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THE INNOVATIVE CAPACITY OF THE RAIL INDUSTRY: HIGH EXPECTATIONS AND AMBITIONS VERSUS LIMITED RESOURCES AND OPPORTUNITIES

Sumet ONGKITTIKUL
PhD. Fellow
Faculty of Social Sciences
Erasmus University Rotterdam; and
TNO, Business Unit Mobility and Logistics
P.O. Box 1738
NL-3000 DR Rotterdam
The Netherlands
Fax: +31-10-408-9104
E-mail: ongkittikul@fsw.eur.nl

Harry GEERLINGS
Associate Professor
Faculty of Social Sciences
Erasmus University Rotterdam
P.O. Box 1738
NL-3000 DR Rotterdam
The Netherlands
Fax: +31-10-408-9104
E-mail: geerlings@fsw.eur.nl

Abstract: The railway sector is in most countries in a period of transition. Governments hope, by simulating regulatory reforms of the sector, to revitalisation railway in order to go through this phase. This paper aims to analyse the innovative capacity of the railway industry, and give a special emphasis to the development of rolling stock. A carefully executed innovation management process needs to take place within a number of boundary conditions. These conditions form no 'hard' stipulations to be imposed on the specific factors or on the specific capabilities of an innovation, but they are directed at supplying as much clarity as possible during the execution of the complete managerial process. The conditions are derived from the various views that exist concerning the network approach in general, but are confined, given the demands of the technology area. The article concludes that the role of the Research and Technology Development (RTD) policy can contribute to the general objectives of the railway industry.

Key Words: Railway, Rolling Stock Development, Innovative Capacity

1. INTRODUCTION

Rail transport is an important part of transport systems in European countries. The road traffic congestion is rising in Member States and, as a consequence of the externality of road transport, the air pollution, noise and other environmental effects are a major concern to the EU. Compared to road transport, rail creates less pollution as a mass passenger transportation mode and it is seen to be a more efficient transport mode in term of energy consumption.

To promote the use of rail transport is not an easy task. The modal competition is fierce. Therefore a significant change of railway sector is taking place (especially in European countries) by the restructuring of the railway industry. This restructuring process takes place in most European countries, although the process of restructuring differs variedly from the radical liberalization in the Great Britain to the gradually reform in Germany. At the same time, to make the rail transport more attractive, the technological advance would be helpful to achieve this point. In fact, the railway technology has been an issue for several decades and the solid example would be the development of the high-speed rail. However, the railway has struggled to maintain the modal share in the past two decades.

Rolling stock innovation is an essential part in operating railway. The significant development of rolling stock can be observed such as high-speed rail, lightweight material, and energy-efficient propulsion. The rolling stock supply industry concentrates in Europe and these manufacturers are at the same time the major players in this industry. As the railway markets in Europe are changing towards liberalization, the rolling stock suppliers are also in a restructuring and concentration process. To assess the opportunities for a successful implementation of rolling stock, it is essential to clarify several points.

The structure of this article is as follows. Section 2 deals with the general policy developments on the European level. Section 3 outlines the general market structure of rolling stock supplies and the global trend of the supplier industry. This can be considered as the starting point for analysis. Section 4 goes in more detail. In this paragraph the factors are identified that influence the rolling stock development. Section 5 provides policy implications and recommendations regarding the technological development in rolling stock market.

2. THE EUROPEAN POLICY STANCE

Transport is a key factor in modern economies. Plans for the future of the transport sector must take account of its economic importance. Total expenditures in Europe runs to some 1,000 billion Euros, which is more than 10% of gross domestic product. The sector employs more than ten million people. It involves infrastructure and technologies and it forms an impetus for social and economic development. The success of the transport sector creates also severe problems. Due to a disharmonious development of the common transport policy is the reason for current bottlenecks such as:

- Unequal growth in the different transport modes of transport. While this reflects the fact that some modes have adapted better to the needs of a modern economy, it is also a sign that not all external costs have been included in the price of transport, notably in road transport. Consequently, road now makes up 44% of the goods transport market compared with 41% for short sea shipping, 8% for rail and 4% for inland waterways. The predominance of road is even more marked in passenger transport, road accounting for 79% of the market, while air with 5% is about to overtake railways, which have reached a ceiling of 6%.
- Congestion on the main road and rail routes, in towns and at airports.
- Harmful effects on the environment and public health, and of course the heavy toll of road accident.

Bearing in mind the powers and complexities of the transport policy in the European Union, the EU presented in 2001 the White Paper on transport (European Commission 2001b). This document comprises a series of measures to address the negative external effects of transport. The measures vary from the introduction of pricing to the revitalization of alternative modes of transport to roads and investment in trans-European networks.

