Synergies between Trans-European Networks

Evaluations of potential areas for synergetic impacts

Final report

Client: European Commission - DG TREN

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Introduction

Background

Trans-European Networks (TEN) play an essential role in the implementation of the Lisbon Agenda by promoting economic growth and cohesion within Europe. TENs are defined in three different areas:

- Transport – TEN-T
- Energy – TEN-E
- Telecommunication (services) – eTEN (previously TEN-Telecom)

One of the key priorities of the European Commission is to accelerate the implementation of TENs in order to promote development in Europe. All areas have received strong political commitment.

- **Transport.** New guidelines were introduced in 2004 including the definition of 30 priority projects across Europe. In 2005 specific co-ordinators were appointed to enhance cross-border co-ordination and speed up implementation. Also the establishment of a TEN-T Agency was proposed in 2005 by the Commission.
- **Energy.** New guidelines for TEN-E were adopted in July 2006, including a list of priority projects. Co-ordinators to support the implementation of projects of European interest which face difficulties.
- **Communications.** Issue of a communication "Bridging the Broadband Gap" in March 2006, indicating the increased urgency to overcome the territorial digital divide in Europe.

A TEN steering group has been set up to facilitate a common approach and coordinate the different Community initiatives supporting the implementation of the trans-European transport, energy and communication networks. One of the aspects of the TEN Steering Group's work is to examine the creation of synergies between the different TENs.

Purpose of the study

The purpose of this study is to support the work of the TEN Steering Group on the potential synergies between TENs in the field of transport, energy and communications by:

- assessing the advantages and disadvantages of combining networks
- analysing the potential for monetary savings
- exploring other possible impacts of these combinations
- identifying potential efficiencies that may be realised in the medium term.

This exploratory study examines (combinations of) road, railway, electricity, gas and voice/data communication infrastructure.

Approach
The study has followed a two step approach.

First, the individual characteristics of different types of transport (road & rail), energy (electricity and gas networks) and communication (voice/data communication) have been analysed. These characteristics can be both institutional/organisational, regulatory/procedural or technical. On the basis of these characteristics conclusion have been drawn on combinations which are feasible. Next, different combinations have been assessed on their synergetic impacts.

The methodology followed is a combination of extensive desk research, expert consultation and case studies.

Feasibility of combinations of infrastructures

The feasibility of combining different types of infrastructures has been assessed on the basis of different characteristics of each type of infrastructure. These characteristics are grouped into the following main themes:

- Regulatory and planning issues
- Design issues
- Cross-border issues
- Construction, operation and maintenance issues

It can be concluded that although in principle all combinations between the different types of infrastructure are possible, some combinations are not advisable from a technical point of view. In general gas pipelines are judged to be less suitable to be combined with other type of infrastructure due to safety risks.

Particular combinations which are assessed to be less feasible are:

- rail and High Voltage electricity infrastructure, due to possible corrosion of rail due to electromagnetic interferences;
- (electrified) rail and gas infrastructure, as the generally proposed safety distance between both types of infrastructure is 1-2 km;
- electricity and gas infrastructure, as the temperature of electricity lines may cause plastic pipes to melt. In addition there is a risk of induction and electro-magnetic currents for steel pipes.

All other combinations of infrastructure are feasible from a technical point-of-view. Apart from a possible combination with road and rail transport infrastructure, a combination of electricity with inland waterway infrastructure is expected to form an opportunity which might be promising in specific locations/canals.

A specific potential exists by making use of infrastructure which is originally developed/planned for other (more dedicated) use. An extension of the scope of these projects, an enlarged access or an incorporation in a wider network planning is especially relevant in this respect. Clear examples can be found in creating an enlarged (public) access to previously dedicated communication networks connected to roads, rail or electricity networks and integrate them in wider communication networks. Also anticipation on new large scale penetration of e.g. off and on shore wind farms, in view of emerging related energy connection needs, seems to offer possibilities. Combining both developments can reduce costs of investment in these innovative HV line projects substantially.

In addition a number of more innovative technological solutions have been identified which might offer a potential for the future. These include:

- Combining HV lines with rail or train tracks/roads, where using railway galleries for HV cables in mountain areas seems an option to pursuit more seriously
- The use of overhead contact wires of train tracks for power transport;
- Use of new equipment and materials for HV lines such as DC based Voltage Sourced Converters, non-standard connection specifications like variable frequency AC and voltage DC, AC (with more than three phases & extra high voltage levels) and new gases for gas insulated lines for underground cables, reducing costs and time.

Although it should be realised that these options do not offer clear-cut end solutions they are clearly worthwhile to be further investigated.

Synergetic impacts

Three types of synergy

Creating synergies between networks could help to accelerate the pace of implementation of the TENs and enlarge the potential benefits. In the study three types of synergy are distinguished:

- ***Procedural synergies***, arising from the integrated planning of various infrastructure networks.
- ***Physical synergies***, lower costs and impacts due to the combined construction of sections of infrastructure networks and structural works (eg bridges, tunnels, underpasses).
- ***Financial synergies***, being the additional value or revenues that can be created and captured when sections of infrastructure networks are combined.

Procedural synergies

The advantage of procedural synergies lies mainly in time savings during the planning process. This type of synergy can be created through various mechanisms:

- Coordinated planning across modes
- Coordinated planning across borders
- Performing Strategic Environmental Assessments
- Combined land acquisition
- A combined, integrated consultation process for packages of infrastructure.

Longer term integrated strategic planning

Longer term integrated strategic planning (across modes and sectors and across borders) enables a better co-ordination between different types of infrastructure, as well as between cross-border sections of infrastructure. Better planning, for example by identifying potential hurdles in an early stage, will help to speed the planning process, which is often cited as one of the key factors causing delays. Improved planning also involves the creation of institutional mechanisms to facilitate the combination of infrastructure. A SEA is an instrument that fits in this process. It can explicitly address the issue as to whether different sets of infrastructure lend themselves to combination and if so, how a joint process should be entered.

Synergies in reduced local resistance and improved land acquisition process

Reduced resistance from local communities and reduced delays resulting from land acquisition are common procedural advantages associated with the combined construction of different types of infrastructure. Procedural synergies are most common when combinations are made between road, rail and electricity infrastructure. These types of infrastructure are generally planned well in advance, providing time to organise combinations with other types of infrastructure. Gas line extensions usually has a shorter planning time frame (because of dominance more commercial drivers like supply contracts etc.) as does new communication infrastructure due to rapidly changing technologies.

Obstacles in creating procedural synergies

However, there are also obstacles for creating procedural synergy. Common issues concerning all combinations are:

- There may be considerable variation in the planning time frame for each type of infrastructure which stands in the way of joint or even parallel planning;
- Technical standards, regulation and policies are not harmonised;
- Specific issues related to one type of infrastructure may impede the parallel development of another type of infrastructure;
- No framework or organisational body exists to ensure the necessary long term planning across the different involved sectors, countries, stakeholders;
- A source of finance for the joint long-term planning of infrastructure across the implicated sectors has yet to be identified or established;
- The lack of formal procedural mechanisms for joint corridors is a barrier;
- The potential for real benefits needs to be clearly evident and properly/fairly allocated over the various parties involved in order to avoid an attitude of ‘business as usual’ whereby each of the parties involved is focussing on its own sector/mode and not on the potential for combinations. Nevertheless it has to be acknowledged that the party that is investing should receive a decent return on its investment;
- The organisation and regulation of the sector (independent private operators; most incentives are national based) hampers a cross-border approach. There is a "regime change" in several TEN sectors, from national systems, managed by vertically integrated companies, into unbundled (partly) private companies and national network companies (TSOs) inheriting a network that was build up over many decades. This requires new approaches and instruments to invest in infrastructures for the future.

Physical synergies

Physical advantages and disadvantages can arise from combining or bundling of (sections of) infrastructural networks along both existing and new infrastructure.

Construction cost savings are expected primarily for certain combinations especially in expropriation and combined obstacle crossings (bridges, tunnels)

The physical combination of infrastructure has an effect on construction costs. Combinations generally result in substantial monetary savings. Typical costs savings are expected due to:

- Reduced expropriation costs (10-20%);
- Reduced construction costs for combined crossing of obstacles (roughly estimated up to 60-70% cost reduction for other infrastructure that can utilise (existing) road bridges/tunnels for obstacle crossing);
- Reduced costs for measures to mitigate negative effects (e.g. noise barriers);

The largest savings are expected to result from the combined construction of structures (bridges, tunnels etc.), for road/rail infrastructure networks in particular, but also for combinations of the road or rail with communications networks or electricity transmission lines.

On the other hand certain combinations will greatly increase the complexity or introduce additional (safety) requirements that have a negative bearing on cost levels. This includes for example combinations involving gas lines which are expected to lead to only marginal cost savings (if any).

Impacts on O&M and the environment are mostly positive, whereas safety risks are higher

The impacts of combining sections of infrastructure networks on their operation and maintenance of infrastructure are in general positive. The combined controlled environment allows easier maintenance. The environmental impacts associated with the combining infrastructure are in general positive. Clustering of infrastructure reduces the fragmentation of landscapes, visual hindrance, the amount of land used (directly and indirectly) and the negative impact of emissions and noise (although this may differ with respect to the specific location of the infrastructure). However, clustering of infrastructure may have negative impacts on safety. Fatalities and injuries as a result of accidents seem to be more severe on clustered segments of infrastructure networks.

Financial synergies

Financial synergies are mostly related to creating open access to communication networks

Combined infrastructure can provide additional value that can be ‘captured’ by the infrastructure provider or operator. The best instances where additional value has been created are combinations of telecommunication infrastructure along rail, electricity or road networks. In these cases communications infrastructure is required to operate the network. Examples are the Reykjavik power grid and the French railway (TGV). These examples demonstrate that the telecommunication infrastructure necessary for operating a power grid and High Speed Railway respectively, could be an even more valuable asset when leased to telecom operators. An additional example is that of the Indian railway network which is being used to provide broad band internet to rural areas. This shows that a combined infrastructure network can deliver affordable communications services even in poor and peripheral regions.

Conclusions and recommendations

There exists a clear potential to realise synergy within and between Trans-European Networks. The largest potential gains can be obtained when:

- combining road and rail networks (already widely applied in practice), and
- allowing existing communication networks previously dedicated to rail, road (and electricity) to other (broadband) uses for a wider public (assuming that open access to the infrastructure for all market players does exist).

It should be recognised that the communications sector is in general a commercially viable market. Public interventions should therefore be directed at stimulating to open communications networks previously dedicated (e.g. to rail, road, electricity) to wider communication uses. This can also include the option to bring in private (commercial) partner to operate the communication part. Where countries fail to intervene the Commission might consider to develop new regulation on the opening of these communication networks. Obviously opening of these previously dedicated networks should be done in such a manner that it does not distort competition.

The possibility of opening up previously dedicated networks for wider use is something that can be considered for new projects (including upgrading projects) that are still in the tendering/design phase, as well as for networks already in operation. The former option will also enhance the potential for public-private partnerships (PPPs) as it introduces an additional value component in the project.

On a more piecemeal basis, synergies between electricity networks and other transport modes can be expected. The most apparent ones are the use of rail and road tunnels for HV cables in mountain areas. An interesting combination is the use of inland waterways for combinations with HV lines by combining the sheet piling of the canal as a foundation for the HV line, or bury cables in the canal bottom/riverbed.

In addition, a number of interesting technological options have been identified which reduce costs or allow increased use of existing infrastructure. These would deserve further investigation to assess their real implementation potential. It is also worthwhile to examine whether new large scale initiatives related to renewable energy sources (e.g. off-shore wind parks, large-scale application of solar energy in Northern-Africa) could be extended to play a role in connecting national electricity networks.

Gas lines are less likely to be combined with other modes. In all situations attention must be paid to the safety consequences of combining different types of infrastructures in order to ensure that risk factors are identified at an early stage.

The synergetic impacts can be optimised once potential benefits are recognised and taken into account in an integrated planning and programming approach. When this happens benefits can already be realised during the preparatory phase of projects. If a tandem development of different types of infrastructure is not possible from the outset, then a more integrated planning perspective will keep open the possibility for cost savings at a later stage ("planning ahead"). For example by expropriating a wider corridor than necessary for the project at hand; through the construction of conductor pipes; or through astute design, future additions and expansions to the network can be facilitated. However it should be realised that the organisational setting is not always optimal to realise this joint planning in practice.

Large part of the TEN networks aim to connect different member states. This has to be realised in a setting in which many of the organisations responsible for deciding on new investments are still predominantly national oriented. Also the economic and commercial incentives often stimulate national investment above cross-border investments. A number of recommendations can be made in this respect:

- give additional financial incentives for (nationally) less attractive parts of the network;
- tie EU financial support to the condition to develop less attractive parts of the network (adopt a more holistic approach);
- further harmonise differentiating market rules and technical standards across countries where still necessary;
- establish truly cross-border project organisations which develop a joint planning, and possible tendering. One step further would be to establish an EU organisation for projects which are hard to realise from a national perspective but are of clear European interest. Such an organisation would need to have a clear mandate and access to funding;
- continue the process of market liberalisation and decreased protectionism;
- allow the Commission's financial instruments to finance multi-theme combined projects if sponsors can indicate a clear synergy;
- draft best practices which serve as examples to be followed.

1 Introduction

1.1 Background

Trans-European Networks (TEN) play an essential role in the implementation of the Lisbon Agenda which aims to promote economic growth and cohesion in Europe. Trans-European Networks are deemed to play a crucial role in the integration of the continent. The legal base for the TENs was established by the Maastricht Treaty (articles 154, 155 and 156).

Trans-European Networks are defined in three different areas:
- Transport – TEN-T
- Energy – TEN-E
- Telecommunication services – eTEN (previously called TEN-Telecom)

TEN-T: Transport
In contributing to the implementation and development of the Internal Market, as well as re-enforcing economic and social cohesion, the development of the trans-European transport network is a major element in economic competitiveness and the balanced and sustainable development of the European Union. This development includes facilitating both interconnection and interoperability of national networks as well as creating access to such networks.

