THE ROLE OF INNOVATION IN THE PUBLIC TRANSPORT SECTOR: AN ANALYSIS FROM A EUROPEAN PERSPECTIVE

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Abstract:

European transport policy aims to increase the market share of public transport. A major element in this policy is the need for a better product. In several countries, supported and stimulated by the EU, legislation and regulation for public transport companies is changing. By deregulation and/or privatisation new possibilities are created to develop better services. Technological and organisational innovation plays an important role at this stage. This means there are high expectations of the innovative capabilities of companies to anticipate on the new requirements. The question is whether this also applies to public transport companies. The paper distinguishes seven trends of technological innovation in public transport which then classified into three categories namely cost efficiency, higher quality of service, and better environmental performance. Furthermore, the paper identifies three paths form empirical evidences in public transport namely cost-driven, quality-driven path, and environmental driven paths. Suggestions are also made regarding the technology policy for public transport industry.

Keywords: European policy; Public transport; Technological innovation
Topic Area: H5 Innovation in Transport Policy

1. Introduction

Transport is important for economic development and other social dimensions. Technology also brings transport into the unique position. The development of transport systems over time proofs to be a significant driving force, ranging from railway, road and air transports.

Technology plays an important part in the development of transport system. In fact, technology affects transport in two contrasting sides. On the one hand, technology brings about the higher quality at the lower cost (of individual). As a result, the demand of transport is increasing rapidly resulting in the social loss due to transport's externalities where individual did not bare those costs. On the other hand, technology is also considerably improving overtime as a part of solution in reducing these external effects. For example, the improvement of propulsion system have been developed in the past decade to improve environmental performance, i.e. reduction in CO_2.

This paper aims to connect the role of technological innovation in public transport with the policy in transport in general. It appeared that there is a considerable gap between the way policy maker view technology and the way it has actually been used in the reality.

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The organisation of the paper is as follows. Section 2 reviews the development of transport sector from a historic perspective. Section 3 discusses European transport policy regarding the contribution of technology. Section 4 presents the future trends of technological innovation in public transport sector based on the opinion of practitioners in the industry. Section 5 identifies innovation paths that public transport policies have been followed in recent years. Finally, section 6 gives conclusion and policy recommendation.

2. The development of the transport sector: a contextual framework

Transport is a fascinating phenomenon in society of all times. Since the ancient times fast and efficient transport is connected with connotations as economic prosperity, social desire and welfare, with a lot of positive (side)-effects. In the early days animal power played a dominant role in travelling; camels, mules, and horses were frequently used until nineteen's century. But in modern times the combustion engine took over and we became almost 100% dependent on fossil fuels. What remains are the symbols such as the measuring of the power of engines in terms of 'horsepower', but the transport sector is today a sector with a strong innovative capacity (Ongkittikul 2003).

Were there in ancient times limitations in the human capabilities to travel, from around 1600, the great discoveries made it possible to enter a 'new world'. New patterns of economic activities were created; contacts (economic, political, etcetera) were made to places all over the world and the city centres became centres of economic activities with a huge transport demand. And as if there were no limits, many books and articles were published in these days that speculated on the almost unlimited potentials of transport. Some of the authors, like Jules Verne, frankly acknowledged that they hardly used any serious method in their writing when they had their adventures of travelling to the moon. We know nowadays that the idée fix of Jules Verne became a reality.

The evolution of transportation has always been closely connected to technological development. New transport technologies have been vital for economic development. In fact, they have been so influential that economic historians have termed whole periods of economic development after various transport infrastructures, e.g. the `age of canals' in the first half of the 19th century, or the `railway and coal era', the expansion of which ended with the Great Depression in the 1930s. The oil and automobile alliance was the symbol of `the age of automobile'. The car is one of the main contributing factors to a period of expansion unprecedented in the economic history of mankind. For this reason the process of innovation and diffusion of technological developments traditionally enjoys a great deal of attention in the transport sector. In some cases, like the steam engine or the telegraph, technological revolutions became usefully applied in the transport sector for the first time (Geerlings 1999).