The objective of shifting the balance of transport involves not only implementing the ambitious program of transport policy measures proposed in the White Paper. Some 60 specific measures are proposed to be taken at Community level under the transport policy. It includes an action program extending until 2010, with milestones along the way (see Geerlings and Stead 2003). One of the priorities is the revitalization of the railways.

Rail transport is literally the strategic sector, on which the success of the efforts to shift the balance will depend, particularly in the case of goods. Revitalizing this sector means introducing competition between the railway companies themselves. The arrival of new railway undertakings could help to enhance competition in this sector and should be accompanied by measures to encourage company restructuring that take into account social aspects and work conditions. The priority is to open up the markets, not only for internal services, as decided in December 2000, but also for cabotage on the national markets (to avoid trains running empty) and for international passenger services. The opening-up of the markets must be accompanied by further harmonization in the field of interoperability and safety.

From 2004 onwards, the Commission will propose a package of measures, which should restore the credibility, in terms of regularity and punctuality, of this mode in the eyes of operator, particularly for freight. Step by step, a network of railway lines must be dedicated exclusively to good services so that, commercially, railway companies attach as much importance to goods as to passengers.

Rail is a mixture of ancient and modern. On the one hand there are high performance high speed rail networks serving their stations; on the other, antediluvian freight services and decrepit suburban lines at saturation point with commuters jammed intro crowded trains which are not on schedule. It is remarkable that there are significant differences in the railway technologies between the member states of the Union. Each national operator has its own, based in historical reasons, its own standards. For instance the Eurostar that connect Great Britain to the European continent has 5 different safety systems on board and is able to deal with three different energy systems.

Still new technologies and rolling stock will have to play an important role in the new policy agenda of the European Commission. For instance digital techograph will be introduced as satellite navigation systems. The enforce safety further standardization of procedures will be dealt with. The European Community has already heavily (over 1 billion Euro between 1997 and 2000) in research and technology development over the last few years in areas as varied as intermodality, cleans vehicles and telematics applications in transport. Now it is time for less concrete and more intelligence in the transport system. These efforts must be continued in the future, targeted on the objectives set in the White Paper, the European Research Area (ERA) and one of the main instruments. The new research framework program for 2002-2006 will provide an opportunity to put the principles into action and to facilitate coordination and increase efficiency in the system of transport research.

But is should also be understood that the majority of the innovations has to come from the manufacturing industry. Like the car industry, the manufacturers are the global players; they play a guiding role in R&D, but the question is that ‘are they capable to play this important role?’

3. THE PERFORMANCE OF RAILWAY INDUSTRY

There is a growing imbalance between modes of transport in the European Union. The increasing success of road and air transport is resulting in ever worsening congestion, while paradoxically, failure to exploit the full potential of rail and short sea shipping is impeding the development of rail and short-sea shipping is impeding the development of real alternatives to road haulage.

Between 1970 and 1998 the share of the goods market carries out by rail in Europe fell from 21.1% to 8.4% (down to 283 billion tonnes per kilometre to 241 billion), even though the overall volume of goods transport rose spectacular. But while rail haulage was declining in Europe, it was flourishing the USA, precisely because rail companies were managing to meet the needs of the customers (especially the industry). In the USA rail haulage accounts for 40% of total freight compared with only 8% in the European Union, showing that the decline of rail need not be inevitable. The growing awareness on the part of the operators about the poor performance recently lead to a cooperation between major stakeholders UIR (International Union of Railways), CER (Community of European railways), IUTP (International Union of Public Transport) and the UNIFE (Union of European Railway Industries). They engaged a joint definition of a common strategy to create a single European railway system in 2020, and to achieve objectives such as: increase of marker share of passenger traffic from 6% to 10% and of goods from 8% to 15%, a 50% gain of energy efficiency, a 50% reduction of emissions, etc.

The persisting situation is leading to an uneven distribution of traffic, generating increasing congestion, particularly on the main trans-European corridors and in towns and cities. To solve this problem, two priority objectives need to be attained by 2010, namely a) regulated competition between modes, and b) a link-up of modes for successful intermodality.