To achieve these objectives, the Community has established guidelines for the development of the trans-European transport network (TEN T). These guidelines concern roads, railways, inland waterways, airports, seaports, inland ports and traffic management systems, serving the entire continent, carrying the bulk of the long distance traffic and bringing the geographical and economic areas of the Union closer together.

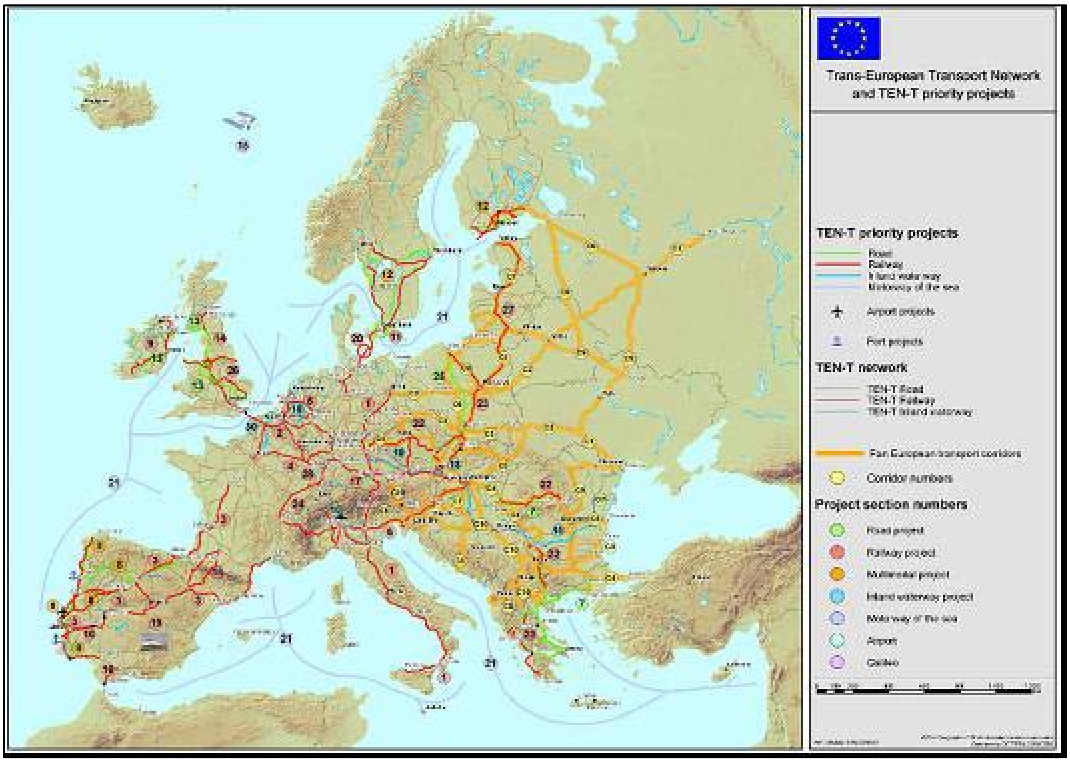
A first action plan on TEN-T was adopted by the Commission in 1990 and fourteen specific priority TEN-T projects were endorsed at the Essen Council. Following the advice of the "van Miert Group"[1] revised guidelines and financial regulations were adopted in 2004[2], together with a list of 30 priority projects including the original 14 (see figure 1.1).

In 2005, the Commission nominated six co-ordinators to oversee cooperation on a number of priority axes[3]. Their task was to coordinate between the numerous actors

[1] High Level Group on the Trans-European Transport Network, 27 June 2003.
[2] Decision No 884/2004/EC of the European Parliament and of the Council of 29 April 2004 amending Decision No 1692/96/EC on Community guidelines for the development of the trans-European transport network.
[3] Decision of 20 July 2005 designating six European coordinators for certain trans-European transport network projects.

involved in the various Member States and to accelerate the implementation of the TEN-T networks. Also in 2005, the Commission proposed the establishment of an TEN Executive Agency to support the realisation of the TEN-T priority projects[4].

Figure 1.1 TEN-T priority projects



TEN-E: Energy

The European Commission finances electricity and gas transmission infrastructure projects of trans-European importance. Most of the projects cross national borders or are of importance to several EU Member States. The Trans European Energy Networks are integral to the European Union's overall energy policy objectives, namely increasing competitiveness in the electricity and gas markets, reinforcing security of supply, and protecting the environment.

The first set of guidelines for trans-European energy networks was adopted by the Council and the European Parliament in June 1996[5]. They have been amended several times to reflect developments in the internal market for electricity and gas supplies[6]. The new guidelines issued in 2003 set out priority projects which chiefly concern the security of supply and the competitive operation of the internal energy market[7]. Twelve priority axes were identified, seven electricity networks and five natural gas networks.

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[4] Draft Commission Decision establishing the Trans-European Transport Network Executive Agency pursuant to Council Regulation (EC) No 58/2003, 2005

[5] European Parliament and Council Decision of 5 June 1996 (1254/96) establishing a series of guidelines on trans-European networks in the energy sector.

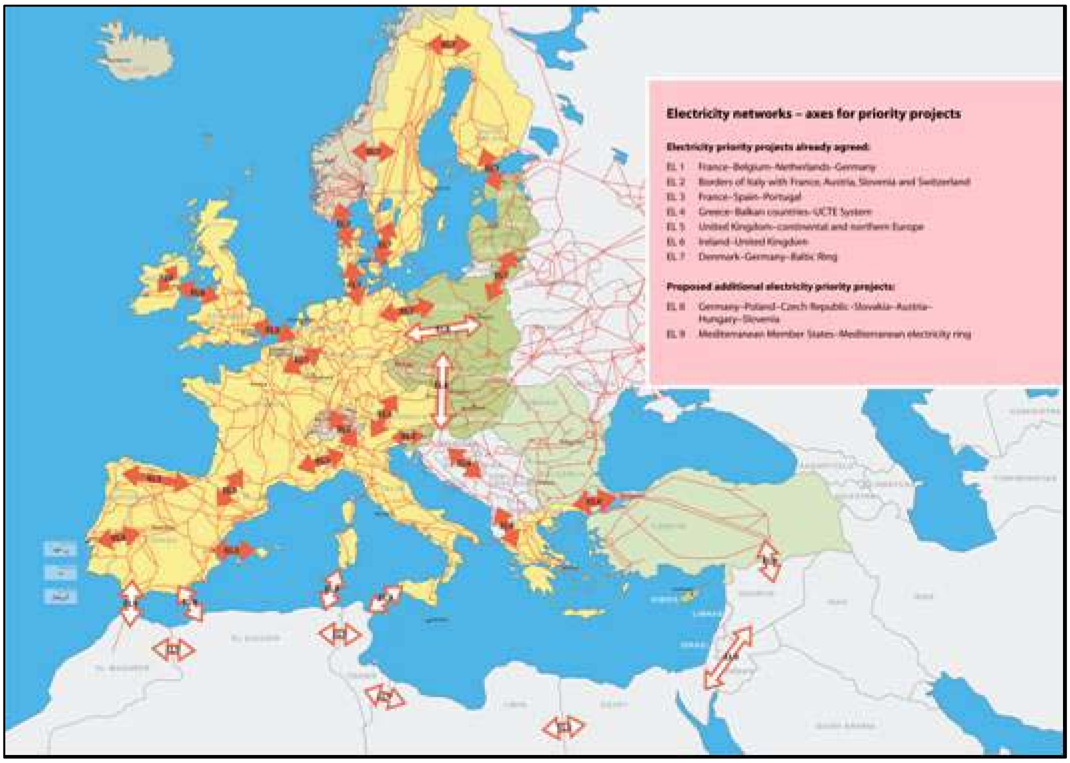
[6] Amendments have been made through **Commission Decision (97/548) of 11 July 1997; and Decision 1741/1999 of the European Parliament and of the Council;**

[7] **Decision No 1229/2003/EC of the European Parliament and of the Council of 26 June 2003**

On 24 July 2006, the Council adopted the Commission proposal for a revision of the Trans-European Energy (TEN-E) Guidelines, confirming the favourable vote of the European Parliament in second reading in Plenary on 4 April. In this resolution certain projects of European Interest were given a top priority, including with respect to funding[8]. A European coordinator was appointed to projects (or parts of projects) of European interest which were encountering implementation difficulties. The coordinator was tasked with facilitating and encouraging cooperation between the parties concerned and ensuring that adequate monitoring is caried out. With respect to cross-border sections of infrastructure, the Member States concerned need to exchange information regularly. Joint coordination meetings are to be held to ensure the harmonisation of public consultation procedures and carry out project evaluation. If delays occur then the Member States are to report on the reasons behind these delays.

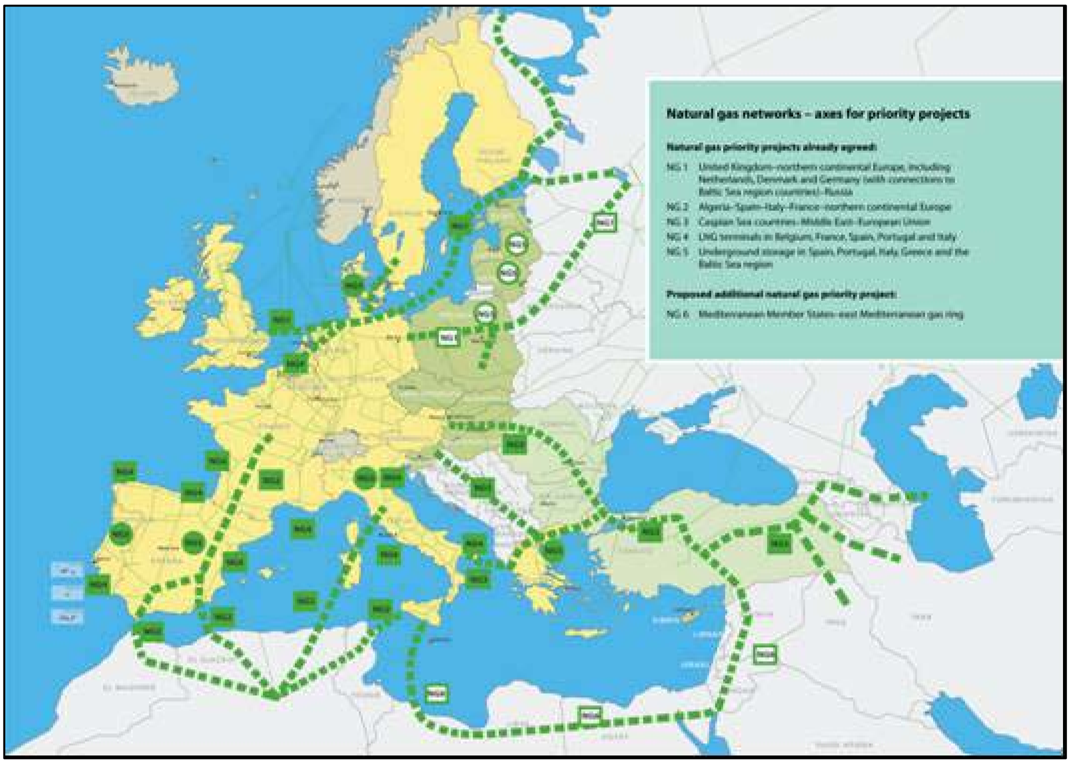
Figures 1.2 and 1.3 depict the priority axes for gas and electricity networks that have been identified.

Figure 1.2 TEN-E axes for priority projects in electricity networks



[8] MEMO/06/304

Figure 1.3 TEN-E axes for priority projects in gas networks



eTEN (previously TEN-Telecom): Telecommunications

In 1997 guidelines[9] were adopted for trans-European telecommunications networks in which the main objectives were to promote the interconnection of telecommunications networks, the setting-up and the deployment of interoperable telecommunications network based services (e-Services), applications and necessary infrastructure and to facilitate the transition towards the information society. Since 1997, the emphasis has shifted away from infrastructure and towards telecommunications based services.

The 2002 amendment to the Guidelines Decision aligned the programme's focus areas with those of the eEurope 2005 strategy and redefined areas of Common Interest[10]. It identified the public sector as a major driver behind the deployment of eServices (particularly using mobile and broadband), focusing on the practical realisation of eEurope general interest objectives concerning the interconnectability and interoperability of networks necessary for the operation of specific public interest services.

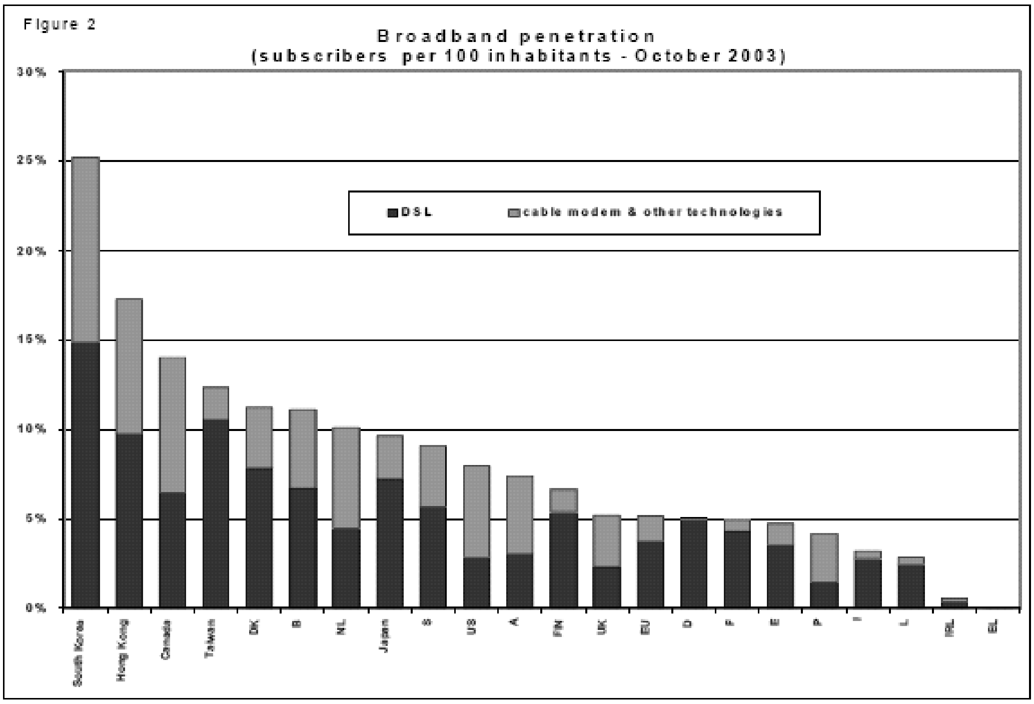
Bridging the Broadband Gap

In parallel to the eTEN initiative, the Commission issued at the end of March 2006 a Communication[11] indicating an increased urgency to overcome territorial divisions regarding broadband access. This relates both to a lack of access in rural areas and to the general low network coverage in the new Member States (see figures 1.4 to 1.6). Public and private stakeholders have been urged to give the highest priority to the development

[9] Decision No 1336/97/EC of the European Parliament and of the Council of 17 June 1997
[10] Decision No 1376/2002/EC of the European Parliament and of the Council of 12 July 2002
[11] COM (2006)129

of this type of infrastructure. The Commission has pledged the use of structural funds to support this initiative.