But understanding the developments in the transport sector can't be explained by a 'techno centric' analysis. Of course there is a direct relation between the technological development and the transport performance. But this development goes hand-in-hand wit a changes in society. A complex equation has to be solved in order to curb the demand for transport. Transport is in most cases a derived effect to fulfil certain needs. Economic growth will almost automatically generate greater needs for mobility. Looking back we observe that passenger transport growth in Europe with 2.8 % per year and freight transport by 2.4 % per year (Korver & Harrell 1999). The success of transport refers to the changes in society, the need for transport and the opportunities offered by technology.

Some countervailing developments

Based on research and policy documents (EU 2001) we observe that there are also side effects related to the success of transport technologies. For instance technology development contributed to an *unequal growth* between the different transport modes of transport. In more detail we see that with respect to the unbalanced growth the fastest growing modes of transport are air transport and road transport. Air transport shows an average growth figure of more than 10%. Especially the cheap carriers contribute to an impressive growth. But even nowadays we observe that in total of 16 of the Union's main airports recorded delays of more than a quarter on more than 30% of their flights. Altogether, these delays result in consumption of an extra 1.9 billion litres of fuel, which is some 6% of the annual consumption. Car ownership increased in Europe to the average of 488 cars per 1000 inhabitants (EU 2003). Around 10 % of Europe's surface is used for road infrastructure.

This observations leads us to a second concern. We observe increasing *congestion* on the main roads and rail routes, in towns and at airports. In Europe some 7.500 km, i.e. 10% of the road network, is affected daily by traffic jams. And 16.000 km of railways, 20% of the network, are classed as bottlenecks. The cost attributed to congestion is estimated on EUR 80 billion a year, which is approximately 1% of community GDP. During the 1990's Europe began to suffer from congestion in certain areas and certain routes. The problem is beginning to threaten economic competitiveness. The European Commission observed already in 1993 the need to fight congestion.

And although transport is considered as an essential for the well being of society and of each individual, increasingly it is coming to be perceived as a potential danger. The end of the 20th century was marred by a series of dramatic rail accidents, the Concorde disaster and the wreck of the Erika, all of which are etched into the memory. However, the degree of acceptance of this *lack of safety* is not always logical. In 200 road accidents killed over 41.000 people in Europe an injured more than 1.7 million. The age group most affected is the 14-25 years old, from whom road accidents are the prime cause of death. The directly measurable costs of road accidents id in the order of EUR 45 billion. The indirect costs (including physical and psychological damage suffered by the victims and their families) are three to four times higher. The annual figure is put at EUR 160 billion, equivalent to 2% of the EU's GNP.

Also from the *emission side* it is remarkable that speed is not considered as the strong point for policy making. Table 1 below illustrates how beneficial it can be to reduce speed to 90 km/hour. The figure is based on emission standards that are not applied anymore, but it illustrates the relevance of looking to speed as the starting point of environmental policy making.

Table 1 Comparison the emission standards over time

In gr/km	*By 90 km/hour*			*By 120 km/hour*		
	CO	*HC*	*Nox*	*CO*	*HC*	*Nox*
1 1983 standards	4,7	0,8	3,1	9,2	0,9	4,9
2 Lux –'85 1,4 – 2,0 ltr	1,4	0,2	1,3	3,5	0,1	1,7
3 Lux-85 > 2,0 ltr	0,1	0,1	0,1	0,3	0,1	0,5

As stated in the European Commission's White paper on security and supply (2000), in 1998 energy consumption of in the transport sector was responsible for 28% of emissions of CO_2, the

leading greenhouse gas. According to the latest estimates, if nothing is done to reverse the traffic growth trend, CO_2 emissions from transport can be expected to increase by 50% to reach 1.113 billion tons in 2010, compared with the 739 million tons recorded in 1990. Once again, road transport is the main culprit since it alone accounts for 84% of the CO_2 emissions attributable to transport.

This brings us to a striking observation. Technology has a double meaning in transportation. On the one hand technology is the origin of many serious problems created by transportation. But at the same time technology might be part of the solution to fight these negative external effects. We will explain this role and illustrate this with an analysis of some cases in public transportation.

3. Determinant factors of European transport policy and research

In Europe transport policy is traditionally considered as an important policy domain. The 1957 Treaty of Rome, which marked the foundation of the European Economic Community (EEC) stated that the aims of the EEU would be "*to take care of the continuous improvement of the living and working conditions of its population*" and that at the same time the EEC would strive for "*harmonious development of her economies*". This might suggest and balanced approach but in practice the emphasis in policy making was mainly on economic development and attention for non-economic issues was of a second order. Looking back, policies were based on a sectoral approach in which transport was strongly valued as a driving force for economic prosperity. At the same time the importance of European environmental and spatial policy was low.