The European Community involvement in the sector came late, at the beginning of the 1990s, when it attempted to ‘fresh-up’ the railways performance and end the operating difficulties by geographical fragmentation and a culture of inert ion when it come to modernization. The first step was laid in 1991 with a directive requiring the separation of accounts to be kept for rail infrastructure management and railway operation. Amongst other things, this Directive opened the way for independent, transparent management and for future competition between rail companies. A second package of measures to help open up the market comes into force on 15 March 2001[1]. Opening up railway transport to regulated competition is a central precondition nowadays for revitalizing the railways. By 2008 the entire European international freight network will have been opened up completely, thanks, in particular to the determination of the European parliament[2]. The arrival of new railway companies from other backgrounds, with solid experience of logistics and international integration, must make this sector more competitive and encourage the national companies to restructure while also taking social issues and working conditions into account. This restructuring will thus need to include accompanying measures to minimize its social impact.

If more room is made for competition between operators, the rail industry as a whole will become more competitive against other modes of transport. But it is questionable what this means for the innovative capacity of the sector (see Ongkittikul and Geerlings 2004). The arrival of new operators on an opened-up market will definitely make the industry more competitive by encouraging competition between existing operators and their new competitors. But at the same time it can be expected that the innovative capacity will be under pressure due to a dispersion of number of transport providers (in the past national rail operators had traditionally strong of R&D efforts) and the need to show a good financial figure to the share holders on the short term will create complete new performance indicators. What does this mean for the innovation? It can be expected that there will come a stronger dependency of the innovations offered by the manufacturing industry.

[1] Directive 2001/12EC, 2001/13EC and 2001/14EC. OJ L 75, 15.03.01
[2] Jarzembowski report A5-0013/2201 and Swoboda report A5-0014/2001

4. PRODUCTION CAPACITY AND TREND FOR THE ROLLING STOCK MANUFACTURERS

The rolling stock suppliers play a vital role in rolling stock development. Most rolling stocks were manufactured by domestic manufacturers. However, there is a change in recent years. The non-domestic companies have entered the market in various forms. In most cases, the non-domestics companies bring their products (in terms of knowledge, patent, etc.) to cooperate with the domestic manufacturers.

This trend affects the development of rolling stock into twofold. First, the expansion of the market means reducing the unit cost of production. The more rolling stocks produced, the unit cost is likely to be lower. This factor enhances the manufacturers to develop the technologies according to the market needs. However, it is essential to identify which market is a potential one. Second, the domestic manufacturers also see these threats when they will sustain their market position by either compete or cooperate.

The reason behind the industry's restructuring is that the open market of railway in most European countries. Milz (2002) reveals that, since the introduction of procurement legislation, price of the rolling stock significantly dropped. Figures of 20-30% rolling stock's price reduction have frequently been quoted. Furthermore, operators in different countries are beginning to "mutually recognize" the specifications. This opens up increased competition. In addition, research and development (R&D) costs are high thus railway suppliers tend to team up in joint venture consortia in order to share know how and risk. In particular, the joint development between suppliers and railway operators is also found because the suppliers want both to reduce technical risk and also find a new market opportunity for new technology.

A few manufacturers dominate the world rolling stock market. For the passenger rolling stock market, the big three (Alstom, Siemens, and Bombardier) have dominated the market, accounting about 56% of the total market. Note that Bombardier purchased Adtranz (of DaimlerChrysler) in May 2001, which pushed Bombardier into the top of the league of major rolling stock suppliers. For a locomotive market, the dominant manufacturers are Chinese companies due to its domestic locomotive demand. Table 1 shows the market share of the rolling stock manufacturing.

Table 1 Market share for mechanical orders since 1990 (%)

Companies	Total passenger rolling stock	Locomotives
Alstom[1]	15	6
Siemens	12	7
Adtranz	12	11
Bombardier	17	0
Bombardier[2]	29	11
Italians	2	2
Japanese	8	0
Russians	4	1
Chinese	18	47
Others	9	27

[1] Including Fiat Ferroviaria, [2] Including Adtranz
Source: Railway Gazette, August 2001

The financial positions of the major companies are also depicted in Table 2. Although these financial figures cannot be directly compared due to the currency units and the lagged of their financial calendars, it still indicates some characteristics of these companies. In general, the biggest manufacturing, according to these figures, is Bombardier. Nevertheless, the orders that each company received are not too much differ in value.

Table 2 Financial positions of the major manufacturing companies of in 2003
(in millions/for rolling stock production)

Company	Revenues	Profit	%	Ordered
Bombardier*	$9400	$102.7	1%	$7900
Alstom**	€5072	€49	1%	€6412
Siemens***	€4697	€284	5%	€4674

* Fiscal year ended 31 January 2003, ** Fiscal year ended 31 March 2003, *** Fiscal year ended 30 September 2003

The market of an advanced technology is clearly in the big three’s hand. These advanced technology markets are high-speed rail, Electric Multiple Unit (EMU), and Diesel Multiple unit (DMU). Note that the market for locomotives mainly concentrates in China, so the market share of this market has fallen into Chinese hands. There is at present no export of Chinese made locomotives to any EU-country. The rolling stock procurement breaks down by geographical areas may be of interest here. The main market for the rolling stock is European market, which accounts nearly halve of the world rolling stock market. The North and South America and Asia-Pacific account roughly the rest of the market.