Figure 1.4 Broadband penetration in Europe



Source: EC (2004), COM (2004)61 final

Figure 1.5 European Terrestrial Networks, 2002

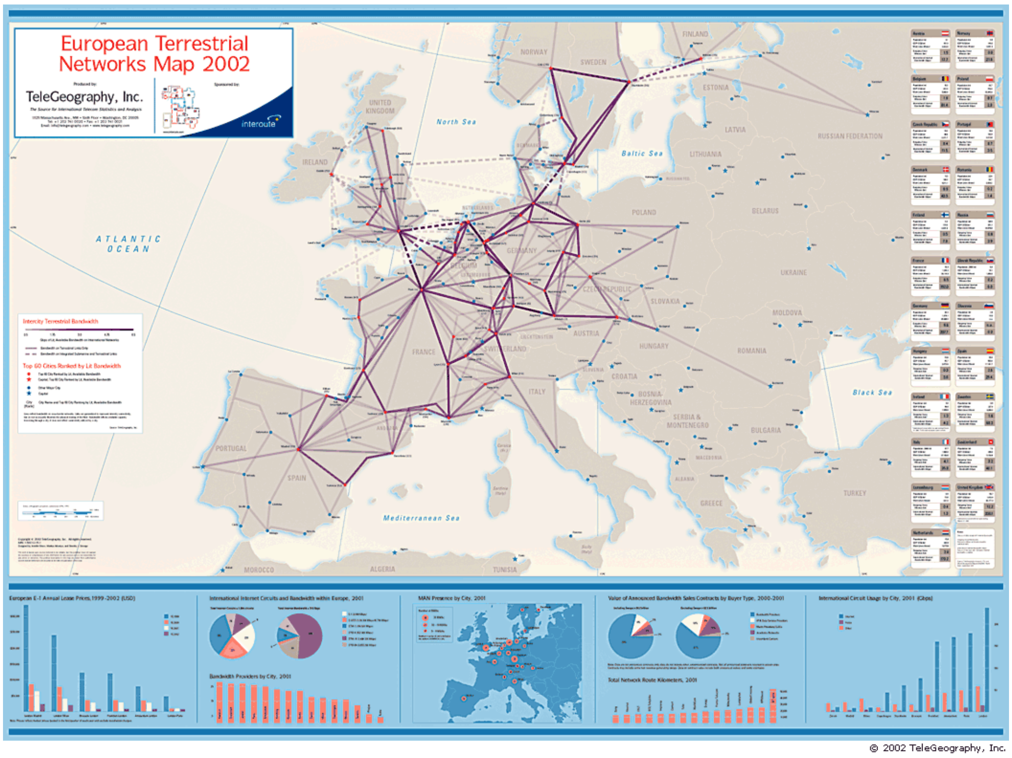
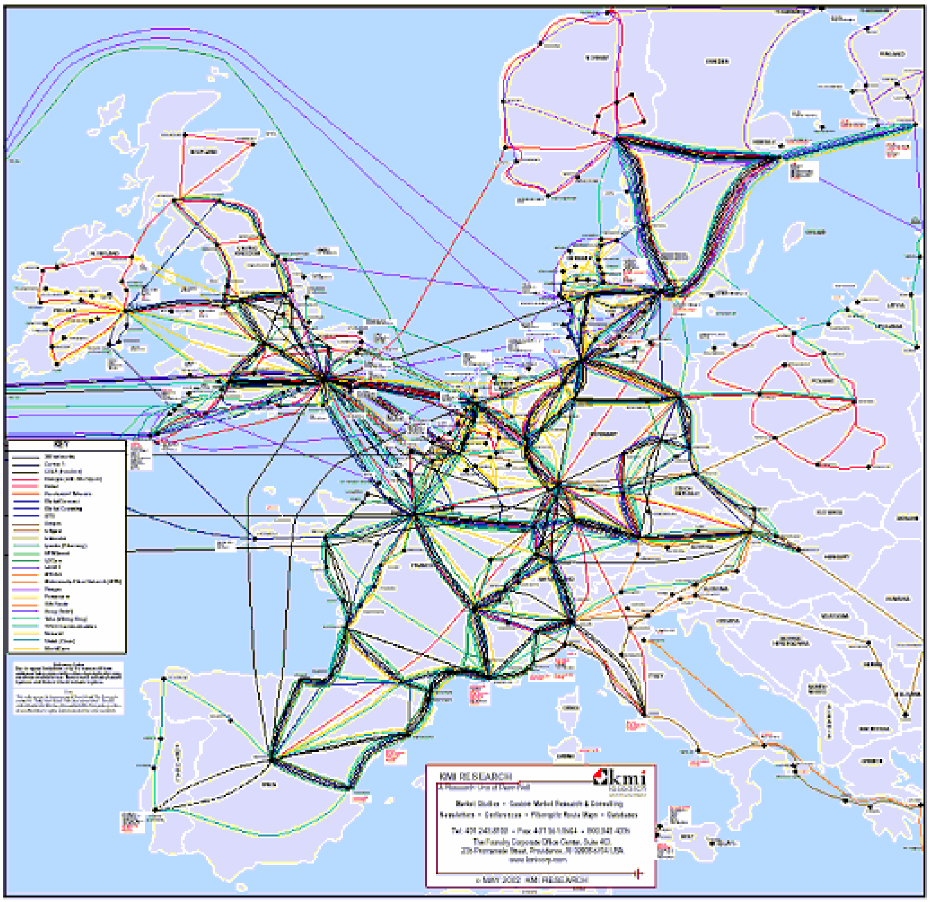


Figure 1.6 European Fibreoptic network routes planned or in place



Towards a common Commission TEN approach: the TEN Steering Group

One of the key priorities of the European Commission is an accelerated implementation of TENs to speed Europe's development. Based on an initiative by the President of the European Commission Mr. Barroso[12], it was decided to install a Steering Group of the Members of the Commission, led by the Vice-President in charge of Transport and further comprising the Commissioners for Information Society, Environment, Economic Affairs, Regional Policy, Budget and Energy.

The TEN Steering Group's mandate is to define a common approach for the improved coordination of the various Community initiatives supporting the implementation of the trans-European transport, energy and communications networks. A report on this new common approach and an outlook for the period 2007-2013 is expected at the end of 2006.

One of the aspects that the TEN Steering Group is look into is the creation of synergies between the different TENs. The development of innovative solutions is of particular

[12] Memorandum to the Commission from President Barroso in agreement with Mr. Barrot: Implementing the trans-European networks (20-06-2005).

importance givin the current situation in which the needs are considerable and the available funding is limited.

DG TREN has invited the consortium led by ECORYS to implement a study on the potential synergy between TENs.

1.2 Purpose of the project

The purpose of the study is to assist the TEN Steering Group in identifying the potential for synergy between the different Trans-European Networks.

The objective of this study can be formulated as follows:

> **To support the work of the TEN Steering Group by carrying out an exploratory study on potential synergies between TENs in the fields of transport, energy and communications by assessing the possibilities and drawbacks associated with combining networks, analysing the cost savings and possible other impacts of these combinations.**

1.3 Structure of the report

The report is divided into two main sections.

First, chapter 2 describes the characteristics of the five main types of infrastructure (road, railway, electricity, gas and voice/data communication) and looks into the technical feasibility of bundeling the various types of infrastructure.

Chapter 3 deals with the synergetic impacts of combinations of infrastructure. Administrative, procedural, physical and financial synergetic impacts are dealt with in turn.

Finally, the main conclusions of the study are summarised in chapter 4.

2 Characteristics of infrastructure

2.1 Introduction

In theory, all types of infrastructure networks can be combined. As a matter of fact, clustering of infrastructure already takes place to a greater or lesser extent in many European countries (see Box 2.1 for the example of the Netherlands).

Box 2.1 The clustering of infrastructure in practice: the example of the Netherlands

The Netherlands, with 452 inhabitants per km^2 the most densely populated country in the EU. Tables A and B show the extent of clustering of road (motorway), rail, inland waterway and pipeline infrastructure in the Netherlands in 1995. The first table gives information on line infrastructure of differing types that lie within 300 meters of each other over a parallel length of at least five kilometres. The second table concerns instances where the separation distance is less than 100 meters. Instances of clustered infrastructure of the same type are not included.

Table A. Clustering of infrastructure, separation distance less than 300 meters, in The Netherlands in 1995[13]

	Motorway	Railway	Waterway	Pipeline	Total
Motorway (2,210 km)	-	10.7% (236 km)	2.4% (53 km)	24.3% (537 km)	37.4% (827 km)
Railway (2,747 km)	8.6% (236 km)	-	2.4% (67 km)	3.2 % (88 km)	14.3% (392 km)
Waterway (4,617 km)	5.1% (235 km)	1.5% (69 km)	-	1.0 % (46 km)	7.6% (351 km)
Pipeline (10,141 km)	5.3% (536 km)	0.9% (90 km)	0.5% (49 km)	-	6.6% (673 km)

Table B Clustering of infrastructure, separation distance less than 100 meters, in The Netherlands in 1995[14]

	Motorway	Railway	Waterway	Pipeline	Total
Motorway (2,210 km)	-	7.6% (167 km)	2.0% (43 km)	9.1% (200 km)	18.6% (410 km)
Railway (2,747 km)	6.1% (167 km)	-	2.2% (61 km)	3.0 % (81 km)	11.2% (309 km)
Waterway (4,617 km)	0.9% (43 km)	1.3% (61 km)	-	0.9 % (42 km)	3.2% (146 km)
Pipeline (10,141 km)	2.0% (200 km)	0.8% (81 km)	0.4% (42 km)	-	3.2% (323 km)

[13] Sources: Rosmuller, N. AND J. Willems (1999), Accident Frequencies and Causes within Transportation Corridors: balance or imbalance?, in S. Hengst, K. Smit and J.A. Stoop (eds), Second World Congress on Safety of Transportation, Delft University Press, Delft, pp. 577-587; and Willems J. (2001), Bundeling van infrastructuur - Theoretische en praktische waarde van een inrichtingsconcept.

[14] Idem

The tables show that clustering in the Netherlands is greatest with respect to road and rail infrastructure. This particularly involves the combinations road/pipeline and rail/road. It is to be expected that the level of clustering has further increased since 1995 due to the recent development of two rail projects, firstly the 'Betuweroute' (a dedicated freight rail line between Rotterdam and the German border) and secondly the high speed rail link from Amsterdam to Brussels. The routing of these two railway lines have been clustered as much as possible with existing highways.

Even though clustering of infrastructure is not a new phenomenon, it is not always taken for granted as a common approach and the possible (dis)advantages are not always realised. Also, some combinations are more feasible than others due to the specific characteristics of the various types of infrastructure. This chapter describes relevant general characteristics of the following five types of infrastructure:

Five main types of infrastructure

TEN-T: Transport
- Road
- Railway

TEN-E: Energy
- Electricity
- Gas

Telecommunication
- Voice/data communication

The characteristics described are grouped into the following main themes (where relevant):
- Regulatory and planning issues
- Design issues
- Cross-border issues
- Construction, operation and maintenance issues

Under these characteristics, criteria have been identified which contribute to assess whether certain combinations between different types of infrastructure are feasible and provide input to the analysis on potential synergies in Chapter 3.

Regulatory & planning issues

The criteria described on regulatory and planning issues could refer for example to organisational or procedural aspects which either aid co-ordination and the realisation of synergies with other infrastructures or, on the contrary, may lead to additional complications?

Design issues

The criteria regarding design are important to analyse whether there are any design limitations which impact on creating a synergetic impact by combining infrastructures. This refers for example to the design requirements (curves, gradients, etc.) of railway and roads, which either support or hinder that they follow the same alignment.

Cross border issues

Another areas addressed in the characteristics of the different types of infrastructure is related to specific cross border issues. There may be specific criteria (either procedural, institutional or technical) that either support or hinder the potential for coordination of infrastructures across borders. For examples countries may adopt different technical standards, or access rights to infrastructure.

Construction, operation and maintenance aspects

Construction, operation and maintenance aspects relate to specific issues that are related to these phases in the implementation of infrastructure projects. This can relate to specific (physical) access requirements and factors which bear a direct impact on the complexity of projects, once different types of infrastructure are being combined.

2.2 Road

The analysis of the road sector[15] is limited to high class roads such as expressways and motorways. It is these types of roads that constitute the national and supra-national road networks alluded to the TEN programme.

Regulatory and planning issues

Planning and development of road networks is carried out by road authorities. This includes the consultation process and preliminary studies (including EIAs and SEAs) as well as design, construction and maintenance. However, public-private-partnerships (PPP) are becoming increasingly common. For major road projects decision making, in terms of ordering analyses and investment plans or approving construction, typically occurs at the political level (e.g. the national parliament).

