize the network economies as well as flexibility: ICE may be operated on all corridors, even those that are not upgraded. Corridors may be upgraded later depending on the demand, allowing for more flexibility in the phasing of projects according to objectives and financing constraints.

One may conclude by the fact that, the Transrapid was finally victim of the change of paradigm concerning the Transportation policy. The prior convergence of the three paradigms (Technology -Industry-Policy) was put back into question in the 1990's by the increasing importance of Interoperability in European Rail Systems, on which the European Community put a strong emphasis.

This underlines the very important role of epistemic communities and paradigms in the emergence of new Technological Trajectories. If the Transrapid could be implemented in Europe in the Future, the market let by HSR technologies will be too small for a sustainable development (critical market size).

However, if the Transrapid emerges as a standard for Marglev HSGT technologies, this could be achieved through its development in China: The convergence of paradigms pushes Chinese decision-makers towards implementing this concept with strong technological rupture:

- Strong support to the rapid development of Transportation networks (Transportation Paradigm).
- Strong emphasis on High-Tech projects, aiming at the future development of the Chinese Industry, with the purpose to compete at an international level (As the HSR Market is already established, they should opt for a new Technological Trajectory).
- Strong interest of the Chinese industry in the co-development of Maglev technologies.

This convergence of Paradigms can lead to its selection for the implementation of a 1250 km track of HSGT system between Shanghai and Beijing, the beginning of which is planned for 2006 (if the Shanghai Transrapid project is successful). The political will to develop a Maglev HSGT network, may lead to reach a sufficient market size to allow network effects and economies of scales (for both the operator and the manufacturer). It should allow to guarantee sustainable improvements of the technology through:

- Providing sufficient orders in order to assure a continuous production (for the related manufacturing plants).

¹¹⁸ Two Landers are interested to implement the Transrapid (subventions are guaranteed by the Federal Government): The Ruhr, for a Metrorapid between Dortmund –Dusseldorf, with possible extension to Cologne; and Munich for a rapid connection to its Airport. Both Lander Presidents (Clements and Stoiber) are supporting the project, looking for the Federal Grant.

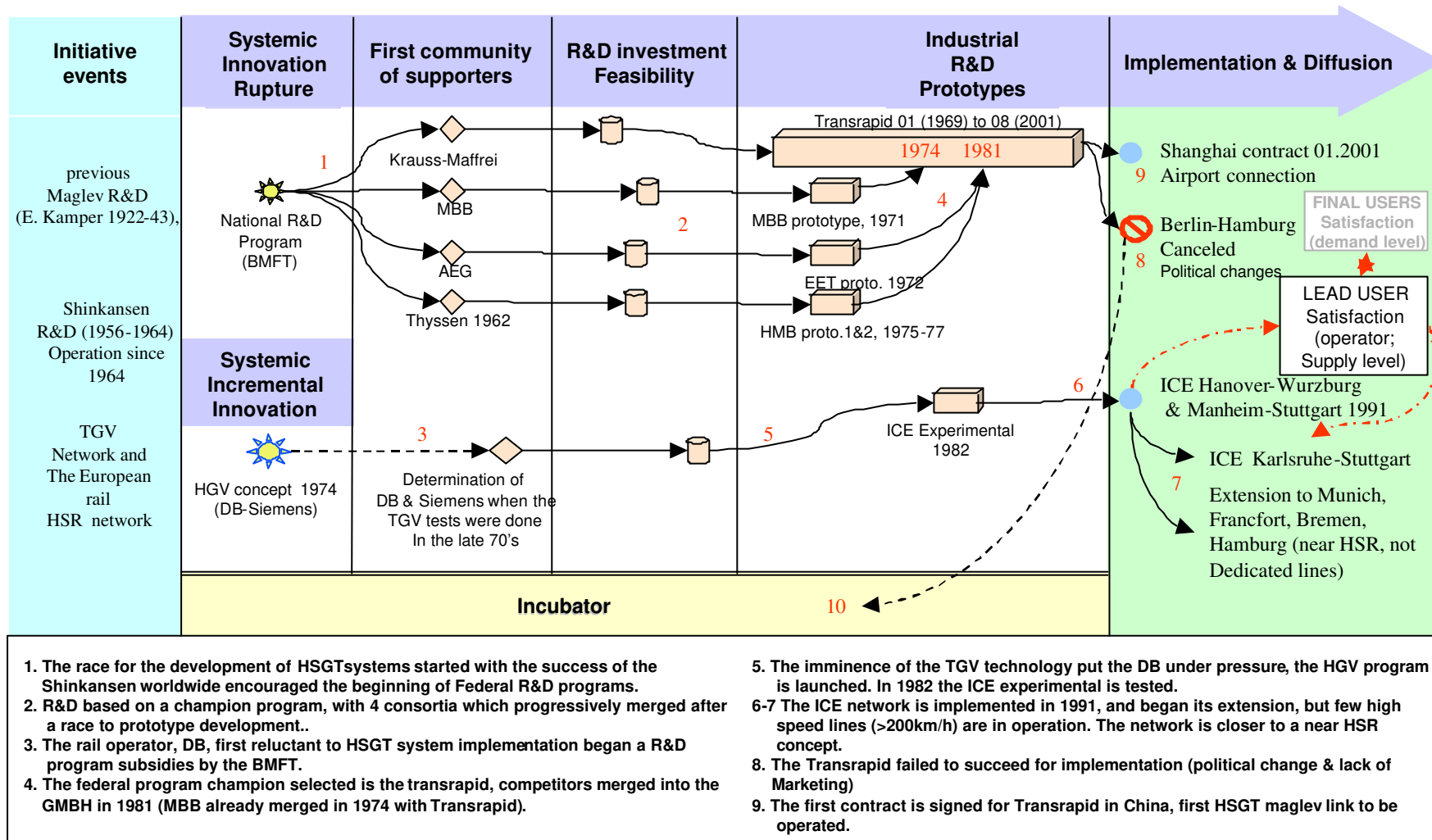


Figure 67: Innovation processes: Transrapid & ICE (Germany)

- Allowing learning by using through daily operation constraints: learning by interference between manufacturer and operator.
- Proving to other operators worldwide the viability of the system in commercial operation (which was one of the main arguments against until now).

4.3.7. The case of Swissmetro: Like a Japanese challenge in a country of wise culture?

- *Swissmetro: a third technological trajectory for HSGT systems*

Swissmetro is a concept of the 1970's, the principle of which is the use of Maglev technologies in a tunnel under partial vacuum. This invention is based on the statement that introducing High-Speed rail services in Switzerland would be too difficult and expensive as regards to the relief. However, this project is still in its infancy, as the R&D phase was achieved in order to define its feasibility in 1999. Since, facing a lack of interest, Swissmetro is waiting for political and industrial support in order to start the development phase. This step is required to solve technical uncertainties through a full-scale demonstration system.

Swissmetro is a concept resulting from the Push Innovation Model, even if some efforts have recently been achieved to justify a Pull approach, as environmental factors have greater importance than before. Such a concept is more related to a Synoptic Approach and a Rational Decision-making, with a separation between objectives and means. If Swissmetro may be seen as a futuristic technology, it may also be seen as a resurgence of 1970's concepts regarding HSGT developments and Innovation Models (with a higher performances–higher price approach).

Developing the Swissmetro is therefore like building the second generation of innovative Maglev systems, whereas the first generation painfully is reaching the implementation stage after 40 years of R&D and full-scale developments: The system required for the vacuum and the tunnel a completely new architecture, leading to a combination of the Maglev technological rupture with a new technological rupture associated with the large-scale vacuum.

Launching a third HSGT technological trajectory is a difficult challenge (as underlined by the other case studies), whereas there is probably little place for two within the actual configuration of the market.

- *Consequence of the rupture and related challenges*

Bringing the Swissmetro innovation to success, will require to succeed in three challenges:

- (a) The successful technological development
- (b) A first successful implementation.
- (c) A sufficient network deployment, as infrastructures are the support of technologies, the size of which allows the sustainability of the Technological Trajectory.

The technological rupture of Swissmetro influences these challenges, increasing difficulties when compared with the existing rail or Maglev HSGT concepts. Before describing those ones, one may argue that such a rupture is justified, from the innovators point of view, by higher performances and therefore higher benefits. However, as it will be analyzed in chapter 6, both investments and benefits are subject to much higher uncertainties.

- (a) Concerning the first challenge, relating to the technological development, it mainly stands in the complexity of the Swissmetro system. Its feasibility will have to be demonstrated especially for the large-scale vacuum system: Technologies and tools will have to be developed, probably requiring competencies from Maglev industry, as well as aerospace industry (for the development of pressurized vehicles, and aerodynamic studies): Technological difficulties will be doubled with the management

difficulties related to this new system architecture. If such a challenge can be overcome, it would be time and cost consuming, requiring a constant effort of development.

(b) The second challenge, relating to a first implementation, requires:

First, to obtain a concession demand, delivered by institutions (usually the Department of Transportation). This consists in an assessment of the System based on safety analysis and feasibility. For technologies with strong technological ruptures, this procedure remains very difficult, as all these standards are usually defined for existing technologies (rail systems, tramways, buses): Institutions are therefore a key actor in the development process, depending on their attitude toward change (elaboration of new procedures and frameworks).¹¹⁹

(b)&(c) To be supported by the current operator, the strategy of which must integrate the new transportation mode in a global network, providing and adapting interconnections. This remains the main challenge for Swissmetro, as the main connections are already operating with new tilting trains – large investments have been made to upgrade these corridors through the Rail 2000 Program. Introducing Swissmetro on these links would lead to losses for the Operator, as intercity trains have to be removed, leading to a negative NPV of the project for this actor.¹²⁰ This implies that the Government should introduce compensation measures to support the emergence of the new technological trajectory (in conflict with current rail investments) in order to see the operator play a leading role.

- *The importance of the timing*

If the crucial step for Swissmetro and the question of its industrial development (with the concession demand) occurred at the end of the 1990's, it was during a period of strong engagement in favor of rail technologies: The completion of the Rail 2000 Program, with the upgrading of the main lines as well as new train-sets orders (introduction of the tilting vehicles and double-deck passenger cars) reached its terminal phase. Moreover, the approbation of the NLFA Project engaged the Swiss Confederation on a CHF 30 Billion for a new rail corridor Switzerland-Italy destined to rail freight freeways and HSR services. Such investments let little place to the development for an actual massive support from the Confederation, leading to a slowing phase for the project.

- *What support and from which industry?*

Swissmetro is an atypical project, which has neither emerged from the will of industry (in order to enter into new market niches) neither from the national operator (CFF), but from a scientific community. Its inventor, R. Nieth was an outsider at the CFF when he proposed the concept in 1974. A group of professors at EPFL rallied his cause and started several researches. The project finally got attention from several politics in 1985 and the DETEC ordered a feasibility study to Dornier (Consulting group working also for the Transrapid). This led to the financing of preliminary studies (CHF 1.8 Million; 1990-93), followed by the feasibility study (CHF 14 Million; 1993-98).

The Swissmetro project was mainly supported by a scientific network, which was strongly connected to academics and allowed the political support to the concept. However, Switzerland doesn't have an industry active in such transportation technologies (Rail or Maglev). Therefore foreign groups such as Alstom or Adtranz were interested, as shareholders, but their motivation was more to sell their technology to Swissmetro (TGV/Transrapid) rather than financing the project (technology watch, and influence).

¹¹⁹ In Switzerland, the Transportation Department (DETEC) intervened for two concepts of rupture: It assessed the Swissmetro mainly based on the rail legislation in 1998 (de Tilière 2000 p. 53); and the Serpentine, a new magnetic guided people mover - 4 to 6 passengers - has been assessed based on the Trolley-bus legislation: tests have been authorized for a public demonstration but without passengers.

¹²⁰ De Tilière 1997 p.149-153; this constitutes the main problem of introducing new HSGT modes on already operated and upgraded links, which profitability is high. Gentinetta 1997 pp. 424, 430; the NPV of the Swissmetro for the intrinsic project varies from CHF -2.3 to -2.9 billion (for three projects: Geneva-Lausanne, Zürich-Basel, Zürich-Bern, with $i=10\%$), and the project NPV calculated for the CFF is between CHF -0.1 to -0.6 billion (See methodology in section 6.4.3).

Therefore, if the first phase of R&D was easy to start, with the strong credibility of EPFL face to politics, the epistemic community won't have the same influence on the foreign industry and the operator. The lack of industrial support since the beginning, in terms of leading role, now becomes a lock-in factor.

If one looks at the future rents of innovation for manufacturers, one can imagine an optimistic scenario of implementation: If a 80 km first pilot track is build in the next 20 years, this will lead to an order of 20 vehicles. Then if another link can be build 25 years after, leading to an order of 20 train-sets in a first step and 40 after including renewals (with 4 vehicles per train-set). If we compare to the HSR market (also benefiting from other rail technologies Infratechnology and support), Swissmetro would be difficult to sustain if it is not linked to other transportation product families, as underlined by the comparison in the table below:

Technology	Average production of railcars per year	Period	Total production
Shinkansen	199 units	1963-2002	7 347 units
TGV	272 units	1978-2002	6 255 units
ICE	170 units	1985-2002	2 724 units
Swissmetro	4 units	2020-2060	80 units

Table 9: Production of vehicles, comparison between HSR numbers and hypothetical Swissmetro forecasts

Moreover, if the average production of TGV railcars per year has been boosted by the exportation of the system, Swissmetro wouldn't find the same opportunities abroad (difficulty in extending rapidly the network in Switzerland and Europe as well as in exporting the system because of its expensive costs and non-compatibility).

The difficulty when compared with other existing technological trajectories, is that Swissmetro doesn't benefit from the same convergence of paradigms, especially the one related to the development of a competitive national industry associated with the innovation: German, Japanese and French technologies benefit from this convergence.

This being said, the Swissmetro development phase, estimated at CHF 600 Million (for a 8 km pilot-track implemented on the future line in order to reduce future investments costs) seems to be locked until a change of paradigm occurs, or until the project is recoded.

- *Conclusion: recoding the project instead of waiting for changes in paradigms*

Waiting for change in Paradigms and their convergence in favor of the project, without reengineering or recoding should lead to its death. Swissmetro is characterized by a very high degree of inflexibility, and work has now to be done to find ways to reduce such a disadvantage without losing its core objectives.

The project must be focused on its core characteristics which is underground High-Speed under partial vacuum and must adapt technologies of vehicle already developed (modified HSR train-sets or Transrapid vehicles): Efforts have to be done to patent results on large-scale vacuum systems and to find alternatives to adapt the system for the use of both rail and Maglev systems in order to keep options open. Swissmetro has to make its concept attractive for manufacturers, arguing that it may lead to the development of a new family for their products (HSR/Maglev). Reducing the gap between the Swissmetro concept and existing HSGT technologies can be the only way for the project to get the support of the HSGT industry.

In the other hand, efforts have to be achieved to propose and discuss alternatives with operators, as they are key partners in the European context (as soon as politics and Governments don't want to support the full cost of implementation).

Recoding the project requires a definition of several alternatives (concepts), and to define how they influence CFF activities and profitability (as European operators are on pressure to become profitable).

Such analysis has not been achieved in the concession demand, and the DETEC asked for pilot track for connecting the two Airports of Basel and Zurich instead of CFF intercity corridors. This puts back into question the idea of a Swissmetro network, without which the development of this technology would not be sustainable.

Current paradigms are not converging towards this futuristic project. This leads to a critical phase where the public support will be required to maintain such an option for the future: The lack of resource can induce part of scientists and know-how to leave. The most difficult challenge for such project therefore consists in managing discontinuities, especially when the cohesion of the consortium is relatively weak.

4.3.8. Toward an Innovation Model for HSGT technologies

- *Analyzing case-studies through Generic Innovation and Decision-making Models*

Innovation Models presented in section 4.1 provide a good understanding of key processes, as well as of mechanisms between actors, leading to change and technological innovation. In order to better understand why an Innovation Model may correspond to rupture or Incrementalism, the analysis of Decision-making Models provided a better insight.

There-hand, understanding the role of actors and the influence of the context (changes in the HSGT market) will now lead to an effort to define the main Innovation Models related to the emergence of HSGT technologies.

- *Modeling the HSGT Innovation Process: HSGT Innovation Model*

Through the case studies, critical factors for the development or failure of innovations have been identified. For each case study innovation processes have been modeled and can now be summarized in the models that will be described bellow.

The main conclusion is that major architectural or systemic innovations in the HSGT market which succeeded were initiated by national operators: JNR for the Shinkansen, SNCF for the TGV and Deutsche Bahn for the ICE. Moreover, all projects led by the manufacturers or the industry in order to develop alternative technologies, were strongly supported by national R&D programs (Aerotrain, Maglev technologies etc).

In other words, innovation with strong technological rupture managed through private R&D programs only (industrial R&D strategies) were only focused on subsystems or component but not on radical architectural innovations.

Concerning Innovation Models, radical architectural innovations can be initiated through two ways:

1. Political choice: New option for the transportation system. Public investment in a R&D Program, aiming at supporting the industry in the development of the innovation as well as the operator for the diffusion of the new Technological Trajectory (Figure 68).
2. Operator Choice: A new strategy envisioned by operators can require the development of technological innovations. Operators therefore finance the R&D achieved by manufacturers, or share expenses depending on the forecasted rents of the innovation (Figure 69). A public support may occur, if these objectives correspond to an active transportation policy.

The HSGT market is too narrow for manufacturers to initiate alone radical systemic innovations, if this is not part of an operator strategy. They therefore try as long as possible to innovate on the same technological path.

The exception is thus when political choices allow to develop HSGT alternatives: They can be achieved only where national R&D policies allowed such innovations (such as the cases of the Aerotrain, the Transrapid or The MLX-01). In this case, the risk taken by private industry is subordinated to massive public funding and a guarantee of political support (long-term transportation policy).

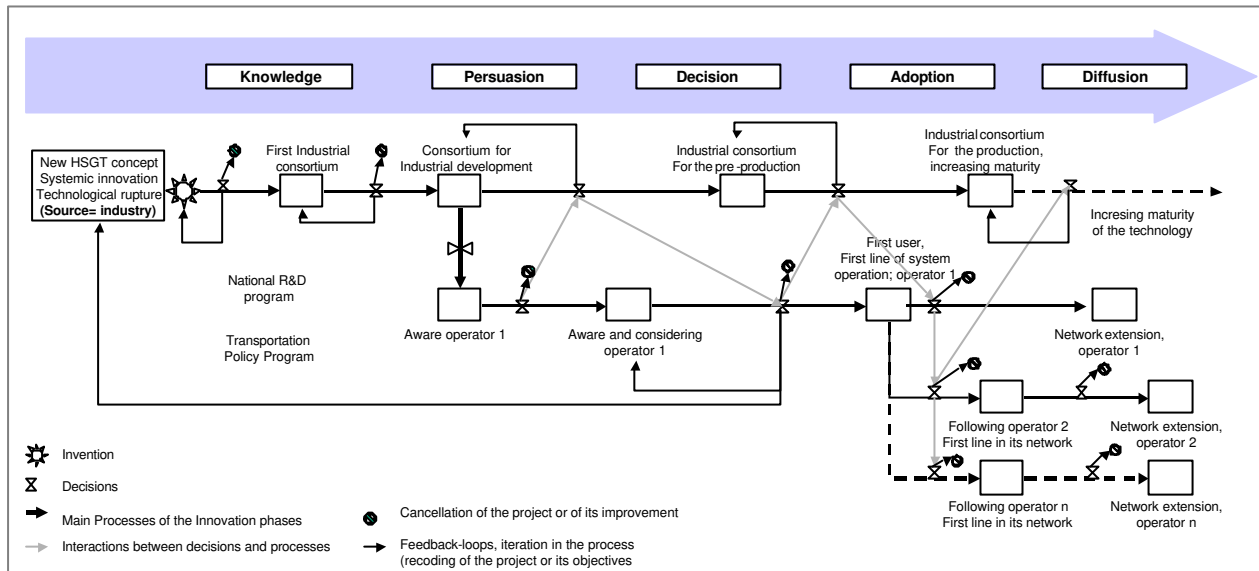


Figure 68: First HSGT Innovation Model; The Industry as the source of Innovation, (role of the manufacturers)

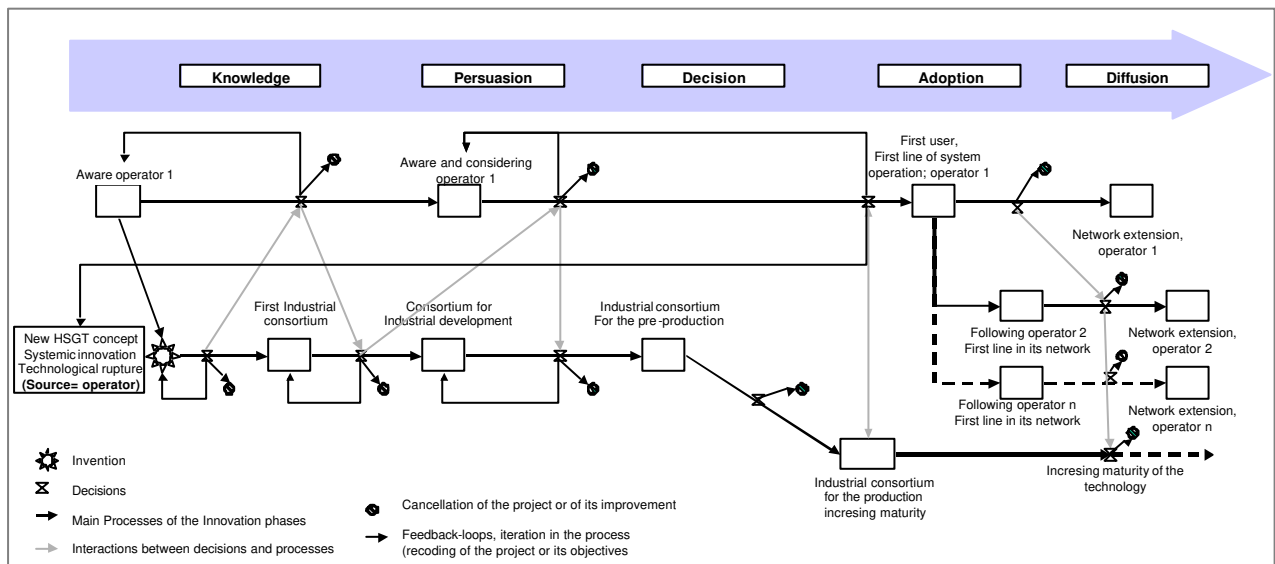


Figure 69: Second HSGT Innovation Model; The operator as the source of innovation (role of the lead-users)

In these models, feedback-loops underline the chaotic process of Innovation, leading some times to redefine the concept or to recode the project in order to avoid its cancellation.

- *Critical factors in the HSGT Innovation Processes*

The cases-studies provided lessons on the critical factors affecting the development or the diffusion of HSGT innovations. The set of these factors can be classified in four categories (Figure 70):

- Technology
- Organizational factors and management
- Market structure
- Strategy & Policy

The figure details these four categories of factors as well as their interactions. These factors can also be classified depending on the following structure:

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. System/Environment factors <ul style="list-style-type: none"> - Organizational - Inter-Organizational - Industrial standards - Operator's standards | <ol style="list-style-type: none"> 2. Decision factors <ul style="list-style-type: none"> - Cost/Benefits - Network externalities/scale economies |
|---|---|

The concept of analyzing interactions of factors (as well as their influence on the Innovation Process) is based on the concept of cognitive maps developed by Axelrod.¹²¹ Such a concept is also well described in the researches of Eden¹²² and Weick.¹²³

- *HSGT Innovation Models: Process and critical factors*

The combination of the two HSGT Innovation Processes defined above with the set of critical factors allows to define two HSGT Innovation Models (described in the figures pages 141-142). In order to don't put too much information on the figures, feedback-loops are not drawn again, but are the same as in the figures above.

These two Models describe the emergence process of HSGT technological trajectories: Architectural or systemic HSGT innovations are possible with the combined support of Operator, Industry and Public sector (Politics and Institutions).

These two models result from a shift in the source of innovation (Industry or operator), influenced by the role of the public sector. This shift leads to the adoption of an Innovation Model or another (configuration), and is achieved through changes in the critical factors described above. In order to better understand these interactions, the next chapter will focus on several important aspects regarding to the building blocks of these models.

¹²¹ Axelrod, R. (1976). *Structure of Decision: the Cognitive Maps of Political Elites*. Princeton NJ: Princeton University Press.

¹²² Eden C. (1989): "Using cognitive mapping for strategic options development and analysis (SODA)", In: J. Rosenhead, ed. *Rational Analysis for a Problematic World*. John Wiley & Sons, Chichester (1989), pp. 21-42. Eden C., Ackermann F., Cropper S. (1992): "The analysis of cause maps", *Journal of Management Studies* 29, 3, 309-324.

¹²³ Weick K.E., Bougon M.G., (1986): "Organizations as cognitive maps: charting ways to success and failure". In: H. P. Sims and D. A. Giola, eds. *The thinking organization*. Josey-Bass, San-Francisco, pp.102-135.

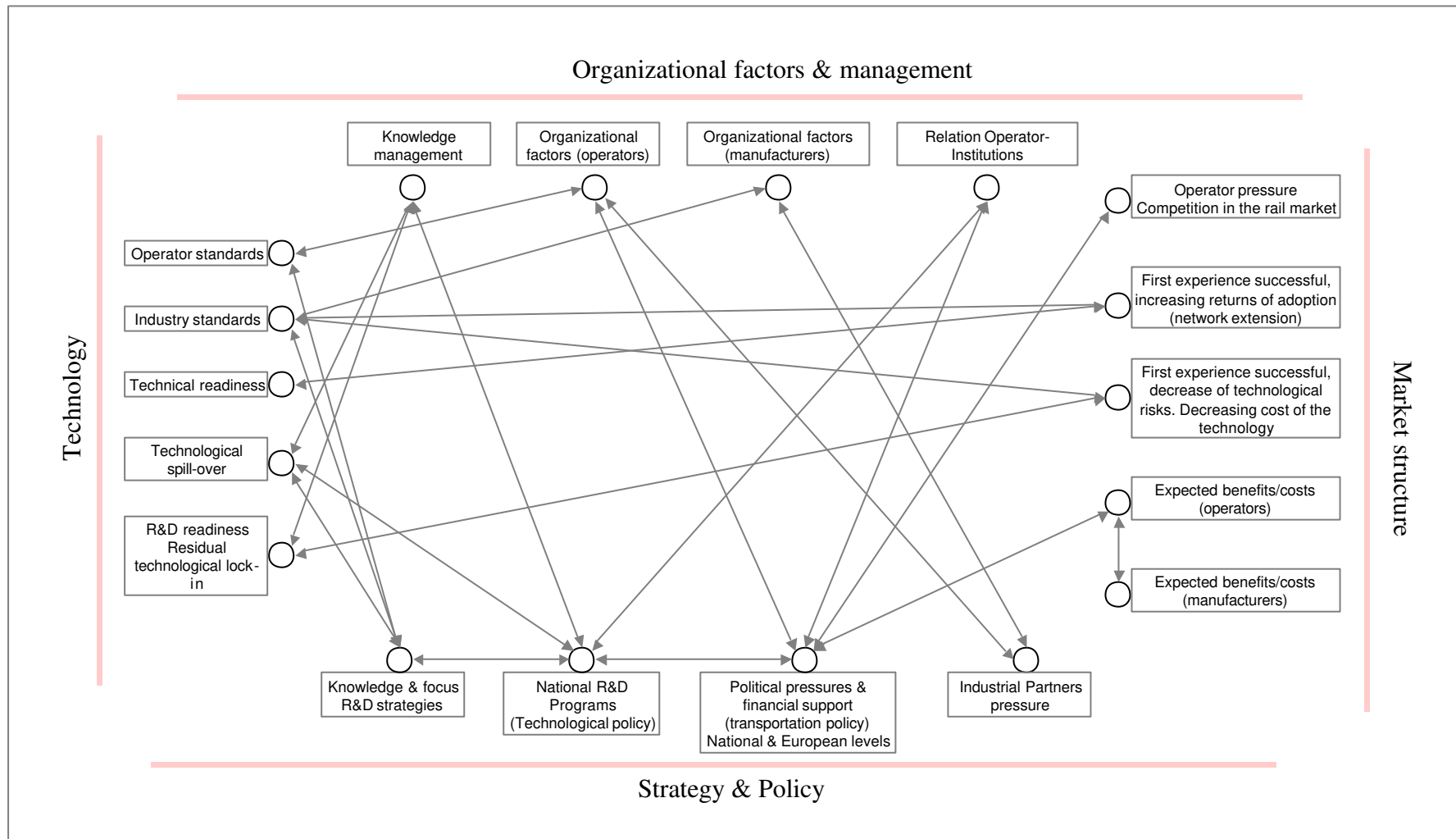


Figure 70: Main decision factors of the HSGT Innovation Model and their interdependencies.

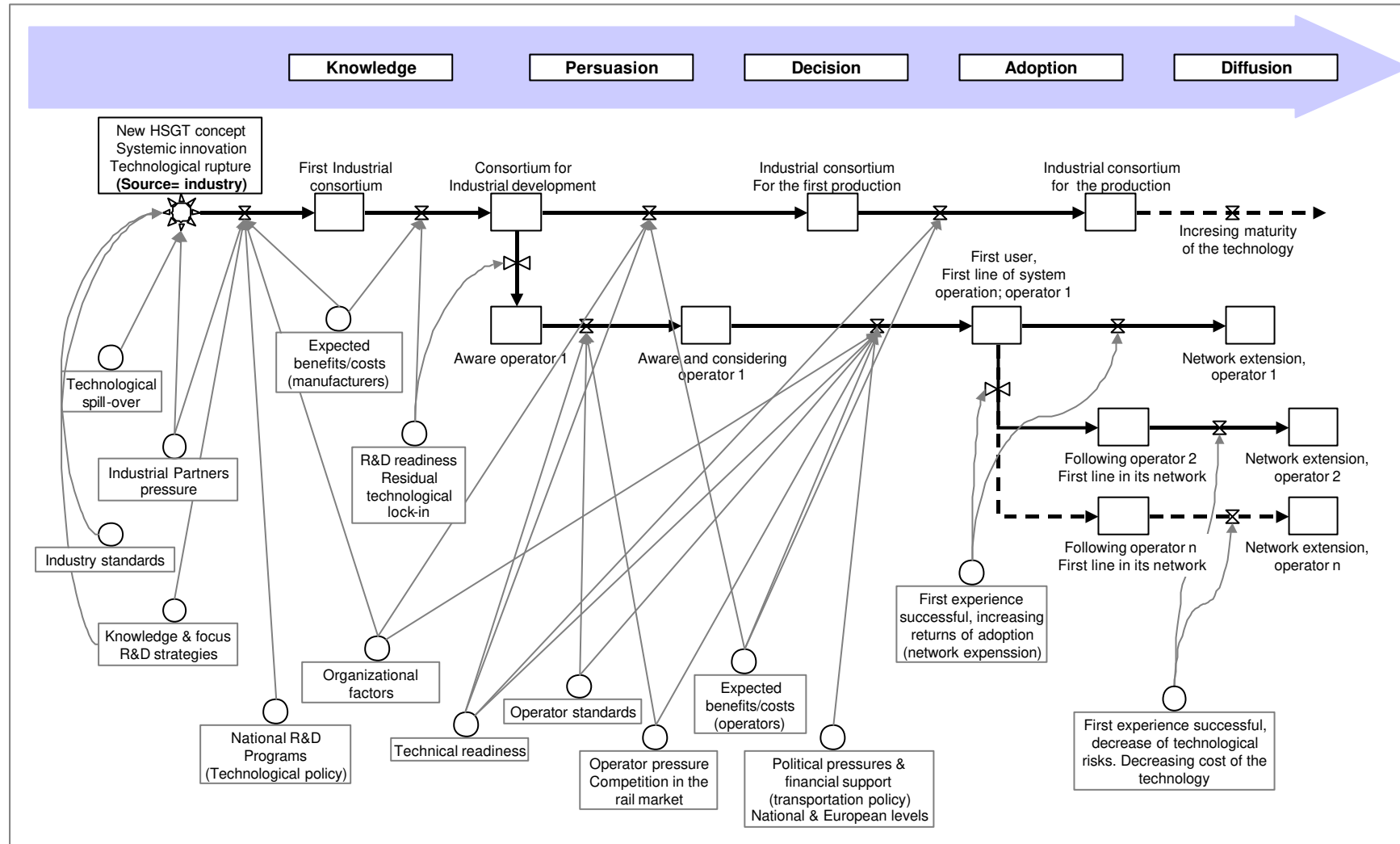


Figure 71: Innovation Model – Industry as the source of innovation through national R&D programs: Structure and Processes

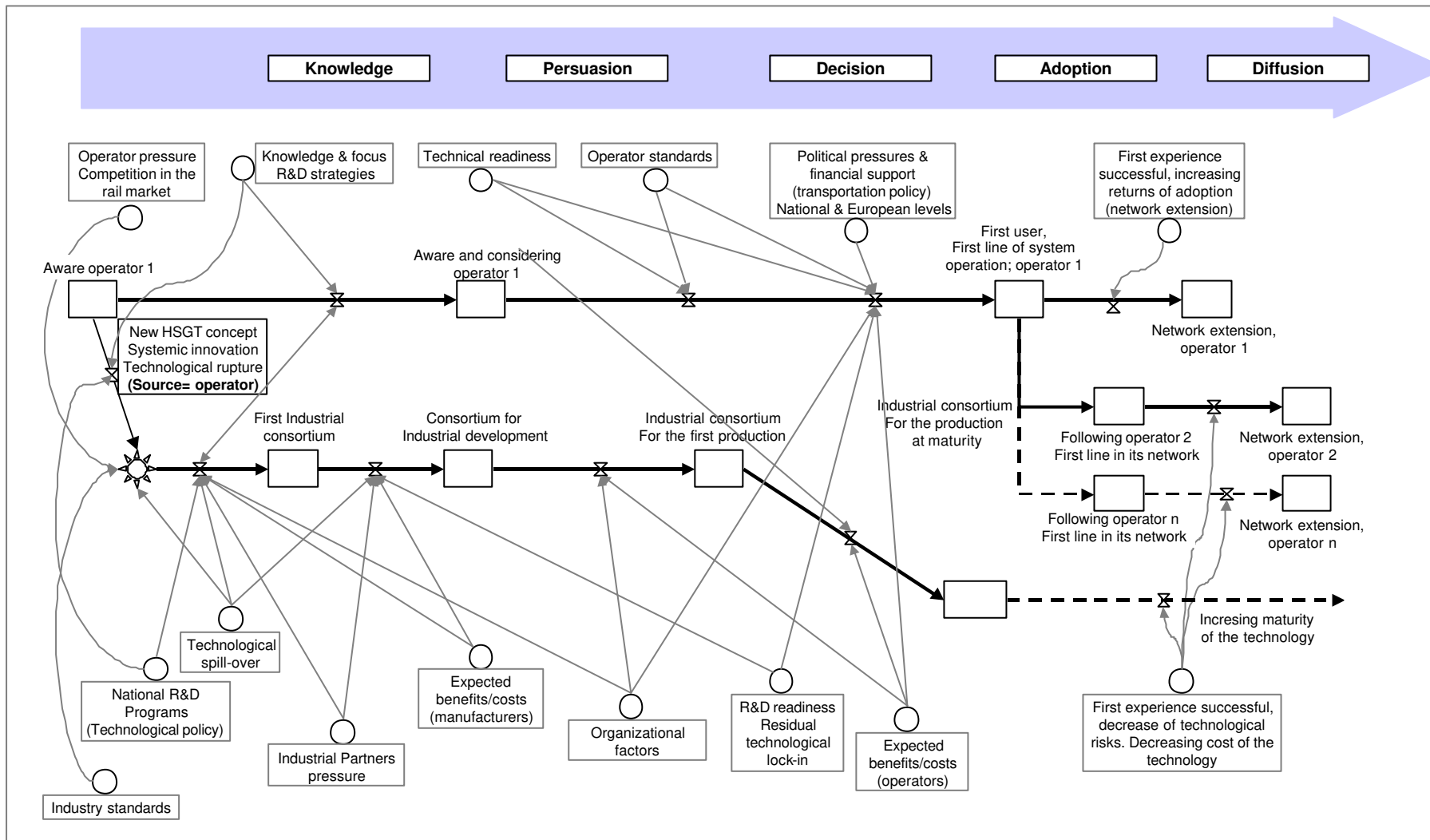


Figure 72: Innovation Model –Operators as the source of innovation

4.4. Conclusion

- *Decision-making Models and Innovation Models*

This chapter first emphasizes on Generic Innovation Models, underlining the particularity of HSGT Innovations and allowing to develop accurate tools in order to understand innovation processes (such as the HSGT Diffusion Models). Five generations of models, including the “push”, “pull” and “interactive” ones provide a good overview of the evolution of innovation management. However, the Specific Innovation Models (such as the “Barrier-Breakthrough Innovation Model” and “Increasing returns of Adoption Innovation Model”) allow to highlight the main patterns of such HSGT innovations. Those Models are important and provide an important basis for the elaboration of an HSGT Innovation Model.

However, understanding decision-making processes remains critical, since they influence strategies and thus the type of innovation. A Generic Decision-making Model, leading into three main types of models was worked out, in order to better understand the main HSGT strategies described in the case studies.

These case studies allowed to define two HSGT Innovation Models, as regards to technological Trajectories, as well as to identify the role of change agents in the HSGT Innovation Model. The identification of the critical factors and their influence on the Innovation Process underlined the importance of a multi-perspective approach that will be developed further in the next chapters.

- *Innovation Model and the role of Innovation Building Blocks*

The diffusion phase of the Innovation Model, underlines the fact that successful innovations do not require only successful product development, nor only a first successful adoption, but also a successful diffusion leading to market success. The market success guarantees the sustainability of a technological trajectory, without what investments are partly or completely lost. The diffusion phase will determine whether the technology will survive in the long-term or not. It will therefore allow the development of a new sustainable Technological Trajectory.

If the diffusion of innovations follows an S-curve, the first adoptions of a system (technology) are critical: a “critical mass” has to be reached for any further adoptions. When this threshold is reached, then the adoption rate accelerates (network extension).

If lead-users (operators) constitutes the “distribution networks” of HSGT technologies, they have the ability to lock-in and control the S-curve of an innovation and allow or not the required “critical mass”.

If a first implementation was usually possible with the support of governments, diffusion in other countries rapidly leads to the difficulty of adoption by existing operators.¹²⁴ Therefore, such thresholds effects are critical for success: Successful HSGT technologies with strong technological rupture were developed through protected national niches and expended to national transportation networks.

The following chapter will analyze the relation between the building blocks of these Innovation Models, looking for more explanation about the formulation of strategies and the mechanisms leading to one HSGT Innovation Model or another. Building blocks will be given into three layers:

- The innovation sources, also including the demand side (paragraph 5.2)
- Organizations (paragraph 5.3)
- The role of public policy and institutions (paragraph 5.4)

¹²⁴ This problem occurred for two technologies of Maglev metro in Berlin and Birmingham, leading to the decommissioning of both projects after few years of operation (increasing costs of maintenance and reengineering due to the lack of standardization).

Finally, the main influence of organizational and institutional factors on the HSGT Innovation Models will be analyzed in paragraph 5.5.

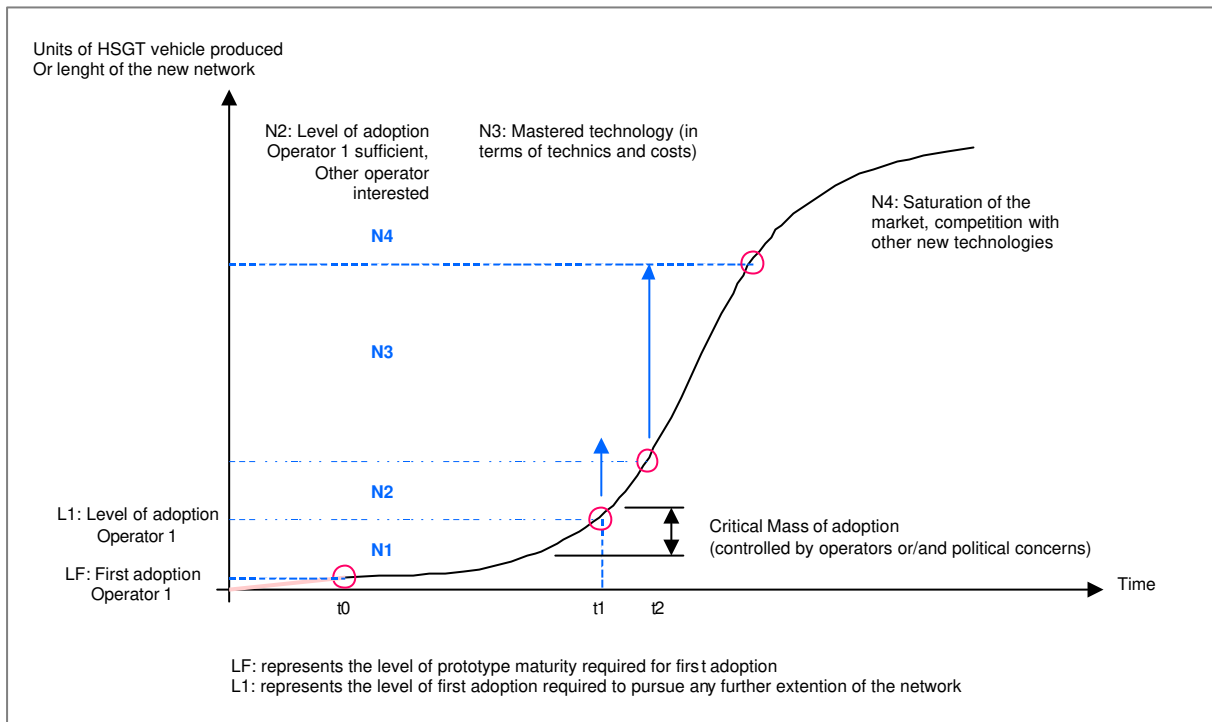


Figure 73: Emergence and diffusion of HSGT innovations, S-curve and the notion of critical mass.

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1. Introduction

2. The case of high-speed ground transportation projects

3. Innovation and rupture

4. Towards an Innovation Model for HSGT systems



5. How organizational and Institutional factors influence Innovation Models

6. Impact of the technological rupture on Risk & Uncertainties

7. Managing the Development of New Technological Trajectories

8. Conclusion

ANNEX: Project Management Assessment System

*“The role of epistemic communities and paradigms in the innovation process:
What makes successes and failures; the importance of networking”.*

5. How organizational and Institutional factors influence Innovation Models

5.1. Introduction

As underlined in the case studies and the two Innovation Models developed in chapter 4, Innovation is a distributed process between the actors contributing to the development and the diffusion of the HSGT technologies. Understanding how innovative technologies can emerge requires the understanding of the role of these actors and what influence they have in this global process.

If the chapter 4 emphasized more on processes, this present chapter aims at better understanding the relations between the building blocks of the two HSGT Innovation Models: Industry, Operators, Institutions (and politics), Academic research (Figure 74). An emphasis will be put on the role of these actors and on how their strategies are influenced by organizational and political factors (based on the Decision-making Models developed in sections 4.2.3 to 4.2.6).

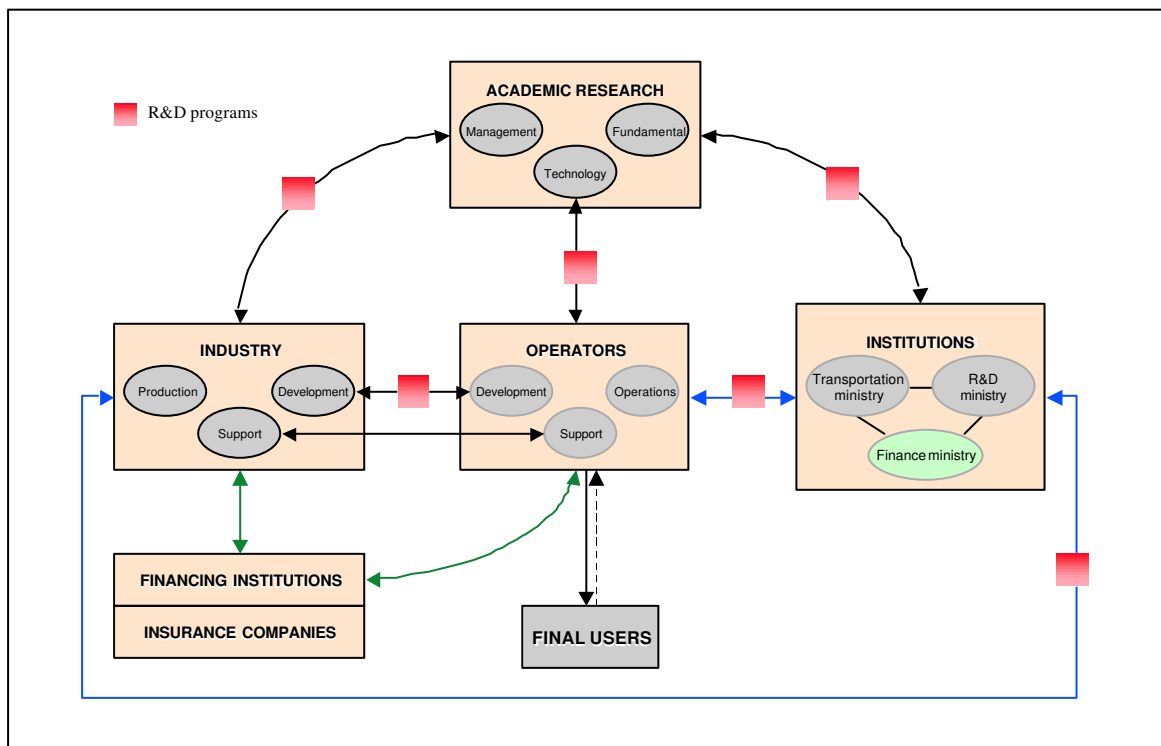


Figure 74: Main Actors involved in the development of HSGT Innovations

5.2. The sources of innovation

5.2.1. The role of Operators as lead-users

- *About the role of operators in the Two Innovation Models*

The lead-users of HSGT systems are Operators, which are supplying transportation services. They play a key role in innovation processes in the two HSGT Innovation Models defined in chapter 4 (page 138). This underlines the notion developed by von Hippel (1988) of the functional sources of innovation: The Operators of a technology bring new ideas on the product and its usage to manufacturers (learning by using and learning by interference with users). Through their experience in systems operation, they have a key position in the innovation process: They define needs as well as new possible applications of technologies. The following points describe several conclusions provided by the two HSGT Innovation Models and the case studies.

- *From the technical to the functional specifications*

Operators push manufacturers to innovate by defining new needs and proposing new concepts that fits to their activities or to the technologies they use. Their role can range from technical specifications (such as SNCF with Alstom until the 90's) to functional specifications. However their role is more and more focused on functional specification, due to the globalization of the HSGT market of manufacturers (see section 2.4.3 p.46).

- *The power of lead-users in the adoption and diffusion process*

In the First HSGT Innovation Model, Maglev HSGT technologies were more the product of a Push Model, resulting from a convergence of paradigms: The source of innovation comes from research institutions, from manufacturers looking for new market niches, and is eventually slightly supported by operators as a future option (Deutsche Bahn for the Transrapid and the Japanese National Railways for the MLX-01). The main problem of Maglev HSGT technologies is that there are no lead-users at the moment, except in China soon. This underlines the fact that one of the main reluctance of Operators in implementing such systems, is that there has been no commercial operation until now (risks associated with the debugging of the first generation of products). In Germany, the DB is reluctant to its implementation (in conflict with the ICE network) and in Japan the future of the MLX-01, currently under the responsibility of the Rail Technical Research Institute (RTRI) is still unclear.

In the Second HSGT Innovation Model, Operators have a leading role in the Innovation process, since they propose the new concept to an industrial consortium. For instance, HSR technologies were clearly developed through the initiative of operators that needed to reverse the strong decrease of their market shares towards car and air modes. In the manufacturer-operator relation, this was more related to a Pull Innovation Model: The Innovation is a tool in the strategy of the operator in order to face competition with other modes or other operators of the same mode.

However, one may imagine the case of a government supporting the development of a new technological trajectory, with the private sector and creating a new operating company (avoiding the adoption problems by current operators engaged in rail activities). However, if this may be possible, the power of operators in main developed countries is very strong: For instance, CFF represents 22'000 employees in Switzerland leading to a strong influence on policy and institutions.

- *The key role of lead users: feed back of experience*

Lead-users know the environment of the product and the conditions of its use, as well as all details that improve reliability (learning by operating; concept of learning curve - figure p.99). The knowledge they

have is crucial for new product development and that is why manufacturers are closely working with them concerning HSR development (Interactive Innovation Model).

Concerning Maglev development, the phase of large-scale demonstration test for the Transrapid and the MLX was a way to create a virtual operator (consortium of manufacturers plus the national operator, strongly supported by public funding). Such an in vitro development aimed at learning more rapidly through the use of the system and at allowing its improvement up to its mature configuration. This is a way to prepare a market barrier breakthrough, but the risk of project cancellation is very costly (irreversibility).

Experience is therefore a key factor to be able to improve technologies with strong rupture towards affordable costs and sufficient reliability, in order to allow a market breakthrough. But such an accumulation of experience is usually embodied in organizations: Section 5.3 will develop the idea that Innovations are influenced by organizational factors.

5.2.2. The Role of Manufacturers

Manufacturers and their subcontractors provide a product to the market of operators: vehicles, track equipments etc. In the case of HSGT systems, the market is still related to HSR technologies, since no Maglev HSGT has been implemented until the first commercial contract in 2001. This led to the predominance of the Second HSGT Innovation Model concerning Systemic Innovations: The direction of the Technological Trajectory is strongly influenced by operators will, providing more importance to the functional source of Innovation (the role of lead-users, who determine the direction of the innovation).

The increasing competition since the end of the 80's, due to the opening of national markets, mainly favored component innovations with a view to improve HSR technologies: After the launch of HSR technologies through the Second HSGT Innovation Model, the continuation of innovation processes has been achieved through an Interactive Innovation Model (defined in section 4.1.1).

In the case of Maglev technologies, the Industry determined itself a new direction of innovation through national R&D programs, with a view to open new market windows. This corresponds to the Second HSGT Model: Maglev HSGT systems were developed as an alternative, with the strong support of governments. For Instance, efforts emphasized on the "after HSR generation" in order to anticipate the market one generation forward. But this was without taking into account market barriers and lock-in effects (sections 3.3.4, 4.1.2 and 4.1.3).

This being said, innovation in HSGT systems was for manufacturers a way to find new market shares and to fight for imposing new de facto standards for the new generation of technologies. The case of defense contractors in the USA is interesting: They were motivated for implementing their technologies in HSGT systems (HSGTA 1965-75, NMI 1990-93) but also for benefiting from spillover of Maglev technologies for rocket sleds applications.¹²⁵

Innovation is therefore for manufacturers and their subcontractors a key issue to win or keep their competitive advantage on the market: The acquisition and the improvement of strategic knowledge is a key issue in this perspective.

5.2.3. Which Role for Final-users and Institutions?

- *Final-users: An emphasis of Operators and Institutions*

The role of final users is finally their acceptance of the new transportation system, given by the level of demand (how many people will use the system during the operating phase). Their role is therefore a sanction of the service offered by the supplier by using the transportation system. In feasibility studies, it is

¹²⁵ See de Tilière 2001 (a) p. 34.

taken into account through demand-forecasts, whose input allows to assess the economical profitability of the system and its level of service.

However, the implementation of the system is subordinated to its social acceptability, which must be analyzed in a technological assessment. In this research the focus is put on the relation between lead-users, manufacturers, and government/institutions. The role of public acceptance is taken into account in the strategy of the government, which represents the will of citizens; and operators, which has to respond to the users needs.

- *The Role of Institutions*

Institutions play an important role in the two HSGT Innovation Models. This role emphasizes on the support of interesting inventions, which correspond to public or political objectives. Therefore, Institutions play a key role in the detection of innovations and in the support of the innovation process. Their roles related to transportation technologies are:

- Administrative support (also for each following phase).
- Financial support through R&D programs.
- Homologation of new technologies and systems.
- Attribution of concessions for Implementation and operation.
- Planning Processes for implementation.

As regards to innovation with strong technological rupture, the role of Institutions becomes crucial: They have the power to accelerate or slow down projects through administrative processes (case of the Aerotrain). Moreover, the necessity to adapt legislation to new technologies remains the main challenge (as developed in the Swissmetro case study in section 4.3.7 p.134).¹²⁶

Specifications in terms of safety norms or regulation measures can constitute important risks in large infrastructure projects. They significantly affect the development and the diffusion of HSGT technologies (as underlined in the US case study with the Acela-Express project; section 4.3.3 p.118).

Therefore, if managing Systemic Innovations with strong technological rupture requires managing change and chaos among the industry, managing change within Institutions remains a crucial factor of success.

5.2.4. Shifting the sources of innovation

- *Leverage innovation*

The sources of innovation can be shifted depending on the evolution of the market, and its phases (as defined page 66): Market phases related to the HSGT technologies are: Experimentation, Capitalization, Management, Hyper-competition, Consolidation.

The Two HSGT Innovation Models mainly refers to the three first phases, corresponding to the opportunities of launching new Technological Trajectories. When the phases of Hyper-competition and Consolidation occur, then innovation processes emphasize on improving the Technological Trajectory through Innovation in components: These processes are achieved through the Basic Innovation Models described in section 4.1.1 p.93.

For instance, in the competitive environment of experimentation occurring in China, the Government is looking among different HSGT alternatives: Manufacturers propose innovations with technological rupture as a way of building a competitive advantage on a new technological path (First HSGT Innovation Model).

¹²⁶ See also Gaudin 1978, *L'écoute de silences*, underlying the critical role of institutions in the emergence process of innovations.

If one looks at the situation in Europe, the market of Operators is in a consolidation phase, leading to the last phases of the Second Innovation Model (diffusion). This phase is accompanied by a trend of innovation focused on components, which is mainly ruled by the Interactive Model and the 5th Generation of Innovation Model (Specific Innovation Models in section 4.1.1).