Another significant matter is the worldwide presences of the big three. For example, Bombardier has more than 50 production sites over the world, namely 37 production sites in 16 countries in Europe, 8 production sites in North America, 3 production sites in China, 2 production sites in Australia. Siemens also has a worldwide presence, though to a lesser extent, such as its main facility in Germany, 2 subsidiaries’ company in China, a service site in Australia.

It is depicted by Milz (2002) that railway (and public transport) supply industry has an indication of concentration and globalisation. As discussed earlier in the previous section, the driving factor of these concentration and globalisation is the liberalization of the railway market. To describe these trends, this report first explains the characteristics of rolling stock procurement in recent years. Then the globalisation of the manufacturers is examined.

There are a number of factors that influence the rolling stock procurement, including technical, organizational, and political factors. Firstly, the rolling stock is highly customized as national or private rail operators continue to have specific requirements and infrastructure constraints. The different technical systems in each country; such as different railway gauges, power supplies, or automatic train control systems, lead to the different requirements in each case. Although the standardization of railway systems would lead to decrease in cost of rolling stock production and also, in case of international operators, the cost of extra equipments that allow train sets to operate in different systems, the cost of infrastructure standardization is much higher and also takes considerable time to adopt such a standard. Notwithstanding, the case of ERTMS (European Rail Traffic Management System) is a good example of the implementation of a standard that would lead to lower the cost and interoperability; however, the final outcome is unclear at this moment. EU regulation played a dominant role in setting this standard (demand pull).

Secondly, government support and local manufacturing presence (localized) railway operators have been characterized by their need for local, state/regional and central government funding in order to maintain their financial performance. As a result, rolling stock orders can depend on the level of government support to railways, and order selection may favour suppliers with local manufacturing bases, thus creating and/or sustaining local employment.

Thirdly, the reforms of the railway sector in recent years have also affected the rolling stock procurement. In many countries, deregulation of the industry and privatisation of rail have changed expectations and introduced new customers faced with the competitive pressures of private industry. These new rail enterprises include private operators, leasing companies and private sector infrastructure owners. While presenting major opportunities for development for suppliers, the changing nature of the customer base can also generate new performance expectations from the contractual relationship. However, customers (train operators in this case) in competitive markets tend to concentrate on their core business and increasingly outsource maintenance and service.

In addition, one characteristic of the railway system is that there is a strong relationship between infrastructure and rolling stock. To make it clearer, the interfaces between infrastructure and rolling stock are the important issue for both train operators (who manage the rolling stock) and infrastructure managers. Thus, the decision of new rolling stock procurement has to be closely consulted with the infrastructure manager in the issue of both technical and administrative matters.

As mentioned earlier, the rolling stock is progressing towards the concentration and globalisation. The concentration is indicated by the merger and acquisition of the manufacturers in various countries. Furthermore, the pattern of procurement is also changing. In the past, the procurement of rolling stock usually came from the consortia that consist of the lead supplier (usually called system integrator) and the suppliers that provided the mechanical or electrical parts of the rolling stock. However, the need for such consortia has diminished, due to the on-going consolidation and integration process in the rail technology industry and the introduction of (branded) platform products. As a consequence, suppliers of electrical propulsion have become component suppliers for a platform product or product family rather than partners in consortia (European Commission 2001a).

The EU Commission (European Commission 1995) categorized the market for railway transport technology into the following five product groups: mainline trains, regional trains, local trains, wayside systems and miscellaneous. These product groups were subdivided into inter alia, electrical and diesel locomotives, electrical and diesel multiple units (EMUs and DMUs, respectively), passenger coaches and freight wagons, trams and underground trains, components, spare parts and maintenance. Figure 1 (on the left) shows the EU 1995 category. These subdivisions constitute the relevant product markets. The Commission (European Commission 2001a) then adds some additional subdivisions as follows: high speed trains; EMUs and DMUs for intercity transport; EMUs and DMUs for regional transport; passenger coaches; trams and light rail vehicles; underground vehicles; airport people movers; heavy maintenance services; light maintenance services; and refurbishment of rail vehicles. Figure 1 (on the right) shows the EU 2001 category.