In 1972, it was agreed by the Community Heads of State at the Paris Summit that economic expansion should be accompanied by an improvement of the 'quality of life'. And it was therefore agreed that more attention should be paid to environmental issues. This then led to the first *Environmental Action Programme* in 1973 (Commission of the European Communities 1973), which can be considered as the first step towards an European environmental policy.

An important change took place in 1986 with the amendment of the *Single European Act*. In that same year the European Union gained three new member states (Great Britain, Greece and Denmark) and a decision about the creation of a single European market was made. The name of the European Economic Community would change to European Community to stress the balanced approach of policy issues. There was also the increasing awareness that creating a single market would generate new requirements for policy making, such as stronger coordination rather than further specialisation. It was also clear that the unification would lead to a single marked with economic advantages, but, as a consequence, other policies like the spatial policy, needed attention. As a result, environmental policies and land-use planning were also recognised as important domains since 1986.

For a long time, the European Community was unable to implement the common transport policy provided for by the Treaty of Rome. For nearly 30 years the Council of Ministers was unable to translate the Commission's proposals into action. It was only in 1985, when the Court of Justice ruled that the Council had failed to act, that the Member Stated had to accept that the Community could legislate. Later on, the Treaty of Maastricht reinforced the political, institutional and budgetary foundations for transport policy. For instance, the voting system in the Council was replaced from unanimous by a qualified majority.

The position of public transport: the role of technological innovation in transport policy making

In terms of *transport policy* documents, the European transport White Paper of 2001 (Commission of the European Communities 2001) explicitly recognises that the success of transport created significant negative side effects. New policy incentives were announced aiming at the realisation of a balanced approach: Sustainable Mobility became a central notion in Community policy-making. The white paper highlights that this concept can only be realised when it comes to an integration of environmental considerations into transport policy (and other Community policies), although how integration can be achieved in practice, however, remains unclear in the document.

The document also recognises that transport policy alone is not sufficient to tackle current transport problems and advocates new policy structures and co-operation. Special attention is also given to the role of the public transport in improving the quality-of-life in urban areas. The White paper proposes some 60 specific measures to be taken at Community level under the transport policy. It includes an action programme extending until 2010 with clear milestones. Detailed proposals will be based on a number of guidelines. With respect to the performance of the public transport the following guidelines are quite interesting:

- Revitalisation of the railways
- Striking a balance between growth in air transport and environment
- Turning inter-modality into reality
- Improving road safety
- Adopting a policy on effective charging for transport
- Recognising the rights and obligations of users
- Developing high quality urban transport
- Putting research and technology at the service of clean efficient transport

Especially the last two issues are of special interest to this paper, so we will elaborate on this issues.

In response to the general deterioration in the quality-of-life of European citizens suffering from growing congestion in towns and cities, the Commission proposes to place the emphasis on exchanges of good practice aiming at making better use of public transport and existing infrastructure. A better approach is needed from local public authorities to reconcile modernisation of the public service and rational use of the car. These measures, which are essential to achieving sustainable development, will certainly be among the most difficult to put into practice. This is the price that will have to be paid to meet the international commitments made at Kyoto to reduce CO_2.

But the Commission is quite aware that technology can play an important role to diminish the negative impacts of transport and improve the performance. Therefore the Community has already invested heavily (over EUR 1 billion between 1997 and 2000) in research and technological development over the last few years in areas as varies as intermodality, clean vehicles and telematics applications in transport. The CIVITAS-project and the demonstration projects for instance on the introduction of hydrogen fuelled busses are a good example of actual projects. According to the white paper the scope will change to more intelligence in transport. These efforts must be continued in the future, targeted on the objectives set I the white paper. The European Research Area and one of its main instruments: the research framework programme for 2002-2006 (FP6), will provide an opportunity to put these principles into action and to facilitate

coordination and increased efficiency in the system of transport research (Commission of the European Communities 2002).

Specific action will take place in FP6 on cleaner, safer roads, on integrating intelligent systems in all modes to make for efficient infrastructure management. In this respect the eEurope action plan proposes a number of measures to be undertaken by the Member States and the Commission, such as the deployment of innovative information and monitoring services on the trans-European network and in towns and cities and the introduction of active safety systems in vehicles such as buses and metros.