- *The rents of innovation*

Shifts in innovation sources occur when rents of innovation change for actors depending on market conditions (see also von Hippel 1988 chapter 5).

As expressed in section 4.1.4, the notion of innovation's rent has to be put into perspective with the notion of barrier breakthrough, which costs are decisive. The rent of innovation is defined by future economical benefits, plus the competitive advantage in the market. The competitive advantage is also embodied in the organization, through knowledge acquisition and experience that may be available for future challenges.

From the manufacturer point of view, the rent of innovation is defined by the future revenues from sells balanced with investments: R&D investments and production costs which are associated with the development of the technology. Innovation with strong technological rupture requires substantial efforts to develop knowledge and infra-technologies, to manage change within organizations and to adapt production plants.

From the operator point of view, the rent of innovation is defined by the future revenues from operating activities balanced with investments: Specific R&D investments (concerning operation activities: maintenance costs, reliability etc) and implementation costs (associated with the technology) as well as operation costs. Systemic Innovation requires substantial efforts to manage change within the organization: knowledge acquisition and building a new experience (new formation to employees, new training).

The cost of change related to knowledge and organizations required in the case of systemic innovation represents often hidden costs, which can be very important, and are difficult to assess.

The rents of innovation also take into account more qualitative factors, dependant on knowledge, experience (defined as "sticky" by von Hippel 1988) and organizational characteristics. Since, shifts in the sources of innovation concerning HSGT technologies depend on the innovation rents expressed above, they are therefore also influenced by organizational patterns.

5.3. The influence of organizational structures

5.3.1. Introduction

- *The relation between innovation and organizational structures*

Understanding the emergence of innovation also requires a good understanding of organizations: The adoption of one Innovation Model or another depends on such considerations: It is not a hazard if HSR dedicated Networks were first developed in France and Japan, which are very centralized countries.¹²⁷ Incremental solutions (near high-speed rail) were developed such as the US Metroliner or the Swedish X-2000 in less centralized countries: Complex decision-making structures lead more often to emerging strategies, whereas centralized decision-making structures allow more deliberate strategies.

Innovations are the product of organizations, and managing projects with strong technological rupture requires to find adapted type of organization: Large firms can established a routine of innovation

¹²⁷ See also Dobbin F., 1994; *Forging industrial policy, the United States, Britain and France in the railway age*, Cambridge university press.

processes, newer and smaller companies may respond more rapidly to major shifts in the market. By the way, understanding the relation between organizational structures and innovation in the HSGT context will allow to define how project management can meet the challenge of disruptive change.¹²⁸

- *The notion of strategic management*

In the economic theory of the firm, decisions are supposed to be made depending on market prices (equilibriums) and firms are essentially alike, having the same access to information and technology. Decisions are essentially rational and predictable, virtually compelled by cost and demand conditions. The strategic management recognizes more options of choices open to managers of firms¹²⁹, underlying the importance of a knowledge market, based on the core competences of the firms.

Chandler (1962) shows that managers engage investments and modify organizational structure to make their long-term strategies work. These changes underline the relation between innovation and organizational structure, which are more than adjustments for simple efficiency reasons. The relation between the changes in strategy (rupture or Incrementalism) has an impact at all levels on organizations, as described in the table below:

	Changes in strategy (direction)	Changes in organization (state)
More conceptual	Vision	Culture
↕	Positions	Structure
	Programs	Systems
More concrete (action)	Facilities	People

Table 2: Levels and spheres of organizational changes (Mintzberg & Westley 1992)

The purpose is to understand how systemic innovation can occur and how organizational structures can shape (or be shaped by) these processes and the nature of innovation.

5.3.2. Anatomy of organizations

Providing recommendations for project management concerning technologies with strong rupture requires understanding organizational structures, coordination mechanisms. One must also look beyond existing configurations to find adapted schemes.

- *The organization and its components*

Managing projects of technological innovation requires improving the role of each of its components, with a view to reinforce innovation processes and to ensure market analysis and penetration.

Organizations are defined by six components (Mintzberg 1998): Strategic unit, techno-structure, function of logistic support, operational center, hierarchic line (which link the four first components) and an ideology (which brings them together - Figure 75).

For innovation processes, the operational center has to be divided into two major functions: conception and production. Decision-making concerning innovative strategies is based on a set of choices defined by the strategic unit, but strongly shaped by the conception unit (The conception unit, “white shirts”, is also a source of the bounded spectrum of strategic choices).

¹²⁸ Christansen C. & Overdorf M., “Meeting the challenge of disruptive change”, *Harvard business review*, March-April 2000.

¹²⁹ Teece D.J. 1998; *Strategy, technology and public policy*, Vol.2 ed. Edward Elgar; p.161.

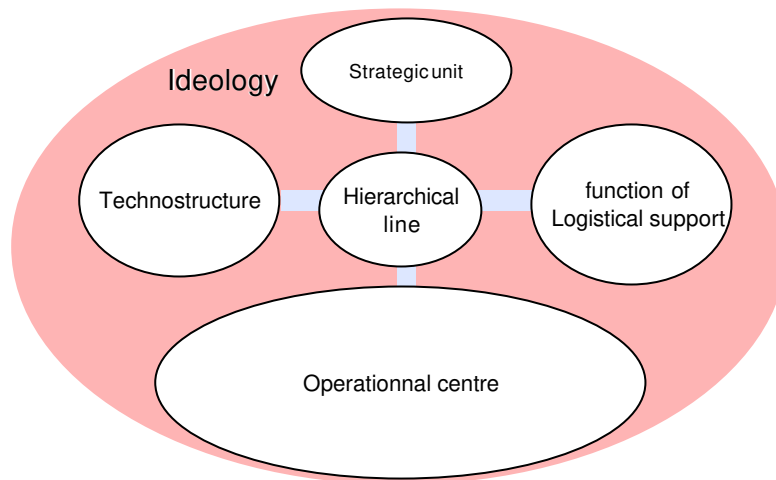


Figure 75: The components of Organization (source: Mintzberg 1998)

Ideology can be associated with culture or paradigm (see also section 5.5.2). It can define virtual organizations and integrate partners, outsourcers, suppliers and institutions. This was the case for the emergence of the Shinkansen, the TGV, the MLX and the Transrapid in a few measure: strong consortia supported by institutions (see section 5.4.2).

- *Coordination mechanisms*

Introducing changes is required in order to manage innovation processes. This implies to break several management rules (referring to the “destructive creation”) as well as to perform routines very efficiently. In order to ensure that the technological innovation won’t end into a costly technological dream, coordination mechanisms are crucial to prevent organizational breakdown: Those can induced miss-forecasting, miss-evaluation of technological lock-ins or risks.

Three of the coordination mechanisms proposed by Mintzberg (1998), are pertinent regarding our research:

- Mutual adjustment (through informal communication),
- Direct supervision,
- Standardization (of work processes, results, qualification and norms).

Mutual adjustment is probably the most important one as regards to innovation, especially in the case of complex systems: Project development requires a lot a feedback loops and interactions. Since innovation and rupture create disequilibria, flexibility and adaptability are required in this challenge. This has to be done through the improvement of mutual adjustments within the organization and between partners.

Direct supervision allows to keep the pressure on the project teams and on partners as regards to reliability, quality control and planning. One of its purpose emphasize on the control and the improvement of mutual adjustments.

Standardization doesn’t rhyme with innovation and the chaos introduced by the rupture. However, efforts achieved with a view to rationalize and standardize innovation processes are important. This allows to create rules and habits that enable to innovate more efficiently. If standardization is very difficult in the first phases of the two Innovation Models, it becomes an increasing challenge when reaching the stage of the dominant design. However, Incremental Innovations present a serious advantage, as standardization is

much more rapid, or already developed when compared with Systemic innovations with strong technological rupture. This allows to decrease costs of both products and production processes.

- *The role of the firm's culture in the innovation framework*

What Mintzberg (1998) defined as "Ideology" in his anatomy of Organization is the culture of the firm or of the organization. Ideology is the symbol of its cohesion and brings together its components as described in Figure 76 (p.158). The Ideology or the culture of the firm can be a very important element in the definition of strategies (Decision-making Models), and therefore in the Innovation Process (corresponding to one Innovation Model or another).

In order to illustrate the importance of firm's culture, one can refer to the statement of C. Lamming¹³⁰, (professor and instructor at SNCF-rolling stock department): *"Rail operators' engineers, selected among best universities, have a professional practice based on the everlastingness of a certain number of proven values. These ones, with the accumulation of experience, lead to these constant technological choices. Responsible for these choices, engineers feel on their shoulders the pressure of all constraints of a system, which requires a certainty in results and continuity in a public service. The rolling stock is build in the rules of the art, but an art which evolves slowly and carefully within a technical thought relatively closed on itself."*

The main influence of the firm's culture has, in fact, already been developed through the Generic Decision-making Model developed in section 4.2: Culture influences decisions and strategies because it shapes:

- Preference, Causality and Certainty Models (defined page 109)
- The Generic Decision-making Model: toward a Rational, Organizational or Political Decision-making Model (depending on the strength of this culture, and its impact on the structure; see Figure 76).

5.3.3. Organizational Typology and Models

- *Age and size of the organization*

The age and the size of the organization influence the formalization of its comportment. Larger and older organizations are, the more formalized they usually become, with a specialization of tasks, a strong differentiation between units and an administrative part more developed.

Moreover, organizations have the tendency to perpetuate their initial structure, which can be a difficulty in challenging the introduction of changes required for innovations with strong technological rupture (The case of railway companies is often quoted).

- *The complexity of the technological system*

Technological complexity implies functional specialists with more management responsibilities in their field. This high level of specialization induces a vertical specialization, which requires an accurate level of mutual adjustments between fields, especially for architectural/systemic innovations.

- *The environment of organizations*

In a very dynamic environment, the structure becomes more organic: In an unstable situation or when a situation is in constant evolution, standardization becomes more difficult and flexibility becomes a priority.

¹³⁰ Lamming C. 2000; « La deuxième rentrée de l'aluminium dans la construction ferroviaire », *Revue générale des chemins de fer* n°10, November 2000, pp 27-32.

In a complex environment, the structure becomes more decentralized, especially when decision-making is based on a complex core of knowledge.

When the organization has diversified markets or activities, then there is a tendency to create specialized units. In very hostile environments, the centralization of the structure (even temporarily) can allow delivering a rapid and coordinated response.

- *Typology of organizations*

Organizations models evolved from the “one best way” before the 60’s toward a more contingent approach “it all depends” (Mintzberg 1998)¹³¹. This last approach can be defined when the structure is designed with the purpose of reaching a coherent organization face to a specific environment. Concerning projects with strong technological ruptures, this last approach is more adapted in order to anticipate the effects of the rupture.

The typology of organizations can be defined by the relative importance of its components, making a pressure to increase their influence within the organization (Figure 76).

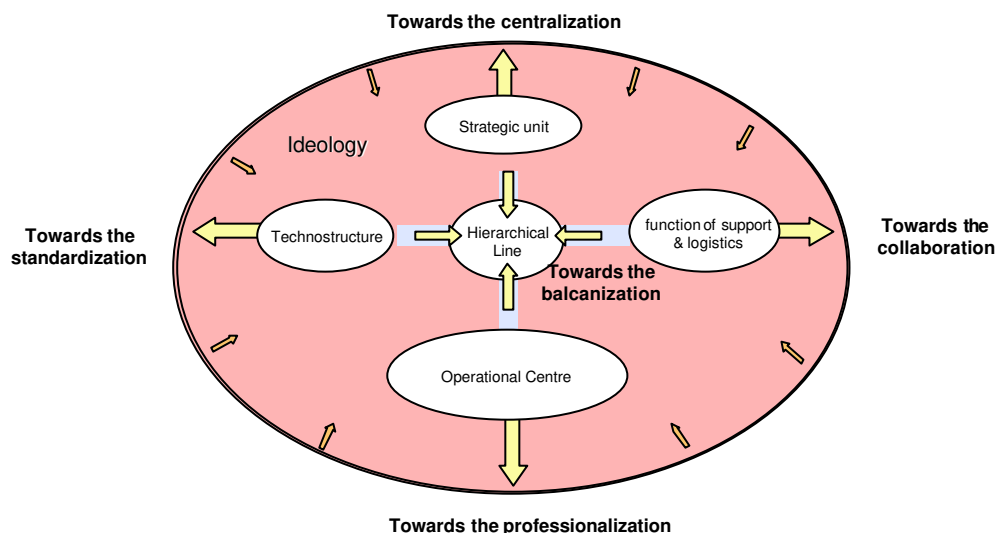


Figure 76: Influence of the organization's components on its structure (Source: Mintzberg 1998)

- *Towards the centralization: the entrepreneurial organization*

The strategic unit keeps the control on decision-making and achieves coordination through direct supervision, whose result is the centralized configuration. This trend is usually observed when there is a strong need of strategic vision.

This structure can be very efficient in order to face radical changes, such as in the case of radical systemic innovations. Concerning HSGT technologies, the most famous example of this configuration is the Aerotrain Company led by Bertin. But this structure was even used in large firms, like operators for the development of the Shinkansen and the TGV technologies: Centralization of decisions and concentration of means as underlined below.

The CEO of JNR created to some extent a project platform (creation of a new structure) in 1956 and a Project Manager followed this platform until 1964, when the first line was implemented (see case study p.115).

¹³¹ Mintzberg H, 1998; *Le management, voyage au centre des organisations*; les éditions d'organisation.

The case of the TGV is also interesting and more detailed with the creation of the TGV platform, directly put into the responsibility of the CEO of SNCF in 1966 (see case study p. 126).

Such an organizational strategy aims at shortening decision processes in order to react rapidly and to increase mutual adjustments through more direct control: This allows a better adaptation to chaotic situations, induced by the technological rupture.

- *Towards the standardization: the mechanist organization*

The techno-structure puts in place a rationalization of processes through a standardization of working processes, favoring only a limited horizontal decentralization. This kind of organization appears when there is a strong need of efficiency in routine tasks.

Such focus is mainly related to the phase of commercialization of systems: This allows reducing costs of development (for manufacturers) and of operation (for operators). Standardization can be focused on the product or on the processes; which are improved on a regular basis during the innovation diffusion process (through the experience accumulated on the technology: learning by interference and by using).

This is actually the main trend, as the HSGT Market enter into its hyper-competition and consolidation phases: Industries and operators are working on more standardization in order to decrease costs. They try to incorporate innovations, and are therefore more focused on components and subsystems: Such organizations are therefore more interested in incremental innovations.

- *Towards the balkanization: the divisional organization*

Looking for more autonomy, managers seek to increase their power in their units. This leads to a limited vertical decentralization, with a division in distinct units specialized by market activities or market sector. Performances are controlled through the standardization of results and units are structured as a mechanist configuration.

- *Towards the professionalism:*

Professionalism comes from more influence of the operational center, through the necessity of improving formation programs for experts. This implies a vertical and horizontal disintegration. Coordination mechanisms are achieved through the standardization of knowledge and qualifications.

- *Towards the cooperation: the innovative organization*

This configuration happens when functions of support and logistics push the organization for more cooperation, implying them-selves in this activity. This leads to multi-disciplinarily teams of experts, achieving coordination through mutual adjustments.

This is a key in the success of systemic innovations, especially when the technological rupture requires a multidisciplinary expertise. However, even incremental HSGT innovations are complex, involving numerous partners, and therefore require such a configuration.

The result is an increasing trend toward cooperation or "coopetition"¹³², through recombination of alliances depending on projects or contracts.

- *The role of ideology/paradigm: the missionary organization*

¹³² Coopetition describes the actual situation of HSGT manufacturers, competing for contracts, but obliged to cooperate in order to penetrate national markets or to be able to deliver big orders in short deadlines.

The ideology/paradigm encourages all members of the organization to pull together in the same direction. When this force becomes strong or predominant in the organization, the configuration turns to be missionary.

Culture, Ideology and paradigms can play a significant role, especially in the cohesion of consortia. If in incremental projects this role may be important, as actors are already in place, forming an epistemic community, it is even more crucial for projects with strong technological rupture: Paradigms and Ideology allow to surpass difficulties and discontinuities in the management of innovation. Examples of the Transrapid or the Swissmetro underline this importance for the cohesion of the project consortium (which has been strong for the Transrapid, and weak for the Swissmetro).¹³³

- *Towards an innovative organization*

Is there an organizational configuration adapted to advanced technologies and complex innovations? Managing innovation with strong technological rupture requires a flexible organization, organic with limited decentralization to keep a strong ability to make rapid decisions to face a complex and dynamic environment (discontinuities). The fusion of diverse disciplines has to be achieved through mutual adjustments. The strategy is essentially based on learning management and is defined mainly on the basis of the organization.

The main limit of this configuration is the ambiguity related to the evolution of the structure. As the project will evolve, the technology will pass through different stages: The first ones will be very chaotic (R&D phase), whereas later stages require a mechanistic structure in order to improve the system through the standardization of processes.

Therefore, this underlines the importance for managers to understand phases' characteristics as well as their related challenges, and to adapt the organization towards its more efficient configuration.

- *Beyond configurations*

Success in managing change or innovation can be less explained by the use of a unique organizational attribute, rather than the way different parameters are combined: The capacity of adaptation of the organization and its ability to create adapted configurations is a major determinant for successful project management.

Changes in organizations occur mostly by quantum jumps rather than gradually. This Darwinian evolution is achieved by punctual equilibria. For example a SWISSMETRO organization will evolve, adapting itself to the project's phases: R&D, Industrial development and realization. This is due to the fact that the structure of its actors and stakeholders will evolve along the project lifecycle (see Figure 106 p.202). These organizational changes are sometimes needed in order to solve technological lock-in, which requires new transversal teams.¹³⁴

5.3.4. The influence of Organizations on Innovation

- *Introduction*

A product can be seen as a concentrate of the organization that created and produced it. The link between organization and innovation is therefore a critical element to understand in order to provide recommendations for project management. If the link between organizational options and the degree of

¹³³ Except the strong support of the scientific and academic community for Swissmetro: The Industry and the Operator (CFF) have not a leading role.

¹³⁴ This strategy was used by the French operator SNCF to develop the TGV-01, with a new organizational platform in 1974 independent from other existing divisions (see section 4.3.4). The same strategy was used by IBM for the development of the first personal computer.

innovation has been underlined in the definition of R&D strategies (section 3.2.5), one may summarize the relation between innovation and organizational options through the Figure 77 (see next page).

This relation between Innovation and organizational structure is critical in order to understand and anticipate changes in the configuration of the HSGT Market or Industry. Opening of national markets, privatizations and mergers have consequences on the development of future innovations. Therefore decision-makers and project managers ought to understand current trends and their impacts in order to formulate adapted and sustainable strategies.

The following paragraphs analyze this relation for the HSGT industry to point out what consequences on strategic management current trends might have.

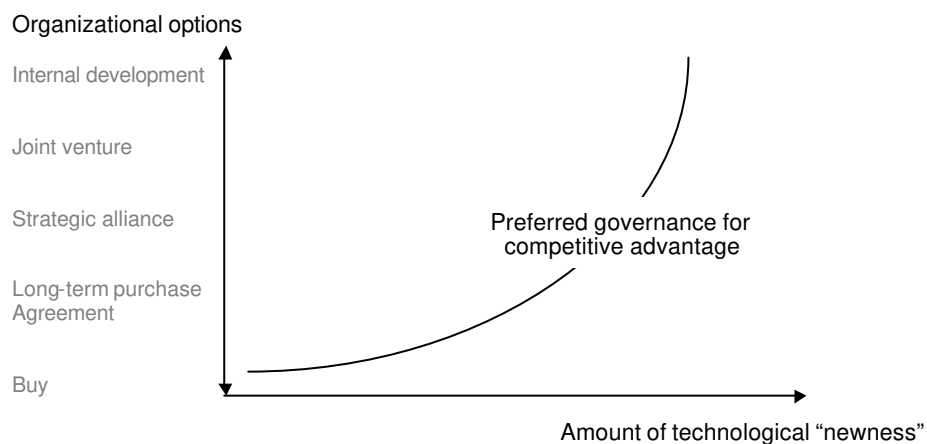


Figure 77: Finding the right degree of centralization (adapted from Teece 2000)

- *HSGT Strategies: project oriented versus organization oriented*

Innovation projects analyzed through case studies can be classified into two categories, corresponding to the two HSGT Innovations Models developed in chapter 4 (p.137). These categories are based on innovation strategies and the role of organizational structures, leading to two approaches in the development of technological innovations:

- Project oriented: Project Based Strategies

The innovation project is the leitmotiv for its stakeholders and its nature determines the organizational structure (Figure 78). This characterizes more the projects with strong technological rupture like Swissmetro (whose organizational configuration is close to a virtual organization) or Transrapid.

It corresponds to the First HSGT Innovation Model, where the convergence of paradigms leads to a consortium aiming at the long-term development of the new Technological Trajectory.

- Organization oriented: Organization Based Strategies

The organization defines innovation projects, which minimize its transformation (ruptures related to knowledge and organizational structures): The nature of the organization determines the spectrum of option for projects and innovations, which purpose is to ensure the sustainability of its activities (Figure 79).

It corresponds to the Second HSGT Innovation Model, where a systemic incremental innovation is the result of a strategy, the purpose of which is to maximize the benefits of staying on the same Technological Trajectory (rail for instance). This was the case of HSR and Tilting technologies, developed through the impulsion of operators.

- *The notion of Organizational path dependency*

In order to explain choices between Project Based or Organization Based Strategies, the notion of organizational path dependency can be developed: Operators have usually a strong sub-system logic, with a structure based on professions. Therefore, introducing systemic change becomes much more difficult than Incrementalism, which allows to innovate in sub-systems.

With the development of rail networks, rail operators are big actors on national scenes. They are therefore usually not avoidable in the transportation debate, giving a strong influence to such organizational path dependency. Considering final users as the market of transportation systems, operators can be considered as a commercial distribution network for the access of this market.

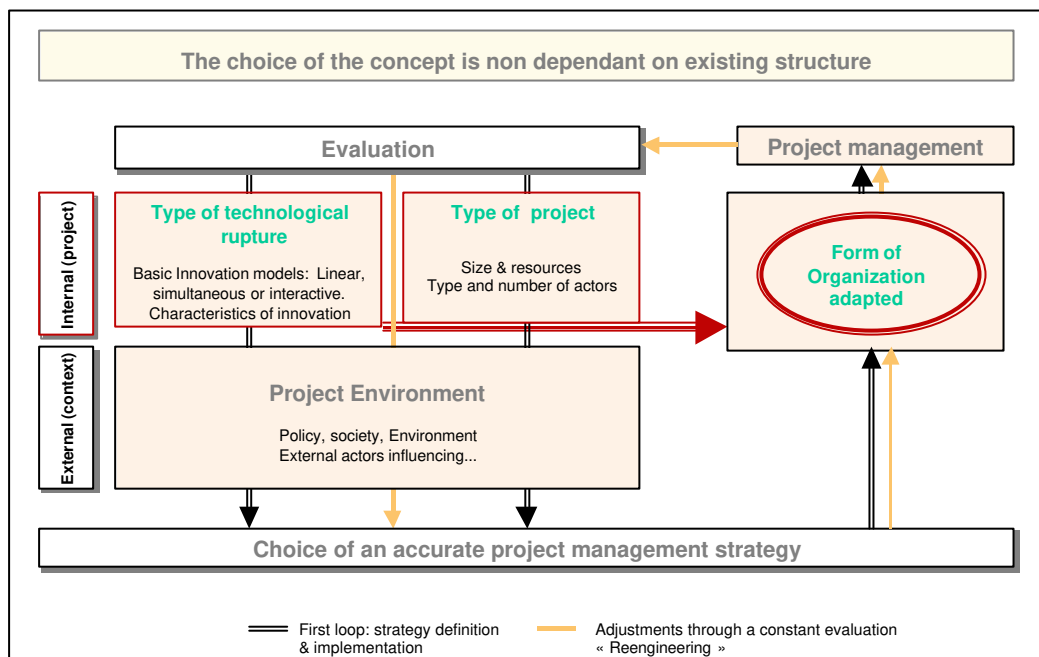


Figure 78: Project based organization; case of Maglev technologies

In both German and Japanese Maglev projects, the national operator was also a key player, bringing the project into an advanced stage (before the introduction of the ICE network for the Deutsche Bahn): Maglev technologies were thought as to be the future generation of HSGT systems. In Switzerland, the Swissmetro project is in competition with the most profitable lines of the CFF: This rendered the position of the CFF more ambiguous towards the Maglev project (especially when budgets for the Rail 2000 program were discussed).

The abandonment value of the current system (technology) has therefore also to be included into economical analysis and can be a major brake to innovation (support of the lead-user). This has to be analyzed deeper in further research programs for the technological assessment. These mitigation measures for project management have to describe what organizational changes have to be conducted: These changes concern mainly the transition between the actual rail system towards a rail system focused on regional and freight traffic, since the Maglev network will focus on high-speed intercity connections.

As said before, the organizational path-dependency is even stronger for large and old organizations, such as rail operators. This constitutes also a side of the lock-in described in the model of section 4.1.2.

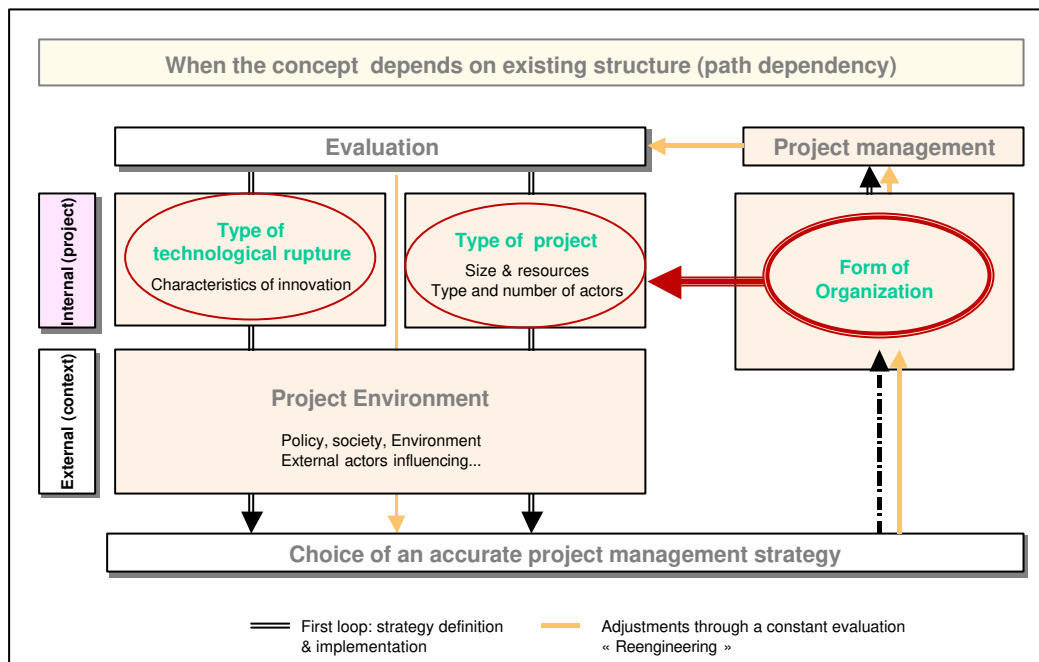


Figure 79: Organization based strategies. HSR technologies maximizing transition path, Incrementalism.

5.3.5. Towards the definition of HSGT Organizational Models

Based on the case studies, three Organizational Models can be developed in order to complete the understanding of the two HSGT Innovation Models. These Organizational Models might fit to both Innovation Models, but rather explain the speed of the development phases or of the diffusion process of innovations. These Models are developed below with the lessons drawn from case studies.

The influence of the three HSGT Organizational Models on the Decision Making Models and on the HSGT Innovation Models will be analyzed.

- *The Integrated HSGT Organizational model; Industry-Operator-Institutions*

HSR innovations such as Shinkansen or TGV were the result of strong consortia, including the national operator and the manufacturer (JNR/Mitsubishi-heavy or SNCF/Alstom) through a quasi-vertical integration (Quinet 1999). This strong integration favored the emergence of systemic innovation. Moreover, the relation between national operators and institutions also reinforced this effect of vertical integration, through the cohesion of an epistemic community bringing together these three building blocks (Figure 80).

This first Model is the Centralized HSGT Organizational Model (Industry-Operator-Institutions), whose vertical integration of innovation actors (building blocks) was mainly underlined through national R&D programs. These programs aimed at the development of national technologies (mainly concerning countries that have national manufacturers and operators in the HSGT or rail sector).

The impacts of this first Organizational Model on Decision-making Models and on the HSGT Innovations Model are significant. This induces a more centralized decision-making, bringing the Generic Decision-making Model closer to the Rational Decision-making Model (when compared with the two following

Organizational Models). Moreover, it can lead to significant shortenings in the phases of the two HSGT Innovation Models (especially in transition phases, since decisions can be taken more rapidly than in decentralized systems).

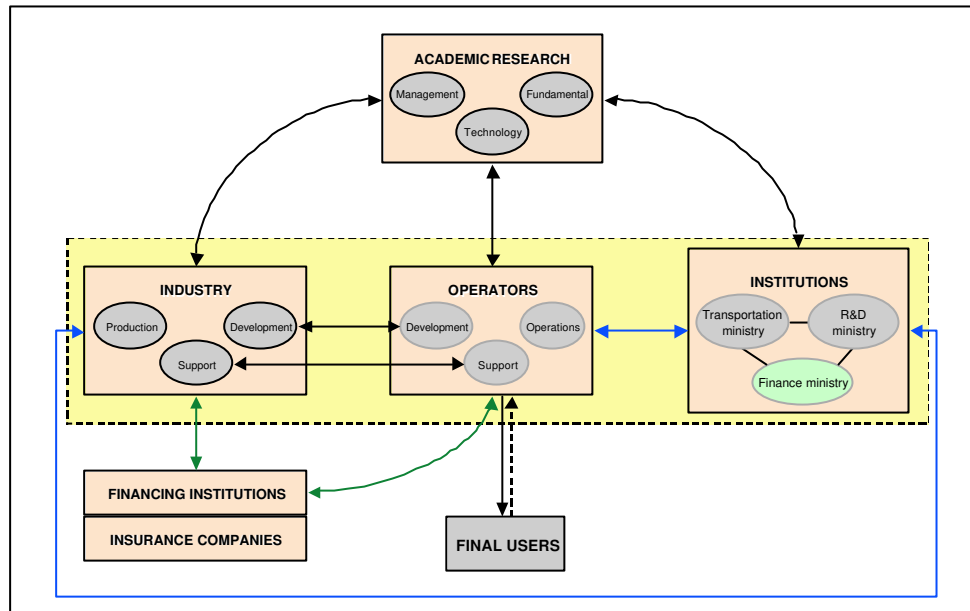


Figure 80: The Integrated HSGT Organizational model, Industry-Operator-Institutions.

- *The Integrated HSGT Organizational model; Operator-Institutions.*

This Second Model is characterized by a strong relation between the Operator and the Institutions, but by a market-relation with manufacturers (figure 81).

For HSR technologies, it mainly corresponds to countries where the operator put in competition the manufacturers. Experiences such as in the USA or in Sweden show that less centralized relations between manufacturers and operators led to more incremental solutions such as rear HSR systems (component rather than systemic innovations).¹³⁵ The absence of a national manufacturer or a more complex manufacturer market had an impact on the type of relationship/partnership with the operator, which renders a systemic rupture more difficult.

In the case of Maglev projects, this model underlined the fact that Maglev Industries were not benefiting from a strong relation with the operator. Maglev technologies were born through national R&D programs in the 60's-70's: The organizational structure was therefore since the beginning shaped by the innovation (project based). As the rent of such innovation was mostly related to public investments in the short and medium-term, the involvement of the industry in Maglev was stronger in Japan and Germany and episodic in the USA.

In Japan and Germany, consortia were composed of the national operator and private industry interested to be in this new market niche. National industries and operators were determined to set future HSGT de facto standards for their national market and therefore for the international market.

¹³⁵ See de Tilière 2001 (a), Hulten 1999.

In Switzerland federal programs where only focused on feasibility until now and the engine of the project is mainly academic related people. There is no national manufacturer pushing for the development of a Swiss technology as it was the case in the US National Maglev Initiative.

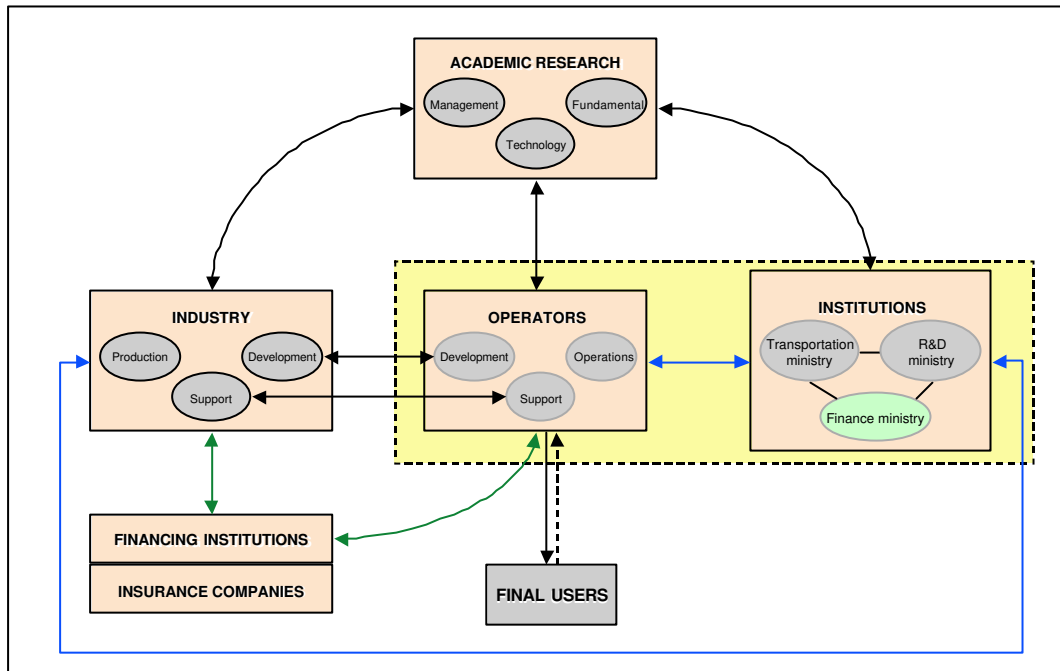


Figure 81: Centralized HSGT organizational model, Operator-Institutions.

Thus, the structure of the Swissmetro consortium is closer to a virtual organization rather than to a strong partnership between industries. In this last case consortium, the consortium defines an organization in itself as Transrapid international or the MLX.

Therefore, this second Organizational Model leads to more difficulty for operators and manufacturers to define together a new systemic innovation when compared with the first Model: They don't necessarily share the same paradigms and the epistemic community (associated with the new technology) is more fragmented. This requires more negotiation processes and concessions, pushing the Generic Innovation Model towards its Political configuration.

- *The Disintegrated HSGT Organizational model*

The two first Organizational Models both summarize the context of the rail and HSGT market until recently. However recent changes happening in Europe since a decade with require taking into account:

- The liberalization and the harmonization of the rail market.
- The globalization of the market of manufacturers.

The first point leads to a vertical disintegration between operators and national institutions, with the introduction of concurrence through a separation between operation and infrastructure activities. The result is the apparition of the Disintegrated Organizational Model, showed in the figure below:

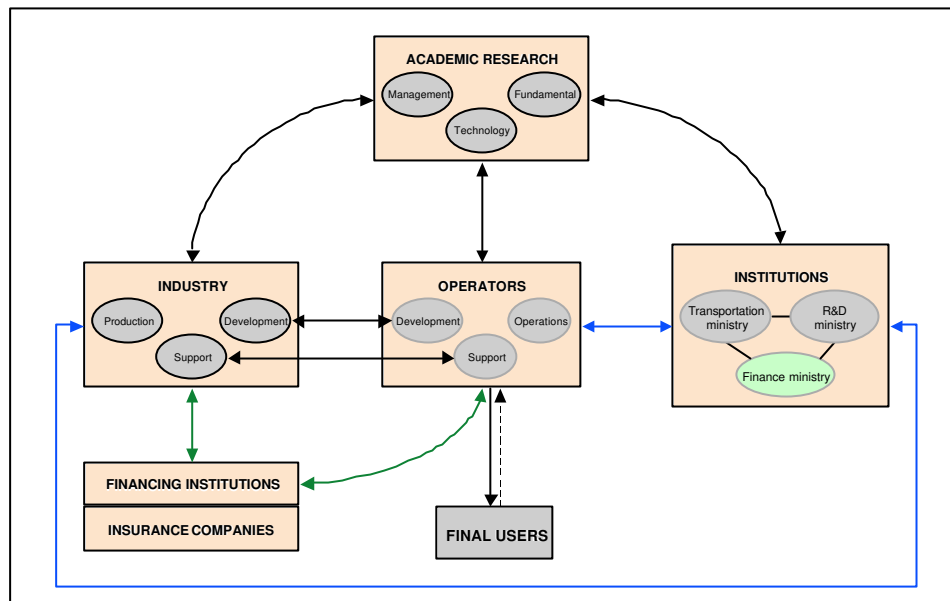


Figure 82: Disintegrated HSGT Organizational Model, towards a redefinition of roles

The impact of the evolution towards this new Organizational Model leads to a redefinition of roles: The role of operators is evolving from technical towards functional specification. Moreover, the increasing competition among operators and among manufacturers leads to more “coopetition”.¹³²

The impact on Decision-making Models is an increasing complexity due to the globalization of the market. The increase of the numbers of actors or partners can lead to more importance of Political and Organizational Decision-making Models, since the size of consortia and partnerships are more important than before.

Concerning HSGT Innovations Models, their configuration is unchanged, but it has shifted from a national to an international level. However, this can have an influence on paradigms that lead national industrial policies (which have been a very important driver in the First HSGT Innovation Model): Concerning the degree of public support for National R&D programs, governments might be less interested in co-financing the development of a technology at a national level if the manufacturer is a multinational company (rather than a national actor as they were mainly before). However such industrial paradigms can shift to the European level, aiming at supporting the European industry (for instance Alstom -Siemens). But it will be in favor of rail technologies, led by the achievement of the Trans European Networks (HSR projects).

5.3.6. Conclusion

This paragraph aimed at underlining the influence of Organizations on Innovation. This was achieved through the definition of a Typology of organizations. The case studies allowed elaborating three Organizational Models, characterizing different configurations of the HSGT market. In each case, it allows to underline how Organizational Models influence Decision-making Models as well as Innovation Models.

However, the two HSGT Innovation Models also underlined the critical role of Institutions and Policy in the Innovation process. Therefore, their role will be analyzed in the next paragraph.

5.4. Public policy and innovation projects

5.4.1. Introduction

The role of public policy in the development of new infrastructures and new related technologies has been decisive for the development of successful innovations. Industrial policies were forged with the idea/purpose to reinforce the competitive advantage of national manufacturing sectors or/and to support the national economical development.¹³⁶ Depending on national experiences, different industrial policies were conducted, inducing different types of innovation.

As worked out in case studies and underlined in the First HSGT Innovation Model, the private sector rarely carried alone radical systemic HSGT innovation without the support of the public sector: One of the main components of risk remains political, as regards to the implementation of transportation projects.

The case of HSR projects' failure in California and Texas in the 90's underlines this critical link with the political and institutional framework (Lynch 1998, Thompson 1999). If one looks at the innovation development in the past decades, the link between transportation policy and innovation is very important and influences the paradigms that drive changes.¹³⁷

This being said, regulations or deregulations appear to be a powerful factor of change¹³⁸, modifying market mechanisms between the actors of innovation. The development of the transportation rolling-stock in Europe from the rail to the automobile sector was strongly influenced by the state interventions (Frybourg 1987 p.31). However this role is also limited as know-how depends mainly on firm's strategies.

The boundaries of actions followed by institutions and governments are explored bellow. The definition and understanding of a typology of their roles, is crucial in order to manage innovative HSGT projects.

5.4.2. The role of Institutions and Governments

- *Looking for new alternatives and supporting competing options*

The role of public institutions is very important in order to support the elaboration and the assessment of alternatives or solutions for future transportation needs. This role must be a support for the private sector when this last one can't afford to undertake such projects alone (and if the NPV for the public at large is sufficient). This role has been critical for the HSGT programs during the 60's and 70's in UK, France, Germany, Canada, USA etc. Such R&D programs have supported the development and improvement of existing technologies or alternatives, with a view to provide sufficient elements to meet the requirement for assessment and decision-making.

In that sense, the role of public policy is to define the boundaries and the framework of alternatives within which the industry has to innovate. This underlines the importance of the role of institutions and the influence of their attitude towards innovation and change (see also Gaudin 1978).

- *Development and diffusion of a technology: the competition for setting new standards*

After the selection of one option or more (as in Japan or Germany supporting both HSR and Maglev alternatives), the public sector can also support the industry for the development of the technology aligned

¹³⁶ Difficulty in distinguishing R&D programs which finality is socio-economic or industrial, especially when those programs concerns services destined to the collectivity (Frybourg 1987 p.31).

¹³⁷ Dobbin F. 1994 *Forging Industrial Policy: the US, Britain and France in the Railway Age*, Cambridge Univ. Press.

¹³⁸ See also Haour 1998 n.2

with the goals¹³⁹ of transportation policy. The support can also consist in securing the network development or improvement: Guarantying a sufficient deployment of the innovation through a voluntary transportation policy can make R&D investments for both private and public profitable (scale effects, case of HSR networks in France, Japan, Germany etc.).

Such deployments of networks increased the maturity of HSR technologies at a national level and allow private consortia to export their technologies. Even for exportations, public and private sectors are working closely, especially when governments have supported strongly the development of a national technology. Therefore, governments support exportation in order to maximize network deployments based on their technology and try to set their standards abroad. This is the case for the Shinkansen technology concerning the Taiwan contract, where a 50% discount on the system was achieved¹⁴⁰, in competition with the European consortium, led by Alstom and Siemens. The same strategy was used by the German government in the contract with Transrapid international for the Shanghai project, providing 300 million US\$ for the implementation of the project.¹⁴¹

Subsidizing the exportation or the development of a technology in order to maximize scale economies for the industry can be a strategy aiming at maximizing the profitability of initial investments or reduce losses. Once again, this underlines the importance of long-term path dependency associated with these technological choices for both private and public sectors.

- *Influencing the market structure (Operators and industry)*

The structure of markets, including operators and the industry, has a strong impact on the kind of innovations that are implemented. Therefore, the link between transportation policy and the market structure is crucial.

The European transportation sector began its harmonization and liberalization process, with interoperability and Trans European Networks as keywords.

Changes have first concerned operators, with the separation between infrastructure and operation as well as a progressive vertical disintegration. Financing HSR in Europe has evolved during the past decade from a purely public sector enterprise, to one with an increasing level of support and long-term commitment from the private sector (Lynch 1998). While the role of the public sector remains important in HSR infrastructures, private sector responsibilities are becoming well defined. The decision in 1989, concerning the development and improvement in the Trans European Network was very important: It contributed to redefining the roles of public and private sectors in a cooperative way, allowing to finance such investments.¹⁴²

Concerning the industry, these changes are coming from an increasing pressure from politicians, who push for more cooperation between European manufacturers. This new period of increasing co-development or "coopetition" between European firms is seen as strengthening cooperation for costly R&D programs. The purpose is to decrease high investments required for developing new technologies that were before supported mainly at a national level as well as to share risks. Behind this trend stands the increasing pressure for standardization (interoperability), also related to economies of scale for operators and industry.

Concerning the influence of transportation policy on the industrial market structure, another interesting case is the HSGTA¹⁴³ (1965-75) or the NMI¹⁴⁴ (1990-93) program in the USA (de Tilière 2001). The US-DOT favored the entrance of aerospace industry in the ground transportation market (rail and Maglev) in order to boost the innovation capabilities of this sector. But the implementation of the Urban Mass Transit

¹³⁹ Case for the US-FRA supporting 50% of the development costs of a HSR gas-turbine locomotive with Bombardier to extend the HSR network on non electrified areas (Source: US-DOT 12.2000).

¹⁴⁰ Interview with M. Takabayashi, Osaka University, 02.2001.

¹⁴¹ Signed in Shanghai in January 2001, the 30km line will be put into operation in 2003. Earlier in 2000, The German government has offered to pay DM 1 billion for a 100 km Maglev test track in China in an effort to get China to choose Germany's Transrapid Maglev for the new high-speed railway linking Beijing and Shanghai.

¹⁴² At the European level, the result was the creation of the European the Cohesion Fund established in the Maastricht summit and the Investment Fund.

¹⁴³ HSGTA: High Speed Ground Transportation Act.

¹⁴⁴ NMI: National Maglev Initiative.

Administration (UMTA) Act destabilized investments and all the US railcar manufacturers left the market before 1981. Preoccupied by the increasing role of HSGT in transportation policies, the NMI was launched with a view to look for future generations of technologies. The focus on Maglev systems was based on the interest of US military contractors. Indeed, facing the same difficulties than other HSR projects in the USA, the NMI hasn't been followed up. Finally, a tilting technology has been implemented in the Northeast Corridor and starts its operation in November 2000. Indeed, the US-DOT had selected two projects among seven candidates for Maglev implementation. However, both are led by the consortia based on the Transrapid technology. An incentive of 900 million US\$ is planned to be attributed by the US-DOT to the most promising Maglev project if no cancellation occurs.

- *Towards a typology of the role of institutions and governments*

The roles of governments and institutions can be defined with the following purposes, underlining the their role of integrator:

- Defining the market framework and standards (Regulation & deregulation).
- Maintaining alternative options for the future by supporting the industry if insufficient direct rents of innovation but large positive externalities (problem of technology assessment). This has been achieved through the support of "in vitro" development of Maglev technologies in Japan and Germany on demonstration sites, and in France with the Aerotrain between 1963-74.
- Subsidizing the exportation of a system in order to increase the diffusion of an innovation, to set future standards and therefore to increase scale economies.

More generally government's supports can be multifaceted funding, ranging from subsidies, loan guaranties to preferential rules giving advantage to the new transportation mode on the others.

5.4.3. Evaluation of innovation projects by institutions.

Case studies underlined the critical role of Institutions in the assessment of innovations, such as the case of the Swissmetro and the Serpentine in Switzerland, the case of the TGV in France (with the Finance Department) or the case of the Shinkansen (with the World Bank).

The role of institutions in the assessment of innovations has always been subject to discussion, especially on their ability to deal with innovation and change: Such items are by definition into a paradoxical phenomenon with organizations based on routine (Gaudin 1978).

Assessing projects with strong technological rupture, which induce rupture in their environment, requires new procedures or a new evaluation framework in order to be assessed. The cases of the Transrapid¹⁴⁵ and Swissmetro are interesting and underline the difficulty in assessing innovations on the basis of procedures that have been designed for an old/existing system (for instance railway network).

- *Technology assessment: innovations require new procedures*

However, the role of institutions is critical for concession demands (infrastructure networks) and also to enable public support for R&D programs. Assessing the benefits of an innovative transportation system requires apprehending the rupture (technology, market, society) and reconfiguring the procedures of comparison and evaluation. For example, the concession demand for SWISSMETRO was assessed by the Swiss Department of Transportation (DETEC) in 1999. The evaluation framework was mainly based on the rail legislation, which can appear to be not appropriate because of the differences between the two supplies: Swissmetro is still at an early stage of development, and further adaptation of the legislation has not been achieved until now.

¹⁴⁵ See Kopecky M., « La sustentation Magnétique », *Transport, mars-Avril 1999*, p.119.

Several research programs focus on this problem and propose guidelines for such technological assessment (Rossel 1999). However they don't emphasize on the critical role of institutions in the assessment process and the accuracy of their procedures. But they propose new methodologies and recommend establishing specific assessment commissions.

The emergence of such innovations requires the approbation of institutions, sometimes reluctant to innovation or to change because of their risk aversion (see also page 175, note 152). This represents another challenge for researchers and the project management team, who have to provide a consistent and accurate assessment framework/methodology. This can serve institutions during the transition phase, where legislation procedures and tools are still not adapted for the evaluation of such disruptive systems.

- *The need for new regulation basis for innovative systems*

In Germany, a new legal basis was established to face the problems of the emergence of the Transrapid Maglev system. Two laws were edited in 1994 and 1996, plus a regulation text in 1997:

- Law of the 23/11/94 concerning the planning of Maglev infrastructures (MBPIG).
- General law of the 19/07/96 (AMbG)
- Regulation text added to the general law the 23/09/97 (application law MbBO). This regulation law (RW MSB) includes articles on passengers' security, collisions, fires as well as impacts of the system on the environment.

This regulation came after the technological maturity of the system, thus far after the technology assessment realized by the related institutions: Regulations are usually achieved ex-post, improved by the accumulation of knowledge and experience.

5.4.4. Institutional structures and the diffusion of innovation

If Organizational Models were developed before for the HSGT market, one may argue that the three Models developed (depending on the Integration degree between manufacturers-operators-institutions) must be completed by an emphasis on institutional structures:

- Centralized countries (case studies related to France and Japan)
- Decentralized countries: (case studies related to the USA, Germany, Sweden)

These two different models of state have a significant influence on Decision-making Models, especially concerning political orientations towards transportation systems. Decentralized systems lead to more complexity in the development of national transportation systems (which is the support of the diffusion of technological innovations).

Depending on the degree of centralization of states, the rapid diffusion of networks has been possible or not. Examples of France and Japan underlined the fact that national networks were rapidly developed through the support of centralized institutions.

5.4.5. Public policy in the transportation sector: Towards an increasing complexity?

- *Changes in the context and social acceptability*

Since the 90's the golden age of new high-speed rail projects has ended. In this period of Concorde, Superphenix and TGV, HSR projects were designed and build much easily with a strong cohesion of politics, institutions, operators and industry. The belief in a certain type of progress also allowed escaping

from the social debate (60's, 70's). But social acceptability became a major issue since that time, added to an increasing complexity of technological and industrial policy structures with the deregulation of the transportation sector.¹⁴⁶ For operators this induces for the long-term a separation of infrastructure and operation, and an opening of national markets. Therefore, the restructuring of the main European rail operators make them more concentrated in keeping their market shares than in launching new high technological projects with the industry.

Concerning the industry, the increase of co-development¹⁴⁷ and mergers¹⁴⁸ is the current trend for rail-car manufacturers. Politicians are also pushing for an increasing cooperation of European rail-car industry, probably influenced by the example of Airbus (cooperation between Alstom and Siemens).

The paradigm of a race for high-speed and the tension between radical and Incrementalism concerning systemic innovation has ended. The current context now gives place to more autonomous innovations in components. This new paradigm is more customer-oriented, focusing on service quality (comfort, security etc.). Therefore, the completion of the Trans European Network lets little place for radical systemic innovations such as Maglev systems, and market niches are becoming small to provide sufficient economies of scale.

- *Consequences on Public-Private partnership models*

Innovations produced by an institutional and organizational system strongly depend on its decision-making structure and processes. Accurate models of public-private partnership are extremely important to establish a long-term development of such infrastructure systems. Financing of HSR systems in Europe has been supported, until the last decade, by the public sector through direct commitments of governments or national public enterprises. Since the 90's the evolution of the transportation framework led to an increasing role of the long-term commitment from the private sector. Indeed, the role of national companies and the public sector will still remain the basis for such transportation and land-use projects, because of the predominance of their external benefits.

Both public and private sectors have to complement each others limited resources. Their roles and responsibilities are becoming more crisply defined. Each project has a financing plan made to measure, based on risk sharing strategies between the public sector (national and local levels) and the private sector according to the benefits of the projects.

Two types of models describe the actual trend towards public-private partnership (Lynch 1998): The first one consists in the constitution of a private company whose shares are held by the government. This configuration allows the company borrowing capital at very competitive rates with government backing. The second model is a company established with mixed private and public ownership. This last model often used in France allows the use of complementary competencies. Efficient management of the private sector can be developed with an efficient management of the government policy regarding to land-use, right-of-way, or environmental concerns. This solution provides an integrated management team, but this underlines the importance of cooperation and coordination between the private and the public sectors.

- *Coordination as a critical element*

Managing complex projects that involve strong uncertainties related to innovation requires a strong coordination of actors. Therefore, the importance of the cohesion of these organizations and institutions leads to the notion of shared paradigms or of convergence of interests. Strategies of organizations and institutions are also driven by national or European economies, by changes in the market structure or in

¹⁴⁶ Those last changes introduced in Europe concerning the deregulation of the rail transportation sector was embodied in the Directive 91/440/EEC: management independence of railway undertakings, separation of infrastructure management and transport operations, reduction in debt, establishment of access rights.

¹⁴⁷ Co-development: Alstom and Bombardier for the US Acela-Express (1997-2000), Siemens and Adtranz for the ICE, Alstom-Siemens for the Taiwanese submission (2000) and for the AVG, Talgo and Adtranz for the EMU with passive tilting technology (proposition for the Madrid Barcelona line, 1999).

¹⁴⁸ Mergers: Siemens Rail division merger with Bombardier announced as a pressure on DBAG for the purchase of another 50 ICE 3 trains in 1999. Bombardier and Adtranz (August 2000), Alstom swallowed 51% of FIAT rail division in June 2000.

political priorities.¹⁴⁹ Thus some periods are more propitious for the engagement of these actors in a partnership to develop such infrastructure projects. This implies to better understand which components influence these “cycles” bringing together public and private wills. The role of institutions is therefore critical to define frameworks of partnerships and to manage interfaces. This also underlines the central position of institutions regarding to systemic innovations in HSGT technologies.

5.4.6. Conclusion: Influence on the innovation processes

The role of institutions and governments is critical in the development of HSGT innovations as regards to the transportation Policy. Their roles are the following:

- Identify future needs for transportation systems as well as the ability of the industry to fulfill its role in innovation.
- Define national/federal R&D programs, and incentives (When the rents of innovations are not enough for the industry to be involved alone, institutions can put incentives and enable state intervention if external benefits justify such a support).
- Coordination of actors related to innovations: manufacturers-operators-institutions.
- Planning and administration of the implementation phases (infrastructure projects).
- Elaboration of norms, regulation measures (safety, environments, definition of standards).