A road usually has a single owner, which is advantageous when it comes to seeking combinations with other infrastructure and agreeing on joint infrastructure corridors.

Although most of the European roads are managed by the government it is important to note that also some roads (most times motorways, bridges and tunnels) are operated as PPP.

Design issues

Routing and road alignment are highly dependent on the type of road in question. Specifications on road design are typically provided in national standards for road design. The following specifications are examples from such standards[16].

In general, a road will be designed to provide an appropriate driving rhythm for the expected traffic flows. Where possible long straight sections will be avoided as will be sharp curves. Road design is determined by requirements for curve radii and gradients in combination with the given terrain conditions. For high class roads with speed limits of 110 km/h and the separation of traffic the minimum horizontal curve radius is approximately 5.4 km, which ensures a line of sight sufficient to enable stopping when queuing traffic is obstructing the view. For speed limits of 90 km/h the minimum horizontal curve radius is approximately 2.7 km. The corresponding minimum vertical curve radii are approximately 25.1 km and 12.5 km for speed limits of 110 km/h and 90 km/h respectively. Gradients over 30‰ may result in erosion caused by rain and

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15 The analyses are based on examples of national road standards for Denmark, American road capacity specifications and a key informant interview with Mr. Henning Pedersen - PhD, MSc Engineering, COWI A/S.

16 "Danish Road Standards: Tracing", the Danish Road Directorate 1999 (in Danish: "Vejregelforslag, Veje og stier i åbent land: Tracering") and "Highway Capacity Manual", Transportation Research Board, 2000. The Danish Road Standards are to a large extent based on the German Road Standards.

gradients of more than 35‰ over longer sections of road will significantly affect the speed of heavy vehicles. The gradient should never exceed 60‰.

The total amount of land used can be reduced by the development of joint infrastructure corridors. Furthermore, such corridors help to reduce the segmentation of privately owned plots and areas of natural beauty, etc. The road itself requires an approximate corridor width of up to 40-50 meters including a safety zone for 4/6 lane high class roads. For 2-lane high class roads the necessary corridor width is approximately 30-35 meters, including the safety zone.

Combining roads with other types of infrastructure makes it possible to concentrate (and therefore limit) negative visual impacts on landscape and scenery. The road itself generally provides flexibility in terms of minimising radical terrain alterations via the requirements for gradient and alignment. Also measures to mitigate negative environmental impacts (e.g. noise barriers) can be combined.

There are no immediate technical issues regarding the combination rail-road although the requirement that high class roads should avoid long straight sections may complicate the design of a joint infrastructure corridor.

Cross- border issues

Bundling different types of infrastructure in a road corridor calls for long-term planning involving different sectors within the various countries involved. In fact, the following issues are also valid regulatory considerations within one single country.

For cross-border roads, the road owners have to agree on routing, alignment and road standard. This is chiefly a procedural and financial challenge rather than a technical one since the specifications for high class roads are generally based on common principles across the European countries.

Traditionally, planning for each transport mode occurs separately according to its own criteria. Integral planning therefore involves breaking with tradition which requires extra effort. In most cases, the various modes have different owners of infrastructure, and again this requires additional effort in terms of coordination both nationally and across national borders.

Furthermore, differences in demand for each mode, both present and forecast, may result in different timeframes for the development of new infrastructure. This aspect increases the complexity of the challenge when it comes to planning, coordinating and financing joint infrastructure projects in the long term.

Conclusions

Roads can be relatively easily combined with other types of infrastructure. Especially in densely populated areas, where space is scarce combining road infrastructure with other (space consuming) infrastructure such as rail of electricity can be promising. It has the additional advantage that the environmental impacts are more concentrated and can be mitigated in a more focused manner.

However, also in less densely populated areas road can be combined with other infrastructure to concentrate visual intrusion and fragmentation of landscape.

In view of the increasing demand for intelligent transport systems along roads (for emergency systems, road information or traffic management) communication infrastructure is increasingly installed as a standard option. This creates additional opportunities if a wider access to this communication infrastructure is offered.

There are no major technical issues in terms of conduits or railways following the road tracing. However, the requirements for the high class road to avoid longer straight sections may complicate a joint infrastructure corridor.

Still for most roads governments are the owner, which in principle can facilitate the co-ordination with other government owned types of infrastructure. However, it should be noted that in an increasing number of countries PPP are increasing in importance.

2.3 Railway

This section[17] focuses on major national and international railway lines. Local railway lines are less relevant with respect to TENs.

Regulatory and planning issues

The planning and development of the railway network is usually carried out by a ministerial body. Construction and maintenance are typically carried out by a designated infrastructure owner. New public railway lines usually have to be approved by parliament as they are typically major investments that will have extensive influence on the entire transport network in a region. Policy-making and decision-making processes are usually very comprehensive and complex for new railway lines and often take very long.

Private involvement with regard to railway lines mainly concerns the operation of rail services.

Design issues

The space needed for a rail corridor is limited once the railway line is constructed. The minimum acceptable total width for a single track is 4.5 meters. An area with a width of 4.2 meters to a depth of 1 meter underneath the tracks has to be kept free of other installations as they might be damaged during maintenance of the tracks.

There are no specific requirements pertaining to access roads necessary for the maintenance of the railway lines as all maintenance is carried out from the railway itself.

The minimum radius for a horizontal curve is highly dependent on the design speed. The lowest possible acceptable radius is 190 m. At a design speed of 180 km/h the absolute

[17] The analyses are based on Official Journal of the European Communities, websites and key informant interviews with Mr. Klaus Wassard Hestbek Lund, expert in planning of railway lines and Jan Falster-Hansen, expert in planning of railway lines (both COWI A/S).

minimum radius is approximately 1500 meters although a minimum radius of approximately 2250 meters is usually preferred. The French TGV lines are typically operated at speeds of 300 km/h and horizontal curves with a radius of less than 5 km are usually avoided.

The following values are examples from the "Official Journal of the European Communities":[18]

- The minimum distance between main track centres on lines specially built for high-speed shall be set to 4,50 m
- Gradients as steep as 35‰ may be allowed for main tracks as long as the slope of the average profile over 10 km is less than or equal to 25 ‰ and the maximum length of continuous 35‰ gradient does not exceed 6000 m
- The typical reference height of rolling stock in the EU is 4350 mm above the running surface (the maximum height is 4700 mm).

Cross-border issues

A big issue with cross-border rail traffic in the EU is interoperability. EU cross-border traffic is hampered by technical and institutional differences between member states. The interoperability of railways in the EU is regulated by Technical Specifications for Interoperability (TSIs). The members of the EU must comply with these TSIs when new railway lines are constructed. Existing lines may be maintained without complying with the TSIs, but if an existing line is upgraded, for example to allow a higher speed, the TSIs must be complied with. Having said this all TEN railway lines are required to comply with the TSIs no later than 2016. A detailed description of the TSIs can be found at two websites[19]. A specific interoperability development is the establishment of the European Rail Traffic Management System (ERTMS)[20] which is meant to create unique signalling standards throughout Europe and thus creates not only an enhanced interoperability of train systems across different countries, but also improves the safety of rail transport.

Historically the owners of rail infrastructure and train operators have been the same body in the individual countries. As a result there was a strong tendency towards protectionism as the typically state-owned railway companies were keen to block possible competition from other (foreign) companies. The uncoupling of operators and infrastructure owners (first Railway package) has reduced or will reduce protectionist inclinations.

Construction, operation and maintenance issues

The construction phase of a project in which road and rail are combined is likely to be more complex. The needs of both types of infrastructure must be taken into account. This is not only the case where two new sections of infrastructure are build in a combined manner, but also where for example a new road is constructed next to an existing railway line.

A possible advantage arising from the combination of a railway line and any other infrastructure is the joint use of structures such as bridges, tunnels, underpasses and

[18] Official Journal of the European Communities, document number C(2002) 1948
[19] http://www.aeif.org and http://europa.eu.int/eur-lex
[20] http://www.ertms.com/

cuttings. In many cases, a reduction in the total cost is achievable through the joint use of structures.

The combination rail-communication infrastructure is an obvious one because the railway itself requires communication lines. With little extra cost it is possible to increase the capacity of these communication lines.

When combining power lines with a railway line an important consideration is the proximity between DC power lines and steel constructions, given that steel constructions will corrode.

Operation and maintenance of a railway line is not complicated by combinations with other forms of infrastructure. Maintenance on a railway line is carried out from the railway line itself. On the other hand the operation and maintenance of other types of infrastructure could be impeded when bundled together with a railway line. The combination gas-railway for example may be problematic if the two lines are located too close together so that access to the gas line is impeded by the railway line.

Conclusions

It is possible to combine a railway line with most other types of infrastructure. To a large extent similar criteria are valid for roads and rail where bundling of infrastructure might offer solution in densely populated areas, or where it concentrates the environmental impacts.

Less favourable combinations are railway lines with high voltage (DC) power lines, where it must be taken into consideration that DC power lines and steel constructions cannot be combined closely in a corridor as the steel constructions will corrode. Also electrified rail and gas infrastructure is not suitable as the generally proposed safety distance between both types of infrastructure is 1-2 km.

A combination of rail and communication is an obvious advantage as the railway itself requires communication. With a marginal extra cost it is possible to increase the capacity of the communication lines.

2.4 Electrical power transmission networks[21]

This section only considers electrical *transmission networks* which are the most relevant when it comes to Trans-European Networks and cross-border issues of interconnectivity. The associated *distribution networks* are primarily of local importance and are therefore left aside.

[21] This section is based on a combined analysis of ECN/TU-Delft and COWI. For the assessment an desk research has been combined with direct interviews (including interviews with representatives of Energinet - Thomas Engberg Pedersen, MSc. and Joana Rasmussen Ph.D.) and a specific brainstorm session at the TU Delft to identify more innovative options..

Current situation in Europe
The European electricity network finds itself in the same position as the national electricity grids in the sixties: in the middle of the transition from a connecting grid to a transmission grid. The liberalisation of the electric power markets in Europe resulted in trading opportunities that are fully exploited, which quickly exhausted the capacities of the interconnectors.[22] Relatively small cross-border capacities and insufficient allocation of these capacities can lead to congestion within the EU. The reality of today's electricity network is that Member States are not particularly well interconnected.

Most bottlenecks[23], which are part of TEN-E priorities are located by natural barriers like the Alps, the Pyrenees, the Northern Sea and the Mediterranean Sea. Furthermore, increased transient electricity flows can result in bottlenecks, like the transient flows through Belgium and The Netherlands. Between Eastern Europe and its Western neighbours congestion is enforced by the cost structure of electricity generation. Poland, the Czech Republic and Slovakia have inexpensive surplus capacities for which Germany, Hungary and Austria are potential markets. These profitable exporting lines are almost always congested.

Regulatory and planning issues[24]
The process of liberalisation of the European electricity sector has led to a situation where power generation facilities in most countries have become privately owned in most countries, and regulated in competitive entities. The former vertically integrated national power companies have been unbundled, implying that the power transmission networks have become independent regulated monopolies under state control. The organisations in the EU countries responsible for transmission networks are the so-called Transmission System Operators (TSOs).

On a national level enhancements to transmission capacity, either through the construction of new transmission lines or the upgrading of existing ones, results from a process whereby each TSO undertakes system studies of their network.[25] The studies examine what changes need to be made to the transmission network in order for it to remain compliant with established technical standards against the background of expected changes in generation and demand that affect the electricity flows over the network and consequently affect the need for network reinforcement. In return for making investments in the network to meet security standards, the TSO expects to receive a reasonable rate of return. In most countries, use of system charges provides this return and they are approved by the relevant regulatory authority. This is the fundamental 'regulatory contract' that exists between TSOs and regulators[26] .

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[22] See e.g. Brunekreeft (2004) Regulatory investments in merchant transmission networks. In addition, more effective regulation has led to a reduction in excess transmission capacity, putting an additional strain on transmission systems and making them prone to congestion (IEA, 2005a).

[23] Priority Axes and TEN-E projects, Priority axes as decided in the recently adopted TEN-E Guidelines with extensions and additions as envisaged in the Revision of these guidelines. EC, July 2003.

[24] A more extensive elaboration of the financial, economic and regulatory barriers for common EU HV infrastructure is given in section 3.7.

[25] These observations are derived from ERGEG (2005).

[26] The creation of regional electricity markets, an ERGEG discussion paper for public consultation, ERGEG, 8 June 2005.

Box 2.2 The impacts of the liberalisation and privatisation of energy markets

In general terms, the situation before and after the liberalisation of electricity sector in EU countries and the resulting change from public sector ownership of power generation to private sector ownership, unbundling the previously vertically integrated power companies, can be described as follows:

- **Before**: Prior to liberalisation most countries were strongly oriented towards self-sufficiency and the security of supply. Transmission lines to neighbouring countries were established for reasons of security of supply and in order to utilise synergies between diversified power systems. Despite the presence of cross-border transmission lines, each country (for supply security reasons) placed importance on maintaining a relatively high amount of excess capacity within their own system (for example 20% or more) for supply security reasons. Thus the amount of electricity traded between countries was relatively small and mostly driven by specific load demand.

- **After:** Investment decisions concerning power generation facilities are now made on a commercial (market) basis. This has led to a closer balance between supply and demand because investors are reluctant to invest in spare capacity to avoid possible overcapacity of supplying the required demand load. For example, in the Nordic countries a decision to increase generating capacity is yet to be made since the market was opened up around the year 2000. The liberalisation of the electricity market has completely changed the functions and requirements for transmission connection capacity between countries and systems. Increasing need for cross-border trade between systems and ensuring domestic security of supply require properly functioning transmission system connections, leading to an overall more competitive electricity market in the EU. Relatively large investments in transmission networks need to be made by Transmission System Operators within Europe.

One must conclude that investment procedures in effect in the EU member states typically still remain national. Each TSO has his own methodology for combining the capacity and direct costs of interconnection with the other independencies specific to its grid. Each side is also using its own criteria, economic in the context of its own transmission zone. Next investment plans are submitted to a domestic process of evaluation and approval etc. Structural cooperation for expanding the European grid seems minimal[27].