4. Innovation in public transport: an ex post

The story that has been told so far is that technology is perceived in policies and programs as an important element of a well functioning transport system including public transport. And we observe that, especially on the European level, many initiatives are going on in which public transport plays a prominent role. But to develop transport policy aimed at stimulating the wished innovation it is important to know in more detail what the major trends will be and which technologies will be critical.

Based on a range of interviews we derived a number of trends which by people from the industry itself are seen as **the** trends within the public transport for the coming ten years (Korver et al. 1996). In total we distinguish seven trends.

A. New systems by combining existing systems

Within the collective passenger transport a lot of sub-systems can be distinguished. By combining existing technologies new systems are created. For example 'Light Rail' is a transport concept which should be placed between a street car and a subway system at the one side and a regional train at the other side. Another option is the mixing of street cars and busses. Examples are guided busses (see also http://www.phileas.nl) the TRV in Caen (a streetcar like system, but instead of using an iron rail, it is a vehicle on tyres which uses its own infrastructure). All these developments are steered by the wish to decrease the costs of urban public transport. For example the TRV in Caen claims to realise a cost saving of about 20% to 30% in comparison with an “old fashioned” street car.

B. Integration of existing transport systems towards one collective transport system (seamless transport)

As a follow up of the previous trend there is a movement towards the integration of all sub-systems to one collective system. The future image is that collective transport will be supplied from door to door in stead of from stop to stop. This will be less based on hardware integration but much more on software integration. Examples are one ticketing system and one travel information system. This implies a new structure of the public transport sector. The customer will be confronted with one sales organisation, but the real transport services can be supplied by a lot of different firms.

C. Automation of existing transport systems

As can be seen in the car system as well there is a trend towards automation of the driver task. A good example is the subway in Paris (Meteor). The major driving force is trying to offer the same quality against lower costs. Another aspect is that by automation the control function can be improved.

D. New automated systems

Especially for short distance trips a large range of new transport systems were presented the last years, the so –called people movers. In the Netherlands a number of experiments were made with automated people movers. Similar systems are under development in other

countries. But also new initiatives can be found to stimulate and develop a magnetic levitated train (Maglev).

Figure 1 An example of a automated people mover.

E. Integration car and collective transport system

Whereas in older days the car and public transport were seen as competitors, nowadays more and more the opinion is that both systems have advantages and disadvantages. Therefore, to large extent stimulated by governments, innovations are developed which enable to use both car and public transport in one combined trip. The innovations focus on removing barriers for making an interchange, to give more and accurate travel information and ticketing systems which integrate parking and public transport fares.

F. Environmentally friendly infrastructure

The challenge for the coming years is not to build new infrastructure but to build new infrastructure without hampering the surrounding, both in the building process itself, for instance underground drill technologies, and when the infrastructure is in use, e.g. lower noise levels, no barriers for animals and humans. Especially in highly densed areas it is difficult to realise new transport infrastructure. Whereas at the same time he need for new infrastructure is the highest in urban areas. Therefore more and more new transport infrastructure is going underground. But the costs related to underground infrastructure are high.

G. Environmentally friendly urban public transport

Mainly in the urban area the environmental damage of heavy road vehicles is an increasing source of nuisance. Within public transport the bus with diesel engine creates a lot of environmental damage. For a long time car manufacturers are searching for a cost effective alternative of the diesel engine. LPG, natural gas, electric engines, hybrid electric engines are examples of alternatives. None of them have gained a large market share. Recently a number of demonstrations started with hydrogen fuel cell busses (e.g. Amsterdam, London, Barcelona).

Table 2 shows the trends together with the major technology components involved and the major driving force behind the innovation process. This driving force is classified into three

categories: cost efficiency, higher quality for the customer and a better environment. Based on this table we can say that:

a. the goals to decrease the operational costs and to realise quality improvements are the major driving forces behind the innovation process within the public transport sector. Heuristics such as environment and safety and quality of life play a less prominent role and

b. interfaces play almost in every trend a dominant role. As a consequence of the increasing capacities of ICT existing systems can be transformed towards complete new systems.

Table 2 Overview of main trends and technology development within the collective transport system.