Therefore, Policy and institutional involvement play a key role in the development and diffusion of innovations, through their importance in the implementation processes of transportation networks. Therefore, their role also shapes the nature of innovations (incrementalism versus rupture).

5.5. Organizational and Institutional Models; Critical factors of the HSGT Innovation Models

5.5.1. Conclusions on the importance of Organizational and Institutional Models

Lessons drawn from the sections above underlined the fact that HSGT Innovations Models are strongly influenced by the Organizational and Institutional Models developed in section 5.3.5. Their influences are mainly focused on two important phases, determining the emergence of technological trajectories:

- The phase of recognition of valuable innovations, followed by R&D programs and development.
- The phase of implementation and diffusion of the technology.

In order to underline such influences, Organizational and Institutional Models can be integrated into HSGT Innovation Models such as described in the three following figures.

¹⁴⁹ Case for the Transalpine crisis concerning freight transportation with the accident of the Mont-Blanc Tunnel in 1998. The disturbances in the road network led to the approval of the new rail tunnel project between France and Italy late 2000.

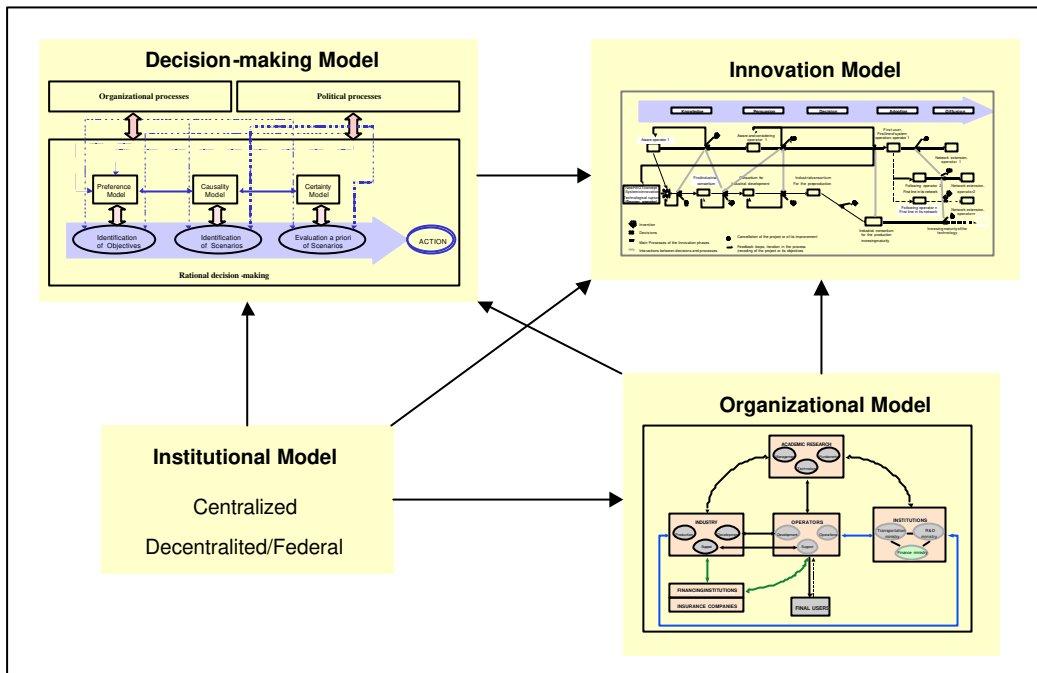


Figure 83: An integrated view of Organizational, Institutional, Decision-making and Innovation Models

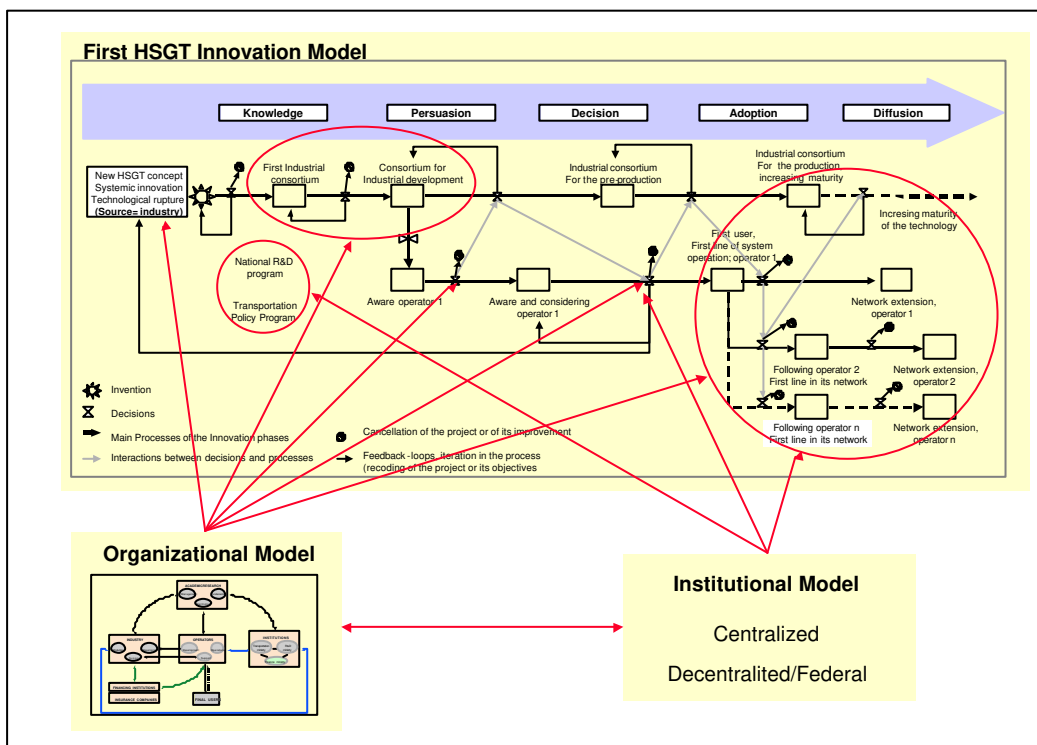


Figure 84: First HSGT Innovation Model and the influence of Organizational and Institutional Models

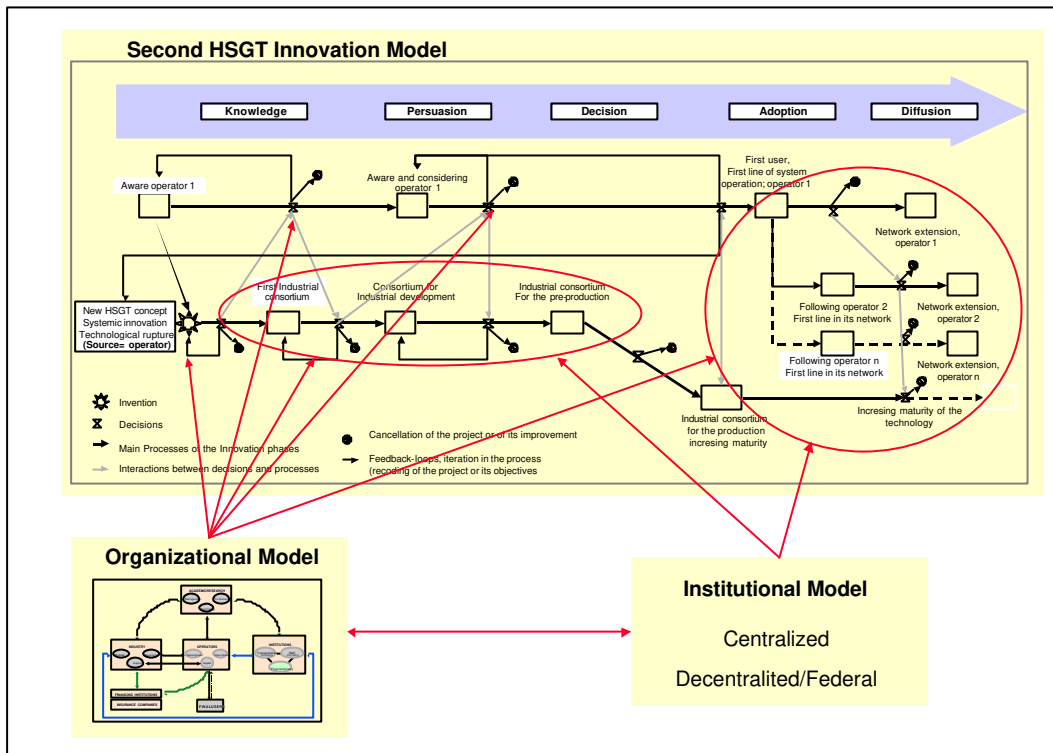


Figure 85: Second HSGT Innovation Model and the influence of Organizational and Institutional Models

These Models underline two critical factors related to Organizational and Institutional/Political factors, which are the role of paradigms and the role of epistemic communities: They provide cohesion between the building blocks of the Innovation Models and allow the concentration of resources of the main actors on the most promising Technological Trajectory.

5.5.2. The role of Paradigm

Paradigms play an important role in the emergence of innovations (Dosi 1982). Complex systems such as infrastructure projects require strong relations among “building blocks”¹⁵⁰: industry, operators, infrastructure-owners and institutions. Introducing changes involves new paradigms in these organizations, which must strengthen the cohesion in epistemic communities. The more systemic and disruptive is the innovation, the more critical is this notion of paradigm and its diffusion among such communities.

Concerning HSGT systems, two main paradigms can be underlined. The first concerns the definition of performance and the second is related to the notion of technological lock-in. What is performance? Obviously, the success of the Shinkansen in Japan rapidly spread over among developed countries as a “techno-economic paradigm” (Freeman & Perez 1988). It first introduced speed as the main criteria for system performance in the development of innovations. Therefore, the apparition of alternative technologies such as Maglev systems was based on the paradigm of “anomaly by presumption”. Based on the idea that rail technologies wouldn’t be able to reach commercial speeds of 300 km/h, a large spectrum of technologies was explored by means of R&D programs supported by public agencies. But two

¹⁵⁰ Interview with W. Garrison, ITS-Berkeley 03.2001.

developments occurred in spite of technological lock-ins: the contact wheel/rail was still effective for very high-speed as the energy transfer through catenaries.¹⁵¹

Paradigms affect organizations and therefore institutions. Two attitudes can be observed: the first one defines performance as strongly associated with compatibility (transition path) and risk aversion. For instance, this can be underlined by the condition imposed by French institutions (Finance ministry) for the TGV development: Engineers of the French operator (SNCF) had to argue that there was no innovation in this system in order to avoid institutional resistance.¹⁵² Compatibility and transition was therefore the main criteria for the assessment of HSGT systems that were finally implemented. The success of the TGV operated since 1981 opened a new area for the development of national HSR networks.

The new paradigm of the 80's until the mid 90's was therefore setting the new standards in the international market with a competition based on "national HSR systems". But the European harmonization concerning the rail sector started in 1989. It brought a new paradigm with the development of the trans-European networks (TEN): Compatibility began to be a critical factor in the mid 90's (technologies/interoperability) and now politicians are pushing for more cooperation among the European Industry.

One interesting case concerns the German strategy with the preservation of two technological options: The Transrapid (Maglev system) and the ICE. In fact, each technology has been supported by a separate institution, with its own paradigm. The Transrapid was supported by the Department of Science and Research, whereas the ICE was supported by the Transportation Department. The Transrapid was developed assuming that winning new market shares against TGV would be better by means of a new generation of technology (anomaly by presumption). This same argument prevailed also for the development of the Japanese Maglev system (MLX-01) and for the NMI¹⁵³ program in the USA. But both Japanese and German Maglev technologies did not find a market niche until recently. In January 2001, China signed a contract with Transrapid international for a 30 km Maglev project between Shanghai and its airport. Obviously, China wants to be a technological showcase and this decision shows how strong paradigms can influence decision-making processes. In the extreme inverse, the failure of the introduction of new technologies can set the paradigm that innovation leads into trouble. This has been the case in California, with the technical problems of the BART and the MUNI (Boeing-Vertol) at the end of the 70's. As promoters claimed that their systems was based on very innovative components, their technical problems set this paradigm among politicians, institutions and planners for at least two decades.

However, paradigms are also influenced by the role of culture and sociology: Alain Touraine¹⁵⁴ notices that "Innovation can be slow-down by the fear of technology" in Occident. Roger Lesgards¹⁵⁵ concludes with the fact that "the technological empire and the society divorce with reciprocal fault" (notion of technophobia).

Social acceptability therefore remains a critical factor in large infrastructure projects and transportation policies, as those ones are very visible when compared to technologies related to defense and aerospace contracts.

5.5.3. The role of epistemic and professional communities

- *Role and structure of epistemic communities*

Epistemic communities enable the diffusion of paradigms that create consensus to favor or block innovation processes. The emergence of new paradigms is allowed by the support of epistemic

¹⁵¹ Interview with J.C. Raoul, R&D manager ALSTOM; meeting PREDIT Paris 12.2000.

¹⁵² Presentation M. Cornil, R&D manager SNCF, meeting PREDIT Paris 12.2000.

¹⁵³ National Maglev Initiative (1990-1993) to assess the opportunity for the US industry to develop Maglev technologies.

¹⁵⁴ Ettighoffer D., 2001, «La clé c'est l'innovation organisationnelle », in *Expension Management Review* n°102, page 104 ; September 2001.

¹⁵⁵ Lesgards R., ex-président de la cité des sciences et des Techniques. «L'empire des sciences», avants -propos, *Point Science*.

communities: They build the argumentation that brings innovation acceptable for the key communities and support the diffusion of key information.

Concerning Innovation with strong technological rupture, the main challenge is to build an epistemic community able to support the development and the diffusion of the innovative technology. This case is very well illustrated by the duality between Rail versus Maglev technologies: Whereas Maglev technologies are still looking for support, Rail technologies benefit from a wide epistemic community around the world and from a solid support from key actors (such as the largest operators and manufacturers). The figure below provides an idea of the structure of the Rail epistemic community:

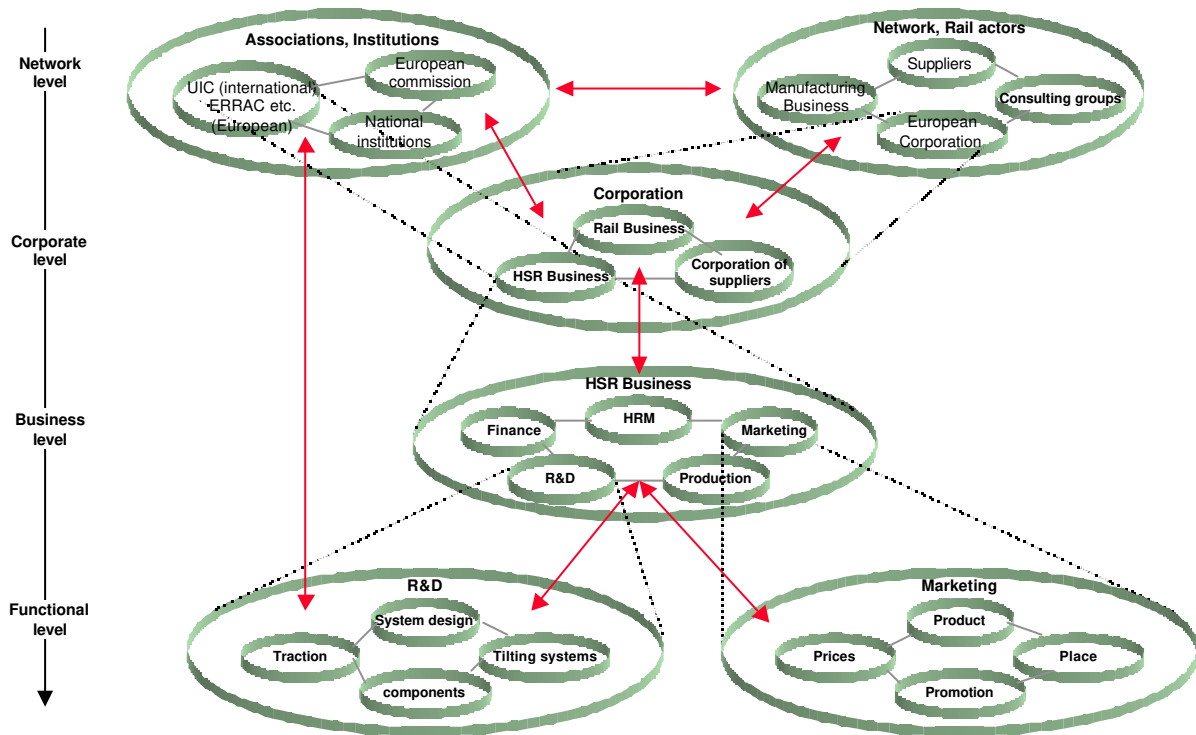


Figure 86: The structure of the Rail Epistemic Community based on Strategic levels

For instance, the case of the European Community is interesting, with the alliances between operators in order to consolidate their national markets and operate on international corridors. The strength of rail networks is also more visible than in the past: European commission, manufacturers and operators organize joint associations in order to better coordinate their activities (through the following organizations: UNIFE, ERRAC etc which are also in relation with worldwide associations: UIC etc.).

- *The technological rupture as a rupture in the structure of epistemic communities*

The main challenge for Maglev technologies is that the technological rupture induces a rupture in the structure of epistemic communities: For instance, a technology such as Swissmetro requires know-how from the aerospace industry for the design of pressurized vehicles (such as the body of airplanes). This induces a rupture in the structure of the HSGT epistemic community, previously associated with rail technologies. This leads to more difficulties in the elaboration of consortia.

5.6. Conclusion

Organizational and Institutional Models developed in this chapter allow to better understand their importance in Innovation Models, as they have a strong influence on innovation processes: These influences are explained by their impact on Decision-making Models, which affect the type of innovation produced.

The notions of organizational path dependency, paradigm and epistemic community show that culture toward innovation and culture of firms can play a driving role in shaping innovations (Incrementalism versus rupture).

However, previous chapters were mainly based on processes in order to understand choices concerning innovation (models of decision-making, innovation, organizational and institutional structure), as well as the consequence of the technological rupture. One must now analyze deeper the consequences of the technological rupture on risks and uncertainties: The ability to deal with risks and uncertainties is a critical factor in innovation success and moreover, strategies toward risk shape also innovations.

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1. Introduction

2. The case of high-speed ground transportation projects

3. Innovation and rupture

4. Towards an Innovation Model for HSGT systems

5. How organizational and Institutional factors influence
Innovation Models



**6. Impact of the technological rupture on Risks &
Uncertainties**

7. Managing the Development of New Technological
Trajectories

8. Conclusion

ANNEX: Project Management Assessment System

“Risk as an opportunity...

...when leverage points can be mastered”

6. Impact of the technological rupture on Risks & Uncertainties

6.1. Introduction

As underlined in the Models developed in previous chapters, technological innovation is the process of bringing a new concept into the market. Managing innovation must, therefore, envisioning what Varian (2000) calls the five habits of highly effective revolutions:¹⁵⁶ Experimentation, Capitalization, Management, Hyper-competition and Consolidation (analyzed in section 3.2.4).

Whereas other chapters mainly focused on innovation processes, bringing a set of recommendations on project management requires to reanalyze these thesis developments under the angle of risk analysis: The main difficulty remains the achievement of all the 5 innovation steps: Even if experimentation, and capitalization steps are successful (less than 10% of innovative concepts), any success also requires acceptable product quality and ad-equation with market needs.

The apprehension of risk and uncertainties, balanced with opportunities constitutes the main filter of technological innovations in the industry.¹⁵⁷ But within a complex framework, such as in the HSGT transportation market, working with a multiple perspective approach requires a good methodology: risks cover various levels of fields and phases. Moreover, the good assessment of risks and opportunities is required in order to define the “acceptable path” in a strategy involving innovation with strong technological rupture. If fostering a new risk management culture based on the realization that uncertainty can be a source of opportunities, those ones can be effectively exploited only if they are well understood.¹⁵⁸

This chapter aims at providing a guideline in the analysis of risks and uncertainties for the projects of strong technological rupture. This will lead to the elaboration of a Risk Model, embedded in tables describing the impact of the technological rupture on the critical factors of such projects. This model will allow, coupled with the Innovation and Decision-making Models, to provide a basis for the elaboration of a set of recommendations for managing the technological rupture (chapter 7).

¹⁵⁶ Varian H. ; *The five habits of highly effective revolutions*, Forbes, Febr. 2000.

¹⁵⁷ Notion of environment uncertainty as opportunity, See also Teece D.J. 1998; *Strategy, Technology and public policy*, ed.EE p162

¹⁵⁸ Chapman & Ward 1997 p.96.

6.2. Notion of Risk & Uncertainty

The widespread and diverse use of the concepts of risk and uncertainty¹⁵⁹ requires defining these notions in order to provide an interesting basis for innovation and project management.

6.2.1. The notion of unattended or deviated outcome

In the context of management and economics of construction projects, risk and uncertainty characterize situations where the actual outcome for a particular event or activity is likely to deviate from the estimate or forecasted value. For example, the ratio between real and estimated costs concerning investments forecasts for US routine airports projects is ranging from 0.6 to 3, leading to an average costs overrun of 25% (source US-DOT).

In the multiple perspective approach, deviated outcomes may be relative to product performance (speed, reliability), project management (delays), demand, social and environmental impacts etc. Such deviances are usually measured in terms of time or costs.

Two phases have to be considered: the project phase (R&D, construction) and the market introduction (operation and maintenance). Examples of unexpected outcomes in innovative systems and large projects underline the fact that both project and market perspectives are critical:

Large-scale and complexity usually increase the deviation of outcomes, as underlined by these examples:

- 300% cost overruns of the new Chubu International Airport in Japan (offshore concept)
- 100% cost overruns in the first phase of the TGV Korea
- Channel tunnel project

But the misperception of the market also contributes to unattended outcomes, especially for high-tech innovations:

- Concorde program: FF.35 Billion¹⁶⁰ for 20 aircrafts (including R&D), with usually a profitability threshold of around 500 units (case of the A380).
- Superphenix, FF. 34 Billion until 1994, for 52 month of production before dismantlement (cost another 9 Billion). The investments costs (2 times higher than for the classical technology for the same power). This technology was economically not viable, allowing for no benefices.¹⁶¹

If the concept of risk and uncertainty in the popular language is tailored towards lack of knowledge (expression of what we don't know) rather than decision-making, making the distinction is necessary.

6.2.2. The difference between risk and uncertainty

- *Definition*

Risks is defined as the exposure to the possibility of economic and financial loss or gain, physical damage or injury, or delay as a consequence of uncertainty associated with pursuing a particular course of action (Chapman, 1991).

¹⁵⁹ Reitan & Hauge 1997 p 84.

¹⁶⁰ This represents 4 times the investments costs of the TGV Paris-South-East (1981 currency).

¹⁶¹ Nifenecker H. 1998, SUPERPHENIX en chiffres, ISN Grenoble.

The difference between risk and uncertainty is that risk is taken to have quantifiable attributes, whereas uncertainty does not. Uncertainty, in the other hand, was used to describe situations where it was not possible to attach a probability to the likelihood of occurrence of an event. Uncertainties tended not to be insurable.

Hence, a risk arose when it was possible to make a statistical assessment of the probability of occurrence of a particular event. Risks therefore tended to be insurable. Using this logic, the actual risk to be carried was quantified as follows:

$$\text{Risk} = \text{Probability of event} * \text{Magnitude of loss/gain}$$

Four categories of risks can be described depending on the combination of the level of magnitude (impact) and occurrence (probability).

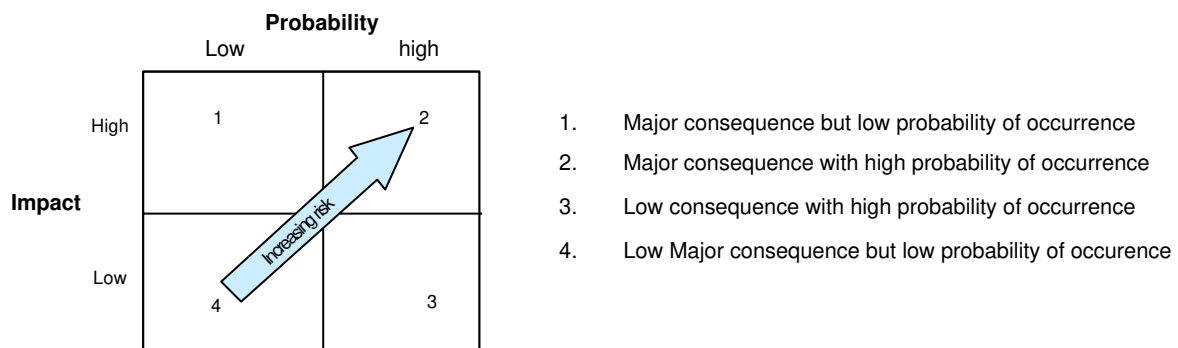


Figure 87: Definition of the notion of risk, combination of a consequence and its probability of occurrence.

After all, risk refers to decision-making based on known probability distribution (or supposed to be) whether uncertainty refers to unknown probability distribution. Therefore the main difference between Risk and Uncertainty is not one of substance, but one of degree of personal knowledge about the future event.

Risk	Uncertainty
Quantifiable	Non-quantifiable
Statistical assessment	Subjective Probability
“Hard data”	Informed Opinion

Table 3: The main difference between Risk and Uncertainty

- *Strategy & Uncertainty: Four levels of uncertainty from the strategy perspective*

Strategies are based on the assessment of risk and opportunities. But the evolution of markets uncertainties redefines both risk and opportunities and therefore requires the constant adaptation of strategies.

Uncertainties can be ranged in four levels (Figure 88), which influences strategies in terms of R&D and technological option choices. These uncertainties may be caused by firm’s strategies (innovators) or political changes as well as regulation measures (policy and institutional changes), which affect the market conditions (operators or manufacturers).

- In the first level of uncertainty, strategies are based on the assumption that innovations and efforts are achieved on a single identified direction or technological trajectory (HSGT options based on rail for example, if most operators are against the adoption of alternative technologies).
- In the second level, several alternatives are possible and the future outcomes are unknown (potential adoption of alternative technologies: Maglev versus HSR, but standards for each technology have already emerged).
- In the third level, the range of possible futures are more open, the competition for standards in each alternative is not achieved.
- The fourth level is characterized by a complete ambiguity: technological trajectories are completely open and standardization phase is far ahead...

Whereas in the levels two to four, firms trying to shape the market and innovating are focused on reducing uncertainty, in the first level they rather focus to raise uncertainty in order to create opportunities.

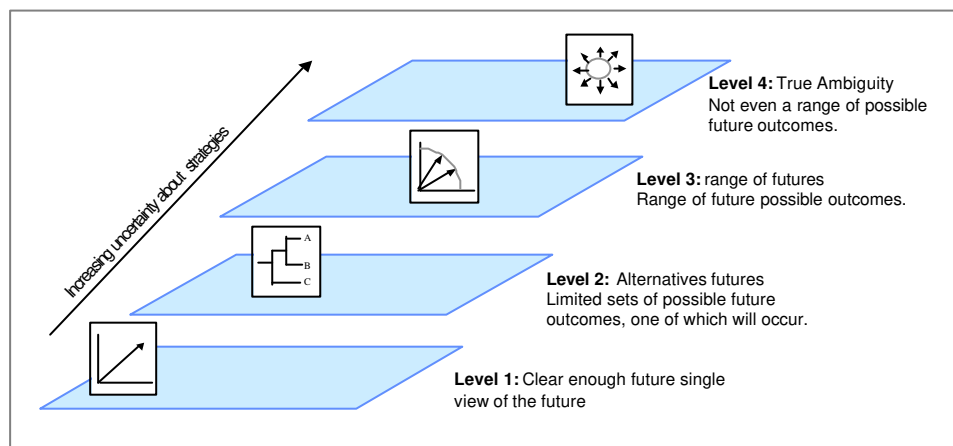


Figure 88: The four level of uncertainty in the strategy perspective (Source: *Mc Kinsey quarterly*, Nov. 2001)¹⁶²

These four levels are interesting as they define the strategic context of Innovation Models. Concerning the case studies and systemic innovations:

- The main HSGT R&D programs in the 60's and 70's were related to the level 4 (exploration phase).
- The configuration rapidly shifted toward the level 2 in the mid 70's: with two main technological trajectory: Maglev or HSR. Actually, firms like Siemens are focusing on two alternatives: ICE or Transrapid.
- The level 1 was adopted by other competitors, focusing on HSR technologies (like Alstom or Bombardier): their strategy is to focus on their core competences and to increase economies of scale (among rail segments).

¹⁶² Courtney H., "Making the most of uncertainty", in *Mc Kinsey quarterly*, Nov. 2001.

• Risk formulation

Risk is define by the product of the probability of occurrence of an event multiplied by the probability that an event i happens at the time t (p_{it}) by its potential consequence (E_{it}). The risk can be describe by the distribution and cumulative curves, as shown below:

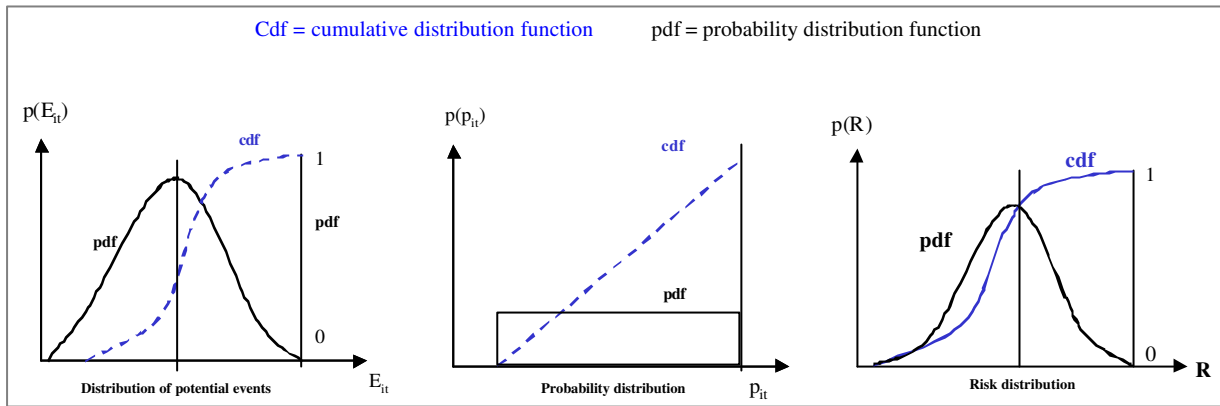


Figure 89: Risk functions, cumulative and distributive curves

$$R = \sum_{t=1}^N \sum_{i=1}^m E_{it} \cdot p_{it}$$

With: i scenario
 t milestone
 E potential event
 P probability of occurrence of the potential event
 N project horizon

The formulation of Risk may also be drawn in iso-risk curves, which can be a good tool to understand attitude face to Risk. Projects can be ranged within this framework in the case of option choice or portfolio selection. This figure can be realized by type of risk, and then an aggregation can be achieved (figure below).

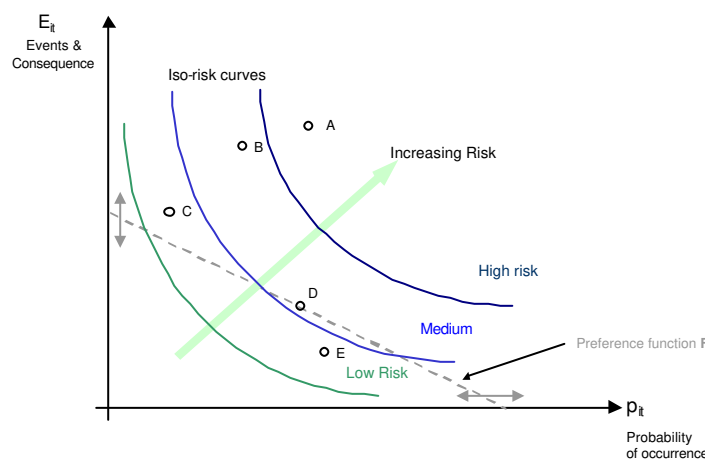


Figure 90: The notion of iso-risk curves and preference function for project comparison and selection

This figure shows for example that projects A and B (radical innovation for instance) are more risky than projects C, D and E (incremental innovation for instance). However the preference function (f) may change from one actor to another and influence choices.

- *Multiple perspective approach and Risk formulation*

In the multiple perspective approach, risk can be analyzed through the projects phases and their dominant perspectives: for example; Technology, Policy and Institutions, Marketing, Construction and Operation:

$$R = \sum_{\alpha=1}^m R_{Techno(R\&D)} + \sum_{\beta=1}^n R_{Politica\&Institutional} + \sum_{\chi=1}^p R_{Marketing} + \sum_{\kappa=1}^r R_{Construction} + \sum_{\vartheta=1}^s R_{Operation}$$

Then a deeper analysis through the nature of risk components is required. Here again, applying the multi-perspective approach will allow to track the root causes of risks, such as quality management, human errors, and management problems, usually affecting the projects' outcomes to a great extend.

However, concerning risk assessment in innovative HSGT technologies, a distinction has to be made, between risks linked to the innovation and risks inherent to classical large infrastructure projects. If the scale of projects is a contributing factor of risk, the degree of innovation or rupture is also very important.

6.2.3. The Innovation Dilemma: About the degree of innovation and rupture

- *Innovation as a condition of success: taking risks to increase opportunities*

In the European transportation market as well as the international rolling-stock manufacturing market, the pressure has been drastically increased. This requires a better consolidation of the actors' position as well as a better capacity to innovate.

If in such sharp competitive markets, the temptation is high to reduce R&I expenses (Research and Innovation), but to perform in the global process R&I becomes the best agents to lead future markets if applied with lucidity (Figure 91).

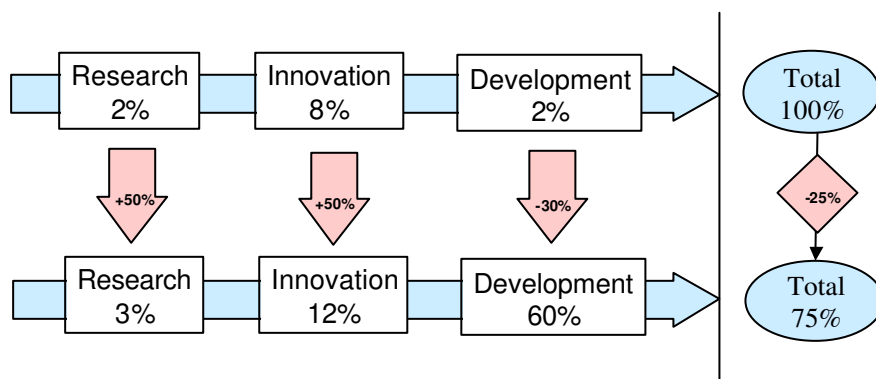


Figure 91: Research, innovation and development: shifts for a sustainable competitiveness¹⁶³

¹⁶³ Source: Lebidois D. 2001, « Management et projets d'innovation : un proces sus pour réduire les risques », in : *Innovation, conception et projets*, AFITEP-2001 proceedings pp. 61-71.

But if increasing resources for research and innovation are required for competitive advantage, the selection of alternatives is a critical task: the mastering of risks stands in the appropriate selection of innovative projects. Killing non-viable projects makes possible to allocate more resources on selected opportunities.

- *Risk as an opportunity, the notion of disruptive options*

Risk is the combination of probability and magnitude of gain/losses or upside/downside risks, which can be associated with an opportunity.

The notion of uncertain environment, to which the strategies have to be adapted, also provides opportunities to firms who are able to take advantage of it.¹⁶⁴ In this context, decision-making concerning innovations and new project development/implementation are an example of the difficulty in making a trade-off between risk and opportunities: Firms involved in the development of the Transrapid took risks in partnership with the government for the full-scale development of the technology, with the hope to lead the “after HSR” market.

In the decision making process, risk in investing in innovative real options (or “disruptive options”) such as Maglev system, has to be seen at a national level as adding flexibility in the future transportation alternatives.

- *The trap of technological wonder*

If the innovation worship turns the technology, which is a tool, into a theology, markets sanction is usually sharp. Apprehending the innovation’s dilemma requires an appropriate evaluation of risk and uncertainties, which can lead to failure when they are under-evaluated. The most spread bias is described by Schnaars (1989)¹⁶⁵, as the “over-evaluation of technological wonder” when entrepreneurs fall in love with their invention. If risk and uncertainties may be seen as opportunities, managers have to be aware of the importance of proactive risk management. Christensen¹⁶⁶ underlines the link between new/disruptive technologies and the risk that can cause great firms to fail. If decision-makers have learned about past experiences, such as Concorde, Superphenix and the SST¹⁶⁷ projects, the main difficulties remains to assess the impacts of the rupture by means of a multiple perspective approach.

- *System absorption capacity of innovation*

Concerning the assessment of risks and uncertainties in innovation projects, two questions arise:

- Does radical innovation cumulate more risks?
- Are incremental projects easier to evaluate?

Case history reveals that incremental projects may be much more costly than expected, (Swedish X2000, German ICE lines) and that more radical solutions would have been more efficient. But at the beginning the risk distribution drawn by decision-makers were less spread.

First conclusion of interviews with industrials show that they are reluctant to too innovative solutions: new technology carries risks simply by being new. Innovations imply non-routine tasks, adaptation of personnel and processes and therefore more failures rates.

To prevent failures, some ratios or measures are applied within industry. For example, in the automobile industry, a project is usually not selected if less than 60% of its components are not available in the

¹⁶⁴ See also Teece 1998 vol.2 p162.

¹⁶⁵ Schnaars S.P., 1989; *Megamistakes: forecasting and the myth of rapid technological change*, New-York.

¹⁶⁶ Christensen C.M. *The Innovator dilemma: when new technologies cause great firms to fail*, Harvard Uni. Press, 1997.

¹⁶⁷ SST: US federal program for the development of a Super Sonic Transport aircraft. Project abandoned in the 60's for the 747 project, but new projects are under work since 1994 (around US\$ 4B have been spent since, an additional 10 to 15 B are required for full-scale development).

market¹⁶⁸. The Path research program in Berkeley (self guided vehicles, financed by Toyota and GM) imposed to researchers to work on innovative solutions based only on components available in the market.¹⁶⁹

Thus engineers and decision-makers have to evaluate if the system they are going to build is able to absorb the innovations they want to include without affecting its vital functions (these functions can be defined although by means of a multi-perspective approach):

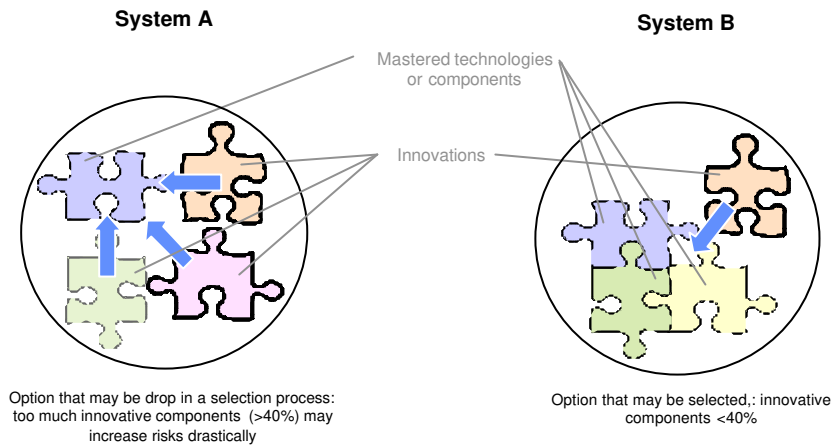


Figure 92: Typical degree of innovation incorporation, industrial projects that are not subject to public R&D programs

In fact as Freeman & Soete (1995:244) observed, “most firms have a powerful incentive most of the time not to undertake the more radical type of product innovation, but prefer focus on product differentiation and process innovation”. This behavior is directly linked to the degree of uncertainty linked with the type of innovation (see Table 4).

1. True uncertainty	Fundamental research Fundamental invention
2. Very high degree of uncertainty	Radical product innovation Radical process innovations outside firm
3. High degree of uncertainty	Major product innovation Radical process innovations in own establishment or system
4. Moderate uncertainty	New generations of established products
5. Little uncertainty	Licensed innovations Modification of products and processes Early adoption of established process
6. Very little uncertainty	New “model” Product differentiation Agency for established product innovation Late adoption of established process innovation Minor technical improvements

Table 4: Degree of uncertainty associated with various types of innovation (source: Freeman & Soete 1995 p.244)

¹⁶⁸ Jolivet F., 2001 ; “Emergence de la culture projet dans les industries manufacturières”, *Proceedings of AFITEP 2001*.

¹⁶⁹ Interview with the Path program Manager, Richmond Field Station, March 2001.

- *Disruptive options and market adoption*

However the degree of innovation doesn't concern only the design and implementation phase but also the market acceptance. If innovations may constitute new opportunities, industry must pay attention to the consumer needs: Siemens knows about it with the development of the Transrapid, Matra with Aramis¹⁷⁰ and ABB for low-tension products: their innovative projects were judged too innovative as regards to markets trends, and lead-users were more interested in maximizing the value of the technologies already implemented (resistance to change).

- *The case of HSGT technologies, future challenges*

The technological rupture of an innovation, such as Swissmetro induces technological risks. These risks were taken in the development (prototypes, demonstration sites) of the Aerotrain in France (1963-74), the Transrapid in Germany (since 1969) and the MLX-01 in Japan (since 1962). Risks were seen as the opportunity to achieve better opportunities in terms of performances. Since 1980, Maglev technologies increased their performances by 50% when compared with 25% for rail technologies.

With higher performances in terms of speed and energy consumption, Maglev systems are 25 to 30% more expensive than HSR in terms of investments. But their performances in speed, curves and slopes make them interesting by reducing construction costs through more flexibility in the route implementation.

If such technologies are justified by a strong increase of the supply performance, and therefore of the demand, the rupture implies also an increase of risk and uncertainties: The evaluation of the system and its impacts, the forecast of the demand are difficult because of the unfamiliarity with such changes. Operators were reluctant until now, to be first to adopt such an unproven technology.¹⁷¹

The case of Switzerland is especially interesting, as the implementation of near high-speed rail services is extremely costly because of geographical characteristics, Maglev solutions may be interesting. This alternative may be the only way to implement high-speed services.

6.2.4. Conclusion: The importance of Risk Assessment and Management

Turner (1993) defines project as an endeavor in which human, material and financial resources are organized in a novel way, to undertake a unique scope of work, of given specification, within constraints of cost and time, so as to achieve beneficial change defined by quantitative and qualitative objectives.

This being said, project management aims at the reduction in risks and deviated outcomes by means of a better coordination, planning and control. However, introducing technological rupture in large-scale systems can increase risks drastically. The following point underlines the main risks of transportation projects and underlines the relation between risk and the projects' scale.

But before entering into management considerations, a clear framework has to be drawn, from the risk identification to decision-making and management. The structure adopted in the paragraph follows the steps in the figure below.

¹⁷⁰ Latour B. (1992), *Aramis ou l'amour des techniques*, Edition la découverte.

¹⁷¹ See also Risk in Maglev development, proceedings of the *Hsgt conference 1991*, p. 620ss.

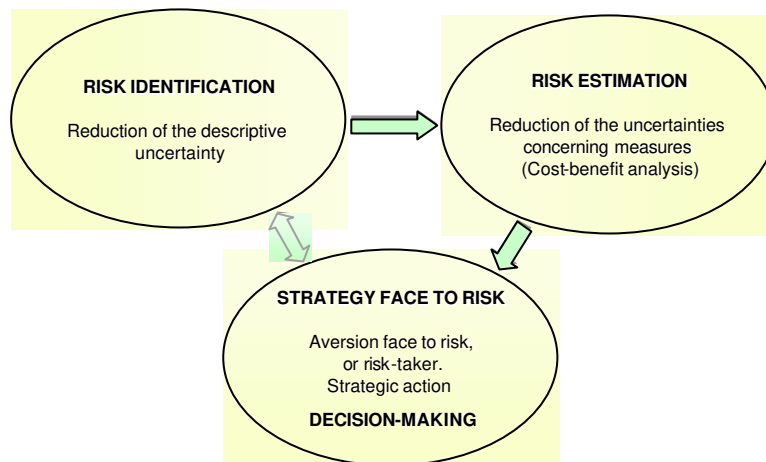


Figure 93: Methodology for risk assessment and management

6.3. Risk Identification; Impact of the rupture

6.3.1. Objectives, and general considerations

- Objectives

Risk identification in the risk management cycle is the most time consuming. Identifying internal and external risks of the project requires from analysts to be systematic, experienced and creative.

The phase of risk identification aims at:

- Identifying the structure of causes and their contribution to risk (for the definition of probabilities or of the magnitude of consequences in the assessment phase).
- Identifying of possible alterations of this structure in order to enhance the reduction of risk (for the evaluation of associated benefits and costs in the assessment phase).

The process of risk identification can be described in the sequence bellow (Figure 94). In the case of innovative systems, impacts of innovation and rupture have to be analyzed for each step.

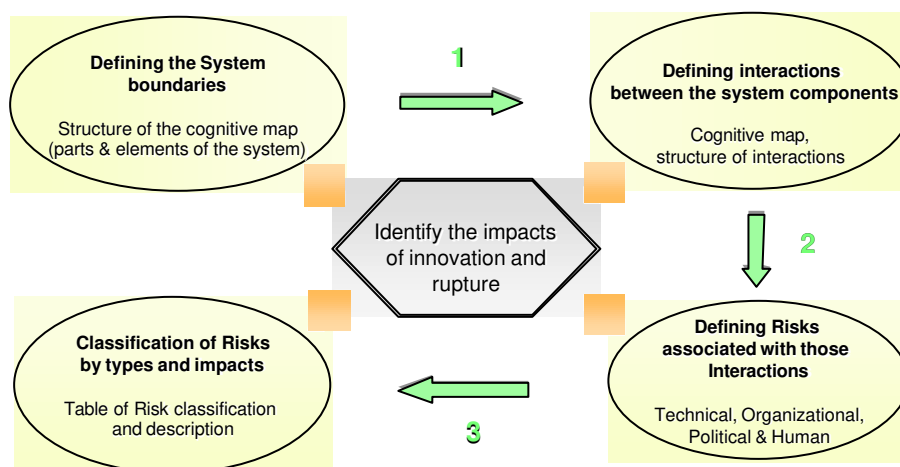


Figure 94: Risk identification: reduction in the descriptive uncertainty; methodology

- *Descriptive uncertainty*

Descriptive uncertainty affects the understanding and representation of a particular system, phenomenon or event.¹⁷² This first phase of risk identification aims at reducing the descriptive uncertainty, through a better understanding of the project, its environment as well as the main interactions that influence decision-processes, the project development and outcomes. This paragraph describes several concepts and methodologies to help managers to develop their understanding of project complexity, rather than trying to model and simplify only in order to manage more easily quantitative methods.

- *Risk and uncertainties about ends or means*

Pearson (1993) argued that uncertainty related to a project or an innovation could be described according to the process or to the output (see figures p.196):

- Uncertainty about ends, concerning the targets of the project.
- Uncertainty about means, regarding how to achieve these targets.

6.3.2. Acknowledgments for Risk Identification

- *Uncertainties about process and about output*

For large infrastructure projects, the long life cycle as well as the time needed for project planning and implementation increases drastically uncertainties related to outcomes and targets. However, for classical projects, means are more or less well defined as industry and managers have a good expertise through past experiences.

If such projects include disruptive technologies such as Swissmetro, even means are subject to strong uncertainties: concessions procedures are new for both project consortium and institutions.

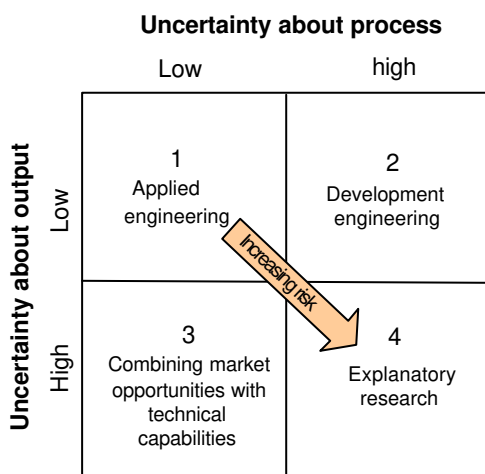


Figure 95: Uncertainty about process and output

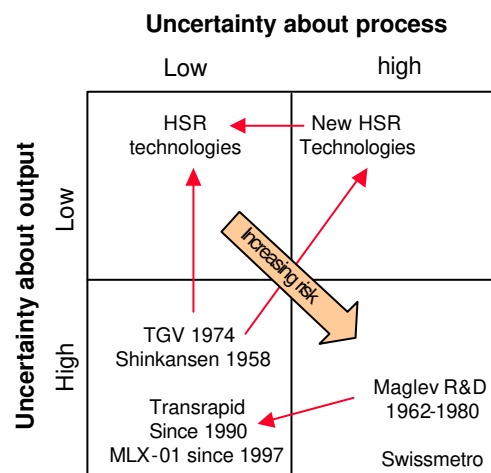


Figure 96: Uncertainties in HSGT innovations

¹⁷² Rowe W.D., 1977; "An Anatomy of Risk", J. Wiley & Sons.

Projects uncertainties increase as described in the figures above, from applied engineering (1), such as the production of current HSR systems (TGV Korea for example), to explanatory research (4) such as Maglev R&D in the 70's or Swissmetro now (figure 96):

- (1) In applied engineering, the market is usually known as well as product performances: outputs constitute low uncertainties when compared with (3)&(4). About processes, they are usually mastered as knowledge and experience allow keeping uncertainties low.
- (2) In development engineering, such as component innovation for the development of new TGV generations (incremental process), uncertainties about outputs are not much higher than in (1). However, adding new components or innovations in the system increases uncertainties: Processes have to be adapted, can require innovative solutions. For example, the development of new generations of HSR systems (incorporation of tilting technologies, duplex train-sets etc.) Such projects are usually conserving the previous technological trajectory (Incrementalism).
- (3) When new market opportunities are explored with existing technologies that have to be improved (such as the TGV or the Shinkansen at their beginning phase, both developed within an average period of 2-4 years by the industry): The Infratechnology is already developed and mastered, but the market is still relatively unknown: If planning processes and the technological development is mastered, real outcomes of the project (impact on demand etc) is still subject to high uncertainties. This case usually concerns projects with incremental technologies but market ruptures.
- (4) Explanatory research concerns projects where both outcomes and processes are subject to high uncertainties: The Infratechnology is not completely mastered, and processes are therefore defined step by step without clear visibility. At the same time, even targets and outcomes are not clearly identified, or will be adapted to future needs, that are currently not well defined. For instance, the Swissmetro project, could be subject to significant changes to interest industrials to enter into the project for the development phase.

- *Influence of the technological rupture in the product development process*

Industrial experiences and case studies show that new product development (NPD) is much more complex than product improvement:

- In the case of small technological advance, uncertainties of time forecasts in NPD are usually doubled when compared with product improvement, whereas uncertainties of costs are only 10% higher (Survey of Mansfield 1971, case of the drug industry, Figure 97).
- When a product requires significant technological advance, uncertainties in product improvement usually is not different as for low tech ones in terms of costs, and a strong decrease of time uncertainty is observed (of around 40%).
But concerning NPD, uncertainties are much higher, increasing by 250% for time and 150% for costs when compared with high tech product improvement, and by respectively 150%, 30% in comparison with low tech NPD.

These numbers underline that cost uncertainties are critical for low-tech products, and if high technologies make product improvement less uncertain in terms of time, they are a very important factor of uncertainties for new product development (NPD). In this last case, time uncertainties are much more higher, underlining that both product and processes are still not well mastered.

Results of case studies also underline the same trend in the rail manufacturing industry:

First the case of time uncertainties related to NPD of technical advance is illustrated by the 40 years that have been required for the development of HSGT Maglev technologies (Transrapid and MLX-01)

The case of incremental NPD failures is illustrated by Boeing Light rail vehicles (LRV) in the 1970s: the difficulties encountered by General Electric in the same period concerning the Metroliner. More recently, the Acela-express, manufactured by Bombardier & Alstom also faced severe difficulties in the beginning¹⁷³. These projects mainly faced crisis causes by managing a new product development, consisting in the recombination of existing technologies. Usually, after enquires, difficulties came from management or organizational dysfunctions. But to go deeper in risk identification and past experiences, several researches provide a good basis for understanding which factors are critical (see paragraph p.195).

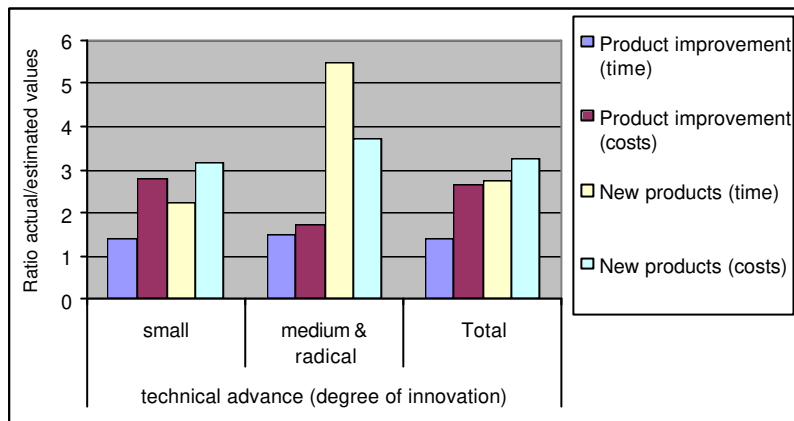


Figure 97: Product Improvement and NPD, influence of the technological advance on uncertainties.¹⁷⁴

- *Technological rupture and market issues*

If technological challenges require a lot of attention in the risks identification, market remains a critical factor (especially when the technological rupture implies a rupture in the market). The notion of resistance to change¹⁷⁵ as well as assimilation phenomenon and real market needs are really important and usually sanction R&D efforts.