Box 2.3 The possibility for merchant lines

Next to network investments by TSOs, merchant network investments can be considered. Merchant network investments, an in USA popular and successful way of investing in interconnections, are facilities that are not built under the initiative of regulators or TSOs, and whose remuneration is determined by the market and not by regulation.[28] Its capital and operating costs are met from risk capital, without mandated guarantees of future traffic or other forms of bankable advance sales, other than those freely negotiated in the market. Currently the merchant model is not considered suitable as a general model for inter-connector investment in Europe.[29] In the current situation investment are carried out by TSOs under a regulatory contract between the TSO and the regulator as a general rule. However, in some exceptional cases it might be envisaged that inter-connectors

[27] Electricity Internal Market in the European Union: What to do next? J-M. Glanchant and F. Lévêgue, working papers March 2006.

[28] Largely derived from CEER (2004).

[29] Next to various problems with the use of a merchant model that are discussed in this section, Joskow and Tirole (2003) give a more detailed overview.

could be constructed on a merchant basis. In that case, the remuneration of the transmission facility is unregulated and is determined by the market value that the transmission owner can obtain from arbitrage or from selling capacity on the line.

Given the closer integration of European power grids we have today, the need for a supranational coordinating and planning body has been acknowledged. For this reason, the regional co-operation organisations of electricity utilities[30] established ETSO (European Transmission System Operators) upon the emergence of the Internal Electricity Market in the European Union. All EU Member States have direct TSO-representation in ETSO as do the non-member states Norway and Switzerland. ETSO deals with a number of matters including bottleneck issues (possibilities for rerouting power according to the demand situation), harmonisation of network access and conditions for usage including the levelling of costs in connection with cross-border trading and reliability of supply. It conducts preparatory studies and advises and supports the TSOs in decision making on cross-border infrastructure with a common interest. However, it is not an ultimate coordinating body responsible for investments in connecting transmission systems in the EU.

The fact that transmission networks are under national control, and that an organisational structure facilitating international coordination is not really in place, is also a disadvantage when it comes to coordinating and planning the combination of electrical transmission networks with other types of TENs.

Design Issues
Electrical transmission networks can be implemented using two fundamentally different methods, each with specific requirements and limitations and each impacting the environment in different ways:

- Overhead infrastructure with cables mounted on pylons (OHL – overhead lines)
- Underground or submarine cable systems

In general, the costs associated with investments in new HV-networks (the interconnection lines itself, as well as transmission of power through countries) are high costs and increase with increasing transmission distances (as a result of loss of power). Construction costs vary greatly, but in general overhead lines are less costly than underground cables.

In addition to the distinction between OHL and underground cabling, a distinction can be made between two types of transmission lines: HVDC (High Voltage Direct Current) and HVAC (High Voltage Alternating Current). HVDC requires the installation of transformer stations at each end of the line where the power is converted back to HVAC. The choice between HVDC and HVAC depends on the desired length of the line and the type of connection required. For technical reasons HVAC can not be sustained over

[30] TSOI, the association of TSOs in Ireland, UKTSOA, the UK TSO organisation, NORDEL (the Nordic TSOs) and UCTE – Union for the Co-ordination of Transmission of Electricity (continental Europe). These organisation have been co-operating for decades, mainly in order to maximise the system's reliability and quality of supply, while optimising the use of primary energy and capacity resources (see www.etso-net.org)

extremely long distances and HVDC must be adopted when the maximum distance is exceeded.

The majority of national transmission networks in Europe use High Voltage Alternating Current. HVAC lines are also used when connecting control areas within a single synchronous region, for example when connecting the power grids of two countries. The major synchronous regions in Europe are NORDEL and UCTE, the latter being the largest. The connection of two synchronous areas requires a High Voltage Direct Current connection in order to balance the supply/demand situation in each region.

Various safety distances are recommended depending on voltage level and the configuration and placement of transmission lines. It is best practice to calculate the respective distances for each application taking into account a number of proximity effects. In the case of (400 kV) transmission lines, the following minimum safety distances are applicable:

- Overhead lines: width of cross section (clearance area) 15 meter either side of the outer cables[31]; no "foreign" objects may obtrude more than 3 meters above ground level within this area.
- Underground cables: cable trench width 6 meters per underground cable system.

Cross-border issues[32]

The situation is in some ways comparable with the cross-border issues mentioned for the railways and the historical perspective of former national state-owned vertically integrated companies that shaped the current structure and connection capacities for transmission of power.

Investments in cross-border interconnection capacity, by definition, span more than one TSO and usually member state boundaries, and therefore extend across regulatory borders. TSOs, however, are national bodies with national networks and investing is normally limited to investment to meet the needs of their own network in accordance with their national obligations.

National obligations on TSOs (as their part of the 'regulatory contract') to maintain and develop their network to achieve technical standards, does not extend across national borders or to connections with other networks. Consequently, investment in cross-border infrastructure is typically driven by factors different to those used for in-country investment, such as local requirements to maintain system security or where TSOs and regulators agree that the construction of a particular line would be beneficial. However, the TSO has the technical knowledge as well as the expertise to evaluate cross-border transmission investments.

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[31] Tennet in the Netherlands applies a safety area with a width of 150m for overhead lines (a/o related to the possibility of cable ruptures) with additional limitations applicable to residential areas due to the possible risks associated with the electro-magnetism.

[32] For a more extensive elaboration of the financial, economic and regulatory barriers for common EU HV infrastructure see also Barriers and drivers of new interconnections between EU and non-EU electricity systems: Economic and regulatory aspects. M.J.N. van Werven and F. van Oostvoorn, ECN-C--06-006, May 2006, and Implementing optimal corridors: Analysis of investment barriers. J. de Joode and F. van Oostvoorn. Forthcoming ECN report (2006).

In order for cross-border investments by TSOs to occur, there needs to be an assured basis for future recovery of the costs of that (high!) investment. However, the 'regulatory contract', which forms the basis for domestic 'regulated' investment decisions by the TSO, does not, in all instances, apply in respect of cross-border investment. In some countries the issue of funding is addressed by government decision. For example, in Finland, Spain and Austria cross-border investment in infrastructure is approved by the government and the cost is automatically incorporated in the Regulated Asset Base (and recovered through network tariffs). However, in other instances, such as the arrangements in place in Great Britain, no such arrangements exist.

Also different market rules impede structural co-operation. Compatibility between key market rules is important so that opportunities for trade can be fully realised. Relevant in this respect is the allocation of transmission access rights, which give access to the transmission network and the interconnection lines, that may differ from network to network. An access right consists of a number of elements, such as the capacity and location(s) for which access applies, the duration of the capacity right, and the degree of firmness of the access right (including the compensation to apply in the event that the right is not available under any circumstance). Some transmission networks (such as Great Britain, Austria and Finland) provide financially firm transmission access rights. In such cases, a market participant that has their physical access rights reduced as a result of constraints or a transmission disturbance, receives financial compensation for lost output or consumption.[33] The effect of these arrangements is to make individual market participants less sensitive to the commercial risks associated with their particular location on the transmission network, or to changes in the physical availability of transmission capacity. This reduces commercial uncertainty for market participants. In other countries, market participants are not compensated for the withdrawal of access rights and bear the commercial risks associated with lost output and consumption. This result in additional costs compared with market participants that have firm transmission access rights.

Political resistance

Apart from organisational and institutional aspects, political resistance may exist towards new (cross-border) interconnections. New interconnection capacity may impede investments in domestic generating capacity, especially for importing countries, where domestic electricity generation is relatively costly. These countries may therefore become increasingly dependent on supply from foreign countries, which may be experienced as a political undesirable development, as it introduces a number of specific uncertainties that do not exist for domestic generation. These include the development of electricity generation in neighbouring countries, the capacity and reliability of interconnectors, including the administration of the interconnection lines, and the regulation that still diverge on a number of points.

Also political resistance may exists with respect to the means of electricity generation in foreign supply countries (esp. opposition towards nuclear power generation), which can effectively block the commissioning of new transmission lines.

33 The TSO would only be able to withdraw access rights by buying them back. This approach would automatically mean that participants would be compensated for a lack of access in the event of transmission failures (ERGEG, 2005).

Need for multi-country co-ordination

A specific issue which complicates the situation, is that in certain cases also the internal congestion within specific EU Member States can be a major (cost) barrier for interconnecting different EU Member States or regions. If, due to this internal congestion, electricity cannot sufficiently flow across national Member State borders, interconnection can at the most offer benefits for one TSO system only. As a result congestion within the EU Member States or EU regions forms a barrier to the investment in an interconnection itself. To solve this issue for all Member States involved requires multi-country co-ordination.

Construction, operation and maintenance issues

Placing electric HV-installations in the same (or neighbouring) trenches as gas lines is generally avoided. The reason being that electromagnetic fields surrounding HV-installations may induce significant voltages in neighbouring conductive infrastructure. Even small imperfections in welding or joints could trigger sparks and result in explosion.

Also, with respect to security of supply, different types of lines (for example electric/gas or electric/oil) are not bundled together, in order to avoid the risk of a complete cessation of energy supply to an area or region in the event of faults occurring on one of the lines.

Overhead lines will, in general, not be routed across densely inhabited areas nor over roads and railway lines, due to possible interference problems and the risk of falling icicles posing danger to people and traffic[34].

Box 2.4 Case: Electrical Great Belt Link, Denmark

Following a major blackout situation (loss of 3GWh between 12h30 and 19h00) in southern Sweden and Denmark on the 23 September 2003, the establishment of a HVDC link between East and West Denmark[35] was once more put on the agenda. The length of the connection will be approximately 20 km. One advantage of this proposed HVDC is that it will enable the faster restoration of electricity supply if a major blackout were to occur again.

In this case the decision was made not to use any of the existing infrastructural links across the Great Belt, namely a railway connection (part bridge, part tunnel) and a road connection (bridge), to host the new HVDC connection. The reason given was that the technical implications and associated costs of using the existing infrastructure made this option prohibitive compared to the much simpler and cheaper option of laying a new sea cable.

Potential combinations which could offer synergetic impacts

Most importantly, the combination of high voltage lines (overhead or underground) with transport infrastructures appears a promising and relatively unexplored track. Well-coordinated simultaneous construction of cross-border roads, railroads, bridges, tunnels etc. and power lines could simplify planning and acquisition processes and possibly shorten the time needed for realization. In mountain areas the studies for using new planned railway galleries between Innsbruck and Fortezza for HV cables draw attention[36].

[34] Phenomenon known also known from cable stay bridges that are occasionally closed for safety reasons due to the formation of icicles

[35] East-Denmark is not directly electrically connected with West-Denmark

[36] Amongst others: R. Benato, P. Brunello, L. Fellin, A. Paoluccil, E.M. Carlini, C. Di Mario, M. Muhr, G. Knollseisen, R.

Limitations are formed by the avoidance of densely populated areas by OHL related to the risk of falling icicles and possible interference difficulties between rail and power transmission lines.

A relatively new combination would be the combination of waterways and energy corridors. This combination of electrical power transmission networks with waterways also seems to be a promising combination, especially in corridors where priority axes from the TEN-T[37] project coincide with those identified in TEN-E. A good example is the proposed Seine-Schelde connection[38], which aims at strengthening inland shipping routes between the ports of Antwerp and Paris.

Box 2.5 Case: New HV power line construction in the Dollard-Eems

One of the few known examples of a combination of waterways and electricity is the construction of a new power line between Norway and the Netherlands in the Dollard-Eems river bed. The Dollard-Eems region is part of the Wadden Sea and is a protected natural area in the northern part of The Netherlands and Germany. Infrastructural works which are necessary for the supply of the neighbouring islands amongst others, gas, water and electricity, or other utilities, shall be carried out in a way that the environmental impacts on the Wadden Sea are kept to a minimum and permanent, or long lasting, impacts are avoided. As a consequence it has been decided to situate a new power line at the bottom of the water to minimise the impacts on the environment. The power lines will be combined with cables that are buried in the river bed so the line has no visual impact. Besides the water will offer natural cooling to the line, which may even result in a higher power transmission capacity.

A less favourable option is the combination of electric HV-installations in same/neighbouring trenches as/to gas lines is generally avoided. The reason being that electromagnetic fields surrounding HV-installations may easily induce significant voltages in neighbouring conductive infrastructure such as gas lines. If gas lines have even small imperfections in weldings or joints, such imperfections can source the formation of sparks leading to explosions.

A general conclusion is that the use of underground cables instead of overhead lines should be reconsidered for some projects. Reliability of high-voltage cable systems has improved significantly in the last decades and costs have been decreasing. Cable connections are less likely to meet challenging right-of-way problems that could hamper the on-time realization of projects, especially in densely populated areas.

Innovative solutions

New innovative technology developments could also facilitate the accelerated construction of interconnector projects. Important in this respect is the use of voltage sourced converter (VSC) based DC for transmission purposes, unavoidable technology

Woschitz, M. Laußegger, W. Stroppa, H. Würle (2006), Italy – Austria Gil in the New Planned Railway Galleries Fortezza-Innsbruck Under Brenner Pass.

[37] TEN-T: The Trans-European Transport Networks, see http://ec.europa.eu/transport/index_en.html

[38] http://ine.dad.be/documents/Waternews/Publications/Brochures/TEN_T_Seine_Nord.pdf

when interconnecting power systems that do not have the same frequency or phase, and a highly desirable when bridging large distances, especially offshore. VSC transmission enables the use of power cables with solid plastic insulation, which is cheaper, faster to produce and more environmentally friendly than the classical cables used for DC, both for submarine and land purposes. Besides, VSC transmission requires smaller, modular converter stations.

Other innovative technological solutions which can stimulate the development of new HV interconnectors are shown in box 2.6.