EU 1995 Category			
Level I	**Level II**	**Level III**	**Level IV**
Rail technology as a whole	Rolling stock	Main line trains	Electrical & diesel locomotives
			Trainsets for mainline transportation
			Passenger coaches and freight wagons
		Regional trains	Electrical multiple units (EMUs)
			Diesel multiple units (DMUs)
		Local trains and systems	Trams
			Underground-railway
			Automatic-guided transportation
	Stationary equipment	Wayside systems	Catenary systems
			Traction power supply
			Train control and protection systems
		Miscellaneous	Maintenance and refurbishment of track vehicles
			Passenger information systems and ticketing

EU 2001 Category
High speed trains
EMUs and DMUs for intercity transport
EMUs and DMUs for regional transport
Passenger coaches
Trams and light rail vehicles
Underground vehicles
Airport people movers
Heavy maintenance services
Light maintenance services
Refurbishment of rail vehicles

Figure 1 Categories of railway’s product markets

These categories imply the rapid change of the railway manufacturing industry. The 1995 category is still applicable, although the EU commission makes an adjustment in the 2001 category that can be applied in the 2001 case. The main reason of this difference is that the category made by EU commission in 1995 is for the ABB/Daimler-Benz merger case and 2001 category is for Bombardier/Adtranz merger case. These cases are clearly different both in the range of products that merger company provide and in the geographical areas that the merger company cover. Nevertheless, the evidence that the structure of railway manufacturing industry is evolving remains substantial. It can be seen that in 1995 the railway product markets are fragmented and producers were presented in various position in various product ranges. But later in 2001, the markets have been consolidated in the direction that producers are forming as a system integrator, and outsourcing railway’s components to subsystem suppliers (see Figure 2 below).

Milz (2002) depicts this interesting development of the rolling stock industry. Figure 3 shows rolling stock supply’s industry activities. He reveals that there is a reduction on the number of market actors regarding the system integrators, which the big three are the dominant players. Further, there is an increased competitive pressure from Asian and American players in the component market.

The driving force of this concentration is that the competition between manufacturers and the pressure from the railway deregulated market, which required a reduction in the rolling stock investment. Milz (2002) reveals that, since the Public Procurement Directive and the opening of the Rail and Public Transport Markets, the prices of new rolling stock decreased by more than 40%. This has led companies to restructure, merge or exit the market.

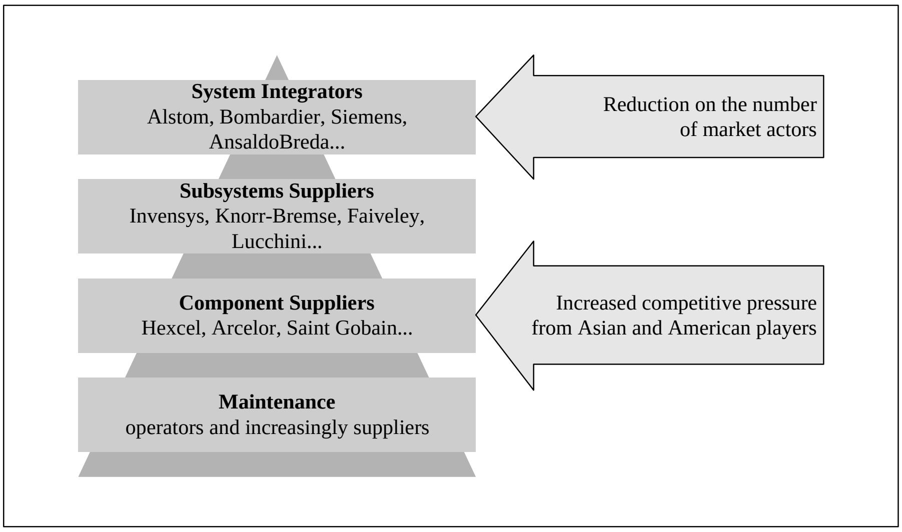

Figure 2 Rolling stock supply's industry activities (Milz, 2002)

The globalisation of the manufacturers exists in various forms, such as establish the overseas production site, take over the domestic manufacturer, or joint venture in bidding the rolling stock supply. Many mergers and acquisitions have been found in Europe and North America. However, the rolling stock production still localize, either produces by local manufacturers or multinational manufacturing firms with the joint venture with local firm. Furthermore, in the less-developed railway manufacturing industries than those in European countries and Japan, orders placed with European and Japanese companies often include requirements for technology transfer. For example, an order of TGVs from Alstom by South Korea stipulated involvement of local firms.