Trend	***Relevant technology bundles***	***Main driving force (heuristic)***	***Examples of innovations***
A. New systems by combining existing systems	Design of the vehicle Control and fleet management systems Adaptation of existing infrastructure	Cost efficiency	Integration street car and rail (S-Bahn) GLT/TRV Dual mode bus
B. Integration of existing transport systems towards one collective transport system	Ticketing and information system Management systems Terminals	Quality Improvement	Chip card
C. Integration car and collective transport system	Ticketing and information system Management systems Terminals	Quality Improvement	Trip planning systems Park and ride
D. Automation of existing transport systems	Control Systems Communication infrastructure	Cost efficiency	Supporting driving task Electronic guided bus
E. New automated systems	Design of the vehicle Guiding systems Physical infrastructure	Quality Improvement	Automated People mover Mono rail Maglev
F. Environmentally friendly infrastructure	Physical infrastructure	Cost efficiency	Underground drilling Automatic maintenance inspection
G. Environmentally friendly urban public transport	Electric hybrid propulsion Alternative fuels	Quality of Life	Electric urban bus Natural gas bus Fuel cell bus

Based on the trends the major technology bundles (critical technologies) are distinguished for the collective transport sector. These critical technologies are in order of importance:

1. *Advanced (Traffic) Management Systems*
2. *Advanced Traveller Information Systems*
3. *Electronic Fare Payment System*
4. *Advanced Vehicle Control Systems*
5. *Terminals*
6. *Physical infrastructure*
7. *Advanced Communication Systems*
8. *Vehicle dynamics*
9. *New transport systems*
10. *Clean propulsion systems*

For every of these critical technologies it is recommended to define the role of the government. Possible roles are an innovator, a R&D agent and a regulator. By defining these technology bundles it is easier to distinguish the major actors.

5. Innovation paths: empirical cases

Technological innovation has contributed to the improvement of public transport in various aspects. The technologies have been developed both exclusively for public transport and generally for other sectors. The exclusive technologies include low-floor buses, tram technologies, and computer-aid technology. Clearly the information technologies play an important role in this development, which some new development has benefited from the development of mobile phone technology. Some technologies were jointly developed with other transport operation, for example, vehicle-scheduling together with freight transport planning and management.

In the previous section, we observe the experts' opinion regarding the trends within public transport. Seven trends are identified which can be seen as the foresight examination. In order to understand the development in more details, we observe the current trends in public transport. This comparison would allow us to examine the possibility of the future trends that we identified in the previous section.

In this section we can identify three innovation paths that public transport system have been developed in the past decade. These paths are considered as the main aims of the decision-makers (at various levels) to improve the performance of public transport service. These innovation paths are: cost-driven path, quality driven path, and environmental driven path. These paths are in line with the driving force that identified in previous section namely, cast efficiency, higher quality for the customer, and a better environment. We give a number of empirical examples to show the innovation paths in each category. All empirical evidence given in this paper concerns urban public transport systems.

5.1 Cost-driven path

The cost is always an important dimension for decision-maker in public transport service. In this path, several instruments have been employed to achieve the reduction in operating costs of public transport service. This cost reduction would directly benefit both operators and public authorities. Operators would prefer to run the service at the lowest operating cost whereas the public authorities want to reduce their subsidy level. Nevertheless, low operating cost may imply the price of public transport may decrease, which users may indirectly benefit from this cost-driven path.

The innovation that decision-maker has chosen to reduce the cost of operation is organisational innovation through regulatory reform process. It is clear that different regulatory regimes would give a different level of (cost) efficiencies. Although we cannot directly compare between countries that have different regulatory regimes and conclude that such a regime has more efficient than others because of several external factors and industry environment, we might say that, in some cases, the regulatory change improves an operating efficiency through the operating cost reduction.

The strong empirical evidence in this case is that the case of UK's deregulation process in 1986. Table 3 shows that after deregulation took place in 1986, the operating cost per bus-kilometre had been dramatically decreased.