Box 2.6 Innovative solutions which can stimulate new HV interconnectors

AC and DC technology related topics

- A problem with (submarine) cables operating at AC voltage is the high capacitance of the cable, resulting in a high charging current. By using a lower frequency AC, the shunt admittance of the cable is lower resulting in less reactive power to be transported. Use of AC has advantages in using transformers for changing voltage levels and circuit breakers for fast fault clearing and switching.
- Variable frequency AC. This could especially be beneficial for interconnectors/grids that also connect RES. Here power quality needs not to be so important, so possibly a varying frequency could be allowed, minimising the requirements on apparatus for grid connection (converters, etc).
- Variable voltage DC, same as above, possible use of a static rectifier is possible.
- Use of extra high voltage levels, both at AC and at DC, will lead to improved link capacity for the same right of way/number of connections. Problems with safety and EM fields should be addressed.
- AC with more than three phases. This will lead to higher transmission ratings and (depending on the actual configuration, lower EM fields).
- The use of HVDC based on voltage-sourced converters (ABB: HVDC Light, Siemens: HVDC PLUS) could offer increased flexibility. Since power reversal with this technology could be facilitated by changing the current direction, the use of cheap and lightweight XLPE (submarine) cables would be possible. In theory, this technology is also better suitable for multi-terminal systems (required for the inclusion of RES on the link).[39]

Grid-related topics

- In densely populated areas close to borders, primary distribution networks could also span more than one country. This will lead to interconnectors that individually have low power ratings, but when constructed in large amounts could add up to high ratings.
- In the future, there should be a focus on optimising the carrier of energy. Nowadays, a fine-grained distribution system for both electric energy and natural gas exist, and the development of gas grid capable of transporting H_2 is foreseen. If all development efforts would be focused at the most suitable technology however, advances will be faster.
- Combination with flexible demand systems (Demand side management, disconnecting large industrial processes that could run for certain time without electric power (blast furnaces)). This reduces the need for reserves and exchange of reserves.
- Use of trans-border storage reservoirs (hydro power) as indirect inter-connector. All ‘connected’ countries could add (pump up water) or withdraw (generate electricity) energy from the reservoir.

[39] See brochure “It’s time to connect” on ABB HVDC website: http://www.abb.com/hvdc

Material-related topics

- If an increased use of underground HV cables is foreseen, there should be more focus on the complete lifecycle of these cables. For instance, the recycling of the conductor material (copper or aluminium) could be beneficial, and old degraded insulation material could be burnt for electricity production (instead of being degraded as landfill waste).
- New gasses for use of GILs could be researched. N_2 was already mentioned above. Also a combination with H_2 could be possible (transport/trade of H_2 in the same infrastructure), or CO_2 in the form of storage. The properties of these gasses as electrical insulation should be assessed.
- New polymers for use in HV towers. These constructions possibly lead to lower EM fields and are cheaper to manufacture and environmentally friendly. If these towers are made so that the visual impact of an OHL is reduced, the planning process could be simplified (less resistance from the public).[40]

2.5 Gas pipeline connections

The following description of the gas sector is limited to high pressure gas pipelines which are the most relevant to national and supra-national networks such as TEN. Distribution gas pipelines with lower pressure are not covered[41].

Regulatory and planning issues

The picture concerning ownership of and decision making on new gas lines is a varied one across Europe. For example gas lines in Sweden are fully privatised, whereas in Austria they are owned by the state. In Denmark the gas lines are owned by a state owned company Energinet.[42] This Danish Transmission System Operator (TSO) owns today the gas transmission grid and the 400 kV electricity transmission grid and is co-owner of the international connections between Denmark and the Nordic countries and Germany. Furthermore, the company has at its disposal the 132 kV and 150 kV electricity grids and has access to natural gas storage facilities.

In the far majority of EU countries however there exist a specific TSO for gas and electricity which are completely separated in responsibilities etc. This obviously increases coordination difficulties for synergetic projects between gas and electricity networks. In most cases, planning issues are handled by the TSO. New gas lines often require the preparation of an Environmental Impact Assessment (EIA) and a Strategic Environmental Assessment (SEA). New gas lines particularly need political support and approval on state level because of its strategic consequences (see for e.g. the North-European Gas Pipeline (NEGP) that is planned to run from Russia through the Baltic Sea and land in Germany).

There are procedural differences between European countries, companies and regulators etc. concerning applications to establish new gas lines. For example, in Sweden companies have to apply to the relevant national authorities. In Denmark, new initiatives

[40] See for instance: http://www.tennet.nl/images/050531_Wintrack_NL_DEF_tcm14-8713.pdf

[41] The description is based on a key informant interview with Mogens Winkler, expert in planning of Gas lines (DK and abroad), COWI A/S and Dorthe Vinther, Plan Manager and Mette Behermann, Planning Department both Energinet.dk and examples from international standards e.g. Swedish rules, Danish handbooks and ANSI-standard GPTC as well as sound engineering

[42] www.energinet.dk (Systemplan2006.pdf)

are regulated by the natural gas law which states that a national directive must be made (usually a formality).

EU directive 2003/55 on Third Party Access (TPA) requires that gas line needs to be (technically) accessible at all times and in all places to solve technical and leakage problems[43]. This is typically ensured during the construction phase by the expropriation of sufficient land and the establishment of rights of access in the future.

Furthermore, it is not often that the planning of roads, railway lines, electricity lines and/or gas lines is planned for simultaneously. This is mainly because the drivers for these investments are so different from each other let alone the regulations. This is an important obstacle to the achievement of potential financial savings through a combined approach.

As an example, the owner of the overall infrastructure in Denmark, Energinet[42] maintains the security of supply in both the short and the long term, and ensures the smooth operation of the market for electricity and gas. Together with the Danish authorities Energinet is in charge of decisions for establishment and reconstruction of new transmission lines for gas and electricity supply. The company's main regulatory and planning tasks are as follows:

- developing the Danish electricity and gas transmission infrastructure
- carrying out coherent and comprehensive planning, taking account of future transmission capacity requirements and the long-term security of supply
- creating objective and transparent conditions for competition within the energy markets and monitoring that competition works

The merged planning of electricity and gas infrastructure in Energinet forms the basis for evaluation of a number of aspects in relation to market[44], secure, safe, emergency prepared and environment-friendly system for supply of electricity and gas. Besides the main objectives the company has national activities and initiatives in connection with energy savings and R&D projects in the energy field. However it should be noted that the situation in Denmark is atypical for the rest of the EU Member States where generally TSO for gas and electricity are separated bodies with separated responsibilities.

Design issues

Gas lines today are generally located underground. They can be constructed to a number of standards and specifications (for example different levels of pressure) depending on location (urban/rural), length and safety. TEN-E gas lines are usually steel pipes operating with a pressure of up to 100 Bar.

The requirements for curve radii depend on type of pipe as steel pipes cannot be bent as much as plastic pipes, although following the routing of main roads and railway lines is

[43] European Parliament and Council Directives 98/30/EC and 2003/55/CE setting common rules for the EU internal market in natural gas.

[44] Electricity and gas market

never a problem regardless of the type of pipe being used. The gradient of the lines should preferably not exceed 30 degrees (approximately corresponding to a 1:2 gradient).

Underground gas lines require a corridor 30 meters wide during construction and 7 meters wide during operation and maintenance. There is also a need for safety (buffer) zones between gas lines and other infrastructure. From the perspective of the “other” infrastructure, these are:

- Roads: 12 meter buffer for main roads carrying more than 5000 AADT (average annual daily traffic) and 6 meters on smaller roads[45];
- Railway: 23 meter buffer for railway lines without electricity and 1-2 km for electrified lines in a parallel configuration[46, 47, 48];
- Residential areas (buildings): a buffer of up to 40-50 meters depending on the pressure and dimensions of the gas line[49];
- Overhead electricity lines: the safety distance should be 1-2 km to gas lines above ground and parallel sections should be kept as short as possible[46, 47, 48];
- Underground electricity lines: in principle these may run parallel to gas lines and the safety zone concerns a "safe distance" for digging between the lines.

From the perspective of the gas line itself the preferred distance from a railway line is at least 23 meters. This corresponds to the length of a typical goods wagon (for the railway a 15 meter separation distance is sufficient. The length is calculated from the bottom of the railway bank edge. The safety distance required is far greater when it comes to electrified railway lines. In this situation a buffer of 1-2 km is required on parallel sections. When this requirement cannot be met, a number of (expensive) measures such as isolation valves, frequent ground connections etc. will need to be applied.

Due to the mentioned technical limitations the transmission systems for electricity and gas these have to be designed with caution and operated separately. For example, the Transmission System Operator (TSO) in Denmark monitors the electricity and gas transmission grids using two respective System Operation Centres with different daily procedures.

On the other hand the Danish TSO has recognised the synergy between gas and electricity transmission systems with regards to common steering of planning, market design, and procedures for safety and emergency preparedness (in case of incidents) as well as a number of centralised and coordinated administrational and organisational functions[50], although the exceptional situation of Denmark in the EU in this respect should be noted..

Cross-border issues

The overall issues related to cross-border gas lines are similar to those described in the section on roads. When bundling different types of infrastructure together with gas in a

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[45] Swedish rules: SRVFS B80 Statens räddningsverks författningssamling föreskrifter om naturgas 6 kap 2§

[46] Sound engineering

[47] Principles for establishment and reconstruction of high voltage equipment, June 1995, Ministry of Environment and Energy

[48] Proximity between gas and electricity supply systems, Handbook, May ½993, (Working group: Association of Danish Energy Companies & Natural Gas Companies in Denmark)

[49] ANSI-standard GPTC: Guide for gas transmission and distribution piping systems, afsnit 192.5 Class locations

[50] Note that this situation (Denmark) is an exception in EU

corridor there is need for long-term planning involving the various sectors from the countries, but and that is even more complicating the investment also involving gas supplying and contracting parties/companies concerned. A greater effort from all the involved parties is called for as traditionally the planning for each type of infrastructure occurs separately according to its own criteria. Furthermore different national infrastructure owners (TSOs) are involved which again requires far greater levels of cross-border coordination. In addition, variations in demand and for future forecasted demand result in higher risk of investors in gas transport capacity than in other new TEN infrastructures. For the investors the risks are increased since long term take-or-pay contracting is generally not allowed anymore in gas markets of EU[51]. This creates an additional challenge when it comes to coordinating and financing joint infrastructure projects with a long planning horizon.

Construction, operation and maintenance issues

Gas lines are usually located underground and can be flexibly adapted in to extreme terrain conditions due to the relatively gentle requirements concerning gradient and bends. Underground gas lines require a corridor just 30 meters wide during construction and 7 meters wide during operation and maintenance.

Generally electricity lines and gas lines do not make a good combination. The temperature of electricity lines may cause plastic pipes to melt. Steel pipes run the risk of induction and EMC if gas lines are not provided with sufficient isolation valves and ground connections.

Communication lines can be run through the same trench next to or obliquely above a gas line.

In instances where roads or railway lines need to be extended it is often necessary to (re)move a gas line from its present location. The removal of gas lines laid alongside roads to make way for work on the road is a common occurrence. E.g. on the short-term the Danish TSO (Energinet.dk) has recognised only marginal synergies/ perspectives by combining the operation and maintenance of the gas and electricity transmission in Denmark. The few benefits are mainly related to company savings due to common organisation of functions such as joint IT- and financial systems, purchase, supply, marine activities etc.

Conclusions

In general it can be concluded that gas infrastructure is least suitable to be combined with other types of infrastructure. In relation to electrified railway the safety zone is so wide (1-2 km) that clustering does not really appear to be feasible.

Also electricity and gas lines do not fit together in general. Electricity lines may be hot and melt plastic pipes and on steel pipes there is a risk of induction and EMC if the gas lines are not provided with sufficient isolation valves and ground connections. The main problem is overhead electricity lines, whereas electricity lines in the ground can run in parallel and the safety zone is then only a "safe distance" for digging between the lines.

[51] Only in exceptional circumstances (Art. 22 in the 2003 Gas Directive)

Due to the mentioned technical limitations the transmission systems for electricity and gas have be designed with caution and operated separately. E.g. the Transmission System Operator (TSO) in Denmark monitors the electricity and gas transmission grids using two respective System Operation Centres with different daily procedures.

In theory a combination with road infrastructure may be created. However, although the risk of incidents related to the gas line should considered to be small and there exist no legal impediments, most road designers and gas line designers would prefer not to place roads and gas lines in the same corridor. This is mainly due to the theoretical risk related to incidents with the gas lines, but also due to coordination and spatial issues. The safety zones are narrower than the risk zone in case of accidents where everything within 500 m may ignite (worst case). However, the risk is considered small and preventive measures are applied via the design, e.g. through the thickness of the steel, which can be quite costly.

2.6 Voice/data communication

It is important to notice in advance that communications in any infrastructure network are needed. For example road and rail infrastructure can't perform optimal if good communications network are missing. Communications networks should always be built with other infrastructure networks.

Regulatory and planning issues
The market for voice and data communication is a dynamic one due to the liberalisation of the telecommunication industry in Europe together with the rapid development of new technologies and services. Both supply and demand have grown quickly in recent years.

When the telecommunications industry considers implementation of new networks or extensions to existing networks cost-benefit calculations are performed with a relatively short timeframe in mind compared to the time frames for other types of infrastructures. Behind this lies the fact that today only the most successful voice/data communication technologies have a lifetime of more than 10-15 years (e.g. GSM). Thus the expected total lifespan of infrastructures for voice/data communication are comparable to the time spent on just the planning of the road and rail infrastructures.

Compared to the other infrastructure networks analysed, private involvement in communication networks is huge. It is therefore very important to allow access to the infrastructure in an open and competitive market, and not to disturb this competition. In this respect it is important to mention the 2002 EU Regulatory Framework on Electronic Communications, which governs all public telecommunications services. This framework is aimed at the implementation of an internal market in electronics communication networks and services through harmonisation and simplification of authorisation rules and conditions to promote competition and safeguard public and user interests[52].

[52] See a/o the Authorisation Directive on the authorisation of electronic communications networks and services. Directive 2002/20/EC

Furthermore, the exploitation of each new technology typically requires huge levels of investment. This specifically concerns licensing, the development of high tech equipment, land/site lease and/or installation costs.