If the research of Seiler (1965)¹⁷⁶ on the R&D in the US manufacturing industry (Figure 98) confirms the figures above, it underlines the fact that the percentage of poor rating is the highest for products revenues when compared with cost, timing or technical success ratings. However, if these data on R&D projects are global, the rate must be much higher for the case of rupture in the market.

This survey shows that market success is more uncertain than technical success; even if the variable, which constitutes most of uncertainties, is the time to complete research. The role of marketing departments and their cooperation with R&D units is therefore a condition to success, since it enable to better identify market risks and needs as well as the timing R&D programs and market introductions.

¹⁷³ De Tilière G., 2001, *Managing projects with strong technological rupture, case for the US HSGT projects*, SNSF report.

¹⁷⁴ Adapted from Freeman & Soete, 1997; *The economics of industrial innovation*, MIT Press, p.247, (reference to Mansfield 1971).

¹⁷⁵ Bauer M. 1995, *Resistance to new technology*, Cambridge University Press.

¹⁷⁶ Adapted from Freeman & Soete, 1997; *The economics of industrial innovation*, MIT Press p.249 (from Seiler 1965 pp.177-78).

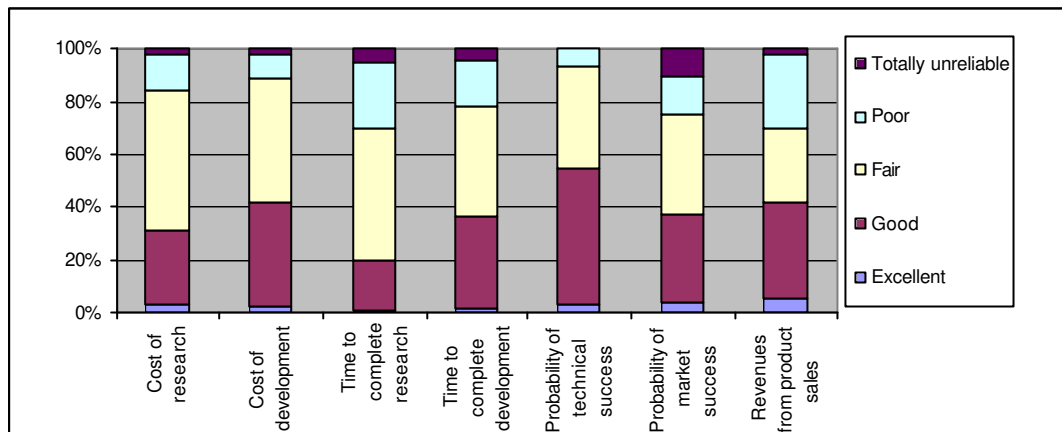


Figure 98: percentage of US firms rating accuracy with which factors affecting R&D can be estimated.¹⁷⁶

- *Causes and sources in civil-engineering system failures*

If NPD and industrial developments constitute with market risks critical milestones in the identification of risks, several surveys allow to better understand risks causes and sources in engineering systems¹⁷⁷ (also representative of large infrastructure projects). These surveys deserve for the incorporation of all the project life cycle (Figure 99).

These data underline that risk management should mainly focus on design and construction. Further analysis indicates that *knowledge* is a critical element in systems failures related to the design phase (primary cause in 36% of failures) as well as *negligence* for the construction phase (54%). Second critical factors are *underestimated influence* for design (16%) and *knowledge* for construction (14%).

This underlines the fact that high innovative systems requires particular attention, especially because if construction errors are more numerous, 5% higher than engineering ones, the cost consequences of design errors are in average 24%.

Hauser (1979) as well as Walker (1980)¹⁷⁸ also provides evidence of the importance of negligence as source of system failure in 54% of cases, but underlines the predominance of insufficient knowledge as second source of system failure in 36% of cases (Figure 100). Other factors of sources are present in less than 16% of cases.

But if knowledge is a critical factor, it also appears for 10% of cases in construction labor, which increases knowledge effects to 43% of failures. This underlines the importance of risk assessment and management, especially in the case of completely new systems such as Swissmetro, where the massive integration of innovative components into a completely new combination will pose a problem of knowledge management in both design and construction. Moreover, random variations are a contributing cause of failures in 10% of cases in conventional systems, and can also increase significantly for innovations with strong technological rupture.

¹⁷⁷ Bea R. 2001; *Human & Organizational factors: Risk assessment & management in engineering systems*; CEE-Berkeley, course document, pp. 30-35.

¹⁷⁸ Walker A.C., 1980; "Study and Analysis of the first 120 failures cases", *Proceedings of the Symposium on structural failure buildings*, Institution of Structural Engineers, London.

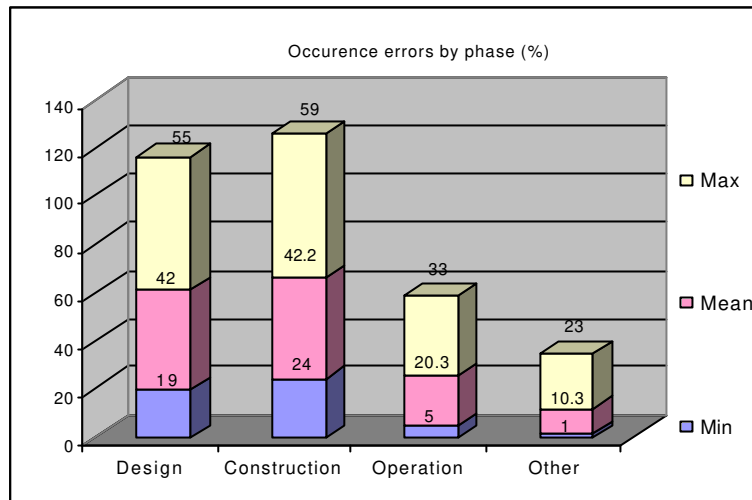


Figure 99: Summary of occurrence of errors in building structures (adapted from Bea 2001 p.35)¹⁷⁹

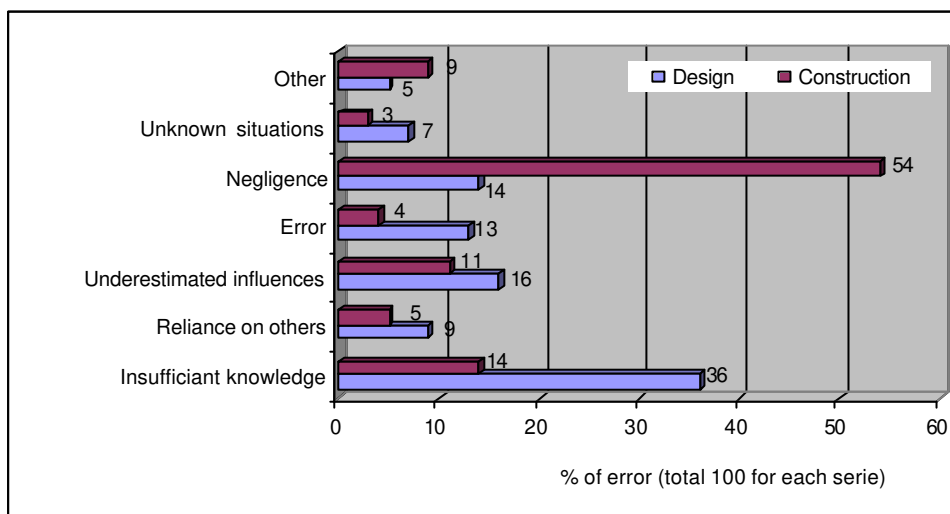


Figure 100: Sources of errors in conventional building systems (Hauser 1979)¹⁸⁰

Eldukair & Ayyub (1991)¹⁸¹ also analyzed primary causes in systems failures (Figure 101), and if negligence is the factor the most cited (present in 82% of cases) among other management or behavioral indicators, knowledge (66.7%), lack of training (57.3%) and unknown situations (33.3%) also underline the challenge of designing and implementing too highly innovative systems.

If significant factors affecting system failures as contribution causes are listed (Figure 102), it is interesting to notice that the critical factor is environmental factors (49%). Then all significant factors are relative to project management, and application of a new technology concern only 1.2% of cases.

¹⁷⁹ Mean of data provided by ten surveys: Eldukair & Ayub (1991), Hadipriono (1985), Matousek (1982), Yamamoto & Ang (1982), Rackwitz, Hillemeir (1983), Mechers & Harrington (1983), Fraczek (1979), Hauser (1979), Gonzales & Okrent (1985).

¹⁸⁰ Hauser R. 1979, "Lessons from European failures", *Concrete international*, Vol.1 n°12, ACI New York, 1223-1334.

¹⁸¹ Eldukair Z. & Ayyub B., (1991), "Analysis of Recent US structural and construction failures", *Journal of Performance of Constructed Facilities*, American Society of Civil Engineers, Vol.5, No.1 Feb.

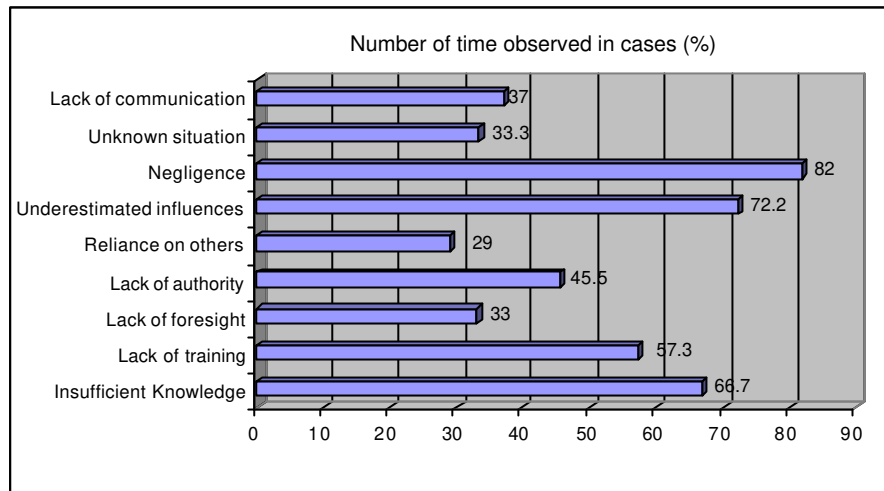


Figure 101 Primary causes in building failures source: Eldukair & Ayyub (1991)

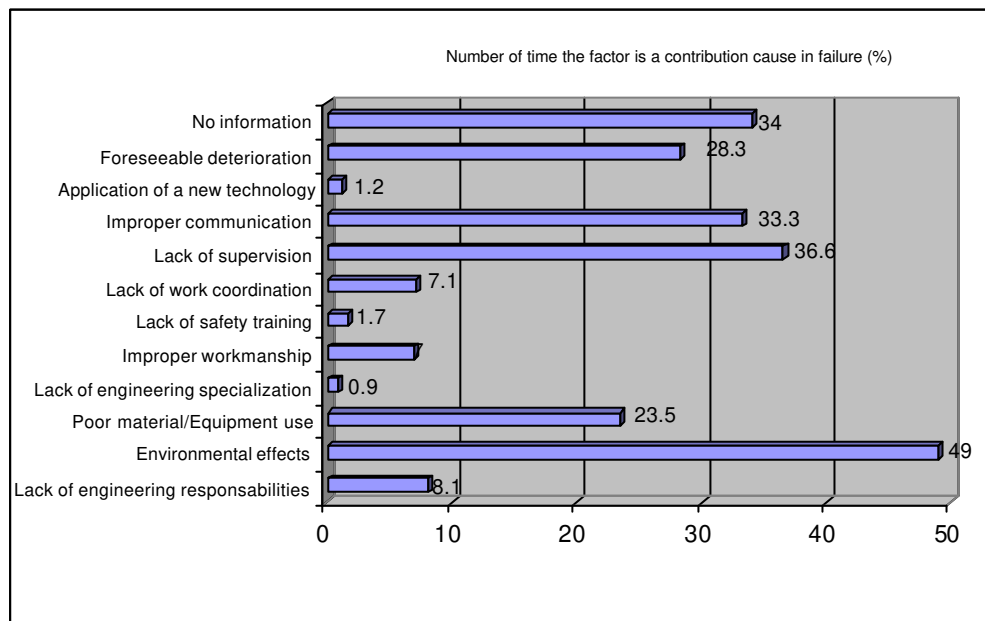


Figure 102: Contribution causes of structure failures, source: Eldukair & Ayyub (1991)

Therefore these surveys show that, behind the introducing of new technologies stands the challenge of project management. If the R&D phase is over, the Infratechnology mastered and the industrial development achieved, risks will be mainly concentrated on knowledge in design phase (40%) and in the construction phase (10%). Largest risks linked to innovation are in the R&D development and in market analysis for project implementation. Then the implementation will be mainly a matter of project management, and risks due to innovation will be lower than those related to large infrastructure projects.

These results underlined the necessity to build a robust methodology for risk identification and assessment: The impact of the technological rupture is diffused through a lot of factors, among which human and organizational factors play an important role. Following paragraphs will therefore aim at

developing an extended approach for RAM and finally lead to a summary and a classification of these risks based on the results of these surveys and of the case studies.

- *Conclusions on risk and uncertainties inherent to large transportation projects*

If the case studies provide a good basis to identify risks and uncertainties, they mainly focus on innovation processes. Failures and their real causes are not always visible from outside¹⁸² (several projects can be a failure in terms of realization, but still be a success in the long-term for different reasons), case histories are very important in order to understand and underline risks and uncertainties. Other surveys focusing on transportation projects can be helpful, as the one of Pickrell (1990), providing statistical results. Such surveys show the difficulty in planning and forecast impacts of such large projects. The highest degree of uncertainty lies in the evaluation of operating expenses, with a standard deviation of +79% between outcomes and forecasts. Concerning capital investments, the standard deviation is +30% and concerning demand – 25% (Figure 103).

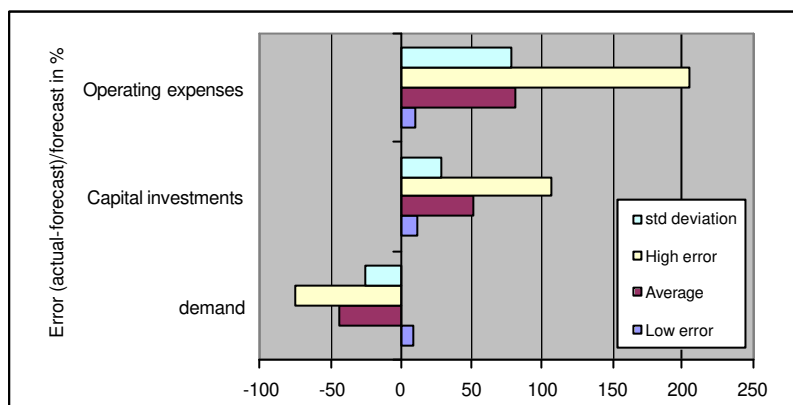


Figure 103: Forecasting errors survey on 10 large US rail projects, investments-operating costs-demand¹⁸³

This survey also underlines the fact that the projects' size increases risks and uncertainties (by 25% for large projects -over US\$ 0.4 billion- see Figure 104). The size of project is therefore a critical element in risk assessment, mainly affecting random effects.

If large-scale projects imply the coordination of a large numbers of partners, from the planning process to the construction, coordination and logistics become very complex with the adaptation to uncertainties and unattended events: the complexity concerns the project and its environment. Both changes and their effects have to be identified.

The consequence is that introducing systemic innovation with strong technological rupture in large-scale projects leads to a very high level of uncertainties.

If cost overruns can usually summarized problems encountered in projects or failures, classical infrastructure projects such as airports (case of Denver)¹⁸⁴, HSR projects (case of Seoul-Pusan in Korea)¹⁸⁵ or tunnels (which usually costs 50% more than expected), the question arise about the implementation of unproven technologies. Most people from the practice, or working in project realization, dislike innovations, contrary to scientists who are always happy to work for future and radical advancements in technology.

¹⁸² Sometimes failure and success are difficult to define for such projects, depending on which perspective the analysis is based. For example, the success of HSR projects in Europe is seen as a failure by few (USA) as the financial government back-ups were too important (Interview with Prof. W. Garisson, ITS-Berkeley May 2001).

¹⁸³ Graph based on the data survey of Pickrell 1990, analyzing 10 US rail projects since 1975.

¹⁸⁴ The Denver's new international airport, which saw costs escalate over the course of construction from \$1.7 billion to \$4.8 billion.

¹⁸⁵ The costs estimate of the new Denver airport have doubled to \$ 20 billion and the project completion has been pushed back from 2002 to 2006.

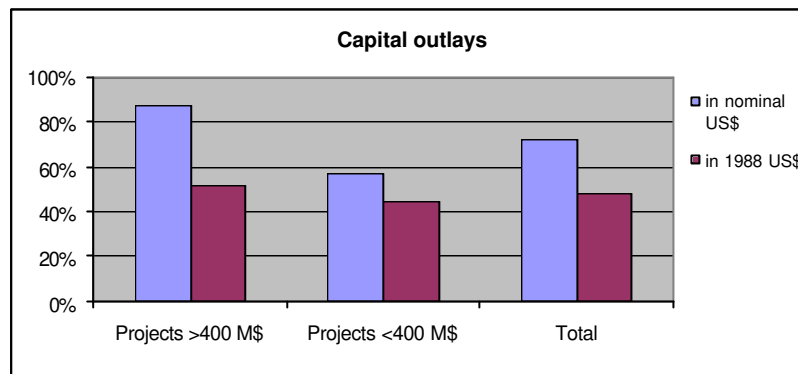


Figure 104: Cost overruns and project size, size as a factor of complexity in project management.¹⁸³

Transportation projects are also subjects to scope and planning uncertainties, whose main significant factors analyzed by Pickrell (1990) are:

- Time to reach project scope (years), with an average standard deviation of +50%.
- Annual inflation rate in construction costs, with a standard deviation of 30% for large projects.

This survey also underlines the fact that for uncertainties on operation expenses, the forecasts of annual vehicle-miles services is not really significant when compared with the forecasts of operation expenses per vehicle-mile. As these data concerns only non-innovative systems, this also help to understand why most operators are reluctant to be the first to operate an innovative system like Maglev technologies, without government backups.

If much studies on transportation projects underlines uncertainties¹⁸⁶ during the planning and implementation phase, these risks also influence the technological development: Since political risks are very important for such projects (case of the Aerotrain, TGV, Transrapid etc), the role of institutions is also very significant. Changes in regulation laws concerning safety or other aspects may affect technological aspects and may change drastically investment or operating costs.

The last example is the Acela Express, built by Alstom and Bombardier: Instead of keeping the same car-body of the tilting TGV concept, safety norms imposed by the FDOT for the Noth-East corridor induced to double the weight of the car-body, inducing significant changes in the design. Afterwards, management problems led to delivery problems¹⁸⁷ and finally AMTRAK to sue the manufacturing consortium in 2001.

- *Conclusions: The five types of uncertainties*

To conclude on this paragraph and before developing a methodology and delimiting the boundaries of the risk analysis, one might keep in mind that uncertainties can be related to five different types:

1. The unknown, consisting on unforeseen situations
2. Occurrence of exogenous events
3. Uncertainties or randomness in the values of measured or predicted impacts
4. Imprecision in the definition of one or more criteria

¹⁸⁶ Mahmassani H.S., "Uncertainty in transportation systems evaluation: issues and approaches"; in *Transportation Planning & Technology, 1984 Vol.9, pp.2-12*.

¹⁸⁷ The rolling stock delivered in 2000 was designed 20cm larger than expected, reducing by 20% the maximum speed on the corridor (AMTRAK news).

5. Uncertainty as the preferential or normative basis of the evaluation.

6.3.3. Towards a methodology for Risk Identification in innovative HSGT projects

After underlining these different factors of risks and uncertainty based on the results of surveys and the case studies, a methodology will be developed in order to strengthen the identification phase: Uncertainties in the evaluation of such projects has to be clearly defined and structured.

For this purpose, this paragraph will mainly focus on defining the boundaries of risk analyses, as well as a systemic approach that will lead to the elaboration of an assessment scheme and the development and the structuring of risk tables.

- *Boundaries of the analysis*

Sources and type of uncertainties in transportation projects are broad, because of the technical, economical and social impacts of such projects as well as the diversity of actors involved from R&D stages to implementation and operation of the system. This requires:

1. Importance of taking into account uncertainties in:
 - 1.1. Resources constraints
 - 1.2. Implementation timing
 - 1.3. Expected impacts
 - 1.4. Political acceptability
2. Importance concerning the knowledge of decision-makers and their appropriate value judgment
3. Importance of the demand side:
 - 3.1. Future growth and evolution of economic and demographic structure
 - 3.2. Transport demand evaluation

In order to summarize lessons drawn from the paragraphs above, uncertainties can be grouped in four categories for programming processes in HSGT projects:

- a. Project development related
- b. Funding related
- c. Delays
- d. Likelihood of implementation

However a good and systematic methodology is required for the apprehension of risks and uncertainties, since HSGT projects have an impact on a very broad range of aspects and actors.

- *Definition of Project's boundaries and actors*

The first step consists in the definition of the project boundaries, as the main actors that support and influence the project. The link with uncertainties is obvious, as the largest is the project boundary and the most actors are concerned (enablers or disablers): HSGT projects for example are subject to great political risks that industry dislike, especially when huge R&D investments are required for the development of new innovative systems.

Mapping the boundaries of the project allows defining the actors (primary or secondary), which are (or may be) concerned by the project (Figure 105).

After this step, actors are defined, but relations between them and the project has to be analyzed (arrows in the figure above). This requires a good understanding and knowledge of actors' strategies as well as the context:

- Institutional framework
- Political framework
- Market trends for operators
- Market trends for manufacturers
- Strategies of operators for the medium/long-term
- Strategies of manufacturers for the medium/long-term

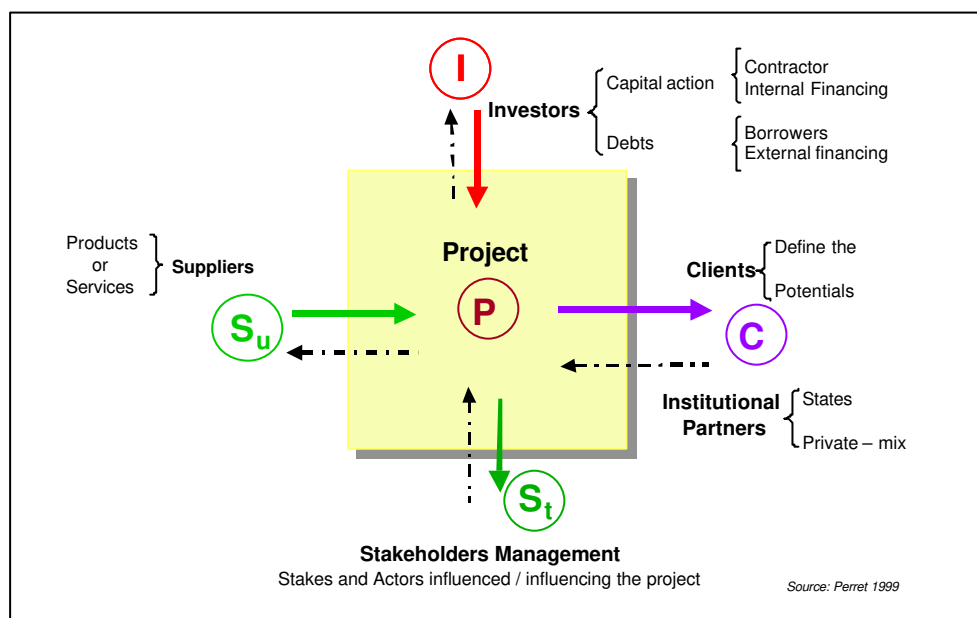


Figure 105: Definition of the project's boundaries as a mean to identify the sources of risk

However, if this process may be fuzzy for complex projects as strategies evolve and the time of innovation HSGT project is long (30 years for Maglev systems), it as to be rethought at each phase of the project, and frequently actualized.

The main problem in the case of innovative systems is that projects evolve from the R&D phase, to the industrial development, and then come to the implementation process. But these three phases are fundamentally different. Therefore, both boundaries and actors may be reconfigured (Figure 106).

This step is crucial for the project visibility, especially when the innovation induces a R&D phase or development that is atypical for the market segment. For example, a Swissmetro or a Transrapid have been developed by industry or industrial departments, which are not directly related to the traditional rail sector¹⁸⁸. Therefore all communication networks with lead-users are different. Therefore each change of

¹⁸⁸ Swissmetro seems to be more related to aerospace technologies (plane body, pressurized vehicles etc), than related to current

step, in the purpose of implementation will induce major reconfiguration in the project structure in terms of organization, communication etc.

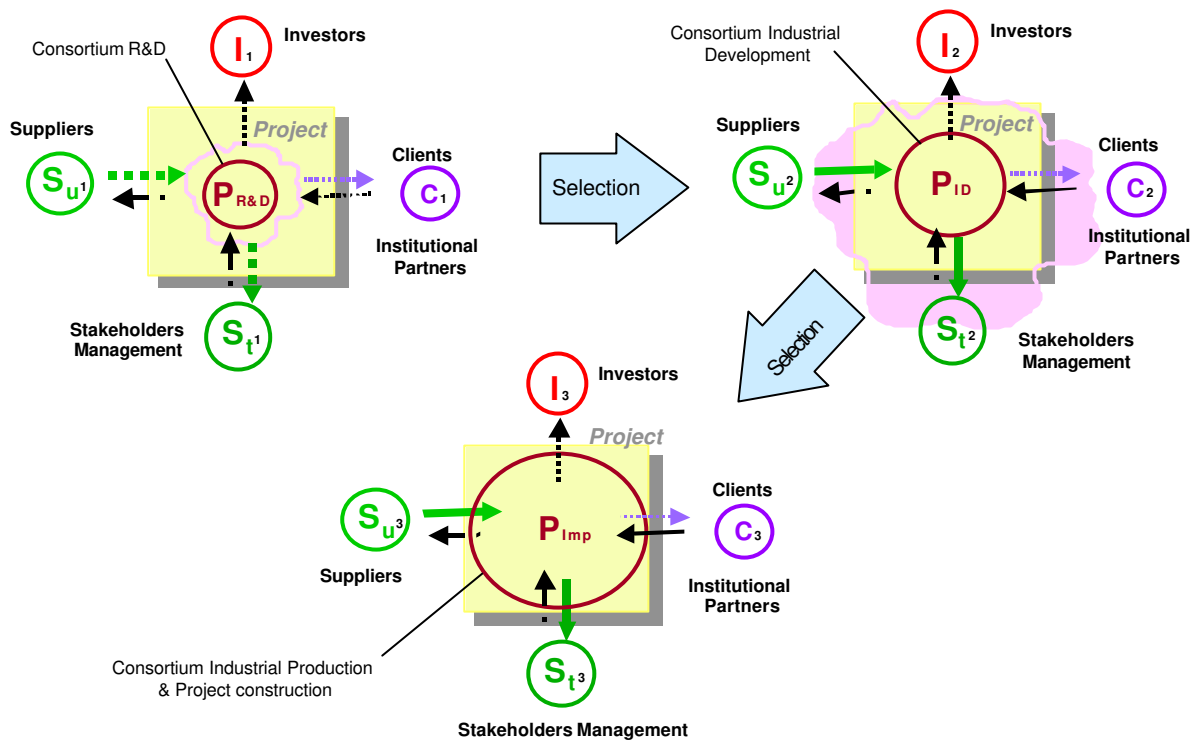


Figure 106: Project phases and definition of boundaries and actors

- *Systemic approach in the risk identification*

In the case of innovation in HSGT technologies, risk and uncertainties may concern three main phases which need to be assessed for any further development or transition: R&D, industrial development and implementation. Risk and uncertainties are related to the well development of the project.

But as innovation and implementation processes are complex, two steps have to be analyzed deeper: the transition phase between R&D and industrial development, and between Industrial development and implementation. As both transition phases are crucial and require special attention and management, they must be analyzed separately, even if they are connected to the three phases.

The systemic approach proposed below subdivides the HSGT innovation process into these three phases, punctuated by two critical transition phases (Figure 107). However, if these phases may overlap in practice and require to be managed in parallel, the analysis remains unchanged.

Concerning the implementation phase, this step should include not only the first implementation, but also the diffusion of the system/technology as the innovation process also concern the market success.

rail technologies: industrial networks, partners and professional communities are therefore very different and this increases the risk of resistance to innovation and change.

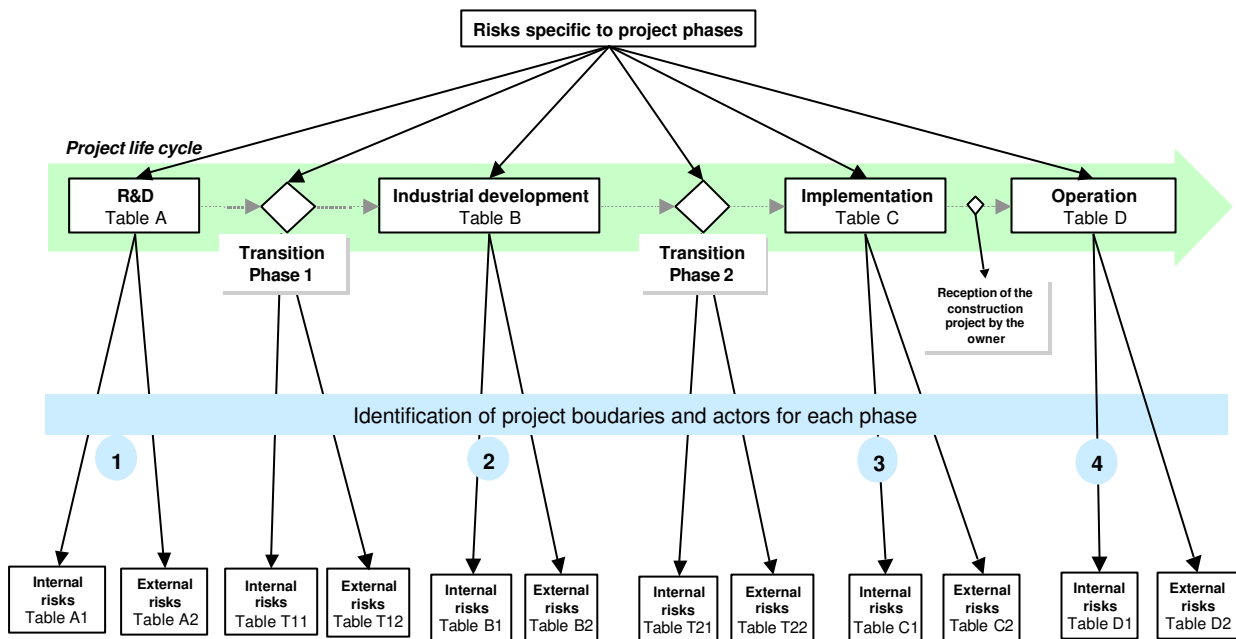


Figure 107: Risk Model; towards a systemic approach in the risk identification

- *Endogenous sources of Risks*

Endogenous sources of risks are linked to the internal project development (*Project based sources of risks*). As underline in case studies¹⁸⁹, they may concern many aspects such as organizational, technical, managerial etc. Major sources of risk and uncertainty are size, complexity, novelty, speed of design or construction and location.

But in complex systems, such as HSGT technologies, the identification of risks has also to be achieved by scope in order to screen the maximum of risk sources in a coherent way. For this purpose, the approach used in Hishikawa diagrams may be useful (Figure 108).

This approach may be used for each step of the project (for example the three main phases and the two transition phases) with the definition of pertinent scopes. For example in an early definition of a project, such as Swissmetro, seven scopes may be defined as in the figure below.

Sources of risks and uncertainties are listed for each scope, and underlines enablers/disablers in the project management.

¹⁸⁹ See chapter 4.3

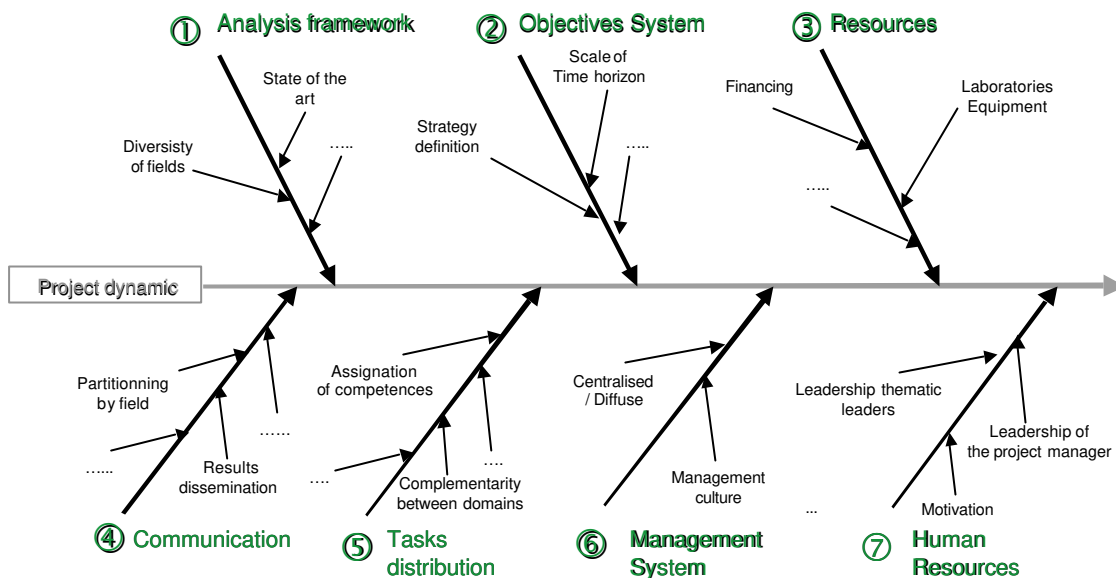


Figure 108: Identification of the internal sources of risk: enablers & disablers in project management

• Exogenous sources of Risks

Exogenous sources of risks/uncertainties are linked to external conditions or actors, as changes of regulation measures¹⁹⁰, political changes, change of the market structure etc.

For large projects, the longer the time scale is, the more likely some interference or outside events will affect the project; for example:

- Market conditions: for example in the 1960s, Maglev leaders thought that the market would have been favorable for implementation (first version/pre-production series of the HSST in Japan and of the Transrapid were tested in the mid 1980s), but the market reacted another way, reluctant to change of its technological trajectory.
- Political changes in Germany surprised the Transrapid consortium in the early 90's, and new politicians were less concerned by the project.

In the same approach than through the Hishikawa diagram, scopes and risks sources have to be developed for each phase of the project. For the success of an HSGT innovation, 7 scopes may be defined to describe exogenous factors: social, political, economical & financial, technological, legislation, environmental, marketing (Figure 109).

• Mapping out the rupture

The process of defining critical scopes for both endogenous and exogenous sources of risks as well as describing all these sources allows tracking the incidence of innovation and rupture on the project.

¹⁹⁰ Risks of regulation changes in transportation projects: Arto K.A. & Kähkönen K., 1997; *Managing risks in projects*, E.&F.N. Spon London. pp 284-293

This step is very important to bring managers and leading actors aware of the consequences of the rupture on management:

- Project: organization, knowledge, resources etc.
- Project environment: market needs, political trends (national and European level), social acceptability etc.

These concepts of describing and visualizing causes and effects can also be achieved with influence diagrams used in “systems dynamics” (Forrester 1958, 1961) or cognitive maps (Axelrod 1976). As Senge (1990) underlined, these tools or “mental models” allow better understanding this “holographic” reality. In this way, the multiple perspective approach can contribute to reduce risks associated with the misunderstanding of the project functions and its environment.

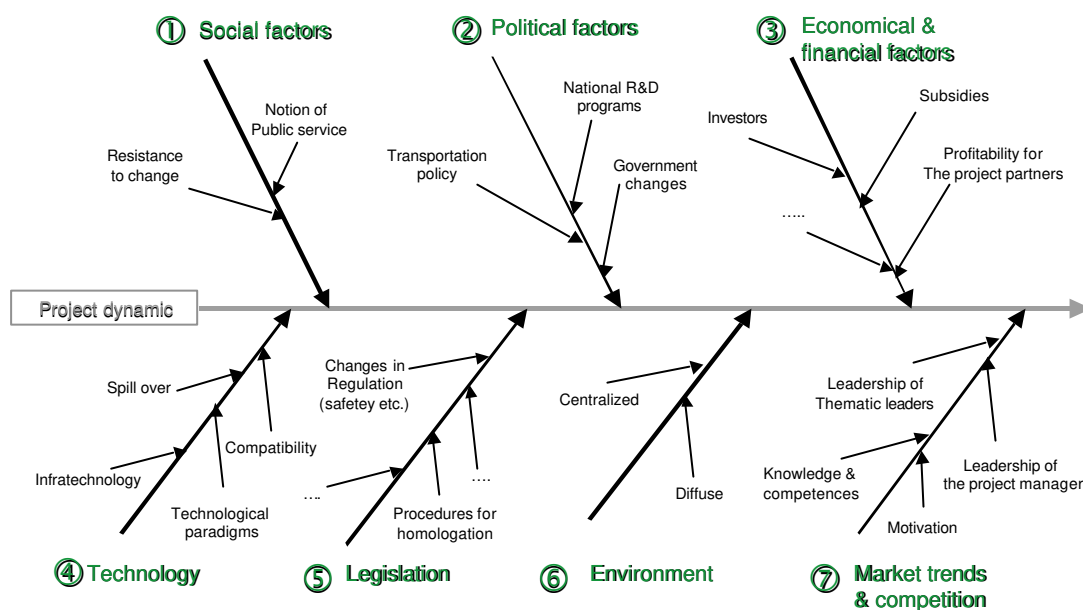


Figure 109: Identification of the external sources of risk: enablers & disablers in project management

• Risk typology

After the definition of scopes and the related sources of risks and uncertainties, the previous approach may be coupled with another approach, which is only a different presentation but may also underline several risks or strengthen the risk perception.

In the perspective developed by Huber¹⁹¹ (in Perret 1999), the risk identification is focused on the project development and implementation. (Figure 110) The R&D or design phase is only integrated through its impacts on the implementation phase. But this approach underlines what expectations have the adopters and financers of the HSGT technology.

¹⁹¹ K. Huber is a financial analyst, managing partner of SEMP.

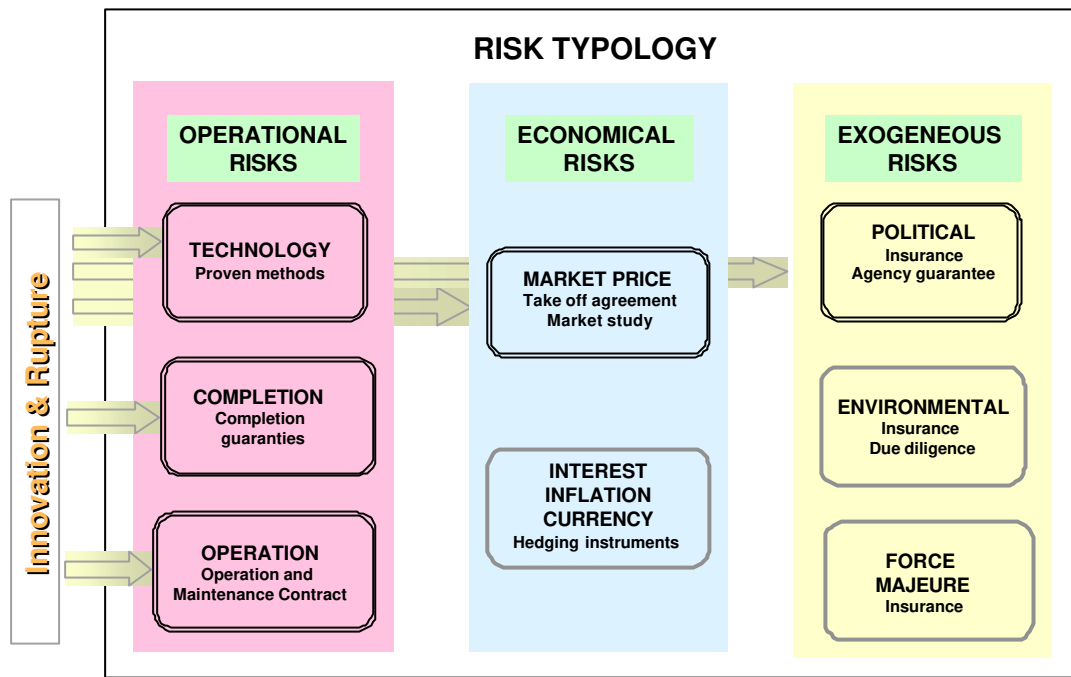


Figure 110: Risk typology: Influence of innovation and rupture (Adapted from Perret 1999)

As defined by Boutron & de Tilière (2000), three stages of innovative HSGT projects have to be defined, each one with a specific and dominant risk typology:

- R&D phase with the industrial development (technological and economical risks for manufacturers).
- Construction and implementation phase (Construction and regulation risks).
- Operation (economical and regulatory risks for operators).

- *Technological risks due to the rupture: the essence of industrial risk*

Concerning project financing, Nevitt and Fabozzi (1995)¹⁹² underline that one of the factor of project failures is the use of new technologies. The technical feasibility is the black spot of project financing, knowing that the role of learning by doing is very important. And if economic feasibility is really important, it only comes after technological feasibility.

In fact most reluctance of operators to adopt innovative systems leads in the increase of risks because of youth defaults of the new technology. For this reason main operators require a few years of successful operation of a technology before purchasing a system.

To illustrate these risks, the Transrapid faced difficulties in operating with snow and winter conditions on the test track in Emsland. The design of the track had to be modified and the cost of these modifications was around 70 M.DM. This is the main risk that may cause difficulties to the Swissmetro project, or induce its cancellation.

But the logic of new product development and the introduction of disruptive technology also induce another condition: the notion of market scale for manufacturers. The development of knowledge,

¹⁹² P.K. Nevitt, F. Fabozzi, « Project Financing », sixth edition, Euromoney Books, 1995, p. 4.

manufacturing infrastructures and competencies for such projects also require a long-term far-sight for two reasons:

- The production scale must be sufficient in order to amortize and for the calibrate the technology (from the manufacturer point of view).
- The contracts of maintenance and repairs (30 years contracts) must be profitable in the long-term (if only 20 vehicles of Swissmetro are produced, this will lead to the failure of the technology in the long-term, as maintenance and repair will be too expensive for both operator and manufacturer).¹⁹³

Small series at competitive prices may be build but without requiring major R&D development activities, except with a strong support of governments (as it has been the case in the aerospace industry for satellites, or rockets through military programs). For example, Bombardier only manufactures small series in its plants of Villeneuve (CH) based on current knowledge and technology. Major innovations are only achieved for larger series. In the Villeneuve engineering office, innovations are achieved on bogies, but these components are also send to other Bombardier plants and therefore produced in large series.¹⁹⁴

- *Construction Risks*

Three types of risks are specific to large infrastructure projects:

- Risks of non achievement of works
- Risks of cost and time overruns
- Political risks (legal, fiscal, safety and environmental norms)

The risk of non-achievement of works is usually related to technical difficulties encountered by constructors. They can be due to conception or realization defaults. The impact of the technological rupture and the architectural innovation is therefore much higher than for incremental innovations: problems occur between the technical feasibility and the full-scale construction. The large-scale and the degree of innovation add to the complexity, such as the superposition of innovative technical systems for Swissmetro: large-scale vacuum with new Maglev technology.

To underline these risks, the Channel project is interesting: complexity in the forage (humid environment) added to special security norms led to management difficulties and several incidents, even with the use of existing technologies in a "new" environment.

The risks of cost and time overruns are very important in large infrastructure projects. Usually, cost overruns are about 25% for usual projects. But technological risks may become very important because of the large-scale of a project as noticed by R. Lyons¹⁹⁵ about Eurotunnel: «*The only certainty about a pioneering project of Eurotunnel's magnitude [...] is that unexpected and largely unpredictable events will arise which will seriously affect cost and time completion. In other words, technical risks inherent in the project are largely unquantifiable*». Therefore introducing the innovation and rupture in both system architecture and in technologies will lead to some reluctance from industry and investors without a public back-up or clear political program defining a new technological path.

Taking the case of Eurotunnel, which may be defined as « a Swissmetro project without the rupture » the construction costs estimated at £4,7 billions was finally £11,5 billions (more than 100% increase). Are engineers too optimistic to give more chance to their project for implementation?¹⁹⁶ But in the case of projects with strong technological rupture, another important source of cost and time overruns may be induce by the modification of the project definition. Changes and corrections after the

¹⁹³ This has been the case for two low-speed Maglev projects in Birmingham and Berlin, were both technologies were abandoned after few years of operation.

¹⁹⁴ Interview with M. Crosier, marketing manager at Bombardier transport, 28.11.2001, and visit of the production plant in Villeneuve (CH).

¹⁹⁵ Lyons R., 1996; "The folly of tunnel vision », Project & Trade Finance", Euromoney Publications PLC, n° 153, January 1996.

¹⁹⁶ Fargette G., 1997 ; *Eurotunnel, Panama : deux grands défis de l'Histoire*, Editions L'Harmattan, p. 13.

design phase are extremely costly. And this risk is much higher for systemic innovation rather than incremental solutions, as the “comportment of the system” is not known as experience is accumulated in learning by doing.

But to increase these risks, lately modification of environmental and safety norms can also affect technical options and require adaptations. For a completely new system such as Swissmetro, norms are not defined, but will be elaborated in parallel, increasing risks of visibility in the project (technical specifications etc.)

Political risks, safety and environmental norms constitute a large part of risks specific to large infrastructure projects and transportation systems. As underline in case studies, political risks are very important, such as the case of the TGV Texas or Florida, the Transrapid Berlin-Hamburg or the Aerotrains: if politics and public institutions may promote or kill projects, they also may promote or kill technologies. And industry has to minimize the impact of such risks. Some times this may constitute strong opportunities such as the Transrapid implementation in China (with a government support from Germany and China). Concerning risks related to environment and safety, they are increased because of the long time period required to achieve the development and the construction phase.

- *Risks concerning the operation phase*

During this phase risks may be evaluated in terms of operation expenses and revenues. The technological rupture may influence operating expenses and revenue through diverse aspects:

- Risks link to the demand-forecast

This is probably the main problem for operators for the implementation of HSGT technologies. The high improvement in the supply on a corridor may be seen as a rupture. This rupture in the supply may or not induce radical changes in users behavior. For example, forecasts for the Paris-Lyon TGV were 50% bellow operation results. This was the same effect in Japan for the Shinkansen. But as demand-forecasts are very difficult to make on 30 or 40 years horizon, the Net Present Value of the project (NPV) is sharply affected by demand levels.

For this reason, operators may be reluctant to combine too sharp rupture in both market and technology at the same time without government backup (case of the Transrapid in Germany). In France where the government was against any support to the rupture to avoid financial risks: the main rupture of the TGV was on the supply, but this rupture was even reduced by the experience of the Turbotrain between Paris-Caen, which was a commercial success. Concerning the TGV technology, the rupture was reduced by an incremental evolution, based on the Turbotrain concept (TGV01 gas-turbine).

However, it must be added that one of the biggest difficulties remains intermodal competition, and as HSGT infrastructure are less flexible than road or air transportation systems, the demand levels are also related to transportation policies (taxes, regulation measures etc.) adding to the complexity of demand-forecasts the complexity of the regulation framework and the main orientation in transportation policies.

- Risks related to operation costs overruns:

Technical aspects: risk that innovative components and the new system architecture bring defaults in the design or/and the realization. Consequences may be a postponement of the operation beginning, or problems during a part or all the operating phase. This may increase costs due to corrections that may be required or due to higher operation expenses (higher energy consumption, maintenance cost and frequency etc.)

Construction aspects: operation costs overruns may also be due to construction defaults that are only imputable to large-scale construction projects (failures in planning, project management etc).

• *Conclusions on the systemic approach: toward the elaboration of risk tables*

Tables of the identification of risks relevant to analyze the impacts of the rupture are detailed below. They will be re-developed at the end of this chapter with the conclusions on the consequences of the technological rupture on each factor.

The phase of R&D is preceded by an analysis of market needs and opportunities, and the definition of a strategy, embodied in R&D choices.

R&D Phase	Item
<i>Table A1</i>	<i>Internal risks</i>
	Forecasts
	Planning
	Scope
	Means
	Adequate tools
	Infra-technologies
	Adequate knowledge
	Technological lock-in
	Funding & cost planning
	Interdisciplinary studies
	Management of interfaces
	Knowledge capitalization
<i>Table A2</i>	<i>External risks</i>
	Involvement of suppliers and partners
	Intellectual propriety and patenting
	Political risks if supported by governments.
	Academic/industrial partnership
	Academic/industrial partnership

Table 5: Risk identification, tables A1 & A2 related to the R&D phase.

When the R&D phase completed or well started, a transition phase begins. It corresponds to the assessment of the opportunity to:

- Maintain the option through more research.
- Go to the development phase.
- Stop the project.

Transition phase 1	Item
<i>Table T11</i>	<i>Internal risks</i>
	Technological assessment
	Market assessment (market of operators)
	Option selection
	Paradigms
	Strategic changes
	Funding problems

	Insufficient marketing and networking
	Transition management
<i>Table T12</i>	<i>External risks</i>
	Operators disengagement
	Infrastructure owner veto
	Assessment by institutions
	Political risks

Table 6: Risk identification, tables T11 & T12 related to the first transition phase.

If the assessment of the technological option (first transition phase) converges toward the decision of going forward in the industrial development, then the risks may be:

Industrial development	Item
<i>Table B1</i>	<i>Internal risks</i>
	Maladjustment of production tools
	Maladjustment of testing grounds
	Profitability
	Problem solving
	Accuracy with resources
	Interfaces management
	Objectives and targets
<i>Table B2</i>	<i>External risks</i>
	Suppliers network
	Support from institutions and associations
	Political risks
	Certification and homologation

Table 7: Risk identification, tables B1 & B2 related to the industrial development phase.

Tables T21, T22, C1, C2 describes relevant risks and the impacts of the rupture, the central actor is therefore the potential operator with eventually the agency responsible for infrastructures (Especially in Europe), and the government/institutions:

Transition Phase 2	Item
<i>Table T21</i>	<i>Internal risks</i>
	Operators attitude
	Strategic changes
	Paradigms
	Forecasts
	Potential market assessment (market of final users)
	Project assessment
	Option selection (methodology and tools)
	Funding problems
	Insufficient marketing and networking
	Transition management

Table T22	External risks
	Political risks (decision making)
	Transportation policy (national level)
	Transportation policy (European level)
	Risks related to institutional aspects.

Table 8: Risk identification, tables T12 & T22 related to the second transition phase (Development-Implementation).

If the second transition phase leads to the decision to implement the technology, the project is going forward to the implementation (construction) phase. The project actors are the future infrastructure owner, the operator (which are now distinct in Europe), manufacturers (vehicles and infrastructure equipments) and construction companies:

Implementation phase	Item
Table C1	Internal risks
	Cost-forecasts
	Planning
	Financing
	Construction difficulties (civil engineering)
	Management difficulties (civil engineering)
Table C2	External risks
	Act of god
	Change of the regulator requirements
	Political changes

Table 9: Risk identification, tables C1 & C2 related to the implementation phase.

After construction and when the project reception is successfully achieved, operation activities begin with the role of the infrastructure owner and the operator(s):

Operation phase	Item
Table D1	Internal risks
	Reliability problems
	Operation costs results/estimates
	Demand level results/estimates
	Organizational changes
	Sufficient knowledge and training of personal
	Excessive maintenance costs
Table D2	External risks
	Change in behavioral patterns (users)
	Act of god
	Change of the regulator requirements

Table 10: Risk identification, tables D1 & D2 related to the operation phase.

These risk tables provide a good basis for the identification of risks and uncertainties, based on the lessons drawn from the case studies and the surveys. However, before detailing these ones with an emphasis on the impact of the technological rupture on each factor (§6.6 page 233), one must detail the assessment framework: assessing risks and opportunities are not easy in the case of innovation with strong technological rupture.

6.4. Risk Assessment: Valuing risks & opportunities of the technological rupture

6.4.1. Introduction & methodology

This chapter will focus on bringing an adapted methodology to assess the technological rupture, stressing the main difficulties and the limits of evaluation and assessment of classical methods. Focusing on the impact of the rupture on the evaluation of HSGT projects, the multi-perspective approach developed before will underline the consequences of the valuation of risks and uncertainties.

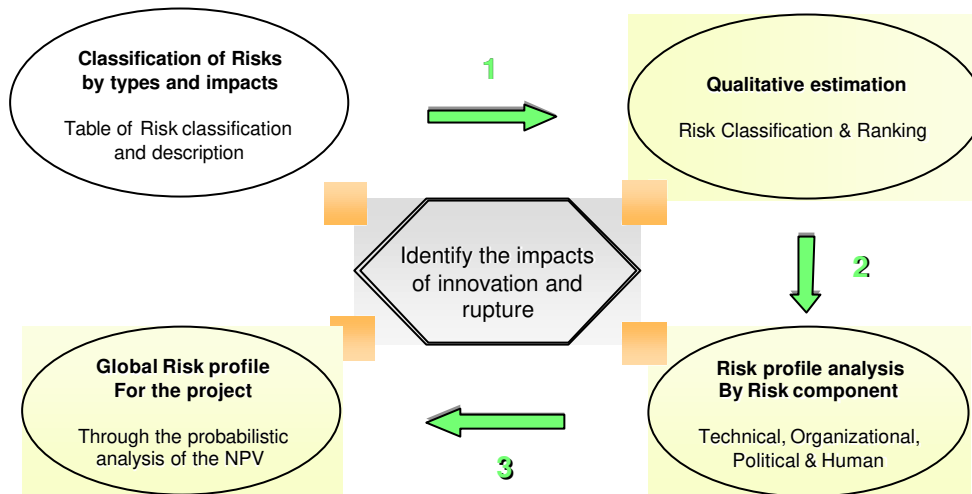


Figure 111: Risk assessment, reduction in the quantitative uncertainty

- *Measurement uncertainty*

As descriptive uncertainty affects risk identification through the understanding and representation of a particular system, phenomenon or event (reference to the notion of “holographic” understanding of the project reality developed by Senge 1990), measurement uncertainties are due to inaccuracies in our measurement tools (physical or statistical)¹⁹⁷ to approach future states of a system. For example, forecasting the demand for Swissmetro at a 20 years horizon is an exercise in which uncertainties are very high: There is no experience for such futuristic disruptive system, whereas HSR benefits from 30 years of experience in Japan, France and Europe, with feedbacks from users and operators. Experience allows calibrating models and to develop a better understanding between supply improvements and behavior changes. At the technical level innovative components and new combinations of systems also add to these uncertainties for reliability, safety, and costs.