With respect to rolling stock production, the suppliers also adopt modularisation and/or standardization of products to reduce their costs. This is due to the fact that the European effort towards the harmonization in European railway systems. As discussed earlier that the railway systems in European countries are different, the supplier may decide on a modular design that may cope roughly 80% of the universal product, and with 20% room for customized design.

The modularisation is similar to the term 'platform-based products' that is used by the EU Commission. The Commission (European Commission 2001a) also observes this trend towards the platform-based products. In the past the development and manufacture of rail technology products took place in close collaboration between suppliers and customers (which are railway national companies), with customers having a strong and direct influence on the products to be manufactured and the selection of the firms producing them, which may call "tailor-made product". The trend is now for rolling stock suppliers to offer their own set products, which are referred to as "platform-based products", from which customers can choose. The purpose of this is to serve all customers from a limited number of platforms rather than to design and produce completely new vehicles for each project. Even where national or customer-specific technical requirements differ, a platform-based approach allows manufacturers to obtain economies of scale and scope for those parts of the train that do not require customisation. We expect that the degree of customisation will be reduced from 100% to around 20%. This process is already going on from the 1960's, when every 'customer' order rolling stock and equipment after its own unique specifications.

European Commission (2001a) summaries the development of the platform-based products as follows. Siemens was the first supplier to introduce a platform-based LRV product, in Potsdam in 1996. At that time, the existence of platform-based products exerted significant price pressure on competitors and resulted in overall price decreases. At present, all major European manufacturers have developed their own platform-based product lines. Alston, for instance, is promoting its Citadis (trams), Metropolis (underground trains), X'Trapolis and Coradia (regional trains) platforms. ADtranz (which now Bombardier) has begun to offer its Incentro (trams), Movia (underground trains), Itino (regional trains), and Crusaris (intercity trains) platforms. AnsaldoBreda has developed a platform in the tram sector called Sirio. Siemens' product portfolio includes the Combino (trams), MOMO (underground trains) and Desiro (regional trains) platforms. Bombardier's Cityrunner (trams) and Talent (regional trains) product lines are also platform-based.

5. THE TECHNOLOGICAL POTENTIONS IN THE RAILINDUSTRY

5.1 The Technology Card: An Analysis

It is obvious that in the rapidly changing environment a strategic approach toward innovation is needed. The starting point for that strategic approach is an appreciation of what technology can, and cannot, achieve. This differs substantially from one kind of technology to another. The prospects of purely technological advance also vary substantially by type of technology. In the following summary some magnitudes of potential savings are suggested (European Commission 1991; European Commission 2001b).

Engine design improvements in internal combustion engines may reduce CO2 emissions by anything up to 30% and efficient catalysation the NOx, CO and unburnt hydrocarbons by up to 90%, though there is usually some trade-off between savings in the former and latter categories. Diesel cars have a 10% overall fuel consumption advantage over petrol vehicles, but are less easily susceptible to treatment for the suppression of NOx. Although industry is sceptical about the use of ceramics in engines, this is one of the areas of further research, which might be facilitated by the establishment of a research centre for heat exchanger design and development. Improved transmission technologies appear capable of reducing greenhouse gas emissions by up to 20% without any penalty in other environmental dimensions.

Vehicle design improvements can reasonably be expected to reduce mass by about 25%, with a 12% fuel saving, rolling resistance by 30% with a fuel saving of 10% and drag coefficient by 0.05, with a fuel saving of 7%, all without cost and within the general dimensions of the current car. It should be noted, of course, that these savings are not additive. Very much more could be achieved by the downsizing of cars, or downgrading of performance without size reduction, but only if the smaller vehicles replaced larger vehicles rather than being owned as second cars for urban driving. In the latter circumstances the combination of the environmental costs associated with the extra vehicle production and the extra driving generated by the increased vehicle stock would almost certainly make things worse.

Fuel technology developments to reduce environmental effects are already technologically available, though only a few are on the market. Gasoline currently has a "cold start problem" with respect to the exhausted emissions until they have reached a certain operation temperature, though this may be overcome by recently developed preheated cats. Gaseous fuels such as CNG, LPG and hydrogen do not have this problem to the same extent. But the benefits remain relatively modest (or in some cases non-existent) for such conventional alternatives as CNG, LPG, reformulated gasoline and diesel. There is also increased fuel consumption on cold starting, due to higher engine friction, which also applies to gaseous fuels. More radical alternatives, such as vehicle power from hydrogen, or ethanol derived from biomass, are longer term and more speculative possibilities.