The relative high level of deregulation and liberalisation in the telecommunications sector does create careful attention when combining this type of infrastructure with less liberalised sector.

Design issues
No significant design issues have been identified with respect to combining voice and data communication infrastructure with other forms of infrastructure in joint infrastructure corridors.

Cross-border issues
There are no significant issues concerning border crossing for communication infrastructure.

Construction issues
In general the infrastructure required for voice/data communication is quite adaptable to changing environmental conditions due to the variety of technologies which exist (electrical, optical and wireless). Furthermore, each of these transmission types is able - from a technical standpoint – to facilitate interconnections to almost anywhere in the world.

Requirements for voice or data communication infrastructures are very dynamic in comparison with e.g. road and railway infrastructure. Until the 1980's copper based infrastructures were used, then the emphasis was put on infrastructures based on fibre optic cables and lately broadband networks based on wireless technologies have started to emerge. The rapid development and obsolescence of infrastructures makes it difficult to include them into joint infrastructure corridors with other types of infrastructures (e.g. road and railway) that require long term planning. This nature of infrastructures for voice/data communication makes it very risky to attempt planning these infrastructures ahead because once an infrastructure is installed - even at marginal extra costs - there lies a job ahead of operating and/or maintaining the installations until actual use becomes a reality. If installations for future use are not being constantly maintained, their value will decrease quite rapidly to a point where installation of new infrastructure becomes more attractive when actual demand exists.

From a technical point of view a clear potential for optimised exploitation lies in the cohabitation of different services on existing communication infrastructures, e.g. when railways require communication infrastructure for the operation of the railway network, use/installation of extra capacity can allow other services to exploit the same physical infrastructure. However such solutions are often discarded by the owner of the physical infrastructure with reference to requirements for availability and safety of own services. Other reasons for making such solutions impossible are the problems of public companies offering services to selected private companies or private companies' reluctance to give up any kind of competitive edge in relation to other private companies.

Conclusions
Voice and data communication offer clear possibilities. The possibilities are mainly derived from the establishment of dedicated communication infrastructure for road, rail and electricity networks, which can be opened up and connected to other communication networks.

Joint planning of communication and other infrastructure by the different end-operators is less likely as the infrastructure for voice communication or data communication shows a much more dynamic development than for example road and railway infrastructure. The rapid development and rapid obsolescence of this type of infrastructure makes it difficult to include into joint infrastructure corridors with infrastructure that require longer term planning.

2.7 Conclusions

Based on the previous sections conclusions can be drawn on the technical feasibility of bundling infrastructures together. The table below provides an overview of the potential synergies with regard to technical feasibility. The potential level of synergy has been given a rating - low, medium or high:

- **Low**: Clear-cut irresolvable problem(s) have been identified which mean a low potential for synergy regardless of the extent of the possible benefits.
- **Medium**: There are neither irresolvable problems nor clear benefits. Negative impacts and benefits are approximately in balance.
- **High**: Significant benefits have been identified while problems or negative impact are absent.

The results presented in the following table are colour coded according to potential synergy level (red = low, yellow = medium, green = high). In the brief explanatory text (N) refers to negative effects and (P) to positive effects.

Table 2.1 Technical feasibility of synergies

Technical feasibility	Rail	Electricity	Gas	Communication
Road	(N) Curved line sections for road and straight line sections for railway.	(P) Road provides structures for obstacle crossing. (P) Electricity lines can in principle follow the road alignment.	(P) Road provides structures for obstacle crossing. (P) Gas lines can follow road routing.	(P) Road provides structures for obstacle crossing. (P) Communication lines can follow road routing. (P) Communication is necessary for road infrastructure.
Rail		(N) Corrosion of rails. (N) EMC issues due to electro magnetic field. (P) Railway provides structures for obstacle crossing. (P) Potential new opportunities by using lower capacity grids for interconnection.	(N) Electrified railways should be kept clear of gas lines. (P) Railway provides structures for obstacle crossing (P) Gas lines can follow railway routing.	(P) Railway provides structures for obstacle crossing. (P) Communication lines can follow railway routing. (P) Communication is necessary for railway lines.
Electricity			(N) HV installation induces significant voltage in steel gas pipes. (N) Temperature may cause damage to plastic gas pipes. (P) Underground electricity lines can in principle run parallel to gas lines, although usually the combination is avoided.	(P) Communication lines can adapt to almost any kind of infrastructure and make use of obstacle crossings.
Gas				(P) Communication lines can follow gas line routing.

Combining of electricity networks and inland waterways seems to be a promising combination.

An important aspect to keep in mind is that high class roads and high speed railways usually determine the minimum requirements for curve radii and gradients and the resulting alignments and routing may be less undesirable for other forms of infrastructure.

3 Possible synergies

3.1 Introduction

The bundling of different types of infrastructure is an existing phenomenon in Europe. Various examples can be sited, such as the parallel installation of fibre optic cables with other communication networks; the expansion or upgrading of rail networks (for example in France and the Netherlands); the combination of (gas)pipe networks with cable networks; a proposal to use the Brenner tunnel for high voltage infrastructure; the use of electricity networks for internet connections; multi-purpose bridges, etcetera.

Approach

In this chapter the possibilities and difficulties for combining various types of infrastructure are assessed. Particular attention is paid to the advantages that arise from the clustering of infrastructure. In this analysis three types of synergies are distinguished, being:

- ***Procedural synergies***, arising from the integrated planning of different infrastructure networks.
- ***Physical synergies***, due to a reduction of net negative impacts of combined infrastructure and cost savings during construction.
- ***Financial synergies***, being the additional value or revenues that can be created and captured when sections of infrastructure networks are combined.

In the following sections these three types of synergies will be elaborated on. The various potential advantages and disadvantages will be described and wherever possible quantified and backed by practical examples. In this way an overall evaluation of the potential for synergy will be made. In addition, a number of case studies is presented to illustrate the potential benefits that may be gained from combining certain types of infrastructure.

3.2 Procedural synergies

Procedural synergies stem from planning (and preparing) various infrastructure networks in an integrated manner.

Procedural aspects are especially important in the preparation phase of new infrastructure. This phase may vary greatly between countries and projects as a result of the complexity of the project, regulatory requirements (e.g. EIA, SEA), consultation, local opposition, expropriation requirements, design characteristics etc[53]. In most cases, the preparation of major new road building projects takes between 5 and 10 years while rail projects often take much longer. Combining different types of infrastructure during the preparation fase might thus benefit the pace of implementation of the TEN networks.

Various assessments of the implementation of TEN-E and TEN-T projects demonstrate that procedural and planning issues often cause delays in the implementation of projects. A conclusion from these assessments is that the implementation of TEN-T network projects at the local level are proceeding at a slower than planned rate[54]. To a certain extent inadequate public finance and difficulties with the mobilisation of private funds are contributing factors. But also a lack of coordination and coherence in investment decisions being made between Member States is also pinpointed as a major bottleneck.

The procedural bottlenecks and causes for delays specified in several studies include a lack of resolute planning, significant changes in project specifications, disputes in local courts and insufficient funding due to both changes in the spending priorities of national governments and the failure to attract private investment. Moreover, the cross-border nature of many projects exposes them to additional causes of delay, as this not only creates additional organisational complexities, but may also expose inconsistencies in local regulations or shortcomings in interoperability.

An extensive report on the primary reasons for delay in the implementation of TEN-E projects for gas and electricity projects[55] demonstrates that the causes are largely similar to those for transport infrastructure projects, in particular concerning issues related to technical regulations, standards and codes, environmental issues, administrative procedures and local acceptance issues. In addition developments in the last years concerning lack of investments in cross-border connections and increasing congestion also demonstrate that economic regulations and limited cross-border cooperation of TSO's add substantially to the delay in implementing TEN-E projects.

Thus a more integrated approach towards planning and management procedures could provide significant synergy benefits. This is further examined in the following sections.

3.2.1 Integrated corridor/axis planning and management approach

Problems related to the planning and coordination of cross-border projects (including interregional borders) have been documented in a number of studies. An integrated corridor/axis planning and management approach has the potential to provide significant efficiency benefits. In order to synchronise investment and promote coordination and coherency between Member States projects should be organised within a transnational framework.

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[53] See e.g. ECORYS (2005) Ex-post evaluation Cohesion Fund, Flyvbjerg et. Al. (2004)

[54] See e.g. ASSESS study: Assessment of the contribution of the TEN and other transport policy measures to the mid-term implementation of the White Paper on the European Transport Policy for 2010

[55] Anderson, study on environmental, technical and other aspects of authorisation procedures for Trans-European projects in the energy sector – Final report, February 2002.

Firstly, **a harmonised system of technical standards and regulations** in place on both sides of a border will help to prevent delays. In TEN-energy projects differences in national technical regulations have not caused significant delays in the construction of cross-border projects[56]. Rail projects on the other hand are still being hampered by the lack of harmonised standards. This has been recognised by the Commission which has issued Technical Specifications for Interoperability (TSIs) to ensure the compatibility of railway lines across the continent. The policy-making and decision-making processes for railway line proposals are generally quite extensive. This usually means that a great deal of time is taken between the inception of an idea and the final decision to proceed. A possible consequence is that it might be difficult or even impossible for other types of infrastructure (e.g. communication infrastructure) to adapt to the long planning timeframe of the rail sector, thwarting promising combinations of infrastructure.

Moreover, **conflicting regulation pertaining to the different forms of infrastructure** may hamper bundeling in a single corridor, irrespective of whether the corridor crosses any borders. These conflicting regulations often concern the field of safety and security. A case in point is the combination of road, electricity and gas infrastructure over the Danish island of Fuhnen. To make the combination of infrastructure possible additional safety and security measures were required in order to comply with “standard design regulations”. These measures were very expensive leading to the conclusion that a similar combination of infrastructure will not be readily chosen for in the future.

Coordinating investment in corridors contributes to more coherent planning within the EU. Planning the expansion of a network is a complex process taking into account parallel infrastructure projects, different stakeholders, as well as the deployment of operating systems (interoperability), the management of demand as well as a range of smaller obstacles and bottlenecks that need to be overcome. These aspects are easier to deal with in a single corridor than in an entire network. The standardisation of procedures and requirements along the full length of a corridor could promote transparency and lead to greater efficiency. Furthermore, corridor planning opens up the possibility for a single management structure in areas such as evaluation and public consultation, avoiding the need for separate procedures (see also sections on consultation and environment). European Commission initiatives such as the appointment of infrastructure corridor coordinators and the facilitation of “European Companies” are very important in this respect and their role should be further stimulated.

Corridor planning provides **more transparency concerning investment priorities**. Through the development of more rigorous mechanisms, committing public authorities to agreements on implementation, projects will be less prone to the vagaries of political opportunism. As a result, ‘missing links’ in infrastructure networks are less likely to occur. Finding appropriate and effective (financial) incentives and penalties to enforce agreements is particularly important in cross-border projects and projects receiving substantial European funding.

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[56] Anderson, study on environmental, technical and other aspects of authorisation procedures for Trans-European projects in the energy sector – Final report, February 2002.

3.2.2 Land acquisition

Land acquisition

The purchase of land and/or obtaining land access rights for infrastructure projects can be a lengthy process. Once planning licenses have been obtained, the acquisition of land can still be a difficult. Often land owners are opposing to development plans and refuse to sell their land. **The bundling of new infrastructure in corridors can lead to considerable advantages with respect to land acquisition**. Not every EU Member State has legislation concerning the forced sale of land for projects of (national) importance and the settling of compensation. For example, such legislation in Belgium does not cover the construction of electricity lines, making it more difficult to obtain land from private owners. This is a reason why electricity networks in Belgium are often built on public domain and alongside local and regional roads. A second example constitutes the construction of the Italian section of the Italy-Greece electricity link, which was specifically planned along the same corridor as a new regional road that was under construction. This type of combined planning also leads to cost savings and lower administrative burden.

When obtaining land and access rights for an infrastructure project, it is important that the potential for developing parts of other infrastructure networks is looked into at the same time. This means **planning ahead**. This requires good insight into the long term planning of various networks. Experience in the Netherlands demonstrates that projects in which the government acquired land rights along an entire corridor and provided space for the bundling of a number of different types of infrastructures, encountered less delays than other projects. In the United Kingdom, care taken to maintain good relationships with landowners plus a well regulated framework covering issues of compensation and land access, has proved beneficial to the acquisition of land for energy and transport projects.

If new cross-border infrastructure sections are made, future extension could already be taken into account. For example, with electricity infrastructure relatively cheap mantle tubes that can be used for both energy and communication cables could be buried at the same time. If, at a later stage, extra capacity is demanded, this can be added without new excavation works.
Such infrastructures could be useful in densely populated areas, or in areas where digging has a severe impact on the local environment. An example is the landing of offshore cables on the coast of the Netherlands, where the sand dunes have to be crossed. These dunes also play a role in the collection of drinking water.

3.2.3 Integrated public consultation process

Consultation process

As pointed out by the work by the Van Miert expert group on the implementation on TEN-T projects and authorisation procedures for TEN-E projects, the lack of **local acceptance** is a major factor causing delays in the construction of many infrastructure projects. In particular electricity, road and rail projects run a high risk of delay due to the 'NIMBY syndrome' ("not in my backyard"). The main reasons for opposition are concerns about health aspects (for example the effects of air pollution and electromagnetic fields associated with electricity and communication installations), safety (mainly for gas), the effect on amenity values (including visual impact and noise) and environmental protection. For example, a study on the construction of new transmission lines can be at times almost impossible due to opposition from residents in the affected areas[57].

There are a number of potential solutions that may contribute to lowering the resistance to infrastructure projects. These include the early involvement of local stakeholders during the planning stage, the encouragement of the formation of community groups, effective communication and (independent) assessment and monitoring of the risks and benefits of projects, also covering issues of compensation.