Table 3 UK's average operating costs per bus-kilometre (pence) at 1993/1994 prices

Area	***1985/86***	***1993/94***	***Absolute change***	***Percentage change***
Metropolitan areas	159	85	-74	-46
Shire counties	114	72	-42	-37
Wales	109	58	-51	-47
Scotland	120	72	-48	-40
Average	129	75	-54	-42
London	231	150	-81	-35

Source: (Banister 1997)

As discussed in Bayliss (2000), a main objective of the UK bus deregulation, which also resulting in the restructuring of the British bus industry, was to halt, and reverse, the trend of increasing subsidies. Table 4 shows that the reduction of the subsidies after the deregulation process.

Table 4 Local bus service financial support by area at 1998/99 price

Area	***1985/86***	***1989/90***	***1994/95***	***1998/99***	***% 85/86 – 98/99***
London	£275m	£144m	£101m	£55m	-80
Metropolitan areas	£435m	£196m	£181m	£178m	-59
Rest of England	£240m	£200m	£192m	£224m	-7
Scotland + Wales	£101m	£68m	£75m	£83m	-18
Great Britain	£1,051m	£608m	£549m	£540m	-49

Source: Bayliss (2000)

Thus the regulatory reforms in the British bus industry have been successful in reducing the need for subsidy – almost halving it between the mid 1980s and the late 1990s (Bayliss 2000). White (1995) examines the reasons behind this cost reduction and concludes that a major factor of this change is the increased labour productivity, and other minor factors are lower wage levels, changes in fuel prices and the role of minibuses.

The use of new technologies would also be seen as a way towards the cost reduction. In public transport, Papaioannou & Reis Simones (1993) report that around 70 per cent of the surveyed public transport operators used advanced transport telematics (ATT) in scheduling process. Table 5 shows the detail of the percentage use of technological innovation in scheduling by public transport operators in Europe.

Table 5 Percentage use of scheduling technologies by public transport operators in Europe

Equipment/function	*Sample*
Timetable planning	74%
Printing timetables	74%
Vehicle scheduling	73%
Driver scheduling	65%
Driver rostering	65%

Source: Papaioannou & Reis Simones (1993)

Although we do not have an official information regarding the use of scheduling technology in UK case, we believe that this technology has also contributed to the cost reduction discussed above. The computer-aided scheduling would help the operator to facilitate their labour force more productive, especially drivers, as driver wages is the largest cost element in bus operation (45%) (Meilton 2001). For instance, Meilton (2001) reports that the use of computer-aided scheduling helps to save around 4% on payable hours at the locations where scheduling had been done without computer assistance.

5.2 Quality-driven path

Quality is also on the top of agenda in public transport development in order to compete with private automobile. There are several aspects of public transport services that can be improved. First and the most important aspect is travel time. Public transport is seen as a slower mode compare to private automobile due to its own speed and also access time. Second aspect, which have been an important issue in recent years, is reliability. Thus public sector has concentrated in these aspects to bring people back to use public transport service. Users directly benefit from this quality-driven path.

There are some evidences that show the intention of public sector to improve the quality of public transport systems. Examples given in Table 6 below are schemes that the new transport systems are introduced. Note that the cases of Leeds and Oxford are based on the quality bus partnerships (QBP) initiatives.

Table 6 Quality improvement of the new public transport systems

Scheme	*Journey time savings (%)*	*Journey time reliability improvement (%)*	*Safety benefits (%)*
Karlsruhe dual rail (Germany)	22% or 12 min	+	+/-
- S4 (KA-Bretten)	21% or 18 min	+	+/-
- S5 (Wörth-Pforzheim)			
Leeds guided bus			
- Scott Hall road	1-5 min	75%	+
- East Leeds	1.4-3.0 min	+	+
Oxford bus lanes			
- Banbury road	51 or 3.4 min%	++	+/-
- London road	47% or 3.7 min	+	+/-

Note: ++ highly positive, + distinctly positive, +/- neutral or only marginal
Source: Brand & Preston (2002)

Moreover, information technology also contributed to the improvement of the quality. Examples are the smart card seamless ticketing which introduced in Paris and London, and also to be introduced in Rotterdam.

5.3 Environmental-driven path

Environmental effects from transport is always an important issue for most urban areas. In the congested area, several types of pollution have concerned such as CO_2, NO_x, Particulate, and noise. Thus environmental aspect would be one of the most important element that can improve the quality of life in the city. In this path, the society as a whole would benefit from the less-polluted and environmental friendly transport systems. It is believed that promote public transport would help to reduce the environmental impacts from the use of private automobile.