The benefit derivable from hydrogen produced by electrolysis of water, or electric propulsion, depends crucially on the achievement of a breakthrough in the creation of electric energy from renewable sources, in order to overcome the penalty of the high levels of fossil fuel energy consumption required in the production of the fuel. Hydrogen from renewable electricity sources is likely to be very expensive - perhaps 30 euro/GJ compared with about 10 euro/GJ if produced from biomass. Indeed biomass might be better employed to produce heat and electricity in combustion, rather than in conversion into alcohol fuels. Any net benefit from biomass, however, clearly must depend on the energy required to produce the biomass, and the environmental effect of biomass production and consumption needs also to be taken into account.

Developments in vehicle/infrastructure interface which should increase the efficiency of movement, particularly in urban areas. In air traffic management improvements in the process of development could substantially increase capacity and improve flow, with, ceteris paribus, environmental benefits. Developments in information technology have the potential to improve efficiency of operation of most modes and to replace the movement of people by less environmentally damaging movement of information. Exploitation of that potential, however, is beset by great behavioural problems. Technologies, which simultaneously reduce unit environmental impact and reduce operating cost or improve operating performance capability may be exploited by users to increase total traffic volume or performance (e.g. greater speed heavier and more sophisticated vehicles) to such an extent that the net environmental effect is negative. The problem is thus not just, or even primarily, that of developing new technologies, but more a matter of securing the effective implementation, within an appropriate policy framework, of those technologies that are, or will soon become, available.

In manufacturing technology and infrastructure technologies there were some material substitutions, which were clearly of potential environmental benefit on which further work is required. The replacement of CFC's is the most obvious case, though the replacement of iron and steel by lighter materials could have impacts of significance in several areas. Also, manufacturing processes based on whole life effects, and particularly geared to disposal and recycling needs, appeared to be important.

5.2 Toward R&D Strategy

The strategic problem is thus how to both get the best out of available and prospective technology and at the same time exercise the level of control on the demand for and supply of transport activities necessary to achieve environmental objectives in areas where no technological solution is available. In attempting to do this the sector should develop a policy stance that is robust against changes in economic circumstances, against the pace of technological change and against the valuations attached to specific societal problems. This requires the strategy to be comprehensive, flexible, culturally robust, institutionally appropriate, and sector appropriate.

Flexibility Historic evidence has shown that societal valuations of the elements of environmental impact are still relatively volatile. For example, two decades ago the emphasis in urban transport planning was largely on noise, a decade ago it was local air pollution, whilst now much more weight is being given to global pollution at the one extreme and the more intangible urban quality of life effects at the other. The strategy adopted must be capable of adjustment to reflect changes in social valuation. Particular attention should be paid to identifying technological policies that do not to any large extent involve sacrifices in one environmental dimension in order to yield benefits in another.

Cultural robustness It is also clearly the case that, even in a static sense, social valuations of aspects of environment vary across the community as a consequence of different national histories and characteristics. A community policy on transport and the environment will not be capable of commanding political support unless it is able to accommodate a range of rather different national and local concerns.

Amongst the most testing problems are:
- technologies that are desirable in some social settings are not desirable in others
- if values change over time the appropriate technological states also change
- the establishment at a community level of agreed bases for action becomes more difficult.

Such difficulties should not be overstated. It has been possible to agree progressive tightening of standards on vehicle emissions at the Community level despite differences of sensitivity and standards between member states. Nevertheless we should seek strategies that are robust against major differences in social valuations.

Institutional appropriateness A further consideration is that infrastructure company should have a role in supporting RTD only where there are good reasons for so doing, in accordance with the principle of railway operator's interests. This principle is of particular importance where there are extensive international interactions, and in the absence of a common policy inefficient "beggar my neighbour" policies are likely to appear attractive to individual countries.

Sector appropriateness. By the same token it might be argued that developments which are capable of being fully funded by the private sector should not be included in the infrastructure company's programme, nor should any developments that are not aimed at achieving the environmental objectives of the RTD strategy. The paradigm would suggest that activities and responsibilities should be left to business interests if they can be effectively performed there. The national state, or the community, should only intervene where it is clear that private business actions will not be welfare optimal for the community as a whole.

There is no recipe for a successful innovation and implementation. From the literature we know that marketing or coincidence (the right idea on the right moment) can be important factors. This can be illustrated for instance by the introduction of the QWERTY keyboard or the introduction of the VHS (in contrast to the Betamax and V2000 video systems). There are also several examples about innovation in transport sector. The bullet train (Shinkansen) can be considered as a successful innovation. The factors that contribute to this success are, among others, the availability of technologies and financial planning (Shima 1994). However, we have to state that an inclusive conclusion cannot be drawn. This statement can also be applied in failure innovation cases such as 'Concorde' (Feldman 1985) and 'ARAMIS' (Latour 1996) projects.