- *Qualitative / quantitative analysis*

In complex and innovative engineering systems, the use of both qualitative and quantitative approaches allows reducing measurement uncertainties. Qualitative approaches are achieved by means of an evaluation of risks by a rating and ranking based on a simple scale (1 to 10, or 1 to 7 for the PMAS application described in Annex).

Two critical steps may be assessed: Opportunities for the industrial development (1), which mainly concern the interest of manufacturers to develop a new technology; and Implementation (2), which concerns the interest of operators of using this new technology and upgrade their services.

¹⁹⁷ Rowe W.D., 1977; “An Anatomy of Risk”, J. Wiley & Sons.

Visualizing risk and opportunities require the use of both quantitative and qualitative methods: the integration of the different factors developed in previous chapters are not always easy to assess. But conceptual schemes may help to represent and assess risks.

Taking the case of the emergence of Maglev technologies, market opportunities may be superposed with risks linked to the technological rupture (Figure 112):

Two different market situation have to be compared: (1) is the market before the 1980's and (2) after the 1990's. In the first configuration, market opportunities for HSGT Maglev technologies in terms of speed were interesting, betting on the technological lock-in of rail technologies to reach high speed. But since that time, performances increased and HSR systems now reach more than 300 km in commercial operation, decreasing significantly potential market shares for Maglev systems. At the same time, market opportunities are also reduced for Maglev technologies with the completion of HSR networks and the use of tilting technologies.

Added to market opportunities, technological risks are mapped below, with the decrease of risks with experience (knowledge and know-how) in both production and operation activities.

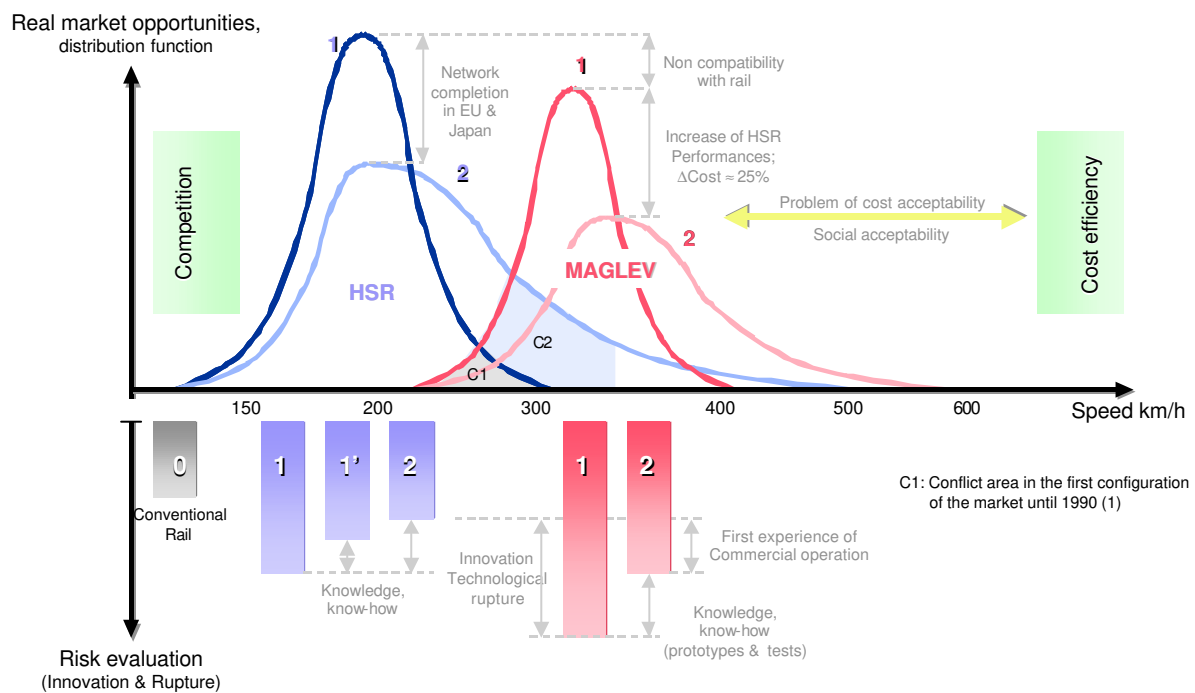


Figure 112: Risk analysis: mapping out the impacts of innovation

- Taking into account HOF into Risk analysis

If net present value (NPV) analyzes are important, apprehending risks with probabilistic NPV approaches is not sufficient in the case of strong technological rupture: impacts of the rupture on knowledge, organizations is usually a critical factor in failures (Bea 2001, Williams 1988).

To better understand the impact of the technological rupture, works developed in risk management by social scientist are interesting (Reason 1990), describing the role of human and organizational factors (HOF) in system failure or accidents. In the case of innovative technologies, understanding the impacts of the rupture on these HOF performance factors may help in a better understanding of risks related to disruptive technologies.

6.4.2. Assessing the impacts of technological rupture: the notion of Performance Shaping Factors

Reason (1997)¹⁹⁸ suggested three models to reliability management: (1) person model, (2) engineering model, and (3) organizational model. If innovation deals with the ability to lead change among the industry and the change of users behavior, the role of individuals and organizations is crucial, as underlined in case studies. If risk analysis and risk management had their origins in the insurance industry in the USA in the 1940's, research on human and organizational factors (HOF) are more recent (Bea 2001).¹⁹⁹

Innovation implies new tasks and new processes. Therefore a large part of the risk may be seen as a result of human and organizational errors (Rasmussen 1987, 1996; Reason 1997; Bea 2001²⁰⁰). These hazards are associated with human and Organizational factors (HOF) which concern: organizations, procedures, Equipments (Infra-technology) and Environment. The rupture related to a technological innovation may affect these 6 modules, influencing projects risks.

The purpose is to define the influence of innovation on these generic shaping factors in order to measure the difference between incremental and innovative projects.

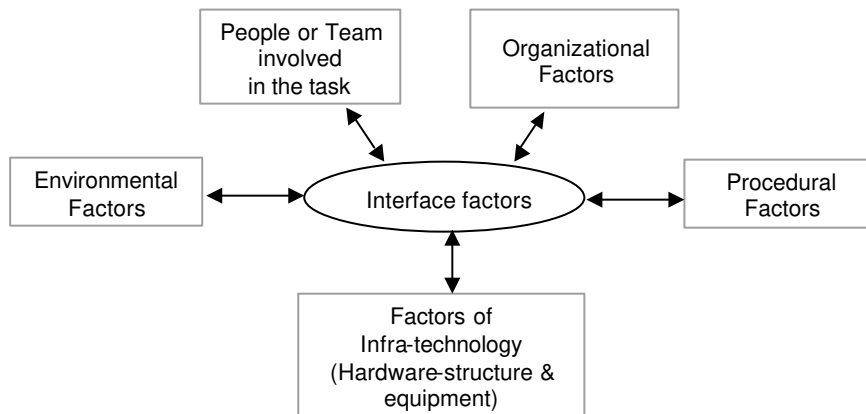


Figure 113: Human and organizational factors (HOF) in the development/construction of HSGT projects

Stressing the influence of innovation and rupture on design, development or construction phases may be achieved by means of the definition of *Performance Shaping Factors* (PSF) (Williams 1988). The principle is to evaluate the influence of the 6 modules detailed above (linked to specific environment or system, for example with a highly innovative technology) on the base rates of errors committed by operating personnel.²⁰¹

The expression of risk may be described by means of the probability of system failure:

$$P(F_{jkm}) = P\left(\sum_k F_{jkm}\right)$$

¹⁹⁸ Reason J. 1997; *Managing risks of organizational accidents*, Ashgate Publishers, Aldershot, UK.

¹⁹⁹ Bea R. 2001; *Human & Organizational factors: Risk assessment & management in engineering systems*; CEE-Berkeley, course document.

²⁰⁰ Bea, R., 2001; *Human & Organizational factors: Risk Assessment and Management of Engineering Systems*, UC-Berkeley, CE-OE290A.

²⁰¹ Referenced in normal conditions, for example in the development or implementation of a technology that corresponds to an average degree of complexity/innovation.

With:

j is the period of the system life cycle ($j=1$ R&D, design; $j=2$ industrial development; $j=3$ construction; $j=4$ operation)

K is the number of parts/activities that may be defined in each life cycle period.

m is the type of malfunctions (for example $m=1$ Problem definition, $m=2$ Task analysis, $m=3$ error identification, $m=4$ representation, $m=5$ quantification, $m=6$ assessment of impacts, $m=7$ error correction).

But the probability of failure may be expressed depending on the probability of malfunctions, for instance related to the problem of knowledge and experience (especially in the case of disruptive technologies and innovation). Therefore the expression of risk may be described as:

$$P(F_{jkm}) = P\left(\sum_m F_{jkm}\right)$$

$$P(F_{jkm}) = \sum_m P(F_{jkm} / E_{jkm}) \times P(E_{jkm}) \quad (1)$$

The failure of the system may be caused by the event E_{jkm} , which is related to a project phase (J), a task or activity (k), and a malfunction (m), which is a combination of what will be defined as a combination of generic human error rate.

The notion of performance shaping (PSF) may be introduced by the following expression:

$$P(E_{jkm}) = P(E'_{jkm}) \times \prod_{\epsilon_{jkm}} PSF_{\epsilon_{jkm}} \quad P(E_{jkm}) \leq 1.0 \quad (2)$$

With: E is an event in the specific context, which is analyzed, and E' is the event of corresponding to E in an environment of reference.

ϵ is the contributing influence or error causing, it may be from one of the 6 modules defined in the figure above, which define 6 type of PSF.

j is the period of the system life cycle ($j=1$ R&D, design; $j=2$ industrial development; $j=3$ construction; $j=4$ operation)

K is the number of parts/activities that may be defined in each life cycle period.

m is the type of malfunctions (for example $m=1$ Problem definition, $m=2$ Task analysis, $m=3$ error identification, $m=4$ representation, $m=5$ quantification, $m=6$ assessment of impacts, $m=7$ error correction)

Therefore, (1) and (2) lead to:
$$P(F_{jkm}) = \sum \left[P(E'_{jkm}) \times \prod_{\epsilon_{jkm}} PSF_{\epsilon_{jkm}} \right]$$

The quantification of $P(E')$ and PSF has been the subject of the research of Swain & Guttman (1983), Dougherty 1986 and a large survey for Chemical Process Safety (1994). These results underline the role of Knowledge, unfamiliarity and complexity in the rate of errors. (Figure 113 and Figure 114)

These figures underline that tasks related to innovation (new or rarely performed task) have a high rate of human error ($10^{-1} < P(E') < 1$), followed by highly complex task ($10^{-2} < P(E') < 10^{-1}$). Concerning the development of a complex technology for small series this may be associated with complex but unfamiliar task such as the production of only 15 Swissmetro vehicles: $10^{-3} < P(E') < 10^{-2}$.

Considering proactive risk management based on three layers: skills, rules and knowledge; knowledge is associated with the higher rate of human errors $10^{-1} < P(E) < 1$. This underlines the fact that the incorporation of too much innovation in a system, requiring the parallel development of the infratechnology is much more risky in terms of error rate.

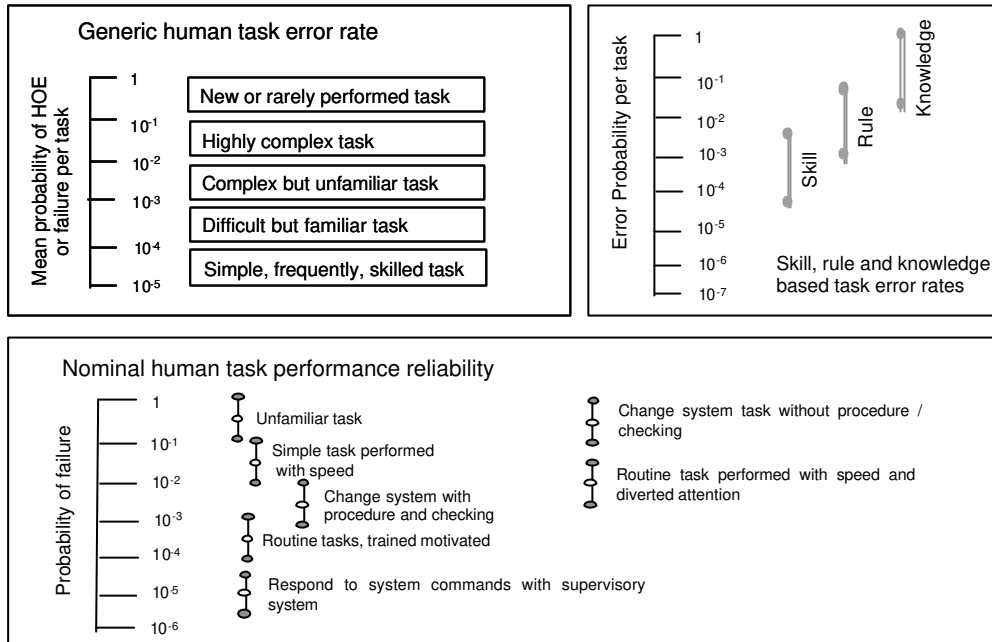


Figure 114: Generic error rates $P(E)$ (Source: Bea 1996, Swain & Guttman 1983)

Error Producing condition	Multiplier	(cont.)	Multiplier
Unfamiliarity	17	Inadequate checking	3
Time shortage	11	Objectives conflicts	3
Features over-ride allowed	9	Limited diversity	2.5
Spatial/functional incompatibility	8	Educational mismatch	2
Design model mismatch	8	Dangerous incentives	2
Irreversible action	8	Lack of exercise	1.8
Information overload	6	Unreliable instruments	1.6
Technique unlearning	6	Absolute judgments required	1.6
Knowledge transfer	5.5	Unclear allocation of functions	1.6
Performance ambiguity	5	Lack of progress tracking	1.4
Misperception of risk	4	Limited physical capabilities	1.4
Poor Feedback	4	Emotional stress	1.3
Inexperience	3	Sleep disruption	1.2
Communication filtering	3		

Source: Dougherty & Frangola 1986, Center for Chemical Process Safety 1994

Table 11: Performance Shaping Factors (PSF), multiplier of error producing condition (human factors)

Comparing new product development in the industry with radical innovations, rates of errors of changing a system (case of the TGV or Shinkansen prototype development) may be associated with “change system

with procedure and checking”, corresponding to incremental solutions²⁰²: $10^{-3} < PSF < 10^{-2}$. In the case of more radical innovations, the reconfiguration of the system with the incorporation of highly innovative components such as Swissmetro, may refer to *unfamiliar task*, or *new or rarely performed task*, with: $10^{-1} < P(E') < 1$.

In the PSF analysis achieved by Dougherty & Fragola (1986) and the Center for Chemical Process Safety (1994), impacts of unfamiliarity are the most critical²⁰³ (multiplying error rate by 17: $PSF=17$). But dealing with large-scale or complex system with technological rupture, other relevant PSF factors are described in the figure below:

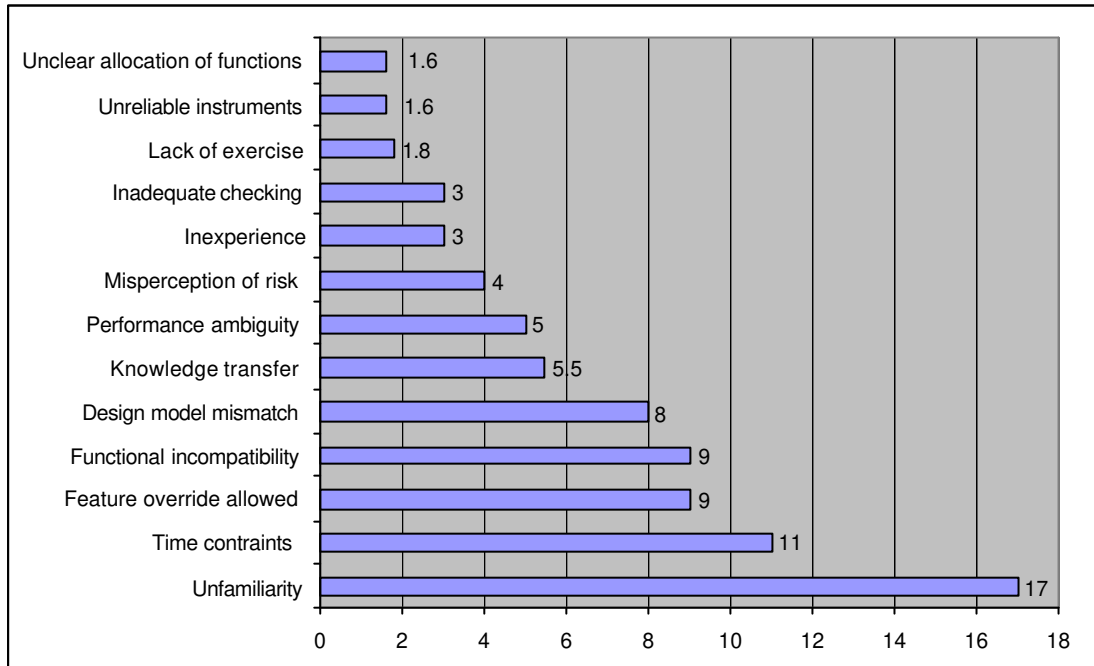


Figure 115: PSF factors related to projects with strong technological rupture (based on Dougherty & Fragola 1986).

For example, each task may be characterized by one or more relevant PFS, and the expression of the risk in the project P(F) is described by:

$$P(F) = P(E'_1) \cdot PSF_a + P(E'_2) \cdot PSF_b \cdot PSF_c + P(E'_3) \cdot PSF_b \cdot PSF_e \cdot PSF_f$$

With PSF(a) relevant in the task (1); PSF (b), (c) in the task (2) and PSF (b), (e),(f) in the task (3).

If this method may be difficult to implement systematically, it brings more comprehension on the impact of innovation on risks. This should influence managers to be aware of the rupture and to consider carefully the relation between innovation, knowledge management and risk in complex projects with strong technological rupture. Finally, this approach stresses the importance of proactive management of risks in such projects, and can be a useful tool to complete classical risk assessment methods.

²⁰² As the development of the TGV-01 prototype based on the experience of the Turbotrain already developed by SNCF-GEC Alstom early in the 1970's.

²⁰³ Unfamiliarity has to be distinguished from Inexperience (PSF=3), which in those cases are not relevant as people involved in such systems are usually highly qualified.

6.4.3. Risk assessment methods & cost/benefits analysis

If several managers assess their opportunities in innovation by means of a simple formula such as the one below, they usually reject a lot of innovative ideas without too much detailed analysis. The judge the probability of success as:²⁰⁴

$$P(\text{Success})=P(\text{Technical feasibility \& development}) * P(\text{Successful market introduction}) * P(\text{Market leadership})$$

If such concepts usually contribute to avoid innovation disasters (mostly market failures), Entrepreneurs and managers need to assess more systematically projects values and investment choices. Investments may concern R&D phases, or industrial development (industry) or implementation phase (operator and public decision-maker).

- *Cost/Benefit Analyses*

Cost/Benefit analyses are usually used in all large infrastructure projects, as well as industrial ones. These methods are used to measure the intrinsic and extrinsic value of a project or an option (Figure 116).

Cost/benefit analyses are mainly using the valuation of the net present value (NPV) including the use of techniques that allow measuring in monetary terms the advantages and disadvantages of the project. The calculation of the NPV leads also to the determination of other criterion as the internal rate of return (IRR) or the delay of investment capital recovering (DICR). These main indicators allow making project comparison and select options presenting most of interest.

The main problem in such approaches remains the assessment and monetization of external impacts. For example, the valuation of time and environmental factors leads to the paradigm of internalization of external costs of the projects in the European transportation policy. But this remains a paradigm as other countries such as the USA have different approaches and don't value much these factors when compared with internal profitability.²⁰⁵

However, some changes induced for example by the accident of the Mt-Blanc and the Gothard constitutes shifts in paradigms among politics and can favor or not a technology. For example, one of the reasons that contribute to the death of the Aerotrain (turbojet propulsion) project for the profit of the TGV, was the new nuclear policy for energy self-sufficiency. Such arguments constitute barriers or enablers that are discrete variables. Swissmetro bet on the underground high-speed as a major factor for environmental policy. But this supposes a very high valuation of externalities.

- *Multicriteria analysis methods*

In fact the main debate in transportation policy remains the attribution of weights for criteria (which depends on political objectives). The integration of numerous factors (with their standard deviation) in the decision analysis leads to a complex selection: uncertainties are not only related to the values of each factor but also on the weight of each criterion. Methods such as LINAM (based on Electre algorithms) allow classifying options and seeing through sensitivity analyses, how selected set of options changes. These analyses are realized based on the variation of weights, for each critical factor.

The use of such methods allows reducing decisional risks, through a better understanding of the impact of uncertainties on the set of selected options.

²⁰⁴ Interview with Prof. Deschamps, (Oct. 2001) about successful innovations, market introduction, and leadership

²⁰⁵ Interview with Prof. W. Garrison, Institute of Transportation Studies, UC-Berkeley June 2001.

- Risk analysis based on NPV probabilistic analysis

Three models relevant to risk comparison may be highlighted in the economic literature (Teece 2000)²⁰⁶: the capital asset pricing model (CAPM)²⁰⁷, the portfolio selection model (PSM) and the prospect theory. The net present value (NPV) is related to CAPM methods and remains the main analysis in large infrastructure projects. The focus will be put on the NPV analysis to underline how such a method can take into account risk and uncertainties in projects with strong technological rupture.

The NPV is defined by the actualized summation of Investments costs and cash-flows:

$$NPV = \sum_n \left((-I_n + R_n - C_n) * \frac{1}{(1+i)^n} \right)$$

with: I: Initial or continuing investments
 R: Operating receipts
 C: Operating costs
 i: Actualization rate
 n: Year, Start of the project n=0, end of the economic life of the project n=40 (usually)

The internal Rate of Return IRR given by the equation NPV=0

$$\sum_n \left((-I_n + R_n - C_n) * \frac{1}{(1+i)^n} \right) = 0$$

The NPV of a project may be analyzed through different sides:

- First as the evaluation of global project, the NPV is evaluated for the whole project but without its indirect externalities: this is an internal assessment, taking into account investments, costs and revenues generated by the project and including its actors: NPV_I.
- A second evaluation is usually achieved taking into account the externalities of the project: NPV_E. This assessment aims at the definition of externalities of the project on its environment: impact on employment, environment (accidents, pollution etc.). These factors usually concern policy and public decision-makers.

These two analyses, intensive and extensive, are also based on the same approach described in Figure 116.

The NPV analysis integrate the following phases of the project:

- ▶ Investments:
 - R&D: New knowledge acquisition, Infratechnology.
 - Industrial development: New process implementation, new competences acquisitions, prototypes and pre-production.
 - Production & construction.
- ▶ Operating costs and revenues
 - Operation and maintenance costs.
 - Operation revenues.

²⁰⁶ Teece D.J., 2000; *Managing intellectual capital*, Oxford Univ. press, pp.79-82

²⁰⁷ The arbitrage-pricing model (APT) is similar to the CAPM in terms of risk analysis.

- ▶ Re-investments: vehicles and equipments
- ▶ Decommissioning (or residual value after a certain period of time)

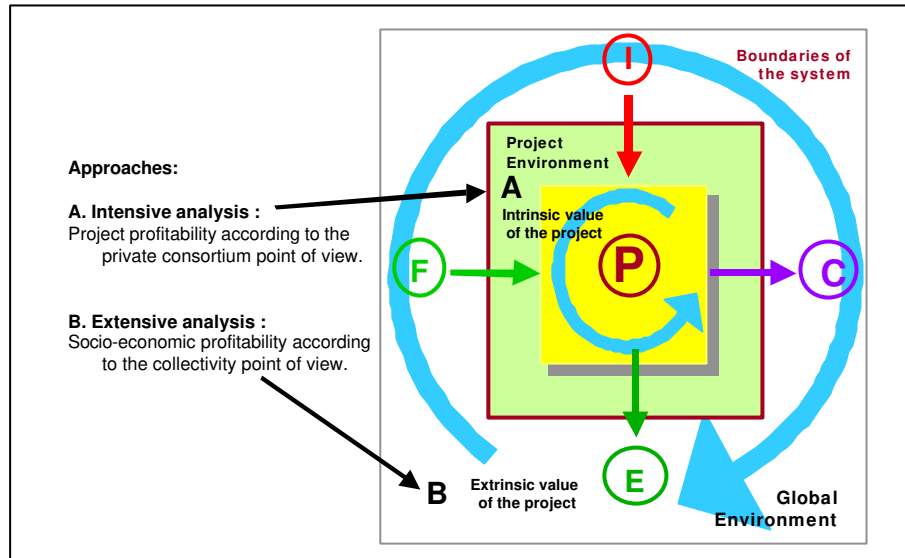


Figure 116: Approaches for the intensive and extensive analysis of the project value (Source: Perret 1999)

The NPV is first based on a deterministic approach, and then the probabilistic approach is possible by means of the assessment of the variance of each NPV component. This constitutes the basis for the elaboration of the risk profile of the project (Figure 117).

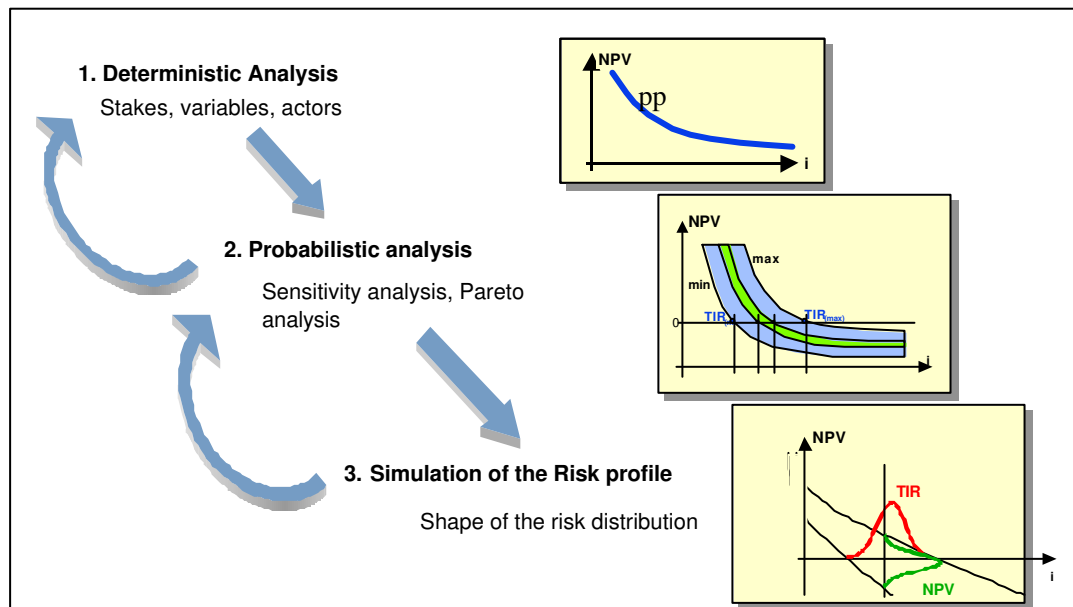


Figure 117: NPV analysis, elaboration of the risk profile (source: Perret 1999)

However, risk profiles are usually achieved with details for industrial projects (aerospace, nuclear, chemicals or petroleum projects) but concerning transportation projects, such probabilistic analysis are less numerous. The use of global risk profile is discussed but with several data and at a global level.²⁰⁸ Decision-makers are reluctant to use studies based on scenario approaches,²⁰⁹ and in the same context they don't favor the use of such results in discussions.

For example, Swissmetro bases its competitiveness mainly on the internalization of external costs, as its high costs of investments aims at the reduction in environmental impacts. But its internal rate of profitability is relatively low and highly uncertain because of the rupture:²¹⁰

- Basel-Zurich 2.9 < IRR < 4.5%
- Bern-Zurich 5.2 < IRR < 7.4%
- Lausanne-Geneva <2% as the 6 other propositions of links which are <3%.

As a comparison, SNCF since more than a decade only finances projects which IRR exceed 8%.

But the NPV analysis may also be achieved for each actor, in order to determine the interest of potential partners and the definition the financing plan. NPV results summarize the opportunity for each partner, taking into account its investments and future cash-flow concerning the project. But such analysis may take into account the costs/benefits related to implementing change: knowledge, R&D, problems of overlaps. Results usually drive strategies of the firm and strengthen (or redefine) paradigms (Figure 118).

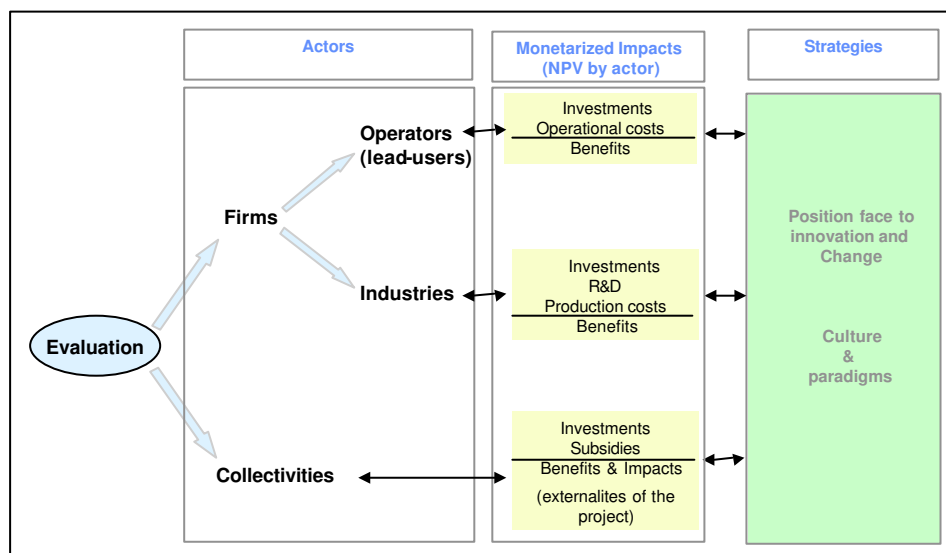


Figure 118: The NPV analysis as a tool to foresee strategies of actors

In the example of Swissmetro, as negative values of NPV are shown because of conflicts with the main intercity lines, the incentives for the operator to take the risk remains low without strong public support:

<i>Example Zurich-Bern:</i>	<u>Group of interest / actor</u>	<u>NPV (for i=10%)</u>
	Private investors	-2298 in M CHF
	Industry / construction	406
	Banks	104
	CFF	-593

²⁰⁸ Interview with Prof. Bea, involved in Risk Management in the Petroleum industry (Mai 2001, UC-Berkeley)

²⁰⁹ Conclusion of an editorial in "Le Temps", decision-making and policy in Switzerland for large infrastructure projects (Nov. 2001).

²¹⁰ Source: de Tilière 1997 for the propositions Geneva-Lausanne and Geneva-Lyon; and Gentinetta 1997 for Basel-Zurich and Zurich-Bern.

Urban transit systems 24
Public collectivities 1667

If previous studies on Swissmetro underlined the low and uncertain profitability (which is somehow such as other comparable large projects but with a risk profile much more spread) as the negative NPV value for the current operator (CFF), none underline the fact that manufacturers wouldn't engage themselves in the production of a small series of complex and high-tech vehicles if they can't plan a continuous production for the maintenance of their plant: Therefore Swissmetro faces the reluctance of both CFF and manufacturers, who won't get involved without the support of the government.

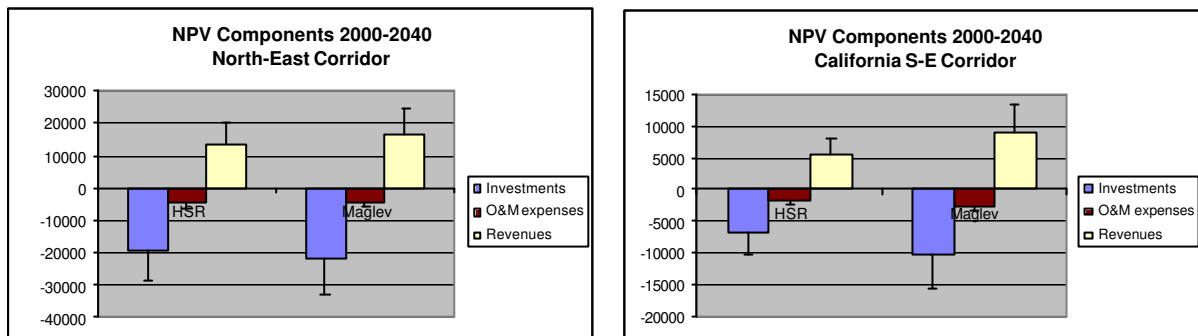


Figure 119: Comparison between HSR/Maglev NPV components for US corridors (FDOT-1997)

Concerning Maglev versus HSR technologies, NPV analyses underline that if the performances of such system in terms of supply are higher (speed especially), investment costs and revenues are higher (Figure 119). But at the same time risks and uncertainties are higher in both demand estimates and investments (values in figures represent minimum and maximum). This increase is due to two main factors:

- First uncertainties are expressed in percentage, which means that for higher cost/benefits there is an increase of risk associated with.
- Second, Maglev technologies have a risk premium based on the fact that there has been no full-scale commercial operation until now, increasing risks of higher operation and maintenance costs when compared with rail system, whose industry has a long experience as well as the choice of manufacturers (open market).²¹¹

In the case of Swissmetro, sensitivity of NPV or IRR is very high to infrastructure costs and demand, whereas operation costs are less significant (figure 120):

This remains a problem, since the value added of Maglev system was mainly based on decreasing operation costs: According to the TRB,²¹² Maglev systems are 70% more expensive than HSR systems for 20% less energy consumption.

Uncertainties in the evaluation of cost of new technologies are for instance underlined in the Figure 121, showing differences in Maglev concepts estimates achieved for the National Maglev initiative in 1993 (financed by the US Congress). Differences between estimates achieved by private consortia and the government vary from 15% to 85%, with an average difference of 23%.

²¹¹ The question of market size is important for the future conditions of maintenance and renewal costs of the rolling stock as well as specific equipments. For e.g., the Taiwanese consortium is trying to buy the Shinkansen technology but require from the Japanese consortium to design components with the compatibility with European standards in order to maintain the competition in future services among manufacturers.

²¹² US Transportation Research Board, 1991.

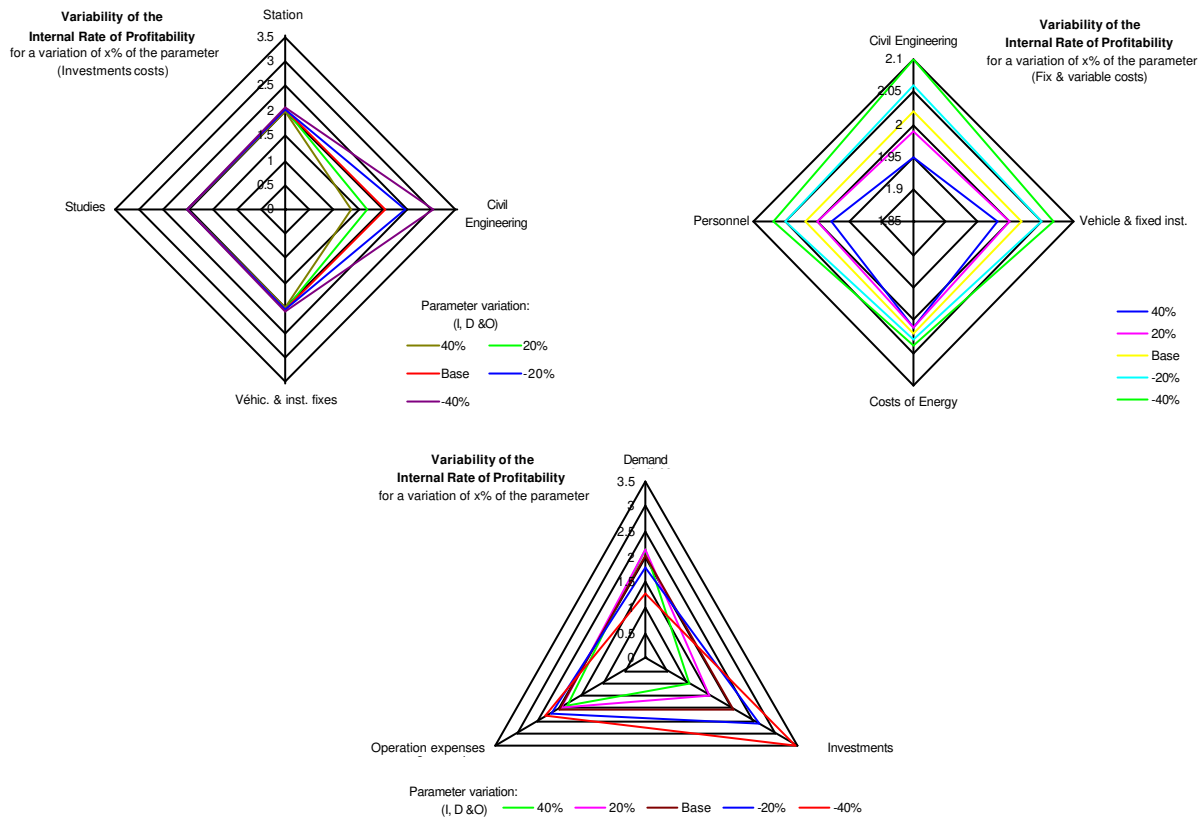


Figure 120: Sensitivity analysis on NPV components for the Swissmetro project Geneva-Lyon (de Tilière 1997)

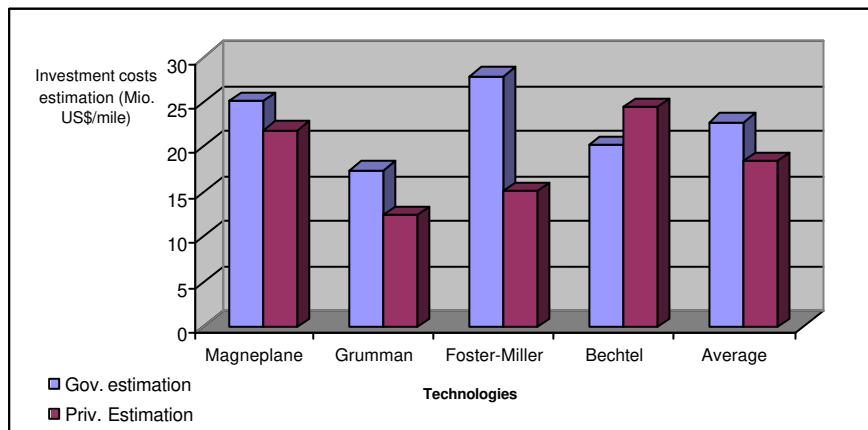


Figure 121: Assessment of the main US Maglev concepts in 1993, comparison industrial/government forecasts.

• The limitation of cost/benefit approaches

If such methods constitute a fundamental basis for decision-making, especially through the analysis of financial flows of projects (by means of the NPV, IRR and DICR), they measure the innovation or project rents for the main actors but without apprehending the notion of flexibility.

In the case of HSGT technologies, the long-term horizon requires to focus on both performance and flexibility, as future uncertainties may reveal new opportunities. But the NPV analysis only provides results on the intrinsic or extrinsic value of the project, assuming that it will be completed. There is no mention about the value of R&D investments in the case of the project abandonment, even if this investment provides a greater flexibility in strategy and may be crucial to maintain or obtain leadership.²¹³

The NPV analysis is therefore asymmetric, because it doesn't take into account the flexibility, which is a crucial point in such large infrastructure projects. As complexity of these projects environments and future changes make flexibility a determinant of the elaboration of strategies, decision-making and investment choices based only on cost/benefit analysis are risky and flawed.

The notion of real options allows better understanding the importance of flexibility to face future uncertainties in complex systems or environments.

6.4.4. Real options: Valuing risk, opportunities and flexibility

- *Valuing flexibility in order to minimize risks linked to future uncertainties*

Taking into account the value of risk & opportunities and the value of flexibility is crucial for both industries and governments. Industries are interesting in the assessment of R&D alternatives or portfolios. Governments focus on the public policy, with the definition of national R&D programs supporting technologies which could provide high returns to the society in the long-term.

In this perspective, the analysis of the value of options may be analyzed by means of the NPV but through a sequential approach, coupled with the probability of success/failure of each option. But in such process involving decision trees, the value of future information on the system is very important (policy changes, market changes etc). This leads to the importance of scenarios approaches.

The calculation of the global NPV along each path of the decision tree is:

$$NPV(option) = \sum_{t=0}^n NPV_{\alpha}^t * P_{\alpha}^t$$

The NPV value may be positive or negative at each step, but in the cost-benefit analysis only, options associated with negative values are abandoned. However, some options not profitable at the period t , may be so at $t+1$ after a change in policy, or in the market structure. The real option approach allows exploring benefits of options even in the case of abandonment of the project after a certain period (total or partial): this induce a better valuation of flexibility through the notion of maintaining an option on the project/technology as it was achieved in Japan (MLX-01/Shinkansen) or Germany (Transrapid/ICE).

The calculation of the growth option may be calculated when new information are available and may change the NPV values. New strategies may be defined according to the re-evaluation of NPV options.

The calculation of real options, achieved through a sequential VAN calculation, is first developed for the analysis of the intrinsic value of the project/option, and evaluates associated opportunities. This sequence should be elaborated for each type of actor: operators, manufacturers, and the public at large. For this last one, it is important to develop the analysis for both intrinsic and extrinsic project value. In terms of public investments in large infrastructure projects, recent events in the transalpine transportation system/policy²¹⁴ show that the notion of flexibility may be very important to deal with future uncertainties.

²¹³ For example, the development by Siemens of Maglev activities in parallel of HSR technologies (within the consortium led by Adtranz) may be seen as an opportunity to become a leader in Maglev: In the 1970's, Maglev was thought as the next generation of HSGT systems.

²¹⁴ Since 1998, accidents in Tunnels (Mt-Blanc & Gothard) underline the weakness of the transalpine transportation system as well as the need of sustainable transportation alternative (See de Tilière 1999). Building alternatives takes one or two decades, and the value of alternative options has not been recognized until this crisis situation. Switzerland now plays a key role in the

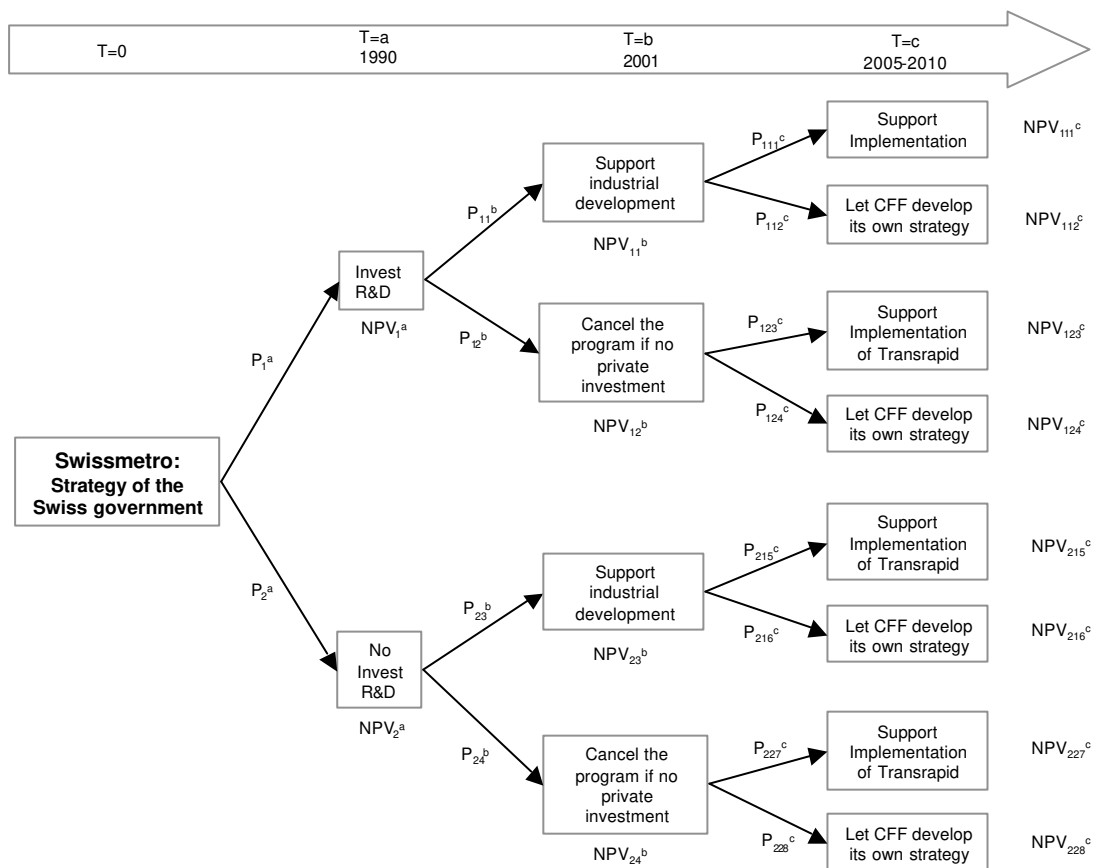


Figure 122: Example of real option analysis, concerning the Swiss government interest in Swissmetro.

• Policy and the limitation of real option approach

Real option approaches are mostly used in industry or private companies to elaborate strategies and resource allocation on R&D projects or for the development/abandonment of new activities. However this approach is rarely used to assess investments in large infrastructure projects, or new HSGT technologies. This fact is mainly because of the reluctance (or disinterest) of politics to base their decisions on scenarios approaches and probabilistic analysis. Do they want deterministic values to protect themselves behind the responsibility of experts? The result is that most propositions of new HSGT concepts only present projects' NPV, without taking into account the valuation of this option for the society when compared with other alternative.

As underlined in case studies, critical political decisions towards HSGT technologies were rarely based on such analysis, but rather on political interests such as the will of national and industrial leadership in some industrial sectors, or the accuracy with other national strategic choices such as energy policy etc.

The experience of project assessment shows that there are of two types, linked into a double helix: technology & policy:²¹⁵

²¹⁵ development of intermodal solutions and the enhancement of the rail supply in Europe. In the double helix, concepts of technology and policy have to be understood in a broad sense (see also Wenk 2000).

- A first type of assessment (technology) is based on a rational decision-making, valuing technological and economical criteria of the project/option. A pertinent approach is the combination of the NPV approach, cost/benefit analysis with the real option analysis, providing a good overview and assessment of alternatives.
- A second type of assessment (political) may be seen as based on cognitive decision-making, where the rationality is based on the perception of interactions between other systems and factors, mainly external to the project system.

6.4.5. Risk exposure, risk attitude and cognitive biases

- *Misperceptions; definition and valuation of options*

Schnaars (1989) develop the notion of “technological wonder” in order to underline biases that affect the evaluation of innovations. His book, “Megamistakes”, developed also the problem of overconfidence of entrepreneurs also underlined by the research of Bernardo & Welch (2001).²¹⁶

The main difficulty in the definition of a set of option and the valuation of real option remains to foresee future changes (that may lead options to be successful or not). This being said, the set of technical options is usually defined within a broader strategy (especially for the case of systemic innovations), taking into account firm competences and future market windows.

However envisioning future changes induces another kind of risks: perception and decision-making are influenced by biases, which also condition attitudes face to risk.

- *Risk attitudes*

Different risk attitudes may drive decision-making and firm’s strategies related to risk exposure: risk-neutral, risk-seeking and risk-averse (Figure 123).

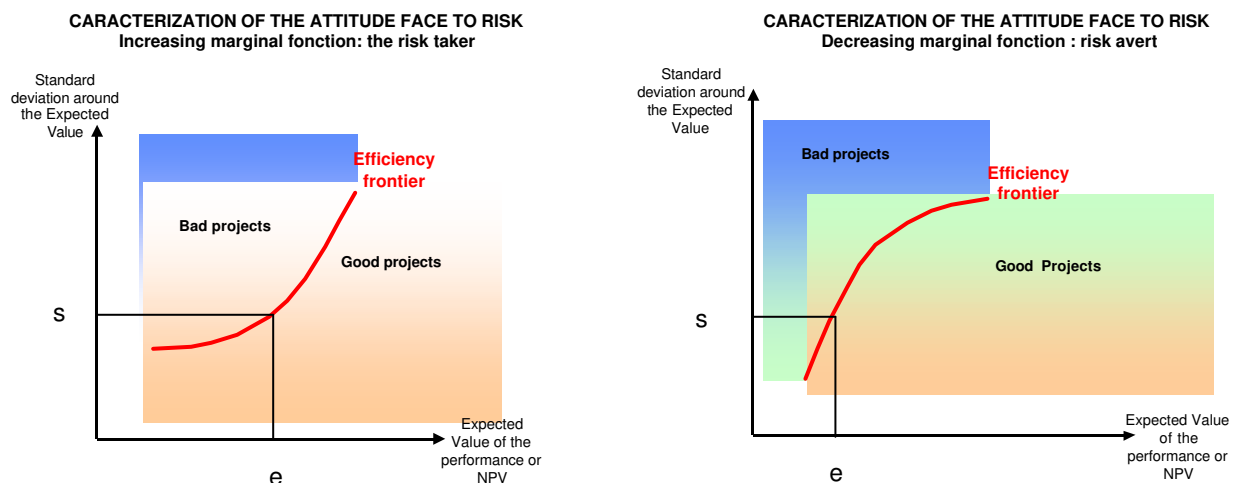


Figure 123: Attitudes face to risk and strategies (Source: Perret 1999)

²¹⁶ Bernardo A.E. & Welch I., 2001; “On the evolution of overconfidence and entrepreneurs”, *Journal of Economics & Management strategy*, Vol.10,n.3 Fall 2001 pp301-330.

Teece (2000 p.69) underlines the reluctance of firms to introduce competency-destroying innovations. Empirical studies of business people attitudes have shown that business decision-makers are often highly risk-averse. These results are in contradiction with the common perception that successful business people are risk seekers. The answer may be that calculated and minimized risk for decision-makers appears as risk seeking for others.

The problem with innovation is that tendency for loss aversion favors inaction and status quo over any alternatives: disadvantages of these alternatives are evaluated as losses and are therefore weighted more than their advantages.

- *Decision-making biases*

In the definition of strategies and of a set of options, biases may influence decision-makers according to two main behavioral factors:

- The notion of bounded rationality and cognitive decision-making frames (1)
- Inconsistent risk aversion (2)

If risky strategies lead to problems of over-evaluation of forecasts in the case of the rupture (Schaars 1989), the biases of the "protection of the certain" (Foster 1986) may also lead to inconsistent risk aversion (concerning both system performances and market opportunities).

Therefore, even if the rupture and its consequences are very hard to identify, even on a same technological trajectories, overconfidence of known elements/events leads to cognitive biases.

As Kahneman & Lovallo quoted (1993),²¹⁷ two main phenomena drive inconsistent risk aversion and lead to biased decision-making: (1) certainty effects and (2) isolation effects. Isolation errors not only lead to risk aversion, but also to bold forecasting.

- Isolation errors occur when decision-makers adopt narrow decision frames, focusing on the unique feature of problems (exactly the opposite of the approach presented in this thesis, developing the multi-perspective approach). The danger of isolation approach is the overlooking of many possibilities for pooling risks between projects and across time. As a consequence, it can lead a firm to pursue innovative prospects or R&D efforts in the case of future failure, instead of cancel this option earlier.
- The certainty effect was developed by Foster (1986) and also Rasmussen (1987) observing that sure returns associated with incremental strategies will often be over-evaluated as compared to risky expected returns of more radical strategies.

To link decision-making processes with biases, Kahneman & Lovallo (1993) argued that if cognitive efficiency may be attained the more fragmented and sequential processes (making more responsibilities with specialist), this also compounds risk biases. Complex and hierarchical organizations, as well as multi-level decision-making usually induced more risk-averse behaviors.

This is also the state on innovation capabilities, where big firms in the rail sector pursue incremental strategies and buy "risky innovations" from SME.

- *Cognitive errors and biases*

Vaughan (1996) underlined the need to involve groups from different profession in the firm to assess projects risk. For example, analysis involving only engineers may impart some very strong organizational biases in the risk assessment. Assessing risk in complex and disruptive projects require multidisciplinary assessment.

²¹⁷ Kahneman D. & Lovallo D., 1993; "Timid decisions and bold forecasts: a cognitive perspective on risk taking", *Management Science* 39/1:17-31.

Moreover, diversity must be represented in disciplines and backgrounds: The assessment of Swissmetro should have involved more industrial engineers, as an excessive part of people come from the research and academic field (except for civil engineering works). But this also comes from the project nature, in between aerospace and rail sector, but belonging to none of these markets.