Beside encouraging people to use public transport more, the public transport itself may improve its environmental performance. The technological innovation provide more efficient and environmental-friendly bus and other urban public transport systems. One instrument that the government level uses is that by tightening emission standards. Table 7 shows the European standards for emissions from heavy duty vehicles (including bus), indicating how these have tightened considerably over time, comparing with US 98 and Japan 2004 standards.

Table 7 Emission standards (g/kWh) for heavy-duty diesel vehicle engines

Pollutant	***Euro 1 (1993)***	***Euro 2 (1996)***	***Euro 3 (2000)***	***Euro 4 (2005)***	***Euro 5 (2008)***	***US 98 (1998)***	***Japan 2004***
CO	4.5	4.0	2.1	1.5	1.5	15.5	2.22
Hydrocarbons	1.1	1.1	0.66	0.46	0.46	1.3	0.87
NO_x	8.0	7.0	5.0	3.5	2.0	4.0	3.38
PM_{10}	0.36	0.15	0.1	0.02	0.02	0.1	0.18

Source: Stanley & Watkiss (2003)

As a result of these tightening emission standards, the technological developments play an important role in this circumstance. The main paths pursued by bus engine manufacturers and bus operators to meet this requirements are a diesel path and an alternative fuels path (Stanley & Watkiss 2003). The former involves development of lower-emission diesel engines operating on cleaner diesel fuel, and the latter uses alternative fuels such as compressed natural gas (CNG), liquefied petroleum gas (LPG), ethanol and biodiesel to deliver lower emission levels. Recently, fuel cell technology is seen to be promising but also seems to be widely agreed as the most likely **long-term** answer to emission problems from buses.

The environmental regulation enforces at the national and international levels. However some local authorities opt this environmental friendly approach to implement. Strong ambitions have put forward in some cities to use the fuel cell or alternative fuels buses. Recently, several fuel cell buses have been delivered to several cities such as Amsterdam, London and Barcelona as a part of European funded program *Clean Urban Transport for Europe* (CUTE). This shows a positive sign in practice, although each city use the fuel cell buses in a small number compare to total fleets they deployed.

6. Conclusions

Sustainable Transport has become an emerging concept since the mid 90s. It's relevance is reflected in many policy document and policy plans on the national level and even on the local

level. Also the EU plays a prominent role in this discussion as is reflected in the most recent policy plans such as the recent white paper on transport.
In the policy intentions expressed by the Commission, technology development is considered as an important tool to reach the criteria of a Sustainable Transport system, however a clear strategy on the R&D and implementation is missing, especially when it comes to the operational level.

Looking at the technological potentials , this study identifies seven bundles of technologies based on their characteristics and applicability to public transport. By studying the implementation of these technology bundles, and based on empirical evidences, we identify that there are three important driving factors considered by industry itself. These three driving forces are; 1) cost driven, 2) quality driven, and 3) environmental driven factors.

At the same time we see some paradoxes in the policy and practice in the field of technological development in public transport. In general it is stated by policy makers that the market share of public transport should be stimulated, especially in urban areas, for instance by increasing the public awareness of the positive characteristics of the system. But in practice we see that these intentions are not made reality due to the fact that government are increasingly confronted with financial constraints.

This financial pressure makes that governments tend to stimulate privatisation and deregulation in the public transport sector. With this evolving process technological innovation it is unlikely that technology will be developed in a desirable way due to the fact that public operators will come under a new regulatory regime that requires different interests. For instance, technological and organisational innovation will become increasingly an activity that is assessed against the background of a continuous need for cost reduction. This does not mean that other dimensions; namely quality of service and environmental performance, are completely neglected: a better environmental performance, or quality improvement can have a financial benefit, however this is sometimes hard to measure. But at the same time trade-offs might occur: new rolling stock requires huge investments which the industry simply cannot afford under the new regulatory framework while in the old days this was a governmental responsibility.

Therefore we think that it is needed to come to a balanced approach to technology policy in public transport. Given the prominent played by the European Commission in the past, and the ambitions expressed in the resent policy plans, we advocate the development of a clear and transparent framework for technological innovation by the EU, so a level playing field will be created, the goals will be clear and unambiguous, and the sector can profit from a government that plays a pro-active by formulating a balanced R&D agenda for the public transport sector and controls the instruments to make this policy reality.

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