Nevertheless some lessons can be learned from past performances. Successful innovation and implementation depends to a large extent on a series of success factors, which have to be considered beforehand. These factors are: costs, technology characteristics, organisation factors, psychological factors, institutional characteristics, and supply industry. These factors have to be dealt with great care. And sometimes the processes are quite complex. As an illustration there is a direct trade-off with economic policy. There are various aspects of the current policies, like the EU policy on the completion of the single market, which will affect the transport sector. In particular liberalisation in the freight sector may accentuate the trends towards more frequent and smaller consignments, and hence shift traffic towards the road and air transport modes. But it will likely have adverse consequences for the environment. The priority that some governments wish to give to the freight sector, and the exemption which they wish to give it from any form of restraint, only exacerbates the problem.

6. IMPLICATIONS FOR RTD POLICY MAKING IN RAIL TRANSPORT

6.1 A Dynamic Environment

We observe that the rail sector is rapidly changing from a policy perspective, an operator's perspective and a manufacturing perspective. All actors have to perform in a changing environment under changing regimes. It is questionable to what extent the classical approach for that strategic approach is still appreciation to consider what can be considered a possible Technology development takes place in different stages. Technological advance may be viewed as the culmination of a number of processes, namely:

- fundamental scientific research
- proving technological feasibility
- product development and demonstration
- product diffusion

The basis is fundamental scientific understanding, advances in which are likely to be necessary in order to find real step changes in technological performance. In the past the most prominent role in fundamental research was taken by the national railway companies. It can be expected that under the new regime of privatisation an liberalisation the short term the financial performance gets more priority.

Where an advance in scientific knowledge has been made, that new knowledge needs to be proven technically feasible in engineering terms. Once this has been done there is a potential technology for incorporation in a new product. Product development consists of the adoption of one or more of these technological developments in a marketable product. That product has then to secure consumer acceptance and ultimately superior products have to be diffused through the market. Firms are very much oriented on market developments end therefore a demand-pull can be in particular circumstances as relevant. We see that Big Three in manufacturing capacity are under strong financial pressure. For some firms are even involved in a battle to prove their continuality. In this narrowing environment it can be expected that the firms take a risk avoiding attitude and that firms will only concentrate on product diffusion in spite of development and demonstration.

This process will even be strengthened under the observation that the RTD is very widely dispersed. Within the industrial sector it is undertaken by vehicle and vehicle component manufacturers, fuel manufacturers, transport operators, etc. For all it is clear that their main interests are primarily related to commercialisation and that the kind of work in which they engage will be responsive to commercial opportunities for exploitation, but also to regulatory constraints or fiscal inducements directed towards them. In some countries, some of these activities are undertaken by government owned or controlled companies, with differing degrees of attenuation of purely commercial motivation.

For the commercial organisation, particularly in highly competitive markets such as rolling stock providers, survival depends primarily on the ability to maintain economic cost effectiveness in production and to improve product quality and attractiveness from the consumers' point of view. The strategic motives are important in ensuring the long-term survival. Safety and environmental motivations may sometimes be coincident with the commercial objectives of the firm insofar as either the consumer values such characteristics or the public authorities enforce them as a condition of operation.

6.2 In Conclusion

The European rail sector is rapidly changing at the moment. Due to stringent policies initiated by the European Commission to improve the performance of the European rail sector, over the last decade there is process initiated that will lead toward liberalisation, privatisation. Furthermore it is expected by the government that technological development can contribute as well to a better performance. The potentials for of new innovations are indeed sincere, especially in the area of rolling stock and related domains as energy supply and new materials.

But are these expectations realistic? It can also be observed that the innovations in rail technologies are accompanied by high risks, in terms of time path and finances. The government is not taking any active role anymore, due to their position of stimulating the privatisation and relocation of responsibilities in the rail sector. Furthermore, it is not expected that new breakthroughs would change the system radically, such as High Speed Train or Maglev. The costs for implementing such innovations are very high, especially for upgrading infrastructure, and operators are confronted with financial constraint due to the increased competition. At the same time we observe that the rolling stock producers show for many years now a poor financial performance: the risks involved in R&D cannot be borne by the producers (as they make hardly any profits). Overall there is the thread for a clear risk evading attitudes by all actors involved in the operation of rail transport. This brings us to the conclusion that the situation is not very challenging. All stakeholders will restrict the level of innovations. Because however there are high expectations, ambitions and potentials for innovation in the rail sector, there is a strong pressure due to limited resources and a risk-evading attitude. The challenge is to mobilise the innovative capacity of the rail industry.

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