Cognitive errors are very important in project failures. Surveys have been achieved to measure the importance of cognitive errors, but in other fields: Wagenaar & Groeneweg (1987) reported 100 accidents in the shipping industry with their causes. Among three groups of factors, cognitive errors are present in 92% of failures (followed by 56% situational and 21% social). Second, among cognitive errors, the most significant are wrong hypothesis (51%) and habits (45%). Even these results are associated with this specific industry, but this underlines the fact that cognitive errors are very significant:

- Cognitive errors:
- Influence the perception of the forecasted project outcomes
 - Shape attitudes and strategies

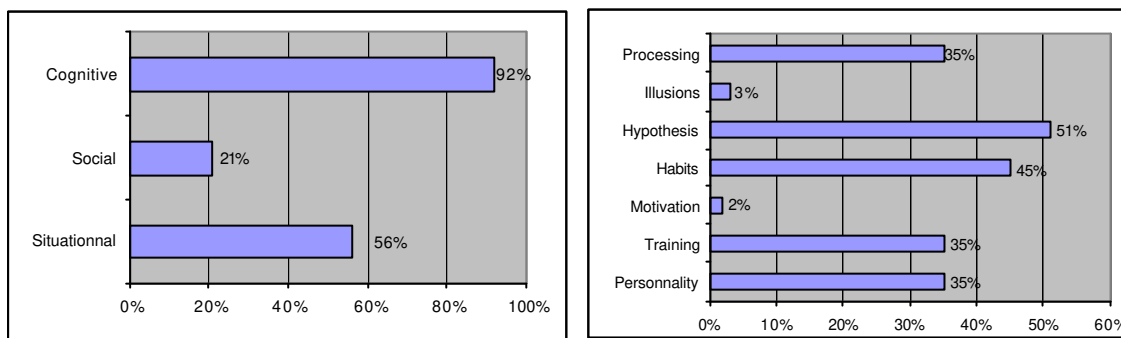


Figure 124: Percentage of shipping accidents in which errors occurs ((Wagenaar & Groeneweg 1987)

- *Consequences of cognitive errors*

A direct consequence of cognitive errors is the simplifying perception (Bea 2001 p.114), which hides a large part of risks:

What is	Is seen to be
Complex	Simple
Dynamic	Static
Uncontrollable	Controllable
Illogical	Logical
Emergent & Organic	Mechanical
Dependent	Independent
Uncorrelated	Correlated
Uncertain	Certain
Expected	Observed
Unknowable	Knowable
Governed by actions of people & organizations	Governed by laws of physics & mechanics

Table 12: Influence of biases on the system perception

If the understanding, the design and the planning of complex engineering systems require the ability to simplify things, most of the difficulties lie in how simplifying without missing critical elements, which can cause the system failure. The table above summarizes the risks of misperception that can interfere with this process.

Misperceptions can be described by 10 types of judgment biases, which are interesting for project managers and decision-makers for identifying those ones:

Type	Influence
Hindsight	Over estimation of the predictability of past events
Rational	Logical construction of events that can not be accurately characterized
Control	Over estimation of personal and corporate control over outcomes
Wishful thinking	Likelihood of desired outcomes judges to be inappropriately high
Small samples	Over estimation of the degree to which small samples represent a population
Knowledge	View what needs to be known is known even not adequately understood.
Correlation	Belief that unrelated variables are correlated
Perception	Expectations distort observations of variables and outcomes
Recall	Likelihood of easily recalled experiences are distorted
Belief	Failure to revise forecasts and beliefs based on new information

Table 13: Judgment biases (Source: Center for chemical process 1994)

Cognitive errors linked to Hindsight, beliefs and recalls are the most significant in incremental projects (for new product development), whereas wishful thinking and control may be more significant to disruptive strategies. However, biases are a combination of all these types, and may vary according to each project/organization.

- *Reducing biases: methods of technology assessment*

As developed in this chapter and before, the use of qualitative and quantitative methods help in the reduction in biases. In the case of complex technologies and when national R&D programs are implemented, a commission of technology assessment may be constituted to evaluate stakes and controversies of such innovation (Rossel 1998)²¹⁸. Such studies build their approach on the following methods:

Classical methods of impact analysis:

- Cognitive maps (relation causes -effects: Axelrod model).
- Cost benefit analysis (NPV, IRR).
- Multicriteria analysis (cf algorithm ELECTRE).
- Risk analysis (and definition of critical threshold of acceptability).

Adaptative methods:

- Delphi (consultation of experts).
- Scenarios.

Participative methods:

Active participation of actors in order to strengthen criterions related to social acceptability. Integration of these actors in the decision making process (However, this may also increase the management complexity).

²¹⁸ Rossel (1998) described changes in TA since two decades and draws a methodological approach for the assessment of Swissmetro.

Reducing biases within organizations/firms is important for the accuracy of their strategies and the pertinence of the set of options (innovations) they define, otherwise they may misperceive opportunities readily apparent to others. For this purpose, they have to be aware and critical about the cognitive methods they use, which are usually consistent with the current routines of the firm.

- *From risk assessment to risk management: financial aspects and risk sharing*

After a first assessment of risks, uncertainties and opportunities, the assessment of possible mitigation measures and their limits leads to the definition of strategies towards technological options. The selection or abandonment of an option is based on both the risk/opportunity assessment.

However, in the case of systemic or architectural innovations, R&D costs are much more important than component innovation or product improvement. Therefore the ability to share risks is crucial, and this will be underlined by the financial side: if usually engineers prefer to think about project financing after the elaboration of options/alternatives, financing constraints must be included much earlier in the project and is an important factor of reengineering.

6.5. Risk sharing and project financing in innovative HSGT projects

If an innovative HSGT technology such as Swissmetro has been assessed, mainly based on the economical value of the project. Financial profitability for industry has only been achieved recently, whereas this constitutes the critical factor for any industrial involvement without the support of strong national R&D programs (case of the German Transrapid and the Japanese MLX-01). The report for the concession demand (1998)²¹⁹ presented the NPV of the project in order to gain support from the Federal government. But concerning the involvement of industry, the financial profitability and the visibility in risk sharing is the critical step, that didn't convinced private partners until now.

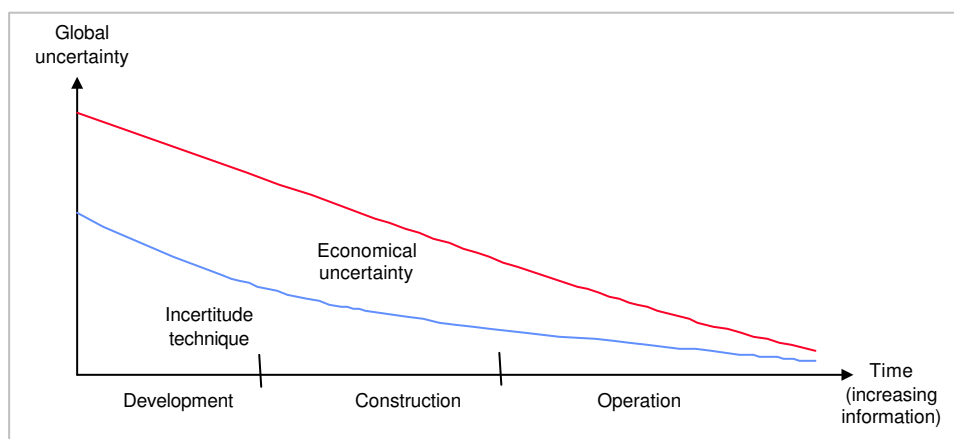


Figure 125: Economical and technological uncertainties

Understanding strategies of industry in the financing of R&D and development phase requires to analyzed financing modes and the impact of the rupture on financial risks and the structuring of risk sharing.²²⁰ If

²¹⁹ Swissmetro SA, 1998 ; « *Demande de concession pour le tronçon pilote Genève-Lausanne* », rapport confidentiel.

²²⁰ Boutron E. & de Tilière G. 2000, *financement des projets à forte rupture technologique* (working-paper)

economical and technical risks are linked to the level of information on the project, economic uncertainty is very important when compared with technical uncertainties only. This underlines the importance of project financing, whose purpose is to transform a technical innovation into an economical success, or at least minimize economical risks.

6.5.1. Hierarchy of financing modes

- *Fundamentals and implications*

The theory of the hierarchy of financing modes (Myers 1977) is based on the theory of agency, which defines the contract between the principal (shareholders) and the agent (borrower-manager). Their relation is characterized by the information flows between these two actors. The asymmetry of information induces a residual loss of interests.

In the case of systemic innovations with strong technological rupture, the information asymmetry increase: the agent, which is developing the technology, is the only one to have the information, and shareholders have few opportunities to comfort their information with other experiences (similar projects etc).

- *Financing Scale & Project financing*

Myers describes 5 levels in the hierarchy of financing modes (table below), which are important to understand the relation between risk and project financing.

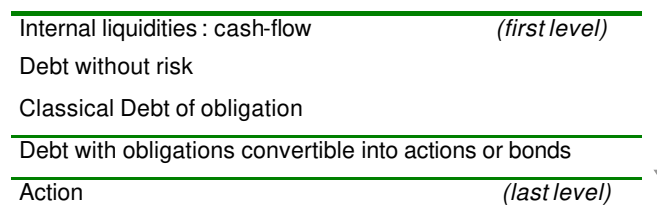


Figure 126: the five steps of the financing scale

During the project phases, the information asymmetry will decrease from the R&D stage (where few information are available for shareholders on the real potential of the technology) to the implementation and operation phase (where first results of the innovation introduction are visible). This is especially true in the case of radical innovations, when few comparisons or analogies are possible with other current technologies or systems.

For the development phase (and R&D stage), the high risk of failure implies that only project developers/actors assume the financing risk. The asymmetry of information is too high and leads to the high cost of even borrowing external capital. Efforts to ask for external capital is usually unsuccessful, but in some cases governments are interested and may support some projects which corresponds to specific policy goals. This has been the case for the development of Maglev technologies, supported by national R&D programs, whereas more incremental projects are

Projects are usually financed by internal capital, until the technical feasibility is proven by means of a full-scale test. Then, one can climb the financing scale through different levels of debts (industrial development, production or construction phase), and finally sell actions (implementation phase).

6.5.2. Impact of the rupture on the theory of agency conflicts

The theory of agency conflicts²²¹ is interesting in order to understand the difficulty to attract investors in the R&D phase of HSGT technologies with strong technological rupture (see also Boutron & de Tilière 2000).

The technological rupture induces an increasing risk of information asymmetry between investors and the consortium. For radical innovations, the development phase may be much longer and requires much more capital, if the rupture also concerns the whole system (systemic innovation). The full-scale operation may be required before having the same level of information asymmetry than incremental projects.

6.5.3. How financing considerations can influence Project Management

The main difficulty of project management is to integrate in early phases or planning the financing constraints. However, if a lot of HSGT assessment studies are mainly focused on the economical project viability (economic profitability), the main difficulties concern usually the financial profitability as well as the elaboration of the financial scheme.

Innovation processes should be adapted early in the project to the requirements of investors or financing institutions. The Model shows how financing structure (Public, Private-Public or Private) influence innovation in the HSGT sector, especially in the strategic Horizons of investment returns.

Another consideration is the efficiency of secured (protected) money circuits, which allow to avoid major failure for small stakeholders (problem of collusion between builders-operators-banks and politics).

6.6. Towards an Innovation & Risk Model

This chapter aims at providing the main lessons concerning the impact of the technological rupture on the critical elements, which have been defined in the paragraphs above. However, before developing the Risk Model into detailed tables (section 6.6.3), a Model of Risk Assessment & Management will be developed, in order to link all the Models that have been elaborated before.

The Model developed by Huber (in Perret 1999), summarize the typology of risks developed above as well as critical links that will be the focus of management concerns in the RAM Model in the next section:

²²¹ Mays & Jensen 1976.

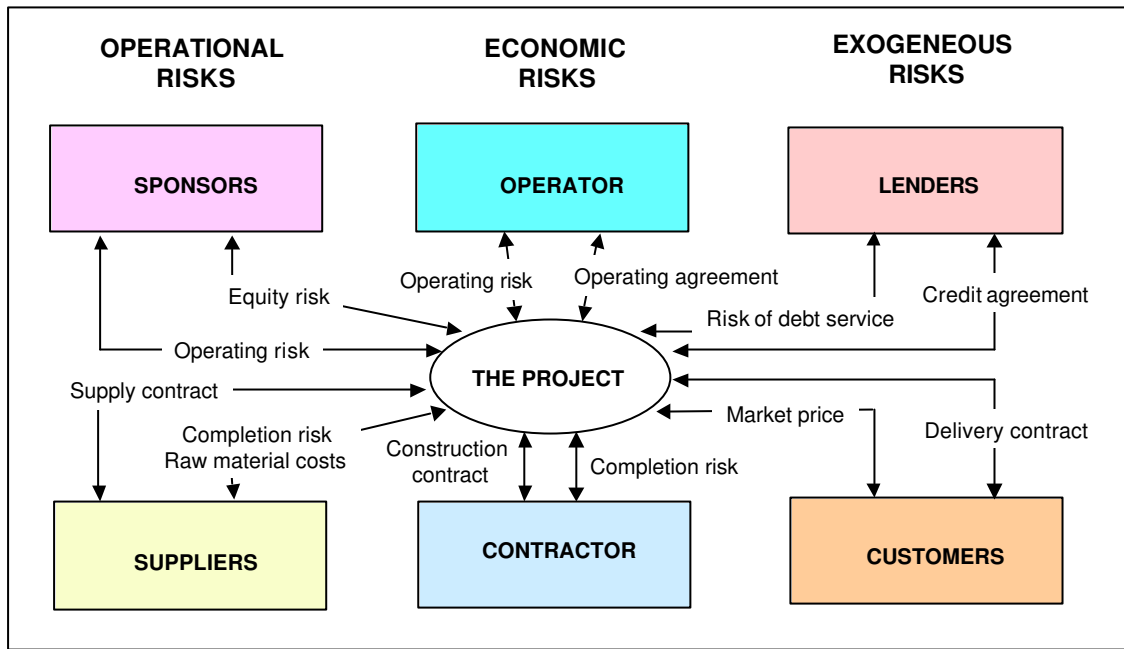


Figure 127: Risk typology and management (source K. Huber in Perret 1999)

6.6.1. Model of Risk Assessment and Management (RAM)

Providing a methodology for the identification and the assessment of risks and uncertainties in the case of projects with strong technological rupture can be a useful basis for recommendations on management (chapter 7).

The RAM Model links risk analysis with the strategic level, and underline processes required for a good managing approach (figure below). The architecture of the model is defined by two levels:

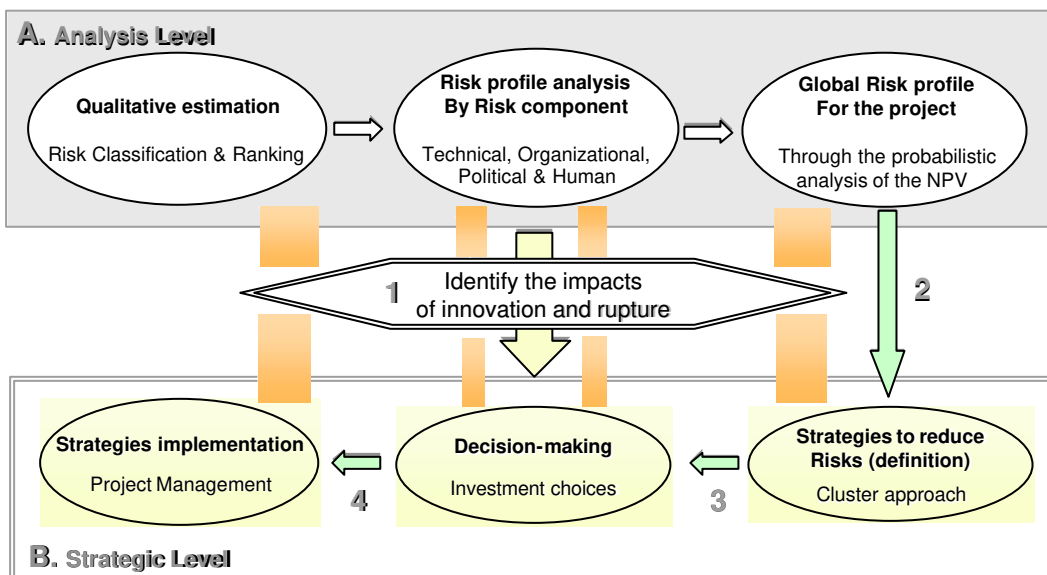


Figure 128: Model of Risk Assessment & Management as a basis for management strategy

- The first one represents the identification and assessment phase, constituting the analysis level. This level aims at providing the best information level on the innovation and the rupture, as well as on their consequences on risks and opportunities. This level therefore corresponds to the Risk Model developed in Figure 107.
- The second one is the strategic level, using the outputs of the analysis level to define, select and implement strategies. The aim of this level is to define and select the best alternative, as well as traducing those strategies into management practices.

The RAM Model presented above integrates the proactive and the reactive approaches of risks management proposed by Rasmussen (1996, 1987)²²², as well as the interactive approach (consisting in using in real time of both proactive and reactive approaches). The processes, from the risk identification to the implementation of strategies or actions, are achieved by means of both linear approaches and feedback or interactive manner: Risks and strategies are redefined all along the project.

This Model therefore allow to reduce the space of risks under three angles, proactive, reactive and real time actions, providing a very good approach to manage projects with strong technological ruptures (see figure below).

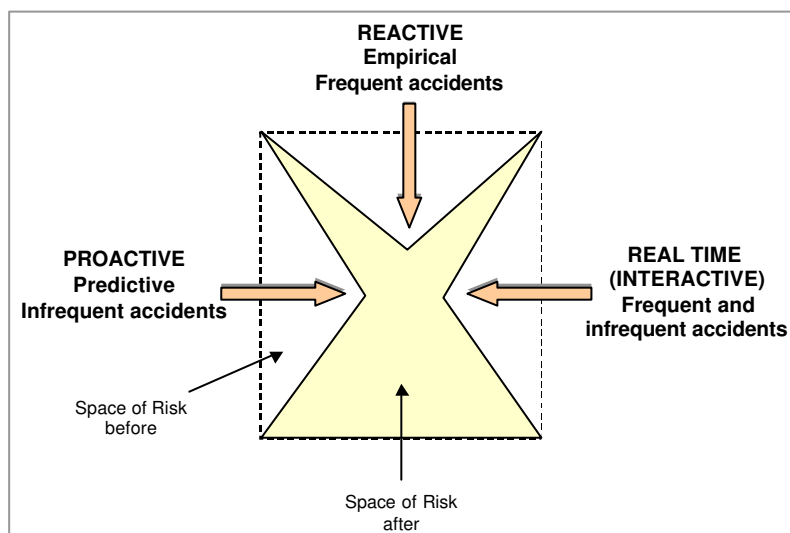


Figure 129: Approaches for Risk Management put in place through the RAM Model (source: Bea 2001)

These risk management approaches as well as the RAM Model are embedded in the projects processes. They can therefore be linked to the Models developed in previous chapters.

6.6.2. Linking the Models of Risk with the Models of Decision-making and Innovation

The RAM Model and the three approaches developed above should be applied to each phase of projects. In the case of innovation with strong technological ruptures (and especially when they also induce other ruptures in the market or in organizations), the RAM model provides a significant guidance for management, based on the outputs of the Risk Model.

²²² Rasmussen J., 1996; *Risk management, adaptation and design for safety, future risks and risk management*, Eds. Kluwer.
Rasmussen J., Duncan K., Leplat J., 1987; *New technology and human error*, John Wiley & Sons, New York.

In order to provide more visibility in how these Models works together, the interactions between the Risk Model and the Innovation Model will be described, as well as these between the RAM Model and the Decision-making Model.

- *Influence of the Decision-making Model on the RAM Model*

The Decision-making Model influences the RAM Model, and conversely, through two levels (Figure 130). The identification and assessment of risks can be influenced by the Preference, Causality and Certainty Models, since they influence potential biases or induce misperceptions (see also page 229-230). If the Decision-making Model influences the first level of the RAM Model (the analysis level), its variants (rational, organizational, and political) also influence strongly the second level (strategic level).

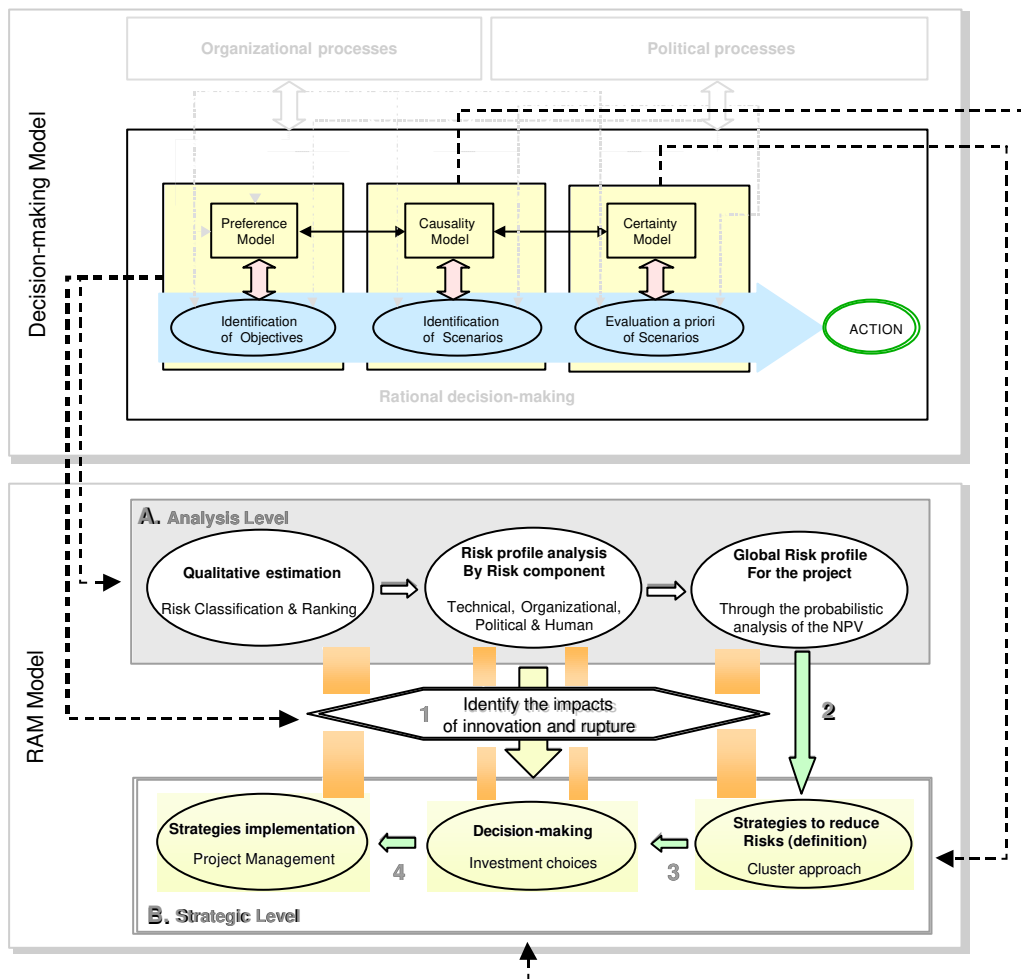


Figure 130: Links between the RAM Model and the Decision-making Model

The figure above underlines the iterative processes of the innovation phases, related to the decision-making process as well as RAM process. Risks and strategies are redefined and actualized all along the project.

The RAM Model can be applied at each stage of the Risk Model developed in the figure page 237, for the case of each risk table (A, B, C, D and T). For each phase of the project, specific risks have to be

managed. Moreover the level of information increases, requiring to update data all along the project (underlining the importance of iterative processes).

• *Links between the Risk Model and the HSGT Innovation Models*

If the importance of iterations and feedback loops in the management of innovation and RAM has been underlined, one can put in parallel the Risk Model with the HSGT Innovation Models: The figure below shows a linear view of the innovation process (macro level), providing more understanding on the focus of each risk table (whose development will be done in the next section).

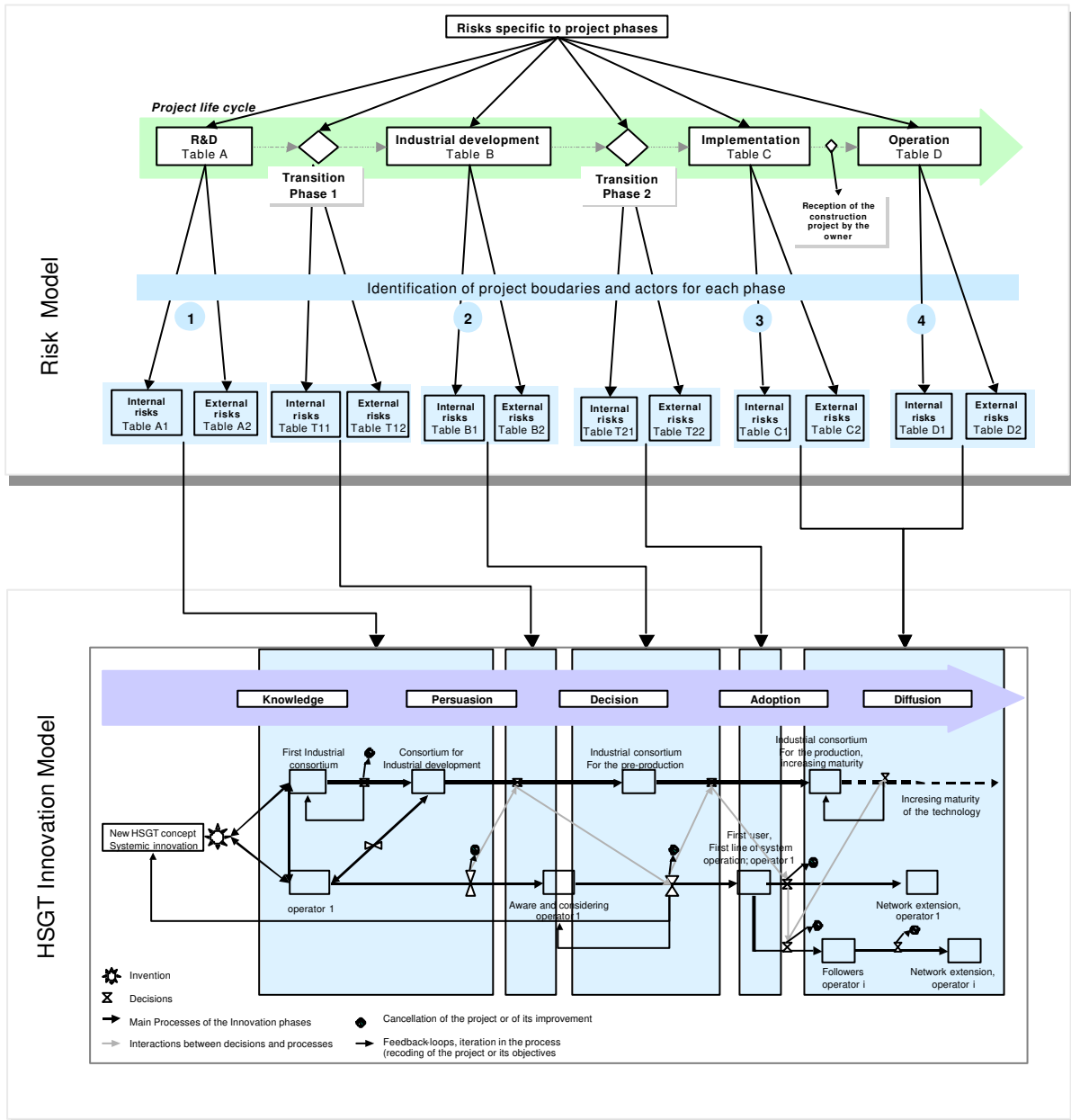


Figure 131 : Linking the Risk Model to the two HSGT Innovation Models

6.6.3. Conclusions on the impact of the technological rupture on risks and uncertainties

The impacts of the technological rupture are summarized in the following tables. This analysis emphasizes on understanding the implication of the degree of rupture, and puts into comparison rupture (First HSGT Innovation Model) with Incrementalism (Second HSGT Innovation Model). The tables below underline the consequences for the project team (the R&D team and the industry responsible for the development of the technology):

The phase of R&D is preceded by an analysis of market needs and opportunities, and the definition of a R&D strategy.

R&D	Impact of the rupture (First Innovation Model)	Impact of Incrementalism (Second Innovation Model)
<i>Table A1: Internal risks</i>		
Forecasts	Forecasts of the project are subject to strong uncertainties.	HSR worldwide experience reduces uncertainties, or at least standard deviations are known.
Planning	Difficulty in planning complex problem solving.	More experience on the system makes possible to reduce planning uncertainties.
Scope	Scopes have to be often redefined with the marketing department.	Objectives and targets are much more precise on both components and system.
Means	Means are not always adapted, lack of experience in processes, new tools required.	Means are mastered and tailored (tools and processes).
Adequate tools	Tools have to be tailored, adding complexity and uncertainties.	Tools and associated experience are fully available.
Infratechnologies	Delays due to the need of developing and improving infra-technologies.	Infra-technologies are improved in order to increase competitiveness.
Adequate knowledge	Difficulty in finding qualified people, learning by doing.	Capitalized experience is the basis, learning by doing for improvements.
Technological lock-in	Difficulty in forecasting lock-in effects for both components and system architecture.	Difficulties are apprehended little by little, through emphasize on components.
Funding & cost planning	Funding may be inappropriate and underestimated.	New rail product development: Business as usual for rail manufacturers.
Interdisciplinary studies	Serious difficulties in bringing together experts from various fields: creation of new networks.	Difficulties are reduced by the experience of networking within the same corporation, communities.
Management of interfaces	All parts of the systems have to be defined, but with strong interdependencies, difficulty in managing iterations.	The good experience in system architecture allows focusing directly on critical parts/factors.
Knowledge capitalization	Difficulty in capitalizing experiences: <ol style="list-style-type: none"> 1. When interdisciplinary studies are achieved through academics, with a high rate of employee turnover. 2. When R&D programs are too much spread in time, with start and go patterns. 	Incrementalism allows more circulation of information between R&D, production and marketing departments. Increase of experience returns and better knowledge capitalization due to transfer between products: HSR, LRV, metro.
<i>Table A2: External risks</i>		

Involvement of suppliers and partners	Difficulty in involving partners and coordinating activities.	Consolidation of networks and partnerships, even when new partnerships are created.
Intellectual propriety and patenting	Problems with intellectual property and information sharing (products).	Idem for products, but more emphasize on processes.
Political risks if supported by governments.	Risk of abandonment, especially if disruptive projects are more subject to budget cuts.	Risks reduced by a better flexibility and lower costs, as well as a greater industrial involvement (or less public involvement).
Academic/industrial partnership	In the case of public R&D programs, the risk of the rupture may induce a decrease of interests from industrials. Their participation constitutes a critical factor for the next phase and private financing.	Incrementalism is often associated with more short-term benefits, which may result in more interests from industrial.
Academic/industrial partnership	In the case of public R&D programs, the risk of the rupture may induce a decrease of interests from industrials. Their participation constitutes a critical factor for the next phase and private financing.	Incrementalism is often associated with more short-term benefits, which may result in more interests from industrial.

Table 14: Risk identification, tables A1 & A2 related to the R&D phase.

When the R&D phase is completed or well started, a transition phase begins. It corresponds to the assessment of the opportunity to:

- Maintain the option through more research.
- Go to the development phase.
- Stop the project.

Transition phase 1	Impact of the rupture	Impact of Incrementalism
Table T11 : Internal risks		
Technological assessment	The lack of experience leads to more uncertainties in the data available for decision-making.	Experience of similar systems may decrease data uncertainties and cognitive biases.
Market assessment	Industrials have difficulties to assess the future level of adoption by operators of disruptive options in comparison with incremental ones: It depends on government support and institutions (validation & concession).	Incrementalism is usually the result of a strong consensus between operators and manufacturers: As lead-users are involved in this process, this reduces risk of project cancellation and maximizes spills-over.
Option selection	Selection will be influenced by attitudes face to risk (risk aversion) / risk of technological wonder, over-evaluation of outcomes.	Risk of under-evaluation of difficulties in incremental solutions (protection of the certain).
Paradigms	Rupture may induce resistance toward change among actors or partners.	Incremental solutions are rather associated with consensus (complex networks of actors).
Strategic changes	Strategic change in the firm may lead to the abandonment of the option.	Incremental solutions may be more flexible toward strategic changes.
Funding problems	The decision to pursue is related to the ability to finance the development phase.	Decrease risks because of a less expensive development.
Table T12 : External risks		
Operators	If operators don't support the project for	Risks are decreased because of a larger

disengagement	implementation, this may be the death of the technology.	market window and a greater flexibility. Technological transfers are also easier.
Infrastructure owner veto	There may be a reluctance to invest in non-compatible infrastructure (profitability). Reluctance linked to the will of maximizing flexibility and benefiting from both freight and passenger activities, regional and intercity.	Incremental technologies may reduce this risk through increasing existing networks.
Assessment by institutions	Agreement by institutions through concession demand may be very complex and requires new institutional frameworks.	Concession demands and procedures have been historically tailored to rail systems, providing greater advantage to incremental innovations.
Political risks	If the rupture implies higher costs and strong uncertainties, cancellation of government support may always be an eventuality (national or European R&D programs). This may lead to the death of the project.	Incremental technologies are also subject to such risks, but the impact is not so radical: The technological improvements may be achieved by the industry in a different way and in a longer period.

Table 15: Risk identification, tables T11 & T12 related to the first transition phase (R&D – Industrial development).

If the assessment of the technological option (Transition phase 1) leads to the decision of going forward in the industrial development, then the risks may be:

Industrial development	Impact of the rupture	Impact of Incrementalism
<i>Table B1</i>		
<i>Internal risks</i>		
Maladjustment of production tools	Both production tools and processes must be tailored: producing Swissmetro vehicles is in between aerospace technologies and HSR systems.	Incremental concepts allow minimizing risks of plants management added to difficulties associated with NPD.
Maladjustment of testing grounds	New tools and testing grounds have to be developed. Test tracks used for HSR validation and debugging are useless.	Experience and tools associated with testing grounds minimize risks and uncertainties.
Profitability	The economical risks are very high, because this is a narrow market, the cost of new plants and test tracks may be disproportionate if not supported by national programs.	Incrementalism allows developing affordable technologies for both operators and manufacturers.
Problem solving	Gods is in details: after the R&D phase, many problems will emerge in the development phase, which will require a longer period of debugging.	Reduction in debugging periods, more efficient problem solving because of a better knowledge and experience, adapted tools and proven infra-technologies.
Accuracy with resources	Difficulty in planning adequate resources, which may have an impact on delays in development, and debugging during first run-tests before validation.	Less uncertainty in resource planning due to a greater experience.
Interface management	Difficulty in dealing with new technology, NPD and new combination of knowledge and experiences: high degree of rupture in both components and architecture.	The reduction in the innovation degree allows securing part of interfaces that are similar to the previous system.
Objectives and targets	Difficulty in reaching the targets (product performances): acceptable costs/prices.	Experience reduces uncertainties in the estimate of product performance and costs.

	quality etc because of newness and lack of experience.	as well as the resource to be mobilized.
Table B2 External risks		
Suppliers network	Lack of standard in Maglev systems: Prices of components may be much more expensive. Other challenge is to convince them to be part of the development consortium (role of paradigm): young and small epistemic community.	Established networks of suppliers and partners provide competitive prices for standard components.
Support from institutions and associations	For the same reason as above, support in federal programs and associations (operators, manufacturers) through the definition of common R&D objectives is weaker for disruptive technologies.	Incremental technologies benefit from an emphasis on compatibility, interoperability and cost efficiency. Powerful networks and epistemic communities provide significant advantages.
Political risks	If the rupture implies higher costs and strong uncertainties, cancellation of government support may always be an eventuality.	Incremental technologies are also subject to such risks, but providing greater flexibility (compatibility) reduces the risk for manufacturers as well as operators (train-sets may be used in different locations or countries).
Certification and homologation	Problem with the requirements fixed by institutions, which may become a critical factor in cost and time overruns. ²²³	Incrementalism reduces institutional risks in homologation and concession procedures, reducing time constraints.

Table 16: Risk identification, tables B1 & B2 related to the industrial development phase.

Tables T21, T22, C1, C2 describes relevant risks and the impacts of the rupture, the central actor is therefore the potential operator with eventually the agency responsible for infrastructures (Especially in Europe), and the government/institutions:

Transition Phase 2	Impact of the rupture	Impact of Incrementalism
Table T21 Internal risks		
Operators' attitude	Operators, which are stakeholders in Maglev consortia and keep disruptive options to maximize flexibility in their strategy, may cancel implementation projects (Transrapid Berlin-Hambourg, abandoned by DB in 1999 for the ICE option): this may be fatal to the technology (critical threshold in the diffusion curve).	Incremental technologies have greater opportunities in adoption: cancellation of a project implementation doesn't mean the death of the technology.
Forecasts	If the technological rupture induces a rupture in the supply, greater uncertainties may affect cost-benefit analysis.	Incremental solutions are subject to the same effect, but data related to the system performance (operation and maintenance costs) are better known.
Table T22 External risks		
Political risks	Disruptive technologies with new kind of infrastructure require political support to validate the planning support as well as the necessary public support.	Incremental technologies can be independently bought by the operator to be operated on existing tracks. For new projects, the same process is required.
Institutional support	Procedures for public assessment (safety, impacts on environment) have to be tailored to the new technology: analyzing the new	Incremental technologies don't require radical changes in institutional procedures, which may reduce lost of time and energy for the

²²³ Case for the Acela express (USA): the Federal Department of Transportation required very strict safety standards leading to an increase of 45% of train-sets load when compared with the TGV train-sets sold in France.

	system with previous methodologies and processes may be inappropriate: institutions play a key role in this phase.	project's actors.
Public acceptance	Resistance toward change may be a critical factor in the case of cutting edge technologies, especially in the case of Swissmetro. The role of culture is important: the technology driven mentality of Japanese is certainly at the opposite of the Swiss mentality, also influencing policies, institutions.	Incrementalism reduces the risks of adoption and diffusion failures, through a better flexibility: higher rate of technological transfer for HSR technologies to other rail segments.

Table 17: Risk identification, tables T21 & T22 related to the second transition phase (development-implementation).

Implementation	Impact of the rupture	Impact of Incrementalism
<i>Table C1</i> <i>Internal risks</i>		
Cost-forecasts Planning Financing Construction difficulties Management difficulties	First time of implementation and construction, lack of expertise in components and construction processes for new equipments. Higher difficulties in management, planning and budgeting.	Incrementalism reduces difficulties at interfaces (higher experience in the system, even if new components).
<i>Table C2</i> <i>External risks</i>		
Act of god	The range of uncertainties is higher as there is no experience: wider range of unattended events.	The range of unattended events is reduced (or better known) by the experience of rail systems and past developments and implementations.
Change of the regulator requirements	System will be more subject to regulatory changes, as institutions will also discover things during the planning process reactively. Consequences on standards, and therefore costs and time.	Reduction in such uncertainties even if it happened such as in the Channel tunnel project about safety measures.
Political changes	Changes may have an impact on the project objectives, and modify the planning as well as the future diffusion of the network (transportation context). Inflexibility of the system (Swissmetro, Transrapid) may bring more difficulties in the long-term.	More flexible solutions may reduce these risks through a better use of the network, which is compatible for freight, passenger regional/HSR activities.

Table 18: Risk identification, tables C1 & C2 related to the implementation phase.

Operation	Impact of the rupture	Impact of Incrementalism
<i>Table D1</i> <i>Internal risks</i>		
Demand level results/estimates Reliability problems	Idem, see also changes in behavioral patterns, table D2 The technological rupture add to the NPD difficulties more uncertainties about the reliability of the system for daily operations (especially in high frequency networks). Debugging may be time and cost consuming.	Incrementalism reduces problem solving and debugging on several innovative components.
Operation costs results/estimates	Uncertainties are much higher because of the lack of experience in operating the new system.	Past experiences in operation allow reducing significantly uncertainties.
Excessive maintenance costs	Problem of non-compatibility with current standards: Risk of expensive maintenance and	Operators now put a strong emphasis on bringing manufacturers into competition

Control & maintenance tools/processes	renewal costs as signing the contract induces a situation of quasi monopole. The new operator must develop maintenance and control tools that have to be tailored and improved.	through the requirements of compatible standards. Such systems are already developed and tailored (available in the market), they may be improved for specific tasks or application
Organizational changes	The new system requires new processes for operation and maintenance (because of technological differences). If a rail operator takes this responsibility, organizational changes will be required.	Current organizational structures, suppliers' networks and epistemic communities are in place, providing strong support to the technological development.
Sufficient knowledge and training of personnel	New personnel have to be trained, and a knowledge management system has to be developed and improved.	Knowledge and competence networks are in place and may have to be improved; experienced and trained personnel are already in place.
Table D2 External risks		
Change in behavioral patterns (users)	Strong uncertainty about reaction of users and the way their behavior will evolve.	Incremental approaches allow testing the market reactions such as the case of the TurboTrain experience (Paris-Caen), whose results enable the TGV project to go forward.
Change of the regulator requirements	System will be more subject to regulatory changes, as institutions will also discover things during the planning process reactively. Consequences on standards, and therefore on costs and time.	Reduction in such uncertainties even if it happened such as in the Channel tunnel project about safety measures.
Political changes	Changes may concern concessions or regulation measures (transportation context). Inflexibility of the system (Swissmetro, Transrapid) may bring more difficulties in the long-term.	More flexible solutions may reduce these risks through a better use of the network with different transportation activities (freight, passenger regional/HSR).

Table 19: Risk identification, tables D1 & D2 related to the operation phase.

6.7. Conclusion

This chapter aimed at providing a methodology, the purpose of which is to identify and assess the impact of the rupture on risks and uncertainties for the case of HSGT projects with strong technological rupture. Results of several surveys and of the case studies provide elements that underline the importance of the consequence of the rupture, leading to the detailed risk tables above.

These tables allow to measure the impact of the technological rupture on each factors, that have been identified as critical through the HSGT Innovation Models as well as the Decision and Organizational models: These factors have been determined through the analysis of innovation processes achieved through the chapters 2 to 5.

However, since managing innovation and risks in a highly uncertain environment requires a good methodology, this chapter provided the Risk Management and Assessment (RAM) Model, underlining the importance of iterative processes and feedback loops. This concept was also linked with management approaches: proactive, reactive and interactive.

However, if this provided elements allowing to better understand the consequences of the technological rupture, this leads to the challenge of managing the critical factors developed in the risk tables and underlined in the previous chapters.


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	1. Introduction
	2. The case of high-speed ground transportation projects
	3. Innovation and rupture
	4. Towards an Innovation Model for HSGT systems
	5. How organizational and Institutional factors influence Innovation Models
	6. Impact of the technological rupture on Risk & Uncertainties
	7. Managing the Development of New Technological Trajectories
	8. Conclusion
	ANNEX: Project Management Assessment System

Managing Innovation within the project organization,

from the technological challenge to the management challenge...

7. The Challenge of Projects with strong Technological Rupture: Managing the Development of New Technological Trajectories

7.1. Introduction

- *From the Innovation Model to Management Practice*

The previous chapters aimed at developing an approach based on several Models in order to identify mechanisms of the innovation processes as well as critical factors of success. They put the emphasis on identifying the consequences of the technological rupture on projects, thus allowing us to now focus on the question of managing successfully such HSGT projects.

Lessons drawn from the context of the HSGT market (Ch.2), and from the notion of innovation & rupture (Ch.3), allowed to develop the Decision-making Models and two HSGT Innovation Models (Ch.4). These Models focused on the processes leading to the development of new technological trajectories. Moreover, the elaboration of Organizational and Institutional Models underlined the role of paradigms and epistemic communities in these Innovations Models (Ch.5).

The definition of a methodology to identify risks and uncertainties related to the rupture (Ch.6) led to the elaboration of Tables describing the impacts of the rupture on the project phases. These tables underlined the fact that risk management becomes a critical issue for leading change.

The question now arises of how to manage such innovations with strong technological rupture, from the identification of key processes and critical facts to the definition of accurate management practices. Ranking the evaluation factors by capital-risk agencies²²⁴ puts management capabilities before product characteristics and financial aspects. This underlines the fact that the main challenge in projects with strong technological rupture remains the capability to manage change (see figure below).

²²⁴ See Ettinger J.C. "Pratiques d'évaluation et de sélection de projets d'activités nouvelles en Europe" *Revue française de gestion* (Janv.-Fev. 1995) p.51. This is a study on evaluation and selection factors of innovation projects in Europe by capital risk firms and CEI (Center for Enterprises & Innovation).

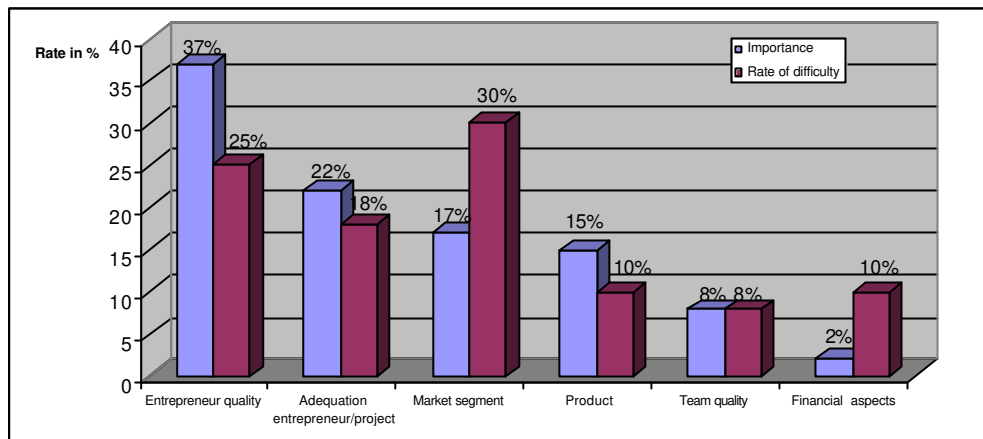


Figure 132: Evaluation factors for innovation project in Europe, rates of importance and difficulty²²⁴

The methodology used for the definition of recommendations is based on the conclusions related to the Models developed in previous chapters, which have been built on case studies results (bibliographical review and interviews). Critical factors in project management are the result of the case studies and a theoretical analysis. They have been integrated in the conceptual model through the Risk Tables (Ch. 6), which will be embodied in the Project Management Assessment System (PMAS). The objective of this tool is to provide a support for the methodology developed here, with the purpose of assessing the management of projects with strong technological rupture. Two examples have been analyzed to field-test PMAS: Swissmetro and Histar²²⁵ (see in Annex). They underline the difficulty of managing radical and systemic HSGT innovations, which is like trying to solve a complex puzzle within the chaotic process of innovation.

7.2. The technological rupture as a management challenge

7.2.1. Innovation and Project Management

- *The antinomy between innovation and project management*

There is an antinomy between innovation (creativity, emergence of newness) and project management (structuring, organizing, planning). This leads to the difficulty of finding a way to balance the approaches related to project management and innovation.

The innovation process is by definition chaotic and uncertain: Resources are provided for new developments, but this requires an independent space, which must be free from pressures. At the same time, external constraints have to be integrated early in the project, in order to avoid that the project fails or is abandoned at a too late stage.

Incremental innovations allow to concentrate innovation processes on part of the system only. This allows for a larger space for project management activities, thus contributing to minimize risks and uncertainties. In this way, managing the antinomy between innovation and project management is reduced to few aspects of the system only.

²²⁵ HISTAR is a project related to Swissmetro, which aim is to develop test infrastructures to model and measure aerodynamics of high-speed vehicles in tunnels (Assessment with PMAS, interviews with the project manager, Dr V. Bourquin - GESTE).

If the strong technological rupture leads to a rupture of the system architecture, requiring a radical reconfiguration of partnerships and networks (suppliers, operators), it also induces a revolution of the traditional channels of new product development and diffusion: Innovation processes go beyond technical processes, and have an impact on networking and political influences between firms. In this case, the antinomy between innovation and management is even more complex to deal with, thus increasing uncertainties and discontinuities.

- *Consequences on risk mitigation and management*

Organizing innovation activities is a crucial factor of success. Project management can be seen as a way of reducing risks related to such R&D activities, through increased work efficiency and a better organized decision process.

Managing innovation is managing chaos up to the development phase, phase in which project management and planning prevail. But managing innovation goes much further, as it also has an impact on the implementation phase (diffusion phase). This phase in infrastructure projects is characterized by “stop and go” patterns, which are related to political decisions, which in turn bring strong discontinuities in the innovation process (as underlined by the Aerotrains and the Transrapid case studies).

In this context, approaches in risk mitigation and management must be proactive and reactive (Bea 2000). Proactive risk management is achieved through risk identification and by mapping out the impact of the rupture. Mitigation measures are then put in place in order to reduce the risks and the uncertainties which have been identified (proactive approach).

However, the degree of uncertainties is such, especially in a non-mastered environment, that the ability to manage reactively is also a critical factor for success. Reengineering the project, its specifications or its objectives is a key factor in order to minimize the impact of discontinuities.

Qualities of managers and teams are therefore very important; they must be adapted with the project/innovation difficulties set out below, when dealing with the reasons increasing projects risks and failures.²²⁶

- ⇒ Technical problems
- ⇒ Incompetent staff
- ⇒ Regulatory changes
- ⇒ Political decisions
- ⇒ Changes in the players
- ⇒ Actions of competitors
- ⇒ Environmental constraints
- ⇒ Poor time and costs estimates

7.2.2. Managing change: The HSGT experience

- *Technology and policy: the double helix*

If the support of governments has been a prerequisite for all successful HSGT innovations (national R&D programs), difficulties in project management in new product development (NPD) processes have also been common.

Case studies have revealed and underlined the fact that managing the technological rupture is not only a matter related to engineers and R&D managers. The political dimension also rapidly becomes apparent,

²²⁶ Frame J.D.; “Establishing risk assessment teams”, p23 in *Managing risks in projects* edited by Kahkonen K. & Arto K.A. (1997), printed by E&FN Spon.

not only with regard to implementation, but also to technological choices. Policy can be seen at the firm or at the transportation policy level and under the following two angles:

- R&D, development stage: Networking of suppliers, lead-users, institutions and corporations for the validation of safety standards etc.
- Project implementation: Project acceptability, social acceptability (public decision-makers, operators, final users).

Managing the double helix, technology & policy, is common to all large infrastructure projects. This is common to all projects involving both private and public interests, where politics play an important role. This is radically different from the case of ordinary consumer goods, which can be more independently launched on the market.

This being said, if technological aspects in HSGT innovations are a prerequisite for leadership, this is by far not enough: Political considerations and the ability to manage networks of suppliers and partners are a prerequisite for the success of any HSGT innovation (as well as close relations with operators or institutions responsible for the implementation of such technologies).

- *Critical factors in managing the rupture, case studies as indicators*

If one looks at the experience of NPD in HSGT technologies, many cases show that many failures have been caused by mismanagement. The following points, which mainly concern incremental technologies, focus on the impacts of mismanagement and their consequences on operation results; they also underline the challenge of managing the rupture at a large-scale:

- NPD, lack of experience & impacts on reliability:

The experience of Boeing-Vertol, which tried to enter into the railcar manufacturing market in the 70's, is significant. Severe problems of reliability show that even for competent industries, acquiring new knowledge and experience is not an easy task: it was necessary to develop several series of vehicles in order to improve performances to an acceptable level. The same difficulties were encountered with the Turbotrain, developed in the USA and Canada by United-Aircraft.

- Difficulties in managing complex consortia:

The latest example to date of mismanagement in the NPD of HSGT technologies is the Acela Express, developed in partnership by Bombardier and Alstom. This contract was awarded to the consortium in 1996,²²⁷ with the aim of improving operations in the Northeast corridor (USA). Operations were due to begin in September 1999, but many problems occurred during the first test runs, revealing management failures within the consortium. First, the rolling stock was built with 10 cm more in width than specified, thus reducing the maximum permissible tilt from 6.5° to 4.2°. This reduced significantly speeds, because of the configuration of the tracks. Moreover, wheel wear problems, which were not discovered during the first tests in 1999, led to a delay of 14 months in the start of operations (from Sept. 1999 to Nov. 2000).

This underlines the fact that even in the case of mastered technologies, new product development, involving two leaders of train-set manufacturers (in this case Bombardier for train-sets and Alstom for tilting systems), is an important management challenge in terms of providing a reliable product in a timely manner. Operators (in this case Amtrack) asked for severe penalties for time overruns and problems related to reliability.

Such difficulties in project with strong technological rupture can rapidly have an impact on the projects profitability. Manufacturers and operators, conscious of the difficulties of managing the rupture in complex consortia, are reluctant to undertake such projects without a strong backup by governments.

²²⁷ Between 1993-1996, the Acela Express was in competition with the ICE (Siemens-Adtranz) and the X2000 (ABB). The Acela Express was chosen because of the attractive financial package offered by Bombardier. This swayed the decision more than the relative technical merit of options. (Amtrack source, January 2000)

- Innovation and resistance to change in firms:

Change remains the main difficulty when strategies are oriented towards innovative solutions. It is therefore important to be aware of the importance of innovation management and to take adapted measures (resources, competences and organizational reengineering). This was also underlined by Potter (1989), whose conclusion was that innovation management was a factor which has been neglected and which led to the APT project failure.²²⁸

This project was led by British Rail in the 1980s and its objective was to produce a near high speed train using tilting technology. Maximizing the use of infrastructure led to a more complex train technology, also requiring a high performance brake system.

This new product development (incremental innovation) concerned a consortium of 30 industrial partners. Prototypes were built and a first train-set produced in 1979; but the unreliability of the system for daily operation led to the cancellation of the project. These main technical failure led to the cancellation of the project in the mid 1980s, due to an excessive unreliability of the train in the operation stage. Only one train was finally put into operation and the project was canceled. Then the focus was put on the Intercity 225 which was less complex, less risky, less expensive (without the tilting system).

Looking closer to the causes of failures, Potter reveals that the main cause was the failure in managing innovation, which led to the inability to correctly solve technical problems: The innovative system induced technological ruptures of a type which was unusual in the railcar manufacturing industry. Managing such rupture was such a challenge in terms of managing change in knowledge that it led to an organizational breakdown.

- Irreversibility and the difficulty of project abandonment

The real option analysis provides a good approach in order to evaluate the question of the timing of the abandonment of an option or the question of the benefits of pursuing R&D options. The nature of HSGT technologies induces a very high cost in order to overcome innovation barriers. When too high investments are put into R&D options, there is a risk in continuing investments in order to justify previous decisions. This is the case of the MLX-01 technology developed by JNR and now RTRI. Technological choices proved to be flawed for economical reason (high price of the cryogenic cooling system).

Because the Maglev technologies involved required new test tracks or a pilot track - added to the new installations needed to test infra-technologies - very high investments were required when compared with incremental technologies. It is very difficult to abandon the option once such investments are made, especially on the political level.²²⁹

Lessons learnt from HSGT case studies finally show that technological rupture is mainly a management challenge: Technological failures have most of time been caused by the inability to manage change in organizations or to deal with the complexity of supplier networks/consortia. In the case of a project failure, the main causes are usually also to be found in the lack of political skills and the difficulty to manage or influence epistemic communities.

In conclusion, these experiences underline that project initiators have tended to underestimate targets and to overestimate their managerial and political skills when challenging technological rupture. Critical elements are the need to adapt realistic strategies to resources and organizations and the ability to provide adequate resources and to adapt organizations to the strategy.

²²⁸ Potter S. 1989, "High-speed rail technology in UK, France and Japan; Managing innovation-the neglected factor"; in *Technology Analysis & Strategic management*, vol.1, No.1, 1989.

²²⁹ Case for Superphenix in France in the energy sector (see Nifenecker 1998 and Bell 1997)

As ironically noticed by Bartlett & Goshal (1995): “corporations now commonly design strategies that seem impossible to implement, for the simple reason that no one can effectively implement 3^d generation strategies through 2nd generation organizations run by 1st generation managers.”

7.2.3. Managing revolutionary and evolutionary changes

- *Kaizen versus innovation approach, two different challenges*

In management theories, the Kaizen and the innovation approaches have often been opposed²³⁰; likewise the notion of evolution versus revolution. Both require different management styles and competences, as underlined in chapter 3.5 and in the table below:

	Discontinuous change perspective	Continuous change perspective
<i>Emphasis on</i>	Revolution over evolution	Evolution over revolution
<i>Strategic change as</i>	Disruptive innovation / turnaround	Uninterrupted improvement
<i>Strategic change process</i>	Creative destruction	Organic adaptation
<i>Magnitude of change</i>	Radical, comprehensive and dramatic	Moderate, piecemeal and undramatic
<i>Pace of change</i>	Abrupt, unsteady and intermittent	Gradual, steady and constant
<i>Fundamental change requires</i>	Sudden break with status quo	Permanent learning and flexibility
<i>Reaction to environmental jolts</i>	Shock therapy	Continuous adjustments
<i>View of organizational crisis</i>	Under pressure things become fluid	In the cold everything freezes
<i>Long-term change dynamic</i>	Stables and unstable states alternate	Persistent transient state
<i>Long-term change patterns</i>	Punctuated equilibrium	Gradual development

Table 20: Discontinuous change versus continuous change perspective (source : de Witt & Meyer 1999)

The Kaizen approach suggests incremental changes and improvements in the continuity in order to focus on total quality management (TQM). This strategy is based on a gradual approach that allows for a constant improvement of processes, structures and organizations. But strategies are the result of an emerging rather than of a deliberate process.

Operators and rail manufacturers have mostly adopted this managerial approach: Operators want to maximize the effects of the economies of scales, by using the existing infrastructures, while manufacturers adopt the evolutionary strategies (in terms of technological trajectory) in order to maintain sustainable activities. The nature of the market usually leads to very large, but punctual orders, which in turn leads to great difficulties in maintaining constant production activities. Partnerships are needed in order to be able to produce and fulfill orders rapidly (importance of compatibility of products and components). Providing continuity in products allows for a reduction in disruption and to focus on the renewal of train-sets, which is becoming an important market (TGV, ICE, Shinkansen etc).

HSGT technologies have mostly followed the same technological trajectory (HSR), while rupture and radical changes have mostly been focused on specific targets and functions. The HSGT market has been deeply reorganized and transformed since a decade. Reengineering has been a key word in adapting organizations and structures to globalization.

Managing change and innovation has been a key determinant in the HSGT market. For both Maglev and HSR technologies, the focus has been on improving processes, reliability and costs. Launching a new technological trajectory seems currently out of mind in this industry.

²³⁰ Bob de Witt & Ron Meyer 1999 ; *Strategy synthesis resolving s strategy paradoxes to create competitive advantage*.

- *Innovation dilemma & managing uncertainty*

The main challenges of management in HSGT technologies, as underlined in the table below, are therefore:

- (a) Finding ways of continuity and sustainable evolutionary improvements in the cases of disruptive technology (architectural innovations).
- (b) Managing innovation and radical changes in evolutionary systems (incremental innovations).

	Innovation	Kaizen
<i>Effect</i>	Short-term but dramatic	Long-term and long-lasting but undramatic
<i>Pace</i>	Big steps	Small steps
<i>Timeframe</i>	Intermittent and non-incremental	Continuous and incremental
<i>Change</i>	Abrupt and volatile	Gradual and constant
<i>Involvement</i>	Select few "champions"	Everybody
<i>Approach</i>	Rugged individualism, individual ideas and efforts.	Collectivism, group efforts, system approach
<i>Mode</i>	Scrap and rebuild	Maintenance and improvement
<i>Spark</i>	Technological breakthrough, new inventions, new theories.	Conventional know-how and state of the art.
<i>Practical requirements</i>	Requires large investments but little effort to maintain it	Requires little investments but great efforts to maintain it.
<i>Effort orientation</i>	Technology	People
<i>Evaluation criteria</i>	Results and profits	Process and efforts for better results
<i>Advantage</i>	Better suited to fast growth economy	Works well in slow growth economy

Table 21: features of Kaizen and Innovation (source de Witt & Meyer 1999)

Innovation implies managing people and knowledge in an environment that is changing permanently. Managing innovation and change is managing uncertainty:

In (a) the challenge is to establish a sustainable technological trajectory and to find its political and market supports. The main difficulties are in the creation of a new technological network, which includes manufacturers, operators, institutions and politics. The main uncertainty lays in the constitution of a corporation, and the new technology must convince all building blocks of this corporation.

In (b), the corporation has been constituted, but the challenge is how to implement strategies of change in order to remain competitive in a changing market.

- *"The ambidextrous organization: Managing revolutionary and evolutionary changes"*²³¹

Projects need different kinds of managers, depending on the phase of the project: managing a Swissmetro project is entirely different from managing the new HSR product development. However, organizations have to be able to manage both revolutionary and evolutionary changes in order to face future challenges.

But this ability depends on structural changes within the organizations, allowing for the adaptation to each phase of the market or of the project. Managing technological rupture is one thing; but one also has to bring the product on the market. On the other hand, managing evolutionary changes, without having the ability to follow market needs, will leave this actor outside the market.

²³¹ Terms used by O'Reilly Ch. & Tushman M.; 1997, "Winning through innovation: a practical guide to leading organizational change and renewal"

Successful innovations require that after the introduction of a system, a continuing effort is made to keep the system up to future standards and to improve it. But this effort also requires having a sufficient market in order to allow for this continuous effort (Figure 133). Without which the system will rapidly become obsolete and the maintenance costs will become too expensive, as in the case of the Maglev systems in Berlin and at the Birmingham Airport (Maglev people-movers, which finally have had to be decommissioned).

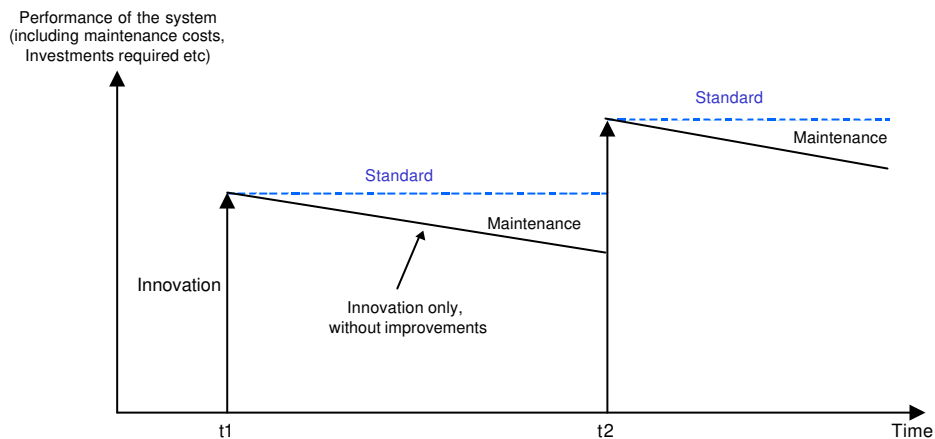


Figure 133: Innovation alone, difficulty in maintaining standards through maintenance only

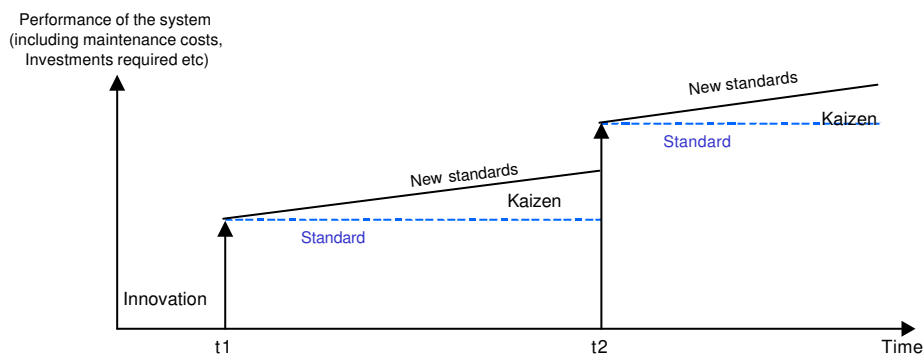


Figure 134: Innovation plus Kaizen, managing revolution and evolution

This will certainly be the dark spot, in the case of Swissmetro, as regards the future interest of vehicle manufacturers: If only 15 vehicles are ordered every 30 years, the cost of the technological improvement will be too high when compared to the costs related to HSR technologies (Figure 134) or even to Transrapid systems.

7.3. Managing critical factors in disruptive HSGT systems

7.3.1. Defining critical factors: Lessons to be learnt

Lessons drawn from the case studies and from the two innovations models presented in chapter 4 have provided the main elements in order to identify the critical factors and the challenges in the management of projects with strong technological rupture.

Previous chapters have underlined the impacts of the technological innovation and have led to the elaboration of the risk identification tables (pages 209-211 & 239-243). The following table shows the critical factors identified for each actor in the present research:

Module	Factors	Manufacturers	Operators	Infrastructure owner	Government	Institutions
HSGT context	Technological lock-in	○				
	Paradigms	○	○	○	○	○
	Structure of the market	○	○	○		
	Political support and transportation policies	○	○	○		
	Innovation barriers	○	○	○		
	Economies of scale	○	○	○		
	Infrastructure: network flexibility (Freight and low speed, multi corridors)		○	○		
	Institutional changes		○	○	○	○
	Globalization of the market	○	○	○		
	Relation Infrastructure owner-operator		○	○	○	○
	Relation operator-manufacturer	○	○		○	
	Problems of Narrow markets	○	○			
	Influence of strategic networks (UIC, ERRAC, UE etc).	○	○	○	○	○
	Problem of oversupply		○	○		
Innovation: product and process (link with market phases)	○	○				
Innovation & rupture	Emergence of the innovation	○	○	○		
	Difficulty in managing innovation	○	○			
	Difficulty in managing technological trajectories. When introducing changes?	○	○		○	○
	Phases of innovation depends on phases of competitions (Speed, Reliability, costs)	○	○	○		
	Infra-technologies	○	○			
	Relation between innovation and development		○	○	○	○
	Resources needed for the rupture	○	○	○	○	○
	Resources needed to improve processes for a sustainable development	○	○	○		
Research networks in order to minimize risks: difficulty in managing rupture?	○	○	○			
Innovation Models & diffusion	Maglev systems are the product of first generation of Innovation Models (Push)	○			○	○
	Now evolution from 4 and 5 th models, networking model. Systemic ruptures are more complex	○	○	○	○	○
	Barrier-Breakthrough Innovation Model, case for Maglev emergence.	○	○	○	○	○
	Increasing returns of adoption Innovation Model	○	○	○		
	Innovation diffusion model (centralized/ decentralized)	○	○	○	○	○
	Decision-making models (rational, organizational, political)	○	○	○	○	○
Decision factors (Type Axelrod)	○	○	○	○	○	

	2 HSGT Innovation Models	○	○	○	○	○
	Critical mass of adoption & diffusion	○	○	○	○	○
	Organizing development and implementation, managing discontinuities	○	○	○	○	○
Building blocks & actors	Organizational models and innovation	○	○	○		
	Public policy				○	○
	The role of institutions (Assessment & validation)					○
	The role of Epistemic communities	○	○	○	○	○
	The art of influence	○	○	○	○	○
	The importance of paradigms (importance of communication and networks)	○	○	○	○	○
	Organization of debates					○
						○
Risk & Uncertainties	Innovation & competitiveness	○	○			
	Risks & degree of innovation	○	○			
	Risk assessment and management, methodology	○	○	○	○	○
	Impacts of innovation and rupture on risks	○	○	○		
	Cost-benefit analysis	○	○	○	○	○
	Real option approach, valuation of flexibility	○	○	○	○	○
	Risk attitudes & cognitive biases	○	○	○	○	○
	Project financing & risk sharing	○	○	○	○	○

Table 22: Critical factors in the management of innovation with strong technological rupture; sequential approach.

Technological rupture goes largely beyond the engineering and scientific fields: Managing projects with strong technological rupture requires the ability to manage innovation within technologies, organizations, policy, networks (epistemic communities), without failing at the interfaces. The following table provides the list of critical factors, which can be used to assess the ability of actors to lead change:

Module	Factors	Manufacturers	Operators	Infrastructure owner	Government	Institutions
Managing the rupture	Innovation & project management	○	○	○		
	Organizing the debate: reduction in subjectivity	○	○	○	○	○
	Managing change (within organizations)	○	○	○		○
	Technology & policy	○	○	○	○	○
	Managing complex consortia	○	○	○		
	Managing interdisciplinary projects and large scale rupture	○	○	○		○
	Building new networks (problem of new collaborations, interfaces)	○	○	○	○	○
	Innovation plus Kaizen: managing revolutionary and evolutionary changes	○	○	○	○	○
	Looking for compromise, Learning through negotiations	○	○	○	○	○
	From supplying to co-development (integrated conception)	○	○			
	Inertia of learning returns	○	○	○		
	Difficulties of inter-project capitalization	○	○	○		
	Experimentation as a key of collective learning	○	○	○		○

Table 23: Critical factors in the management of the rupture; transversal approach.

Most important points resulting from the conclusions of case studies and this research are analyzed in details in the following paragraphs.

7.3.2. When technological rupture induces broader changes: Managing Technology & Policy

Management challenges depend on both amplitude and scope of changes. These changes are the result of the type of technological rupture, which can be incremental or radical, systemic (architectural) or not. Changes can be broad or narrow, low or high (see figure below).

		Scope of change	
		Broad	Narrow
Amplitude of change	High	Revolutionary change	Focused radical change
	Low	Comprehensive Moderate change	Evolutionary change

Figure 135: Amplitude and scope of changes as a consequence of technological rupture

As underlined in previous chapters, technological rupture rapidly goes beyond the field of engineers and scientists. The innovation process is embedded in the so-called double helix, linking technology and policy (figure 136). This combination of technology and policy is situated at two levels:

- The level of the firms: strategies, alliances and co-operations (operators, manufacturers, infrastructure owners).
- The level of the public policy: transportation policy, public finance etc.



Figure 136: Managing the double helix: the combination of technology and policy as a critical factor for success

One important lesson of case studies is the need to foresee the cycles of combinations linking technology and policy: Technological trajectories are linked to political strategies. In Europe for instance, the common transportation policy is leading to more interoperability and standardization, which leads to the strengthening of rail technologies. In the other hand, in China or Japan, choices towards technological trajectories are still open between Maglev and rail HSGT systems.

Favorable political ground is a precondition for the success of disruptive HSGT technologies, as financial backup and guaranties from governments are always required for implementation, as well as the support of institutions in the planning process (characteristics of large infrastructure projects).

7.3.3. Launching new sustainable technological trajectories: The headache puzzle of innovation

Launching new technological trajectories goes beyond mere technological capabilities, as underlined through the multiple perspective approach.

HSGT Innovation Models are closely connected to Decision-making, Organizational and Institutional Models, thus increasing the complexity in managing systemic innovations with strong technological rupture. Part of the complexity induced by the rupture, as also developed in the risk tables, has also been underlined by Potter (1989)²³²: His assessment of the innovative APT/Electra project, led by British Rail in the 1980's, also corroborates the conclusions of the present research.

Launching new technological trajectories is a headache puzzle, requiring managers or promoters to be aware of the following points:

- *Being realistic about Risk and Opportunities of radical innovations*

Introducing systemic innovation with strong technological rupture induces a very high level of uncertainties, when compared with incremental solutions where the main uncertainties can be related to a few parts of the system. This leads to high costs of research, development and production.

However, increasing these costs can be interesting if interesting market opportunities are identified. But as such innovations induce strong ruptures in the market, uncertainties rise to a very high level, as underlined in the demand forecasts of Swissmetro (de Tilière 1997).

The identification of risks is therefore a critical step. If promoters of such projects usually focus on the final market (final users), several studies also focus on assessing risks and opportunities related to the market of operators (whose role is critical in the adoption of such technologies). However, this is the most critical part, since it is related to the sustainability of the market: for example, launching a new technological trajectory for a 60 km network doesn't allow for sufficient economies of scale for the industry to improve the technology (with a new generation of products, new production processes and Infratechnology). Thus a critical threshold of the market size has to be reached (this is for instance the critical element for the industrial development of Swissmetro).

Qualitative and quantitative analyses (NPV etc), as presented by means of the systemic methodology contained in chapter 6, can help to provide more realistic results.

- *About the assessment of resources required by Radical innovations*

Being realistic is also very important in the assessment of resources required for the success of radical innovation. Chapter 6 underlined the very high uncertainties in the planning of R&D programs: unidentified technological lock-ins and problems related to the development of the Infratechnology can be fatal for the project (importance of the timing of the innovation introduction on the market).

Several ratios can be useful to determine the degree of difficulty or complexity: the number of innovative components / standard components etc. Such ratios, which are usually used by the industry, are very important or even a precondition for an active role of the industry (without public support).

Launching a new technological trajectory requires answering the question whether resources will be sufficient and accurate:

- Will the personnel be available, qualified and able to deal with the rupture and the system complexity?
- Will the financial resources be sufficient to allow for the development of the Infratechnology, for the development and the phases of testing and debugging?

²³² Stephen Potter 1989, "High-speed rail technology in UK, France and Japan; Managing innovation-the neglected factor"; in *Technology Analysis & Strategic management*, vol.1, No.1,1989.

- Will potential partners for the consortium be able to provide sufficient support for the project?

Resources must allow to overcome the transition barriers of the new technology, which can also concern technological, financial and market aspects (reference to chapter 3, notion of barrier breakthrough).

- *R&D management in complex systems*

If resources are one of the critical points, which should lead to the abandonment of Swissmetro or the MLX-01, the ability to manage very complex R&D programs is a key factor for success.

Miss-management can lead to unanticipated technological lock-ins, or system failure as the main difficulty stands in the fact that systemic innovation is a collective process, involving numerous people, fields and partners.

Coordination and communication becomes critical elements in the innovation process, leading to the fact that successful innovations are not based on maximizing functions of components (very high-tech and performing components) but rather on maximizing the whole system integration. This underline the fact that large projects usually fail at interfaces, requiring a management by object, rather than by field.

Managing R&D projects with strong technological rupture is very different from those with incremental innovations: the uncertain environment leads to a management mainly based on an interactive and reactive approach. There is too many degrees of freedom in the components and options, which reduces the impacts of proactive management. Managing innovation is therefore radically different from project management (more focused on planning and process control), and this leads to a great impact on the project organization.

- *Technological rupture and organizational revolutions*

Managing innovation with technological rupture requires strong reengineering capabilities in order to deal with uncertainties related to the project. This also necessitates frequent reconfigurations of teams and therefore a high communication level. Introducing innovation with technological rupture leads to organizational revolutions: Well established organizational structures will have to provide an adhocratic structure for the innovation project. This adhocracy, based on a consortium, will have to evolve and transform itself all along the project in order to better answer to challenges.

This stresses the importance of Organizational Models in the management of innovation processes. However, the technological rupture also impacts Institutional Models, since evaluation frameworks are put back into questions, as well as regulation framework, safety norms etc.

If innovation induces organizational revolutions, the type of innovation can also be selected to fit to organizations (incremental approach). The choice between incremental or rupture (strategies) may depends of the ability to influence virtual corporations or networks.

- *Managing virtual corporations and networks*

The success of innovation with strong technological rupture depends on the ability to manage change within corporations and networks. This requires the leading role of influent actors, able to convince partners and manage systemic innovations (the role of managers and the importance of leadership is analyzed in § 7.4). For instance, the passive role of the industry in Swissmetro leads to little perspectives for the project at the moment: The leading role is played by small actors whose influence can hardly rally other key partners (no industrial groups or operator behind).

But part of the problem is that the technological rupture induces a rupture in the HSGT corporations or networks: Swissmetro vehicles are closer to aerospace technologies rather than rail technologies: The effort required to create a new corporation and influence network is time and cost consuming.

- *Managing discontinuities; stop and go patterns*

Innovations projects are subject to stop and go patterns, as underlined by Latour (1990) or by Midler (1993). HSGT innovations face the same patterns, but the difficulties related to large infrastructure projects and their implementation (market diffusion) brings more complexity and increases discontinuities (stop and go patterns, related to the implementation process of large infrastructure projects).

Are resources sufficient in order to avoid discontinuities to kill the project? Maintaining the pressure around the project is critical when during the transition phases (when the project dynamic is stopped). Avoiding people to leave and therefore to lose knowledge and experience may be costly for the project.

The ability of the consortium to manage the continuity in such crisis situations is crucial in order to not lose the previous advances (especially during the phases when the project is suspended). The support of large industries or firms allows to maximize spillover as well as the rapid recombination of teams, without losing experts (experience and knowledge of the project).

For instance, the Tranrapid and the MLX consortia were composed by influent actors, whose activities allowed to provide some inertia in crisis situations and provide a strong continuity and support.²³³

Moreover, the cohesion within consortia is a critical element, allowing to better overcome crisis situations. Cohesion is mainly a function of the consortium structure (Organizational Models) as well as of the strength of shared paradigms.

7.3.4. The power to influence paradigms

- *The art of influence*

In the game of innovation, when epistemic communities are very well established, such as in the rail sector, being an outsider requires strong capabilities and influence to change paradigms. This may be only possible with strong industrial and political influence, as underlined by the Tranrapid case: The German Government provided € 200 Million for the Shanghai project, and accorded € 2 Billion for the project implementation in Germany.²³⁴

Therefore, the importance of knowing the large innovative framework, involving Industry, Operators, Institutions and Politics is very important. However, the ability to influence key actors is essential:

- Influence within the industry for the selection of R&D options, (underlined by Midler 1993, p65, 107).
- Influence on industrial networks and partners for the co-development of the systemic innovation.
- Influence in the market of operators to sell and diffuse a technology.
- Influence on institutions for the homologation of the system.
- Influence on politics for financial support and project implementation.

²³³ The very good implantation of Siemens in China allowed for Tranrapid international to sign a first contract in Shanghai (interview with M. B. Lamour, Scientific Adviser in the French Embassy in Germany).

²³⁴ Herald Tribune, *Tranrapid's subsidized future at home looks bright when seen from China*; 27.11.2001.

- *The role of Paradigms in the HSGT Innovation Models*

Managing complex projects related to systemic innovations (and involving a high level of uncertainties) requires strong cohesion and coordination of actors. Therefore, the importance of the cohesion of related organizations, institutions and politics leads to the notion of shared paradigms or convergence of interests.

Strategies of organizations and institutions are also driven by national or European economies, through changes in the market structure or changes in political priorities.²³⁵ Thus some periods are more propitious than others for the engagement of these actors aiming at the development of such innovations and infrastructure projects.

Changes in paradigms can bring together the public and private wills, leading to one HSGT Innovation Model or the other. These mechanisms are achieved through the changes that paradigms operate in the reconfiguration of Organizational and Institutional Models (impacts on the Decision-making Models).

The first HSGT Innovation Model, which provided systemic innovation with strong technological rupture, was initiated by a paradigm from the 70's and 80's, focusing on technological advance and supremacy of national industries (paradigm shared by politics). The current paradigm is more focused on standardization and cost efficiency (rather than pure technological challenges), with a strong emphasis on operators' requirements. This leads to the second HSGT Innovation Model: central role of operators as lead-users and incremental innovations.

However, the roles of institutions and politics are critical in order to define the frameworks of partnerships and in order to manage interfaces. This role underlines the central position of institutions regarding to systemic innovations in HSGT technologies.

7.3.5. Marketing the system

The main default of the first HSGT Innovation Model is its "push approach" towards the market. This also explains why Maglev technologies begin to be implemented only 30 years after their full-scale experimentations. Marketing is a critical factor, whose function in the innovation process is very important early in the definition of R&D projects.

R&D teams have to work closely with marketing teams in order to avoid "the technological trap" and waste resources: The lack of market understanding can lead "technological objects" to be developed in laboratory for the pleasure of their inventors only.²³⁶

However, the main difficulty remains the identification of market barriers, as the development of such systemic innovations takes more than 10 years, and 20 years before any implementation: Markets evolutions are uncertain, lock-ins may change as well as paradigms. Systemic approaches as well as interaction between R&D and marketing teams allow to reduce biases and risks. But one may observe that marketing functions in radical innovation projects (Swissmetro, MLX, Transrapid) are not enough developed, leading to the risk of a too techno-centered approach of problems.

7.3.6. Resistance towards innovation, Political Risks and Market Barriers

²³⁵ Case of the Transalpine crisis concerning freight transportation with the accident of the Mont-Blanc Tunnel in 1998. The disturbances in the road network led to the approval of the new rail tunnel project between France and Italy in October 2000.

²³⁶ W.H. Davidow, 1986; *Marketing High Technology – An Insider's View*, The Free Press.

- *Public acceptance*

The HSGT market, as other transportation systems is a highly visible market, subject to frequent controversies, in comparison to other sectors such as defense or aerospace contracts. Public acceptance, as well as procedures required for project implementation leads to a highly risky business as regards to time-scale (time to market).

Moreover, resistance towards innovation may be a critical element for technologies with strong technological rupture. For instance, introducing the Swissmetro in Switzerland may introduce radical changes (rupture) in transportation behaviors and land use patterns: what will be the public acceptance towards this rupture? (For instance, the Swiss culture is far from the technology driven mentality of Japanese).

- *Role of institutions in the assessment of innovations*

Institutions play a central role in the validation and homologation of transportation systems. This role is also extended to the coordination of large R&D programs, especially in the case of systemic HSGT innovations with strong technological rupture (as underlined in the First HSGT Innovation Model).

Introducing strong technological rupture requires introducing change in Institutions, since assessment frameworks have to be redefined and tailored. Therefore managing a close relation with institutions as well as the ability to influence them can be a critical factor for success. Such efforts to establish a good communication with institutions and administrations can represent a significant part of the entry barrier (case of the Aerotrain).

- *Political risks and lock-in to implementation*

Political risks in project implementation are a critical element in the diffusion of HSGT technologies, and therefore in the success of innovation. Moreover, political changes often lead to stop and go patterns that can be fatal for projects. As a consequence, the technology “must be able to stand policy” as underlined by a project manager at Matra-Transportation quoted in Latour (1990 p.167).

Project reformulation along stop and go processes are frequent in order to take into account the wills of politicians and key actors. These reengineering requirements for new political purposes show if the technology is able to support political uncertainties.

- *Identifying the market barriers*

If opportunities (potential market) have to be well assessed, they have to be determined in relation with the identification of potential market barriers (see figure p.214 as well as innovations models in sections 4.1.2 to 4.1.4 pages 98-100). These barriers concern:

- The industrial development:

- a) Building a new epistemic community (partners able to deal with the new technological rupture).
- b) Developing the infratechnology.
- c) Managing the R&D phase and foreseeing technological lock-ins (also in terms of costs).
- d) Developing the full-scale prototypes, managing successfully tests and debugging.

- The operators (masters of implementation processes):

- a) They dislike non-proven technologies (cost and reliability uncertainties in daily operations).

- b) Problem of non-compatibility, decreasing economies of scale.
- c) Risk of increasing maintenance and renewing costs if the innovation is not diffused.
- d) Developing the full-scale prototypes, and managing successfully tests and debugging

If some of these barriers are related to technological developments (engineering fields), most of them are related to markets' trends, transportation policies, institutional changes and paradigms. Once again, such a complexity underlines the crucial needs of developing strong marketing capabilities in order to face such challenges.

7.3.7. Valuing Flexibility in the context of high uncertainty

If one looks at the HSGT market like at a game of scrabble, manufacturers and operators prefer technologies that fit the best to the potential windows opportunities rather than the most cutting-edge technology.

- *From the manufacturer point of view*

In the context of high uncertainty, maximizing flexibility appears to be essential. Moreover, due to the narrow market of HSGT technologies, building an entire range of derived products is required in order to succeed in launching a sustainable technological trajectory (diversification and standardization). This has been the main Leitmotiv of rail technologies, the manufacturers of which provide a full range of services, from LRV's to HSR technologies, in order to maximize spillover and economies of scale.

- *From the operator point of view*

However, the valuation of flexibility is also visible in the operators' strategies: They invest in technologies that allow to maximize the use of existing networks, and in vehicles that can be easily re-affected to other tracks. They also pay more attention to decreasing their dependency from one manufacturer only, by increasing the pressure for standardization (pushing for more competition).

- *The case for large infrastructure projects*

Taking into consideration uncertainties related to large infrastructure projects, the inflexibility and irreversibility patterns push for maximizing the future use of those infrastructure projects. Compatibility remains therefore a critical element for decision-makers (politics, institutions and operators), thus leading to the notion of convergence of infrastructures.

Planning systems that increase the convergence of infrastructures allow to face future uncertainties by decreasing the inflexibility patterns of those infrastructures. This requires new schemes in system designs and applying the notion of real options in the design and management of engineering systems.

7.3.8. Conclusion: Forecasting and managing technological trajectories

- *The link between transportation policy and innovation*

As case studies have shown, the private sector rarely carries out a radical systemic HSGT innovation alone, without the support of the public sector. One of the main components of risk remains political: If one looks at innovation development in the past decades, the link between transportation policy and innovation is very important and influences the paradigms that drive changes.

- *Looking for new alternatives, from technical performances to sustainability*

The role of public institutions in supporting the elaboration and the assessment of alternatives or solutions for future transportation needs is very important. This role is necessary for the private sector when it can't afford it by itself and when benefits (NPV) for the public at large are high. This role has been critical for the HSGT programs during the 60's and 70's in UK, France, Germany, Canada, USA etc. Such R&D programs have helped to improve existing technologies or alternatives and to provide sufficient elements to meet the requirement for assessments and decision-making.

In that sense, the role of public policy is to define the boundaries and the framework of alternatives in which the industry has to innovate (case of HSGT systems). This underlines the importance of the role of institutions and the influence of their attitude towards innovation and changes (Gaudin 1978).

- *Development and diffusion of a technology: the competition for setting new standards*

After the selection of one or more options (as in Japan or Germany regarding both HSR and Maglev alternatives), the public sector also has to support the industry for the development of the technology in conformity with the goals²³⁷ of transportation policy, or in order to secure the network development or improvement. This will in turn guarantee the sufficient diffusion of the innovation, as well as the profitability of R&D investments for both private and public actors (scale effects, case of HSR networks in France, Japan, Germany etc.)

The development of networks has increased the maturity of HSR technologies at a national level and has allowed private consortia to export their technologies. The public and private sectors are working closely together even for the purpose of exporting, especially when governments have strongly supported the development of a national technology. Governments support exports in order to maximize the network deployments, which are based on their technology, and try to impose their standards abroad. This is the case for the Shinkansen technology with regard to the Taiwan contract, where a 50% discount on the system was made²³⁸ because of the competition with the European consortium (led by Alstom and Siemens). The same strategy was used by the German Government for the Shanghai project, with regard to the contract with Transrapid International (it provided US\$ 300 million for the implementation of the project).²³⁹

Subsidizing the export or the development of a technology with a view to maximizing scale economies can be a strategy in order to maximize the profitability or reducing losses of initial investments. Once again, this underlines the importance of strong path dependency regarding infrastructure characteristics related to technological choices.

- *Influencing the market structure (Operators and industries)*

The structure of the market has a strong impact on the type of innovations produced. The link between transportation policy and market structure is therefore crucial.

The European transportation sector began its harmonization and liberalization process, with interoperability and Trans European Networks as keywords.

Changes have first concerned operators: a separation was made between infrastructure and operation, on the one hand, and progressive vertical disintegration, on the other. Financing HSR in Europe has evolved during the past decade from a purely public-sector enterprise, to one with an increasing level of support and long-term commitment from the private sector (Lynch 1998). While the role of the public sector remains important in HSR infrastructures, private sector responsibilities are becoming better defined. The decision, in 1989, concerning the development and improvement of the Trans European Network was a

²³⁷ Case of the US-FRA supporting 50% of the development costs of a HSR gas-turbine locomotive with Bombardier to extend the HSR network on non electrified areas (Source: US-DOT 12.2000).

²³⁸ Interview with M. Takabayashi, Osaka University, 02.2001.

²³⁹ Signed in Shanghai in January 2001, the 30km line will be put into operation in 2003. Earlier in 2000, The German government has offered to pay DM1bn for a 100km Maglev test track in China in an effort to get China to choose Germany's Transrapid Maglev for the new high-speed railway linking Beijing and Shanghai.

very important one. It contributed to redefining the cooperative roles of public and private sectors in co-financing such investments²⁴⁰.

Concerning industry, those changes are resulting from the increasing pressure from politicians, who push for more cooperation between European manufacturers. This new area of increasing co-development or “coopetition” between European firms aims at strengthening collaboration in costly R&D programs. The purpose is to decrease the high investments needed for developing new technologies, previously mainly supported at a national level. Behind this trend stands the increasing pressure for standardization (interoperability), concept which is also related to the one of economies of scale, both for operators and industries.

7.4. The importance of leadership: lessons drawn for managers

The Multiple Perspective Approach developed in this research has stressed the fact that managing innovation with strong technological rupture leads to the necessity of introducing change in paradigms and of building a new epistemic community around the new Technological Trajectory. Moreover, patterns of such innovation projects require specific capabilities from managers in order to be able to deal with stop and go patterns (managing chaos).

- *About the role of the manager and the question of leadership*

As underlined in this research and by the research of Navarre & Couillard (1993), the factors critical for projects success are more about management practices than about the application of hard tools (PERT, CPM, Gantt etc).

Managers are responsible for creating and influencing the environment surrounding the project, and for providing cohesion and motivation. The following points aim at developing this concept, on the basis of the conclusions drawn in the previous chapters and of previously analyzed case studies.

- *About the position of decision-makers*

The case studies have allowed to draw lessons regarding the role of managers and their leadership capabilities. The determination of key people is main factor behind the successful development of new HSGT technologies.

Key people were for example CEO's of National Operating Companies (H. Shima, CEO of the JNR and L. Armand, CEO of the SNCF): both were very determined and have used all their influence in order to allow for the success of their new strategy (HSR development). Their role was crucial in creating a dynamic around those projects of (incremental) rupture.

Their position was central because of the critical role of operators for the adoption of any new technology, but also because of their network of influence and their strong connection with politicians and institutions. Thus the success of systemic innovations with strong technological rupture depends in a large measure from the position and the leadership of their advocates. Only such key people can create shifts in paradigms, especially when it concerns projects with high risks and uncertainties.

²⁴⁰ At the European level, the result was the creation of the European the Cohesion Fund established in the Maastricht summit and the Investment Fund.

- *The difficulties of outsiders*

Inventors are usually outsiders who break current established paradigms and bring forward new ideas. However, the innovation success depends on bringing such invention onto the market, and the main difficulty remains the access to this market:

In the case of the Aerotrain, the role of Bertin as a leader was exemplary: He developed a technology, which was in competition with the one of SNCF. His leadership allowed to maintain a strong dynamic during a whole decade. He benefited from contacts with key personalities and laid great emphasis on marketing the project. However, his difficulties started with the administrative procedures necessary for the implementation of the project. The fact that Bertin was an outsider and was working against the SNCF interests led to increased difficulties.

In the case of Swissmetro, R.Nieth was considered as an outsider with regard to the Swiss rail operator, despite he was one of its employees. The main difficulty of this project is that it was initiated outside both the existing manufacturing industries and the rail operator. This made it difficult to influence those actors and made it necessary to convince and influence key people among politicians and in companies' headquarters.

The difficulties for outsiders are also underlined by the German Transrapid case. Considered as an outsider by the German Operator, DB; it has not yet been possible to implement the project. However, thanks to the strong network of influence of the leader of the consortium, Siemens, it was possible to conclude a contract in China.²⁴¹

- *Leadership and the ability to influence Key actors*

Managing and marketing systemic innovations with strong technological rupture requires from managers to have very strong networks of influence. The importance of leadership is crucial, as introducing and managing change is a prerequisite for such projects. The ability to convince and rally influential people around the project is critical (key actors of the HSGT market: operators, manufacturers, institutions, and politicians).

However, one must consider the risk associated to changes in the position of these key people: Political changes or changes in their position can compromise efforts (for instance, the change of the German Government in the mid 90's for the case of the Transrapid).

One must also notice that if influencing politicians or manufacturers can allow launching R&D programs, further developments rapidly depend on the strategies and on the influence of operators and infrastructure owners (implementation). For the development of systemic innovations with strong technological rupture, such as in the USA with the NMI program or in Switzerland with Swissmetro, operators were not part of the process (active role). This now remains the main critical challenge.

The importance of leadership as well as the ability to convince is underlined in the Political Decision-making Model (also part of the Global Decision-making Model – figures pages 108 & 112).

- *Leadership and the ability to resist to strong pressures*

Political and Organizational Decision-making Models are based on the assumption that decisions are the result of games of influence between key actors. Case studies have stressed the necessity of being capable of resisting to strong pressures:

- In the case of incremental innovations, the position of SNCF's CEO, L. Armand, was several times endangered by the Government's determination to cancel the TGV project (see page 123). But his determination allowed the realization of the project: If technological developments were financed by

²⁴¹ Interview with B. Lamour, ex Scientific Adviser for the French Embassy in Germany (1st October 2001).

the SNCF, the implementation of the project mainly depended on the game of influence with the Government and the Finance Ministry.

- In the case of the radical and systemic innovation (rupture), the case of the Aerotrain stresses the necessary determination and resistance of the project manager and leader. Bertin fought during more than 10 years against administrative resistance, even if the project was considered to be the most promising one by the media (against the TGV project) until its cancellation in 1974.

Stop and go patterns of such innovation projects require managers with strong resistance skills, able to reduce the effects of those patterns on the project and to guaranty their sustainability.

- *Creating the team spirit and the Leitmotiv around the project*

Chaotic patterns of innovation projects with strong technological rupture lead us to deal with the following points, especially during transition phases:

- Decreasing interest of investors
- Decreasing dynamics in the project
- Dispersion of talented and experienced people.
- Decreasing project spirit especially at the consortium level. Losing the Leitmotiv

In order to deal with the challenge of inverting these decreasing spirals and negative trends, when project difficulties arise, the manager must use all his leadership skills:

- Increase contacts with Key actors (external)
- Increase communications within the consortium, reestablish the project Leitmotiv (based on the project's memory and passion)
- Try to maintain contacts with the talented and experienced people, who have left the project, using their new contact networks. Look for new talented people, working in related fields.
- Work to strengthen the Leitmotiv and the team spirit (persuasion, motivation, inspiration): enforce the project pressure.

For this purpose, the manager must also delegate specific tasks in order to increase the motivation of people in the team.

The manager is therefore an environment-maker as he has to develop a project "ideology" and to motivate the team. This allows to overcome crisis phases, especially when resources are lacking. Projects such as Swissmetro or the Aerotrain can be put in parallel with the concept of Missionary Organizations developed by Mintzberg (1998).

- *Recoding the project and taking R&D project termination decisions*

Managing and leading HSGT projects with strong technological rupture requires strong determination and strong reengineering capabilities. But the ability to decide to terminate, when necessary, a R&D project termination is also critical. In a way, the leader must be a visionary.

Success is usually synonym with reengineering and recoding. Adapting parts of the concept can sometimes provide a greater chance of success, even if one has to be careful not to lose the identity of the project (core concept or purpose of the innovation).

This also means that the manager must be able to decide to terminate an R&D project when needed, before spending too many resources on an unviable project.

7.5. Set of recommendations

7.5.1. Assessing the real need of launching a new HSGT technological trajectory

The nature of HSGT projects, especially concerning their implementation phase, is strongly dependant on the transportation policy as well as the planning process, which are in turn mainly dependant on the political and institutional will. Politics and institutions shape the framework of the ground transportation systems, and therefore of the HSGT market (underlined through the interaction between Institutional Models and HSGT Innovation Models).

The launch of new HSGT technological trajectories (First HSGT Innovation Model) is dependant on the support of strong public R&D programs, since the small market window does not allow for the HSGT industry to carry out such a rupture alone.

Institutions and governments can therefore either let market mechanisms work, thus leading to incremental innovations (referring to the Second HSGT Innovation Model), or define new ways to solve specific problems or needs, and thus supporting the introduction of disruptive technologies (referring to the Second HSGT Innovation Model).

Public authorities have to carefully assess the cost of launching new technological trajectories (extended NPV analysis for operators, regions and the country). The difference lays in the fact that in the case of technological rupture, R&D and Industrial development will require the support of the government, whereas in the case of incremental technologies, development costs are mainly supported by the private sector.

7.5.2. How to manage projects with strong technological rupture

Assuming that launching a new technological trajectory is attractive for decision-makers in terms of specific transportation needs, this research provides the following recommendations on the management of technologies with strong technological rupture.²⁴²

- ▶ Defining the degree of technological rupture and its consequences by means of a multi-perspective approach (requiring a systemic approach, cognitive maps). This requires engineering teams to work, at a very early stage in the R&D and design phase, with marketing teams and people from trans-disciplinary fields.
- ▶ Defining with realism risks and opportunities, with an emphasis on reducing cognitive biases (systemic approach, cognitive maps, quantitative and qualitative risk assessment). This has to be done in parallel with forecasting the diffusion of competing technologies.
- ▶ Identifying the main paradigms among operators, industry and policies, and see whether a convergence can be defined between them with the technological rupture as an objective.
- ▶ Ensuring that the innovative project is accepted by institutions and politics as an option for the transportation policy (that can be exploited or not at a later stage). Defining a R&D program, which allows to secure the role of the private sector.

²⁴² These recommendations refer to the First HSGT Innovation Model, with comparisons with the Second one (incremental technologies).

- ▶ Defining pre-requirements of the innovation success for the consortium (skills): adapting challenges and resources:
 - Having the capabilities to create a new epistemic community, leading to a strong consortium structure.
 - Being able to ensure that institutions will assess the technology within an accurate framework.
 - Being able to ensure that institutions will provide the adequate support with regard to administrative procedures.
 - Ensuring that the consortium will provide the necessary skills and resources in order to overcome technological and market barriers.

- ▶ Building a strong network of influence
 - Develop strong connections with major operators

7.5.3. Requirements from the Industry concerning the role of governments and institutions

If the industry can have an interest in developing new systemic innovations with strong technological rupture for the HSGT market, its requirements towards governments and institutions are important:

Due to the nature of the HSGT business, which is inherently risky and lacks peripheral new business, the industry requires a major long-term commitment from government

- *About the Maglev market definition*

Market is the critical point for industries since:

- Public acceptance is unclear.
- Feasible routes have not been clearly defined.
- Costs and revenues are not “convincingly” known.
- Technical feasibility/reliability, safety, and environmental questions remain open.
- It is not certain that Maglev is the right answer for the market needs.

- *R&D funding*

Industries are reluctant to finance R&D programs for HSGT technologies with strong technological rupture due to insufficient innovation’s rents. For instance, studies in the USA²⁴³ showed that the Industry refuse to share the costs in R&D programs if their participation exceeds 10% (90% financed by government). Their main concerns are the following:

- No clear market and business opportunities.
- Excessive risks.
- Revenue stream too far away in the future.

²⁴³ Survey conducted by Arthur D. Little on the Maglev R&D Program in 1990 concerning the development of an US Maglev technology: 18 large industries concerned by the program answered to this survey ordered by the US-FDOT (Department of Transportation).

- Available resources needed for other pressing priorities.

- *National policy for ground transportation*

Industries consider that before any definition of Maglev market is done, several conditions on transportation policy are required:

Primary actions

- To define the “next generation ground transportation systems”
- To clearly establish the role of disruptive technology within the transportation system.
- To obtain public and state support for the disruptive technology, within the framework of the global transportation system.
- To provide the coordination needed for development and implementation of the disruptive technology.

Secondary actions

- Legislative changes:
 - Easing policy to speed-up R&D contracting.
 - Better patent protection (introduction takes 15-20 years).
 - R&D tax incentives.
 - Collaboration between states regarding the rights-of-way.
 - Clarify Public-private partnership.
- Definition of a Program Champion.
- Definition of compatibility standards for the future network.
 - Guide-way configuration.
 - Capability to adapt different international standards
- Implementation/operating subsidies.
- Assessment of environmental studies.
 - Responsibility for the government to set requirements in this area.

- *Conclusion on the interest of manufacturers:*

There is a relatively low level of industry interest in Maglev, because business opportunities are unclear (which means that there is no clear role of the potential technology in the national transportation programs).

There is a reluctance of industries to participate to R&D cost-sharing, even if with a share of under 10%, arguing that it is the role of the government to support such programs (nature of the HSGT market).

If skills are present within the industry, the main problem remains the possibility to reduce the costs of this technology for mass production.

7.6. Conclusion

This chapter aimed at providing a good insight of management challenges related to the technological rupture. Recommendations provide management practices, which complement the Methodology developed to assess the rupture with the Innovation, Decision-making, Organizational and Institutional Models. These recommendations were also developed under the light of the risk analysis developed in chapter 6.

7.7. References

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1. Introduction

2. The case of high-speed ground transportation projects

3. Innovation and rupture

4. Towards an Innovation Model for HSGT systems

**5. How organizational and Institutional factors influence
Innovation Models**

**6. Impact of the technological rupture on Risk &
Uncertainties**

7. How managing the technological rupture successfully?



8. Conclusion

ANNEX: Project Management Assessment System

8. CONCLUSION

8.1. Synthesis

- *The Multi-perspective Approach*

Understanding difficulties and challenges in the management of HSGT projects with strong technological rupture requires having a good overview of projects and their related environment. As underlined in the elaboration of the two HSGT Innovation Models, innovation processes are forged at three levels:

- The HSGT market: operators and manufacturers.
- Transportation policies: public investments, regulation measures.
- National/Federal industrial policies: orientation and support through national R&D programs.

For the purpose of apprehending the consequences of the technological rupture, this research provided for an analysis of international experiences concerning the development of several technologies. The case studies allowed to identify critical factors in project management through a better understanding of innovation processes (Innovation Models). This led to the identification of risks and uncertainties, and finally to map out the impacts of the technological rupture.

This Multi-perspective Approach led to a set of recommendations and an Assessment Approach embodied in the PMAS tool (in Annex). Conclusions underlined the fact that challenges go beyond the fields of engineering and science. If investment choices are based on profitability studies, assessing capabilities to innovate within organizations, corporations and avoiding a disconnection with the market remains the main challenge: Leading a market rupture requires the ability not only to understand actual paradigms, but also to lead change through epistemic communities in order to set future paradigms.

- *Underlining how technology and policy are interconnected: the double helix concept*

Managing the rupture requires both technological and political skills. Successful innovations require management skills in order to:

- Ensure a sustainable technological development and set pertinent and realistic objectives.
- Define and maintain strategic networks among key actors, providing critical support.

- *Developing Models in order to apprehend the complexity of HSGT Innovation Processes*

Case studies underlined the complexity of the Innovation Process for systemic innovations with strong technological rupture. This research aimed at providing a better understanding of this complexity, with the description and the development of several Models, which are linked into a Global Model of Innovation and Risk (page 237).

First, the development of Specific Models (sections 4.1 & 4.2) allowed to describe important patterns of the HSGT market and its innovations. The description of five Generations of Innovation Models allowed to better understand the evolution of innovation management since several decades. Moreover, specific patterns driving the HSGT market were analyzed through two Specific Innovation Models stressing the importance of increasing returns of adoption and the notion of barrier breakthrough.

The case studies highlighted the two HSGT Innovation Models (section 4.3) and described the HSGT Innovation Process and the role of key actors. These Models allowed to define the critical factors for the development of HSGT innovations, and especially technologies with strong technological rupture.

This research pointed out that the choice or the adoption of the first or the second HSGT Innovation Model (strong technological rupture versus Incrementalism) is also driven by organizational or political factors. For this purpose, a Decision-making Model has been developed in chapter 3, explaining the basic mechanisms of such processes. The development of Organizational and Institutional Models developed in chapter 5 allowed to explain the choice of the Innovation Model.

This research therefore tried to provide a good understanding of the links between Institutional frameworks, Organizational factors and technological strategies as regards the specificity of the HSGT market. Moreover, the Risk Model, pointed out that the Multiple Perspective Approach is critical in the risk identification, as critical risks cover a large spectrum of fields.

Finally, the PMAS tool (in Annex) designed for assessing the management of projects with strong technological rupture used this extensive approach in order to provide accurate and specific recommendations.

8.2. Main lessons drawn from this research

- *The rents of innovation as critical factor*

Finally, forecasting technological trajectories, and therefore the development of new technologies with strong technological rupture, requires assessing the rents of innovation of key actors. These actors are manufacturers, operators and governments, with the support of institutions. Assessing the intrinsic and extrinsic value of new transportation projects allows to determine the rents of innovation for operators and manufacturers with a private perspective. Concerning governments and institutions, their perspective is centered on a technology assessment in the interest of the collectivity.

When innovation's rents are not sufficient for the private sector to launch new technological trajectories, governments can intervene to support R&D and/or implementation efforts, if benefits for the collectivity are justified. Two reasons can justify such a strategy:

- Support of a technology responding to political objectives (needs of the society).
- Support of the national industry for sustainable leadership or competitiveness.

- *Innovation Models and technological trajectories*

The two HSGT Innovation Models presented in this research have underlined the influence of the Institutional and Organizational Models in technological choices.

- In the First Innovation Model, innovations with strong technological rupture were instigated by industry and developed through national R&D programs. But the main difficulty for the diffusion of the technology being to overcome market barriers, this required further public support in the beginning of implementation in comparison to incremental technologies.
- In the second Innovation Model, incremental technologies (HSR) were developed through the initiative of lead-users (for instance, JNR in Japan for the Shinkansen and SNCF in France for the TGV).

These models show that successful rupture for such technologies are only possible if institutions and governments provide guarantees in order to support the long-term development (diffusion) of the new technological trajectory: The nature of the HSGT market (irregularity of orders for manufacturers) leads to serious difficulties in managing a sustainable business in the long-term.²⁴⁴

Maglev concepts derive from the first generation of Innovation Models (type “push”) of the 60’s and 70’s. Investments and programs were since then prolonged in Germany and Japan with the introduction of a long period of tests and demonstrations until the current final phase of development. Such technologies of rupture were abandoned at an early stage in France, UK, USA and Canada since governments were reluctant to finance costly R&D developments: Incremental technologies (HSR systems) already allowed to decrease the technological rupture as well as the market rupture and to maximize existing rail networks (rupture in infrastructure).

Since the 80’s, Maglev developments have been based on the Kaizen approach. The main challenge for these consortia was problem-solving and cost-killing, as well as overcoming the reluctance of operators to adopt disruptive systems. The main purpose of these two consortia is to find ways and means in order to benefit from the important investments made (around US 3 billion \$ in Japan and 1.5 billion in Germany).

Swissmetro is a third technological trajectory in the HSGT market. In light of the small market window, benefit-perspectives for manufacturers are few. Although it seems to be a technology of the future, Swissmetro is in fact an innovation concept of the 70’s, derived from the first generation of “Push” Innovation Models (even if the promoters of this project argue that the growing importance of environmental factors justify the “Pull” Model).

Moreover, technological trajectories in the HSGT sector are also influenced by national/federal transportation frameworks. Specific policies have to be implemented with accompanying measures in order to secure efforts of manufacturers and operators in the long-term perspective (as there is strong increasing returns of investments linked to infrastructures and standards).

- *Managing systemic innovation and the role of epistemic communities*

Networks and communities in the HSGT market are mostly rail oriented, as operators are the key actors worldwide (lead-users). These epistemic communities have a strong influence on R&D activities as regards both direction and intensity, thus shaping future technological trajectories.

Introducing a systemic innovation with a strong technological rupture can induce a rupture in the epistemic community, as in the case for Maglev technologies. One therefore has to build new networks, capable of influencing or changing paradigms.

²⁴⁴. See table in annex p330: since 1981, only 50 trainsets/year were ordered worldwide (including renewals). Moreover, irregularity of orders increases difficulties, such as for the case of the US crisis in the railcar industry 1970-1980 (de Tilière 2001 (a)).

Networking and the ability to influence the main actors are a prerequisite for any implementation of disruptive HSGT systems: The change of paradigm concerns industry, operators, institutions and the transportation policy. But if one looks at the increasing importance of the paradigm of interoperability and standardization, especially in the European market, technologies such as Swissmetro don't seem to fit into such a policy.

- *Managing change within institutions*

Institutions have a powerful role in the HSGT sector, through the definition of safety and environmental standards. As underlined in the Acela-express project, the US Department of Transportation imposed to the consortium Bombardier-Alstom severe requirements, leading to an increase of 45% of train-sets weight. Bringing disruptive technologies to the market induces severe risks concerning the way institutions can react to change and rupture.

The two Innovation Models show that successful rupture for such technologies are possible only if institutions create a new evaluation framework for concession demands, as it was achieved in Germany or Japan. But in these cases, governments were backing up projects and this was a matter of the future leadership of the national industry in Maglev systems (convergence of paradigms). Cases show that the institutional assessment framework can constitute significant lock-in in project development.²⁴⁵

- *Minimizing the inflexibility as a critical factor in the diffusion of HSGT technologies*

The notion of flexibility is a critical factor to deal with strong uncertainties of the HSGT market (Political risks, strong irregularities of orders, etc). Therefore, the valuation of opportunities through minimizing the degree of inflexibility is very important for the sustainability of the technology. To this end, introducing the notion of the real option approach early in the system design is very important.

For example, Swissmetro should recode its project, focusing on its core innovation: high-speed in tunnel with partial vacuum: Therefore, based on the last generation of Innovation Models: "interactive and networking" the consortium may provide a technology for both HSR and Maglev systems. Focus should emphasize on HSGT aerodynamics in tunnels (project HISTAR), in order to develop stronger relations with operators and manufacturers and to increase long-term flexibility for R&D investments.

- *Conclusion: Private-Public partnership for innovative HSGT Infrastructures*

The development of Systemic Innovations with strong technological rupture in the HSGT market requires a strong public support as well as the definition of a clear transportation policy framework. The development of alternative HSGT technologies has always been supported by "Champion Programs", sponsored by governments and aiming at the full-scale development of a technology.

The industry, looking for sustainable markets, requires from governments a sustainable commitment (such as in the aerospace industry for instance), which can be summarized into the three following points as regards technologies with strong rupture (new technological trajectories):

- Governments must define, in a clear manner, the market and the business opportunities.
- Public funding for initial R&D efforts until the end of the demonstration phase has to be provided for (the industry usually asks for more than 90% of public involvement for such risky and long-term projects).
- A national policy for ground transportation has to be clearly formulated.

²⁴⁵ Case for Swissmetro assessed by the Swiss Transportation department in 1999 through rail procedures and of the Serpentine (personal transit system) through Trolley -bus procedures underlined difficulties to define adequate evaluation frameworks.

If these conditions are not guaranteed, the industry prefers to follow an incremental path, in order to be able to maximize its economies of scale, and to invest in more flexible options, so as to be in a better position to face future uncertainties.

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LIST OF ABBREVIATIONS

AEIF	European Association for Railway Interoperability.
BMFT	German Ministry of Research and Technology.
CFF	Swiss Rail Operator.
DB	Deutsche Bahn.
DETEC	Swiss Department for Transportation & Communication.
ERRAC	European Rail Research Advisory Council.
ERRI	European Rail Research Institute
HSGT	High-Speed Ground Transportation
HSR	High-Speed Rail.
ICE	German HSR technology (developed by Siemens and ex -Adtranz).
JNR	Japanese National Railways.
LIM	Linear Induction Motor
Maglev	Magnetic Levitation.
MLX-01	Japanese Maglev Technology, last version (in run-test since 1998).
NPD	New Product Development
NPV	Net Present Value
RFF	Réseau Ferré de France (French National Infrastructure Owner).
RTRI	Railway Technical Research Institute (Japan).
SNCF	Société Nationale des Chemins de Fer (French Rail Operator).
SST	Super Sonic Transportation (US project cancelled in the 70's, led by Boeing and NASA).
TGV	French HSR system, developed by Alstom (Train Grande Vitesse).
UIC	Union Internationale des Chemins de Fer
UNIFE	Union of European Railway Industries.
US FDOT	US Federal Department of Transportation.
US FRA	US Federal Railway Administration.
X-2000	Swedish tilting train developed in 1990 (consortium led by ABB).

GLOSSARY

Epistemic community

For the understanding of epistemic communities, one can refer to the works of Haas (1992) and Holzner & Marx (1979):

An epistemic community may consist of participants from various disciplines with various previous experiences, and they have the following four characteristics:

- 1) A shared set of normative and principled beliefs, providing a value based rationale for the social action of community members;
- 2) Shared causal beliefs, which are derived from their analysis of practices leading or contributing to a central set of problems in their domain and serving as the basis for elucidating the multiple linkages between possible policy actions and desired outcomes;
- 3) Shared notions of validity – that is, intersubjective, internally defined criteria for weighing and validating knowledge in the domain of their expertise; and
- 4) A common policy enterprise – that is, a set of common practices associated with a set of problems to which their competence is directed, presumably out of the conviction that human welfare will be enhanced as a consequence.

Sources:

- Haas, P. M., 1992. "Introduction: Epistemic Communities and international policy coordination", *International Organization* 46, 1.
- Holzner, B. and J. Marx, 1979, "Knowledge affiliation: the Knowledge system in society" Allyn and Bacon, Boston, MA.

Paradigm

The first edition of Thomas Kuhn's "The Structure of Scientific Revolutions" appeared in 1962. His vision has revolutionized the way we think about science with the notion of "paradigm".

Kuhn envisioned a science as having, at any one time, a world view, or 'paradigm', of its environment. This scientific paradigm describes everything, which the science holds, all of its laws, beliefs, procedures, and methods.

A vision of science that preceded Kuhn saw science as an accumulation of all that had been learned over history, each new law adding its weight to the mass of science. Kuhn saw a science profoundly altered by a major new law, so that all of the science might be affected.

Kuhn felt that most scientists participate in 'normal science', which is any activity consistent with the existing paradigm, with relatively small gains the rule. Eventually, anomalies arise which the paradigm cannot resolve. Then some individual(s) may step out of the paradigm, and propose some new principle or law. If the scientific community accepts the proposed change, the science experiences a 'paradigm shift', and the new science proceeds with a new paradigm.

Technological Paradigm

Constant (1973) defined the Technological Paradigm as a technological operation mode, which is commonly accepted and is a mean to achieve technical tasks. This paradigm is defined by the community of professionals, and consists in an extensive set of methods, processes as well as associated tools. This

set of patterns characterizing the technological paradigm leads to a specific way of perceiving a technology

Technological trajectory

The notion of technological trajectory is defined in this research as a range or family of technologies derived from a same concept (for instance wheel-rail systems, as opposed to Maglev systems). The technologies on a same trajectory can benefit from the same infratechnologies and generic technologies, as well as a common paradigm.

Infratechnology

Infratechnology: Instrumental basis for R&D activities, which requires supplying scientific data for measures, tests and controls. It also includes methods, know-how and knowledge associated with the research (Tassej 1995, Foray 2001).

Generic technology

Concepts of products or concepts from which commercial applications are developed through applied R&D programs. This includes concepts demonstrated in laboratories but not products and processes finally developed (Tassej 1995, Foray 2001).

Resultant technology

Concerns the process or product resulting of the R&D activities, based on infra-technologies and using generic technologies.

INTERVIEWS

Interviews have been held since 1999 in order to provide the material for case studies and corroborate the conclusions/model, which leads to the recommendations. Those ones have been organized on an informal basis focusing on specific subjects and are summarized on the tables below:

Case studies: HSR & MAGLEV projects

<i>Name</i>	<i>Firm / Institute Function</i>	<i>Date</i>	<i>Place/Subject</i>
M. J.C. Raoul	Technology CEO ALSTOM Transport	7.12.2000 8.12.2001	Paris-Dauphine PREDIT meeting TGV & Transrapid, industrial strategies UIC-Paris:
M. Michel Cornil	CEO SNCF R&D President administration Board SYSTRA	7.12.2000	Paris-Dauphine PREDIT meeting Managing innovation within administrations as a condition of success.
Prof. Rothengatter	Karlsruhe University Director of IWW	07.04.1999	Frankfurt, SCENE meeting Germany. Transrapid difficulties.
Prof. M. Wachs	UC-Berkeley Director of ITS	07.03.2001	Berkeley Financing HSGT in California.
Dr. M. Mossi	SWISSMETRO Project Manager GESTE-SA, CH 1015 Ecublens	06.12.1999 16.03.2000 14.08.2001 19.09.2001 12.02.2002	Lausanne Knowledge management. Relation with the DETEC. Swissmetro project management. Alternatives for Swissmetro.
M. R. Nieth	Inventor of the Swissmetro concept Service des voiries City of Lausanne	15.04.1999	Managing the crisis period within the project
M. Ph. Pot	Member of the Swissmetro administration board. Losinger Group.	15.02.2002	Lausanne Swissmetro & project management
Dr. R. Clever	ITS UC-Berkeley	11.02.2001 16.04.2001	Berkeley Transrapid & ICE performances. German Policy towards HSGT.
Dr. V. Bourquin	HISTAR Project Manager GESTE-SA, CH 1015 Ecublens	09.12.1999 15.12.1999 08.03.2000 23.01.2002	Lausanne Specifications problem in R&D. Idem (+ Problem of iterations). Project management strategies. Assessment of the project management.
Dr. V. Bourquin	Projet HISTAR & SWISSMETRO EPFL	06.04.1999 09.12.1999	R&D management Project management
M. Yves Trottet	Ex. communication manager SWISSMETRO Lausanne.	30.03.1999	Project management. Transition EWE-GESTE, Strategies.
SWISSMETRO	Meeting of Shareholders, Berne Management comity, Lausanne	06.06.1999 10.12.1999	Results of concession demand studies. Management issues
Prof. J. Neiryck	Member of the Swiss Parliament	25.01.2000 18.09.2001	Policy issues R&D subsidies for HISTAR

Prof. Descoeurdes	SWISSMERTO Geotechnical studies	13.06.2000	Tunnel options for Swissmetro
B. Lamour	Ex-scientific adviser in charge of Transrapid, French Embassy, Science & Tech. service SST - Bonn	01.10.2001	- Discussions of partnership Alstom-Siemens for the Transrapid technology (1996-97). - Causes of the implementation failure of the Berlin-Hamburg line.
D. Leavitt	Deputy Director California High-Speed Rail Authority	02.10.2001	- Technological choice HSR/Maglev for the San Francisco-Los Angeles corridor. - The impact of infrastructure compatibility.

Project management & Innovation

Name	Firm / Institute Function	Date	Place
	World Bank		Seminar Berkeley
Prof R. Levitt	CIFE Stanford	11.10.2000	Stanford, seminar Assessment of organizations Project management
Prof. I. Tommelein	CEE UC-Berkeley	16.11.2000	Berkeley Lean management seminar
Prof. R. Bea	CEE UC-Berkeley	11.02.2001 20.07.2001 Spring 2001	Risk management. Performance shaping factors. Master course: Risk management & organizational factors.
Richmond field station Team	Path Program	March 2001	R&D strategy, cooperation UC-Berkeley, Car industry (Program financed by GM & Toyota)

Theory: Organizations & Innovation

Name	Firm / Institute Function	Date	Place
Prof A. Bergman	Doyen of HEC Lausanne Prof in Organizational Change	15.03.2000	PHD Seminar HEC Lausanne
Prof. D. Mowery	Haas School, UC-Berkeley Prof. Corporate Strategy & Innovation	Fall 2000	PhD Seminar Berkeley
Prof. D. Teece	Haas School, UC-Berkeley Prof. Innovation Management	Fall 2000	PhD Seminar Berkeley
Prof. W. Garrison	ITS UC-Berkeley	28.02.2001 09.03.2001 23.03.2001 ... 02.04.2001 ... 06.04.2001 08.05.2001 20.05.2001	Case study methodology. FDOT policy, HSGT in the USA. Innovation Model for HSGT technologies. Case of the US industry.

Transportation context

<i>Name</i>	<i>Firm / Institute Function</i>	<i>Date</i>	<i>Place/Subject</i>
M. Crosier	Bombardier Transport Marketing manager	28.11.2001	Villeneuve Production plant (CH), interview on production scale and innovation, Visit of the factory.
Prof. M. Wachs	ITS director UC-Berkeley	15.02.2001	UC-Berkeley US-DOT policy, HSGT constituency.
Dr P.A. Jaccard	ITEP/LEM EPFL-1015 Ecublens	21.09.2001	Ecublens Lyon-Turin rail project, National policies & strategies
Dr M. Takabayeshi	Osaka University Japan	03.03.2001 19.04.2001 08.05.2001	UC-Berkeley Japanese HSGT system Shinkansen exportation – Taiwan. Innovative projects in Japan
Dr. M. Mossi	SWISSMETRO Project Manager GESTE-SA, CH 1015 Ecublens	31.03.2000	Lausanne Economical and financial profitability
Prof. E. Beimborn	Center for Urban Transportation Studies University of Wisconsin UW Milwaukee	26.03.2001 26.04.2001	UC-Berkeley Innovation Models (transportation systems) US Maglev initiative

IT Solutions for project management

<i>Name</i>	<i>Firm / Institute Function</i>	<i>Date</i>	<i>Place</i>
Dr. C. Stricker	EPFL-ITEP/LEM Ecublens	13.04.1999 03.07.1999 16.06.1999	Project management & IT solutions. Methodology.
Dr. V. Bourquin	HISTAR Project Manager GESTE-SA, CH 1015 Ecublens	06.12.1999 9.12.1999 22.02.2000	Lausanne Need for IT tools to support project management for big consortia. ANAISOFT case of Swissmetro

1. Introduction

2. The case of high-speed ground transportation projects

3. Innovation and rupture

4. Towards an Innovation Model for HSGT systems

5. How organizational and Institutional factors influence
Innovation Models

6. Impact of the technological rupture on Risk &
Uncertainties

7. How managing the technological rupture successfully?

8. Conclusion



ANNEX: Project Management Assessment System

ANNEX: Project Management Assessment System (PMAS)



Figure 137: PMAS Entry Window, Tool based on ACCESS

Project Management Assessment System (PMAS): Goals and objectives

- *Overall Goal:*

In order to provide recommendations for the project management of such innovative concepts, the critical factors which have been highlighted in case studies and analyzed in the previous chapters will be incorporated in a project management assessment tool: PMAS.

When technological rupture is added to large-scale, as well as SWISSMETRO, TRANSRAPID, or the MLX-01, the implication of the rupture on project management is critical. Managing and coordinating organizations in order to face the technological, economical and political uncertainties becomes more difficult. The goal of this tool is to systematically identify these critical factors with the management team through an assessment of the project including organizational characteristics.

The assessments with PMAS provide the basis for recommendations concerning project management, based on its weaknesses and strengths according to a pre-established list of factors. This includes proactive and reactive strategies based on the interaction with assessors and decision-makers or project teams.

- *Objectives:*

SWISSMETRO is emblematic of the rupture and constitutes an ideal case study for this assessment methodology. The purpose is to calibrate PMAS and provide generic recommendations for project with strong technological rupture.

Through this case study, three objectives were determined:

- A. To determine if the modules and factors identified through a literature review, are relevant when assessing projects with strong technological rupture.
- B. To determine if the PMAS process can produce consistent results.
- C. To field-test the PMAS software program.

Methodology

- *Principle*

PMAS is based on the TRIPOD theory, which is a checklist based instrument build around a central database with calibrated questions. The Tripod theory has been developed in the eighties by the universities of Leiden and Manchester under a contract from Shell International, in search of the elimination of human error as a target for accident prevention. It was found that human error, which is an important contributing cause in at least 90% of all business upsets, can most effectively be controlled by controlling the working environment.

The PMAS assessment methodology is embedded in a MS-Access application²⁴⁶. The principle is to provide an assessment of the project management with the cooperation of the project team, to highlight critical elements and define reactive and proactive measures/strategies.

- *Conducting the PMAS audit*

Assessment modules and factors are the result of the case studies and the previous chapters. Case studies and literature review made possible to:

- 1...Identify, team and organization factors.
- 2...Identify, team and organization factors.
3. Identify a methodology for assessing these factors
4. Design a process that incorporates the methodology and the factors
5. Design the PMAS software program that facilitates the process
6. Field test the process with the SWISSMETRO management team
 - 6.1 Prepare a list of requested information and a briefer checklist
 - 6.2 Train the management team with the PMAS process
 - 6.3 Conduct first and second field test assessment
7. Analyze results
8. Write up report with a set of recommendations for the project management

After this field test, further audit will be achieved to assess various project management (industry, civil engineering ect.) and the following methodology has to be used:

1. Identify, project characteristics.
2. Identify team and organization factors.
3. Create selection criteria for assessors (those who will use the process)
4. Create a training program for assessors
5. Field test the process
 - 5.1 Send to company a list of requested documents and a briefer checklist
 - 5.2 Select and train assessors

²⁴⁶ SMAS, designed at UC-Berkeley in 1997, was first developed based on the TRIPOD theory for operations in the petroleum and marine industries. PMAS (EPFL-UCB 2001) use the same philosophy as well as the SMAS architecture and focus on the assessment of project management.

5.3 Conduct first and second field test assessment

6. Analyze results

7. Write up report with a set of recommendations for the project management

Note: during the audit, assessors must be aware that people have difficulty with negatives in their models and frequently try to ignore or minimize them.

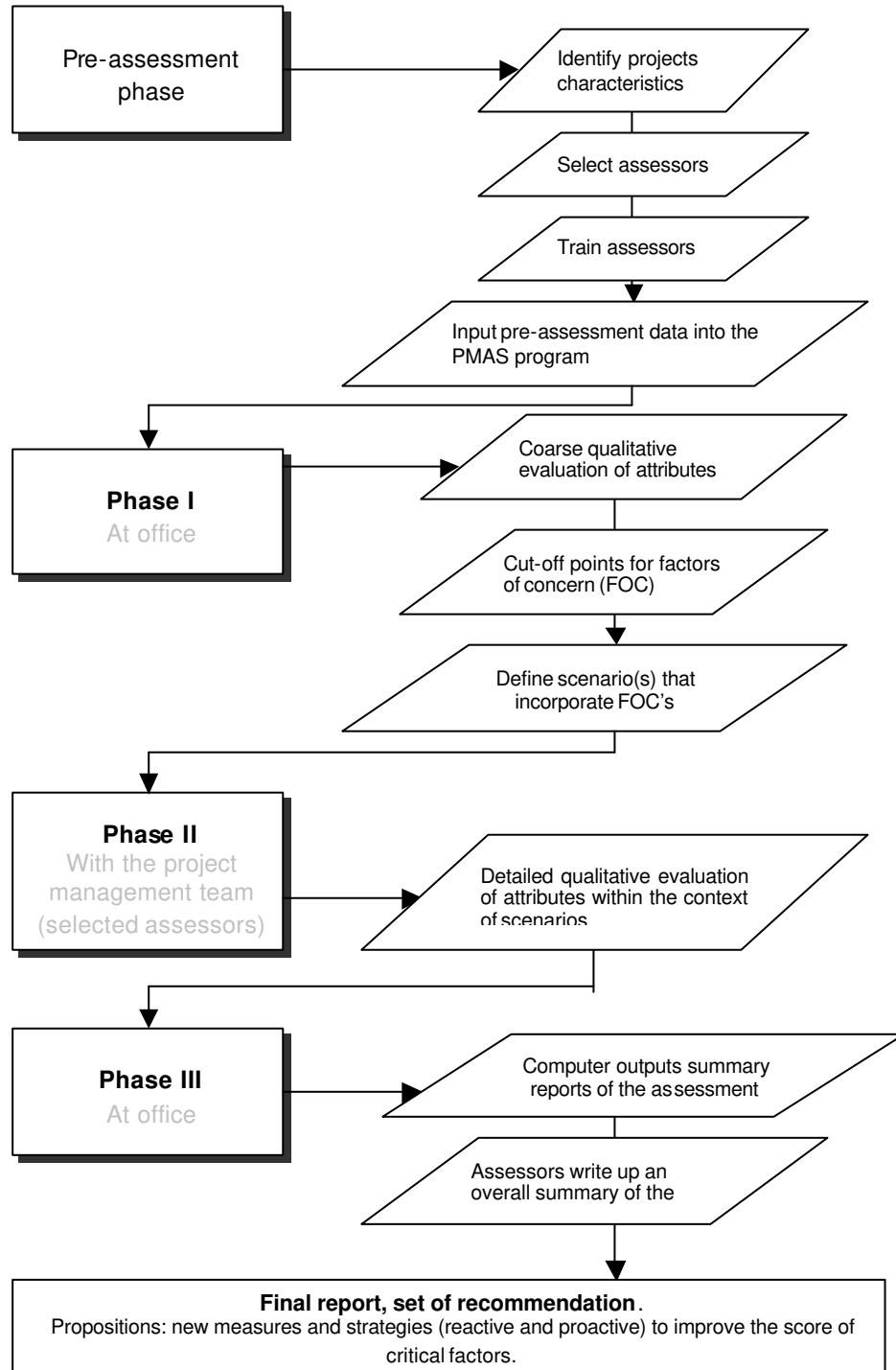


Figure 138: the PMAS process

PMAS Structure

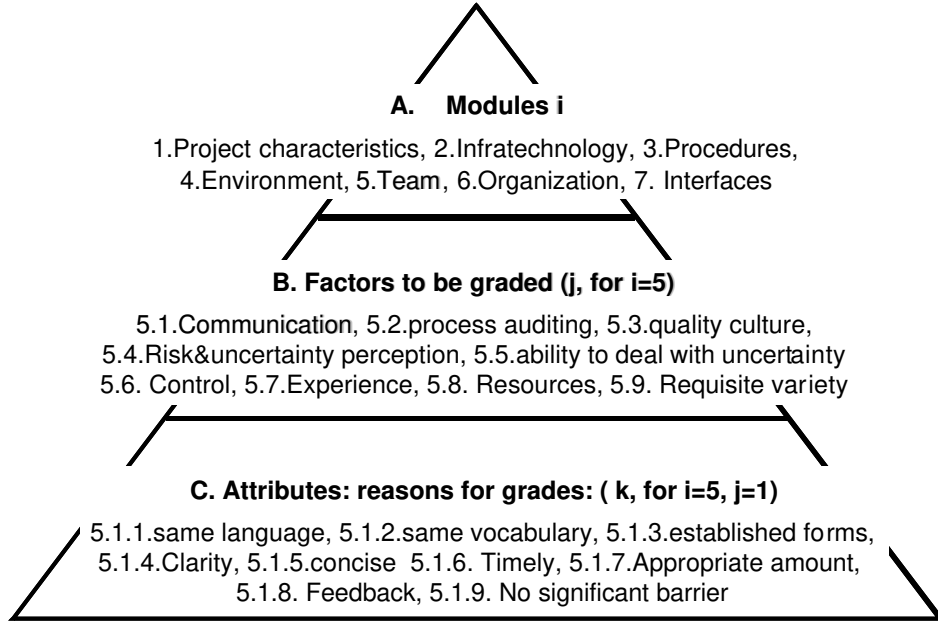


Figure 139: Structure of PMAS, Modules, factors and attributes (adapted from Bea 1996)

- Seven modules of PMAS

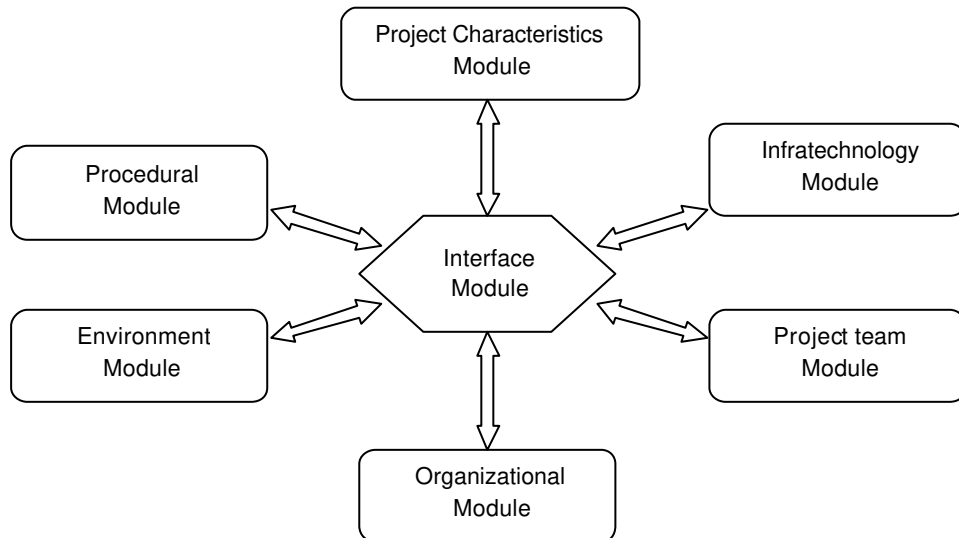


Figure 140: The seven modules of PMAS

Project characteristics: Main characteristics of the project, degree of rupture and complexity.

Infratechnology: State and adequate level of technical support in terms of R&D.

Environment: State of external conditions as economics (public finance), transportation policies and the position of rail operators/industry.

Organization: Consortium and partners of the project.

Project team: The group of people, which is assessed in the project.

Procedural: The management, R&D and organizational procedures associated with the project.

Interface: The interactions between the above six modules.

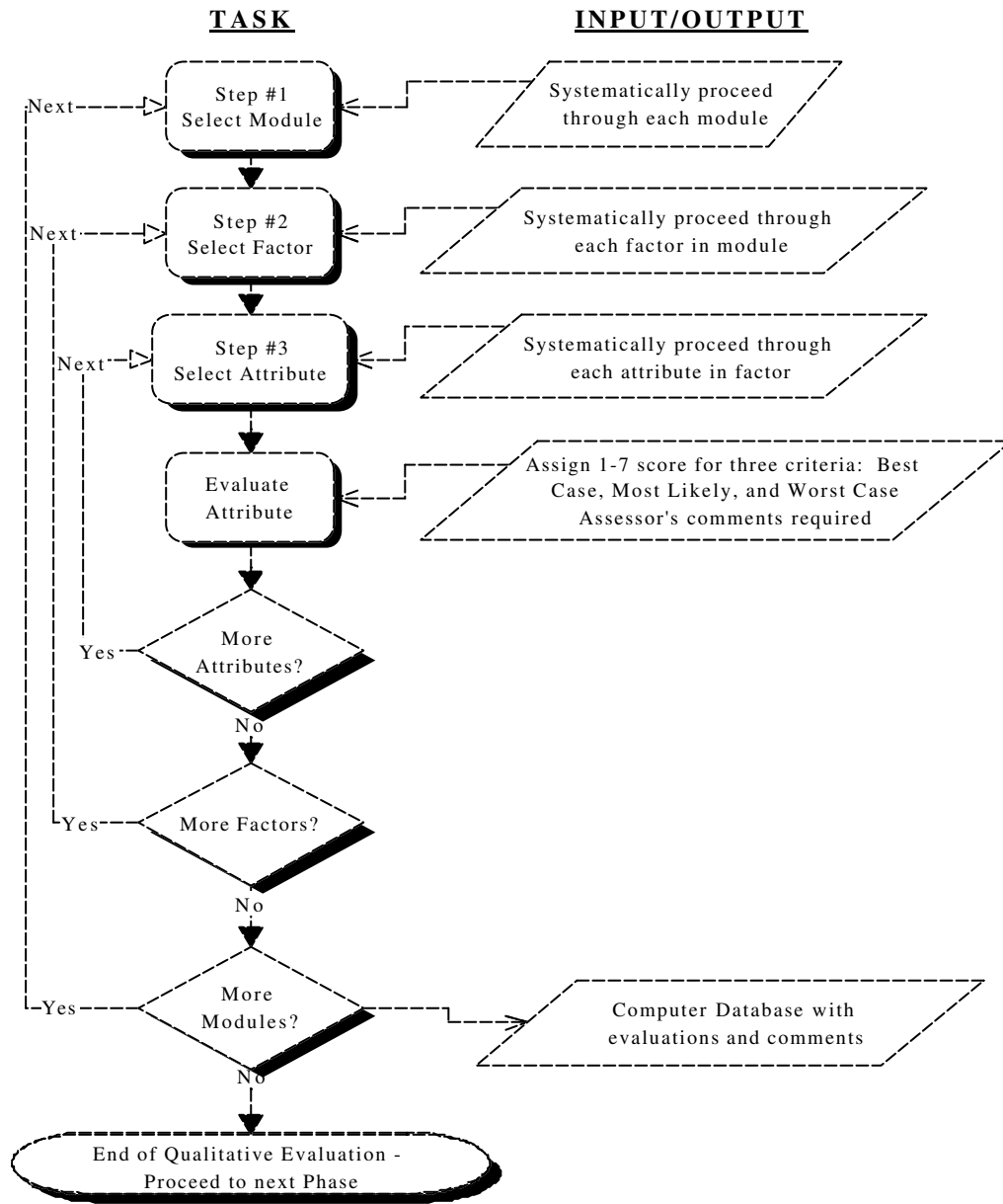


Figure 141 : Qualitative evaluation process (Both Coarse and Detailed evaluations)

PMAS, assessment of the SWISSMETRO -HISTAR Project Management

- *Comparative assessment of different HSGT technologies*

Before beginning the Swissmetro project management assessment, a short comparative assessment is developed in this paragraph to underline the incidence of the technological rupture in the management. Four HSGT projects/technologies are compared through the list of criteria that will be used for the SWISSMETRO case study: an incremental HSR system, a new HSR generation, a Transrapid system and Swissmetro.

Objective: Assessment of project management for project with

- Different degree of innovation or rupture
- Different experience (feedbacks) of system operation (mature / new)
- Different organizational structure (consortia etc...)

A1: HSR without technological innovation or change, production by a consortium of an existing product (Example: Alstom with its current suppliers and partners).

A2: New generation of HSR system, new components part, technology added to the product. Consortium modified for this particular contract (with local industry...) ex: Acela express.

A3: MAGLEV system based on Transrapid technology, without modification. New consortium for implementation in China.

A4: SWISSMETRO, New consortium, Maglev technology in a new environment, very complex system.

- *Factors and attributes*

The project assessment will be focused on the impact of innovation on project management. Four main aspects will influence the evaluation of factors/attributes:

- The type of innovation
- The level of compatibility (infrastructure)
- The Type of organization (structure of the consortium...)
- The role of lead users

The following table describes the factors and attributes for each modules. In order to define a set of recommendation, the controllability of each factor/attribute will be defined related to the project management (degree of efficiency for management measures/alternatives): two dimensions are defined:

- Controlable [C] versus Uncontrolable [U]
- Dynamic [D] versus Static [S]

These qualifications (C, U, S, D) are defined according to the project in order to help assessors in their evaluations and recommendations.

Module / Factor	Attribute	HSR	New HSR	Maglev systems	Swissmetro	HISTAR	Attribute controllability
Project Characteristics							
Innovation degree & rupture	- Rupture / Incremental	1	1	5	6	4.5	US
	- Systemic / autonomous innovation	1	2	5	6	6	US
	- Recombination of existing technologies	1	2	5	6	5	US
	- Non proven technologies (operation)	1	2	5	6	5	US
	- Ratio pure / applied research	1	2	5	6	4	US
Level of complexity	- System Size (components)	2	3	5	6	6	US
	- Number of fields involved for the R&D	1	3	5	6	6	US
	- Linkages complexity (components)	2	3	5	5	6	US
	- Persistent technological uncertainties / lock-in.	2	2	4	5	3.5	US
	1	2	4	5	3.5	US	
Compatibility & standards	- Need new production processes.	1	2	4	6	3	US
	- Can benefit from standard components.	1	2	5	6	3.5	UD
	- Reusability of technologies afterwards.	1	2	4	4	1.2	UD
	- Reusability of processes afterwards.	1	2	4	4	1.2	UD
Level of resource needed available	- Time	2	4	4	5	3.5	CS
	- Financial support	2	3	4	6	6	CS
Infratechnology							
Simulation	- Current tools and methods available & accurate	1	2	3	4	3	CS
	- Knowledge & experience sufficient	1	2	3	5	3.5	CD
Tests and models	- Current production tools and processes available	1	2	4	6	3	CD
Prototype	- Current production site accurate	1	2	3	6	3.5	CS
Production	- Current production site accurate	1	2	3	6	-	CS
	- Current prod. processes accurate	1	2	3	6	-	CD
Procedures							
Procedure definition	- Well defined by the managers	3	3	3	4	4.5	CD
	- Usually known and respected by individuals	3	3	3	5	2	CD
Experience	- Procedure are part of the work / training	2	2	3	5	2	CD
Quality management	- TQM part of the culture	3	3	3	4	2.5	CD
Management of change		4	4	3	2	2	CD
Reengineering ability	- Project recoding abilities	4	3	3	4	2.5	CD
Contractor selection	- Manager can select the best for the task	2	2	3	6	2	
	- Public authority can mandate the best for R&D studies	3	3	3	3	2	
Team							
Process auditing		2	2	3	3	2	CD

Command and control		3	3	3	4	2	CD
Training		3	3	3	4	3.4	CD
Communication		3	3	3	2	2.4.5	CD
Requisite variety in personnel		3	3	3	5	2.5	-
Organization							
Process auditing		3	4	4	6	6	-
Culture		4	4	4	3	3	US
Command and control		4	4	4	5	5	CD
Risk perception		4	4	4	4	4	US
Training		3	4	4	6	3.5	CD
Communication		3	4	4	6	6	CD
Requisite variety in personnel		4	3	3	5	3	US
Environment							
Social (team & organization)	Same purposes	3	3	3	5	3	
Institutional framework	Role in project development	4	4	2	4	-	
Political context	Transportation policy, current priorities Society concerns (Benefits/cost)	2 2	3 3	5	6 5	-	
Market Analysis	Lead-user interest and cooperation	2	2	5	6	6	
	Social acceptability	2	3	5	5	-	
	Demand-forecasts uncertainties	3	3	5	5	-	
	Cost-Benefit Analysis	2	3	5	5	-	
	Economies of scale	1	2	5	5	-	
Industrial context	Paradigm	2	2	5	6	-	
Interfaces							
Team-Organization	Communication Funding	3 3	3 3	4 3	4 5	5.5 5.5	
Team-Environment	Ability to identify the project environment (critical points)	3 3	3 3	3 3	3 3	3 3	
Procedure-Team	Available	3	3	3	3	3	
Procedure-Organization	Auditing	3	3	3	4	3	
Procedure-Environment	Crisis situations	3	3	3	4	3	
Infratechnology-Procedures	Conducting	2	2	3	4	3	
Infratechnology-Team	Experience	2	2	3	4	4	
Infratechnology-Organization	Funding	2	2	3	6	-	
Project-Organization	Funding & support	2	2	3	6	6.5	
Project-Team	Scheduling	3	3	3	3	-	
Project-Environment	Opportunities & external support	3	3	3	5	6	
Project-procedures	Conducting	3	3	3	3	3	

Table 24: Project Management Assessment: Result of the case studies (scale: 1-best to 7-worst)

Swissmetro and Histar were briefly assessed in order to field-test PMAS through several interviews with the project management team.

- *Assessment of the management of SWISSMETRO*

For more detail on the project, refer to the PREDIT report, de Tilière 2000 (Swissmetro case study).

Procedure:

Assessment done based on the interviews achieved through the Swissmetro case study between 1998-2002 (Y. Trottet, R. Nieth, M. Mossi and V. Bourquin) with the project manager, Dr. Vincent Bourquin.

The 7 modules of PMAS are assessed through a list of factors, also described by attributes in order to be more precise rating of each factor with PMAS (55 factors and 108 attributes were defined for this first test, based on the same tables used above).

Results are aggregated by module, and factors of concerns are listed in the table page 328. This allows to define the Modules on which one have to pay more attention. For SWISSMETRO, main concerns must be put on the Environment and Organizational Modules.

Environment is defined by Market opportunities as well as the lack of interest of key industrials, as well as the political context (Transportation policy, mainly focused on rail improvement). The factors of concerns are mainly related to those aspects, which are critical for the project.

However, this assessment underlined the fact that the ability to manage such challenges is reduced by Organizational factors. If the module related to the Swissmetro Team was relatively good (best module score), the Swissmetro Organization suffers from the lack of interest in the project. The consortium structure is weak, and the lack of involvement of partners (due to the Environment Module: Market, Policy etc).

As a result, management of interfaces was difficult, as underlined in the assessment but mainly at the consortium level (Organization module) rather than at the team level.

This project underline the difficulty to launch a new Technological Trajectory without the support of operators and manufacturers, as well as the definition of a specific institutional and political framework as regards to the transportation policy. Despite the good assessment of the research team, the Environment and Organizational Module lead to a status quo in the R&D project, which can't reach the industrial development phase.

This assessment stressed the importance of an interactive management, in order to deal with the very high level of uncertainties.

- *Assessment of the management of HISTAR*

HISTAR is a research project aiming at the development of a demonstration site (model at the 1/10 scale) of Swissmetro vehicles with tunnel infrastructures. The purpose of the project is to provide results on aerodynamics of high-speed vehicles in tunnels. Such results can be useful for HSR or Maglev technologies. The project is located at the Swiss Federal Institute of Technology in Lausanne, and the tunnel will be 500 m long.

The project was financed by ALSTOM (with its Swissmetro shares), as well as Swissmetro and the CTI. The project is estimated at CHF 2.5 Million (1.8 at the beginning), which corresponds to a CHF 5-6 Million project in the private industry.

Procedure:

Interview and assessment with the project manager, Dr. Vincent Bourquin (LEME, January 23 2002). 3 hours of assessments through a rating of each factor with PMAS.

Results are shown in page 329, underlining that most attention in the project has to be focusing on managing the Organization and the project environment (consortium with weak relations, whose partners have no high incentives for an effective participation).

Critical aspects for the management team are finally related to the high uncertainty associated to managing Innovation, and also corroborates the conclusion of Chapter 6: in R&D phase, most uncertainties are related to the planning (time and deadlines).

On the 55 factors used for the assessment (108 attributes), 24 factors of concern were underlined.

During interviews, the importance of factors related to the team has been subject to discussion: If the actual assessment concludes on a good adaptation between the current management and the project characteristics, a first failure happened a year ago. The inability of part of the team to deal with the high level of uncertainty of the project led to reorganize the HISTAR team, including people working more easily in innovation projects.

Conclusion on PMAS:

PMAS is an interesting tool to assess project management, using a Multiple Perspective Approach. Factors and Attributes used for these assessments are the result of this research. These criteria can easily be changed and tailored in PMAS for the assessment of various projects.

Such tools already proved to be pertinent to provide recommendations to project managers, as SMAS developed by Prof. Bea at UC-Berkeley and which has been applied in the Petroleum Industry for safety assessments (who allowed the development of the PMAS version).

The methodology of PMAS refers to the one developed in this PhD research, and allow to provide with the collaboration of the project management team a basis for recommendations (by means of the identification of key problems).

PMAS Assessment results for SWISSMETRO:

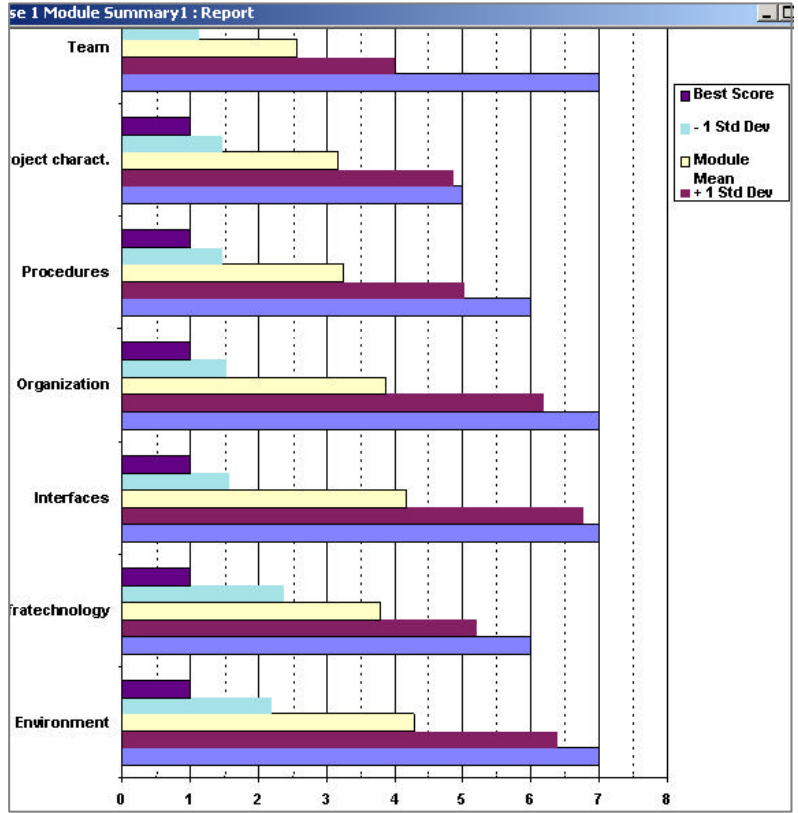


Figure 142 SWISSMETRO Assessment, aggregated results by modules

FOC LIST			O.K.
Factor ID	Factor Name	Module Name	
05	Tests & Models	Infratechnology	
07	Prototype	Infratechnology	
08	Production	Infratechnology	
12	Management of change	Procedures	
14	Contractor selection	Procedures	
15	Process auditing	Team	
21	Culture	Organization	
22	Command & control	Organization	
25	Communication	Organization	
28	Social	Environment	
29	Institutional framework	Environment	
30	Political context	Environment	
33	Project characteristics - Procedure	Interfaces	
35	Project characteristics - Team	Interfaces	
36	Project characteristics - Organizat	Interfaces	
40	Infratechnology - Organization	Interfaces	
45	Environment - Organization	Interfaces	
46	Team - Organization	Interfaces	

Record: 1 of 18

Table 25: List of Factors of concern, whose grade is under 4 (scale 1 - best to 7-worst)

PMAS Assessment results for HISTAR:

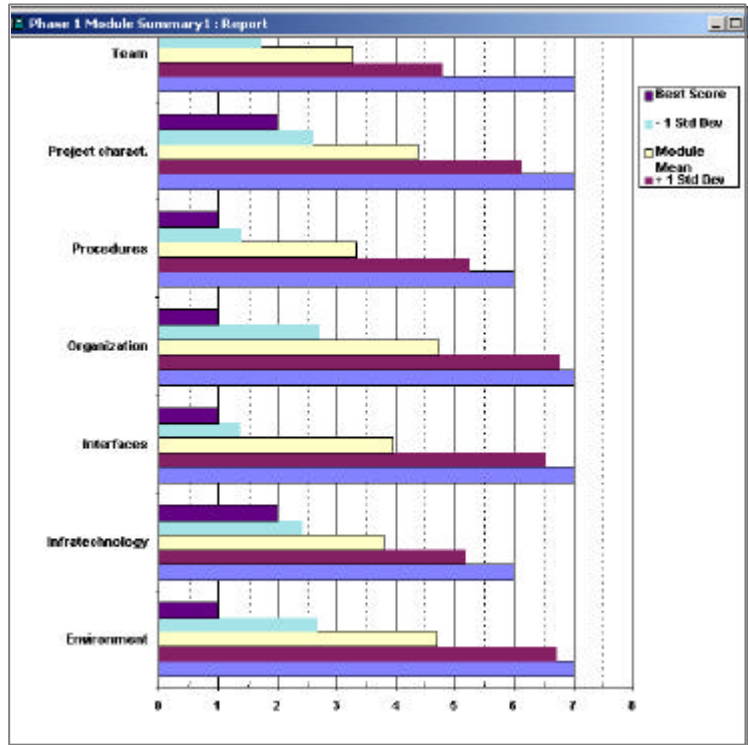


Figure 143: PMAS Assessment results aggregated by modules (rated from 1-best to 7-worst)

FOC LIST			O.K.
Factor ID	Factor Name	Module Name	
01	Innovation degree & rupture	Project charact.	
02	Level of complexity	Project charact.	
03	Compatibility & standards	Project charact.	
04	Level of resources needed	Project charact.	
07	Prototype	Infratechnology	
08	Production	Infratechnology	
09	Procedure definition	Procedures	
14	Contractor selection	Procedures	
15	Process auditing	Team	
20	Process auditing	Organization	
21	Culture	Organization	
22	Command & control	Organization	
24	Training	Organization	
25	Communication	Organization	
27	Personnel & HR management	Organization	
28	Social	Environment	
30	Political context	Environment	
31	Market characteristics	Environment	
32	Industrial context	Environment	
33	Project characteristics - Procedure	Interfaces	
35	Project characteristics - Team	Interfaces	
36	Project characteristics - Organizat	Interfaces	
40	Infratechnology - Organization	Interfaces	
45	Environment - Organization	Interfaces	

Record: 1 of 24

Table 26: Factors of Concern, whose grade is over 4 (scale 1-best to 7-worst)

ANNEX: Tables of HSGT vehicles produced until now for commercial operation

A. HSGT vehicles produced worldwide since 1981

Trains GV (Vmax > 220 km/h)												
Train	Railway	Year	Nr	Vmax	Vop	AxL	IPw	Pw	L	MPU	HV	Seats
WIN 350	JR West	1992	1	350	.	10	7200	i	153	6	0	335
STAR 21	JR East	1992	1	350	.	10	4620	h	205	7	2	528
ICE 3 *	NS	1998	6	330	.	15	8000	h f b	200	4	4	379
ICE 3 (406) *	DB AG	1999	9	330	.	16	8000	h f c b	200	4	4	380
ICE 3 (405) *	DB AG	1999	4	330	.	16	8000	h f b	200	4	4	380
ICE 3 (403) *	DB AG	1999	37	330	.	15	8000	f	200	4	4	391
TGV Sud-Est 300	SNCF	1981-85	63	300	270	17	6420	h b	200	2	8	350
TGV Atlantique	SNCF	1989-92	105	300	300	17	8800	h b	238	2	10	485
ETRY 500	FS SpA	1991	2	300	250	19	8500	c	302	2	10	672
AVE	RENFE	1991-92	18	300	300	17	8800	h c	200	2	8	329
TGV Réseau tricourant	SNCF	1992-94	50	300	300	17	8800	h b	200	2	8	377
Class 373 tricourant	Eurostar SNCF SNCB	1993-95	28	300	300	17	12240	h c a	394	2	18	770
Class 373	SNCF	1993-95	3	300	300	17	12240	h c b a	394	2	18	770
TGV Réseau bicourant	SNCF	1994-96	30	300	300	17	8800	h c b	200	2	8	377
TGV Thalys PBA	SNCF	1995-96	10	300	300	17	8800	i	200	2	8	377
TGV Thalys PBKA	SNCF SNCB NS	1997-98	17	300	300	17	8800	h f c b	200	2	8	377
Class 373 Regional	Eurostar	1995-96	7	300	300	17	12240	h c a	319	2	14	530
TGV Duplex	SNCF	1995-97	85	300	270	17	8800	h b	200	2	8	545
ETR 500	FS SpA	1995-97	30	300	250	17	8800	c	328	2	11	663
ETR 500	FS SpA	1997-99	10	300	250	17	8800	h c	250	2	8	490
ETR 500	FS SpA	1997-99	42	300	250	17	8800	h c	328	2	11	663
TGV Korea *	KHRC	1997-2000	46	300	.	17	13200	h	387	2	18	935
700	JR Central JR West	1997	1	285	.	10	12960	i	405	12	4	1323
ICE 1 (401)	DB AG	1990-93	15	280	250	19	9600	f	305	2	10	495
ICE 1 (401 power car)	DB AG	1990-93	45	280	250	19	9600	f	358	2	12	627
ICE 2 (402)	DB AG	1996-98	44	280	250	20	4800	f	205	1	7	368
E3	JR East	1997	16	275	.	12	4800	h g	100	4	1	270
E2	JR East	1997	16	275	.	13	7200	h i	200	6	2	630
TGV Sud-Est 270	SNCF	1981-85	28	270	270	17	6420	h b	200	2	8	368
TGV Sud-Est 1ère cl.	SNCF	1981-84	7	270	270	17	6420	c	200	2	8	285
TGV Sud-Est tricourant	SNCF											
TGV Sud-Est Poste	SBB	1981-85	9	270	270	17	6420	h f b	200	2	8	368
TGV Sud-Est Poste	SNCF	1984	5	270	270	17	6420	h b	200	2	8	368
300N	JR West	1992	9	270	.	11	12000	i	400	10	6	1323
300	JR Central	1992	37	270	.	10	12000	i	400	10	6	1323
200	JR East	1980-82	55	240	.	17	11040	h	400	12	0	885
400	JR East	1990	12	240	.	13	5040	h g	126	6	1	399
E1 MAX	JR East	1994	11	240	.	17	9840	h	302	6	6	1235
E4	JR East	1997	3	240	.	16	6720	h	201	4	4	817
0	JR West	1964	32	230	.	16	11840	i	393	16	0	1340
100N	JR West	1989	9	230	.	15	11040	i	395	12	4	1321
IC225	GNER	1988-89	31	225	.	21	4540	h e d	224	1	10	480
0	JR Central	1964	30	220	.	16	11840	i	393	16	0	1340
100	JR Central	1986	57	220	.	15	11040	i	395	12	4	1321
Euromed	RENFE	1996	6	220	200	17	8800	h b	200	2	8	325
Total		1981-2000	1082									

Table 27: HSGT vehicles produced worldwide since 1981 (Source: UIC 2000)

B. HSGT vehicles with tilting technology produced worldwide since 1987

Trains Pendulaires _ (Vmax > 200 km/h)													
Train	Railway	Year	Nr	Vmax	Vop	AxL	IPw	Pw	L	MPU	HV	S	
300X	JR Central	1994	1	350	.	9,0	9720	i	152	6	0	335	
	500JR West	1995	1	320	.	11,0	18240	i	404	16	0	1324	
	500JR West	1997	9	300	.	11,0	.	i	382	12	4	.	
TGV pendulaire *	SNCF	1998	1	300	.	17,0	4500	hb	200	2	8	350	
ETR 450	FS SpA	1987-88	15	250	250	13,0	4700	c	208	8	1	390	
ETR 460	FS SpA	1994	7	250	250	14,6	5880	c	237	6	3	448	
ETR 460 bicorr.	FS SpA	1995-96	3	250	250	14,6	5880	cb	237	6	3	448	
ETR 480	FS SpA	1997-98	15	250	250	14,5	5880	hc	237	6	3	412	
Acela *	Amtrak	1999	18	240	.	22,0	9120	hed	200	2	6	345	
Class 680 *	CD	1997-2000	10	230	.	13,5	4000	hfc	179	4	3	322	
ICE/T (ET411)	DB AG	1998-99	32	230	200	16,8	4000	f	184	4	3	351	
ICE/T (ET415)	DB AG	1998-99	11	230	200	16,8	3000	f	132	3	2	250	
S220	VR	1994-95	25	220	200	14,6	4000	h	159	4	2	262	
ALARIS	RENFE	1997-98	34	220	200	15,0	2040	c	87	2	1	161	
Talgo XXI *	RENFE	1998	1	220	.	17,0	3000	k	
Pendoluso	CP	1998-2000	10	220	160	14,6	4000	h	.	.	4	2	314
X2	SJ	1990	42	210	200	18,3	4000	f	164	1	5	394	
X2-2	SJ	1995	14	210	200	18,0	3260	f	115	1	4	214	
BM71 *	NSB	1998-99	16	210	.	16,5	2646	f	70	3	1	184	
ETR 470	Cisalpino	1996-97	9	200	200	14,5	5880	fc	237	6	3	412	
VT 605 *	DB AG	1999-2000	20	200	.	14,5	2240	k	.	.	4	0	
ICN *	SBB	1999-2000	24	200	.	15,0	5200	f	.	.	4	3	
SZ - 310 *	SZ	2000	3	200	.	15,0	2000	c	.	.	2	1	
Total		1987-2000	321										

Table 28: HSGT vehicles with tilting technology produced worldwide since 1987 (Source: UIC 2000)

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PROFESSIONAL EXPERIENCE

- 1998-2002 EPFL-LBM** (Logistics-Economy-Management): Assistant involved in the following projects:
- One-year research project at UC-Berkeley (USA, 2000-2001) financed by the Swiss National Foundation of Research. Innovation & risk management in complex engineering systems (case of the high-speed transportation industry, R&D strategies).
 - Two-years research project on the "management and investments choices in projects with strong technological rupture" (Contract for the French Ministry of Equipment, first prize for strategic research, PREDIT 2001).
 - Several projects in Management & Logistics, of which a project in transportation & logistics for the European community DGVII: collaboration with 19 European institutes, coordination of part of the project.
 - Project management & IT-solutions: Concept for a compatible platform of workflow management systems (WFMS). Strategic and managerial aspects with the collaboration of 4 research institutes in informatics and IT systems.
- Publications and conferences: Annecy 1999, The Hague 2001, STRC 2002, Maglev 2002 and Kansai 2002.
- 1996-1997 EPFL diploma thesis** (4 months), Project assessment and profitability analysis for the Swissmetro pilot track Geneva-Lyon.
- 1989-1997 Several trainings** in Engineering Offices (ERBEIA-Geneva 1989, 1Mth; TONELLO-Aix-les-Bains 1991; PERRETEN & MILLERET -Geneva 1992), and 2 Mth training at SCRASA (Bouygues Group-Geneva 1994).

EDUCATION

- 1991-1997** Swiss Federal Institute of Technology Lausanne (EPFL): civil-engineering diploma, orientation planning & management, logistics.
- 1990** Scientific Baccalauréat, Lycée Vaugelas (Chambéry, France)

PhD PROGRAM

- PhD program at EPFL (1999-2002)** in project management, R&D, innovation with the collaboration of IMD Lausanne, UC-Berkeley, IMRI Paris:
- UC-Berkeley** (USA 2000-2001), PhD & MBA courses: *Corporate Strategy & Innovation, Innovation Management, Risk Management, Finance of transportation systems* (within the framework of the PhD program).
 - EPFL-UNIL Lausanne** (1999-2000): postgraduate seminars in management (*3^{ème} cycle de Gestion d'Entreprise*).
 - MOT (EPFL-HEC)**: Management of Technology, module *Innovation Management (April 2000)*.
 - HEC-Lausanne** (2000 & 2001): PhD seminars in management (organized by the Department of Management). (1998-1999): courses in *marketing & firm strategy*.

PERSONAL REALIZATIONS

- Associations:** Organizing committee of the "Grand prix EPFL" (400 collection cars, 15000 visitors, 2MF). Press relations and sponsoring (1994-1996).
- Assistant:** Lectures in structure analysis, students in 2nd and 3rd year (EPFL, 1994-1997).
- Sports/hobbies:** Rowing (club UNIL): Vogalonga competition in Venice; skiing, windsurfing.
- Cultural trips:** Syria, Jordan, Czech-Republic, Poland, Netherlands, USA, Germany, Great Britain, Austria, Italy, Greece.
- Military service:** Reserve officer of the French Air Force, Dijon BA -102 (1997-98).