When infrastructure projects are bundled, a single public consultation processes could be advantageous because all **costs and (particularly) benefits can be presented together as a single 'package'**. As mentioned in the previous section, the coupling of projects can lead to lower total costs and less detrimental impacts than when two projects are developed separately. For example, the net impact on amenity values (visual impact, noise) may be limited and this is of benefit to the (local) community. Moreover, it may be possible to balance out resistance towards one type of infrastructure with the positive benefits of another type of infrastructure. Effective communication of costs and benefits are therefore crucial.

Box 3.1 Case: The Bilbao LNG Plant; overcoming local resistance

A good example is the Bilbao Liquefied Natural Gas plant in Spain, which was developed faster than most projects of its type. Besides political support for the project, the key reason behind the rapid implementation was the broad presentation of all aspects of the project encompassing the development of the gas plant and the power plant and highlighting the socio-economic benefits for the community. The direct and indirect benefits of the LNG terminal included an increase in maritime traffic in the port of Bilboa and the creation of 2000 jobs during the construction stage and 200 structural jobs during operation. Furthermore, the project had to go through an extensive planning procedure in which environmental issues were dealt with. This, in combination with environmental monitoring requirements helped to alleviate the environmental concerns of the public.

It is important to note that presenting projects together in one 'package' will only be advantageous when **the overall balance of advantages and disadvantages is positive**[58]. Linking or combining two highly complex projects, working out the total costs and benefits and dealing with public resistance may lead to the frustration of both projects. There is a danger that a project with a good chance of proceeding in its own right may be frustrated when coupled with a second project with a higher risk profile. A quick scan of impacts and stakeholders considerations should provide clarity as to whether presenting projects together as 'a package' is a good idea.

3.2.4 The role of Strategic Environmental Assessments

SEA & EIA

Directive 2001/42/EC on strategic environmental assessments of certain plans and programmes obliges network managers to make enquiries and **incorporate**

[57] Keller and Wild (2003) Long-term investment in electricity: a trade-off between co-ordination and competition?

[58] This can also be realised by introducing the notion of financial compensation for specific stakeholders (which have to be added to the total cost of the investment).

environmental aspects as far upstream in the planning process as possible in order to minimise delays at a later stage. As noted in previous sections combining or bundling infrastructure may be associated with significant environmental impacts and these effects will have to be taken into account at an early stage.

The BEACON report[59] addresses the broad issue of Strategic Environmental Assessment (SEA) of transport infrastructure, most notably in connection to EU Directive 2001/42/EC (usually referred to as "the SEA Directive"). SEA aims to promote a better consideration of environmental aspects in strategic decision making through the gathering and analysis of information within a systematic and participative process. It also has the purpose of encouraging greater transparency and integration. **SEA supports more effective strategic planning**, promoting greater coordination between projects and policies. It aids the identification of environmental impacts over a larger area (for example along the full length of a corridor) and can help in the planning of investment flows. For these reasons a Strategic Environmental Assessment can play an important role in assertaining as to whether the total impact of combined infrastructure development is less than separately developed projects.

For both individual projects (requiring an Environmental Impact Assessment, EIA) as well as programmes, **the need to take account of positive and negative effects at a broad level is particularly high for cross-border projects**, as impacts occur on both sides of the border and not only in the state or region promoting a project. The Espoo Convention (1991) and the EIA Directive define the procedures concerning cross-border effects (whether the projects are cross-border or not), setting down the protocol for impact statements and the exchange of information between the countries concerned.

The promotion of a **common perception and understanding of objectives and issues** associated with a major project within a larger (cross-border) region could provide a better basis for sustainable cooperation between stakeholders and help to build wider support among the public at large. An extensive transboundary consultation process may however lengthen the planning process, with delays due to notification (information sharing), gathering responses from all stakeholders, additional consultation and public participation, etc. On the other hand, broad consensus at an earlier stage of the planning process may help to create a climate of cooperation in the organisational, legal, political and public relations related spheres, reducing the risk of delays later on in the process. Such an approach may also provide transparency and greater certainty, both condusive to the attraction of private sector investment.

3.2.5 Socio-economic impact analysis

As for the assessment of environmental impacts of plans and programmes and projects, a similar case can be made for **socio-economic impact analysis**. Assessing the socio-economic impact of programmes throughout an entire corridor could bring the same benefits as described for strategic environmental impact assessments in the section above. Taking account of the socio-economic impacts of both programmes and projects on both sides of a border is again important. However, there is great variety between states and

[59] BEACON consortium (2005), **B**uilding **E**nvironmental **A**ssessment **CON**sensus on the transeuropean transport network.

between types of infrastructure concerning procedures and practices for socio-economic impact assessment. Not only do methods of appraisal differ, so do important criteria and parameters such as discount rates. This has a direct effect on decision-making. Harmonisation in the area of socio-economic impact analysis is therefore desirable.

3.2.6 Conclusions

Procedural synergies contributing in particular to a shortening of the preparatory phase of combined infrastructure projects can take various forms:

- Coordinated planning across modes
- Coordinated planning across borders
- Performing timely Strategic Environmental Assessments
- Combined land acquisition
- Combined, integrated consultation procedures.

Table 3.1 illustrates the potential for procedural synergy of the various combinations of infrastructure.

Table 3.1 Potential for procedural synergies by type of infrastructure combination

Procedural	Rail	Electricity	Gas	Communication
Road				
Rail				
Electricity				
Gas				

High potential; medium potential; low potential

The highest potential for procedural synergy concerns combinations of road, rail and electricity infrastructure. All these types of infrastructures are in general planned well in advance facilitating the possible combination with other types of infrastructure.

Because future extensions to gas networks in most cases tend to have a shorter preparation timeframe (often supply contracts driven), the opportunities for combination with other types of infrastructure are limited. Given the speed of development within the communications sector long term planning for this type of infrastructure is difficult, also limiting the opportunities for procedural synergies.

Allowing existing dedicated (for rail or road) communication infrastructure to be used for wider (open, commercial) purposes, seems to be the most obvious way to create procedural synergies as benefits are relatively easy to measure and tangible (cash flow). Once such use is allowed in the regulatory framework, the implications and benefits of such "double" use can already be taken into account as early as in the planning phase.

Obstacles for creating procedural synergy

However, a number of obstacles to creating procedural synergy can be identified:

- There may be considerable variations in the time perspective and demand related to each type of infrastructure respectively that makes it difficult to pursue a joint or even parallel planning process;

- There is often great variation in economic, strategic and business drivers and benefits between investors and the different stakeholders using the infrastructure networks. This hampers cooperation in the parallel planning and investing in combined infrastructure projects;
- There is a lack of national harmonised systems, technical standards and economic regulations;
- Specific issues related to one type of infrastructure may hinder the development of the other infrastructure;
- No framework or organisational body exists to ensure the required long term planning across all sectors and EU borders;
- Formal procedures for the planning of joint corridors are deficient;
- There is a lack of clarity concerning the financing of joint long-term planning of different types of infrastructure, hedging financial risks etc.
- There is a tendency towards ‘business as usual’ when the potential benefits of a collective approach are not sufficiently highlighted.
- There is a "regime change" in several TEN sectors, from previously national systems, managed by vertically integrated companies, into unbundled (partly) private companies and national network companies (TSOs) inheriting a network build up over many decades in the past. This requires new approaches and instruments to invest in infrastructures for the future.

3.3 Physical synergies

Physical advantages can be gained by combining or bundling (sections of) new infrastructure together with both new or existing infrastructure of another type. Generally speaking the type of effects (both positive and negative) under a combined approach do not differ from the type of effects under a solitary approach. The difference lies chiefly in the magnitude of the effects.

Types of physical synergy
Physical synergy arising from the bundling of infrastructure is related to the following aspects:
- Construction
- Operation and maintenance
- Environmental impacts

3.3.1 Construction

Combining different types of infrastructure has an effect on construction costs. Savings may be achieved due to economies of scale and scope, particularly with respect to ground works, structural works, and measures required for the mitigation of negative impacts.

Road infrastructure
With regard to road infrastructure there is a potential for reducing the total costs of construction for combined crossing of obstacles via bridges/tunnels (roughly estimated there may be up to 60-70% reduction of the costs for other infrastructure that can utilise road bridges/tunnels). The same goes for mitigating measures for noise (noise barriers)

from a combined road and railway corridor (roughly estimated up to 5% reduction of total construction costs).

Conduits typically benefit from utilising obstacle crossing infrastructure of road networks, and are traditionally allowed as "guests" in the road bed. This is sometimes organised together with a sharing of construction costs. It is common practice to place conduits the road bed or in bridges and tunnels to facilitate the installation of line infrastructure at a later date (for example data communication lines). This subsequent installation can then be carried out relatively cheaply.

The expropriation of land for combined infrastructure projects is usually more expensive than for a single stand alone project but is most likely to be cheaper than the sum two stand alone projects. A rough estimate of the cost savings available is 10 to 20 %.

Rail infrastructures
For combinations of rail and gas, power or communication lines, a reduction of construction costs can be expected.

Gas infrastructure
Only marginal financial benefits are expected to arise from the combination of gas lines with current roads, railway lines or electricity lines. A data communication line which is a "guest" of a gas line should deliver savings.

Electricity lines
Simultaneous construction of cross-border railways or roads and high voltage (HV) lines leads to a simpler spatial planning process and lower construction costs. There are several possibilities:

- The combination of overhead lines (OHL) with a dual carriageway. HV towers could be built in the central reservation with the conductors hanging above the roads. To reduce the risk of broken cables hitting the surface and high levels of electromagnetic fields, the towers could be made relatively high and slim[60].
- The combination of (rail) roads on the surface or in tunnels with HV cables or gas insulated lines (GIL)[61]. In the case of GIL, an interesting R&D topic is using concrete as a material in the HV construction. Instead of the greenhouse gas SF_6 that is usually applied as insulation, one could consider the option of using N_2.
- Special attention could be paid to synergies with bridges. Some cross-border interfaces are formed by water bodies, and a road and/or rail bridge infrastructure could perfectly double for transport of energy. Both OHLs and cables could be integrated into a bridge structure. HV towers could be made an integral part of the bridge construction, or conductors could be deployed below the bridge's surface. Cables could be buried in a concrete layer behind the surface, or in a 'tunnel' that is part of the bridge structure.

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[60] The latest ICNIRP guidelines on limiting exposure to time-varying electric, magnetic and electromagnetic fields result in OHLs with a considerably larger distance to ground than the current OHLs. http://www.icnirp.de/documents/emfgdl.pdf

[61] Studies have been made in the framework of the TEN-ENERGY program into the possibility of combining the new planned railway galleries Fortezza-Innsbruck under the Brenner Pass with a double GIL transmission line (IEEE Transactions on Power Delivery, vol. 20, no. 2, April 2005, pp. 704-709

One could consider the option of using the overhead contact wires for train tracks for the transport of electrical power. In several countries incentives exist for upgrading the existing overhead wires (1500 or 3000 V DC) to a higher voltage level (25 kV AC). With the return conductor that operates at −25 kV AC, effectively a cross-border system of 50 kV AC exists, which should be capable of transporting moderate amounts of power (10-50 MVA). Such a solution may be beneficial in areas where it is difficult to plan new lines, but where train tracks are already present.

A smart combination of power cables with glass fibre cables for information backbones minimises time and money for installation. Also, public acceptance will be better if the construction work for both purposes is done in one operation. Combining these cables can be done by inserting cables in the same trench or mantle tube. They can even be more closely integrated by inserting the glass fibre in the power cables themselves. Integration, however, will create the risk that failure within one of the networks will affect the other as well, leading more services to become unavailable simultaneously.

As indicated in chapter 2, combinations of electricity line infrastructure and inland waterway infrastructure appear to offer a clear potential, although this combination is currently hardly implemented. For the combination with a high voltage line, two possibilities seem promising and have impacts on the construction costs as well:

- Combination with overhead lines (OHL): from the beginning of the project an integrated design approach is followed. Sheet piling of the canal can also function as a concrete foundation. When the conductors are allowed to hang above the canal, the right-of-way requirements are minimal (advantages: single construction, easier obtaining the permits for two projects together, only one infrastructure influencing the landscape).
- Combination with cables: if the cables are buried in the bedding of a canal, the HV line has no visual impact. Besides, the water of the canal could offer natural cooling resulting in higher power transmission capacity (disadvantages: risk of anchors damaging cables, reburying of cables required when there are high water currents).

In addition to combinations between electricity and other types of infrastructure, the increased interest in large-scale renewable energy sources offer new possibilities for the development of HV cross-border interconnectors. The development of large-scale renewable energy production facilities that often have an intermittent nature and are located in the periphery of the system, e.g. offshore wind farms, could be combined and/or trigger the construction of new HV cross-border interconnectors (see also text box 3.2). To accommodate for the amounts of renewable energy generated at remote locations upgrading the transmission capacity is essential. The level of extra investments required for extending the grids that are put in place to facilitate the production of renewable energy at these remote locations to neighbouring countries, could be less compared to the costs of realising separate interconnection projects. This makes it an alternative worthwhile to consider. Also the increasing interests for energy storage could be viewed from this perspective.

Box 3.2 Potential synergies of combining HV interconnections with new RES investments

The growing interest in the large-scale application of renewable energy sources (RES) may offer an interesting potential for building new HV lines. Usually the places with the best potential for these sources can be found in remote areas where there is no or limited access to the grid. Examples include: • Offshore wind power. With wind energy leaving the phase of pilot projects, developers are aiming at increasing the size of their projects. Better wind profiles exist far away from the shore, but at these distances grid connection for individual farms to the shore becomes too expensive. Wind developer Airtricity together with ABB launched the plan for an offshore Supergrid[62], connecting countries surrounding the North Sea and providing a cheap grid connection for offshore wind farms. • The fluctuating power output of RES asks for storage of energy. Large-scale storage could e.g. be done with compressed air energy storage (CAES). Air is compressed/decompressed in empty gas fields. To reach these places, new parts of the HV grid need to be constructed, these could also be used to interconnect EU member states. • The construction of large energy buffers in the North Sea. A large reservoir with an increased water level is used as an energy buffer. The dikes could be equipped with wind turbines that are than more easily accessible for maintenance.[63] • Large-scale application of solar energy in Northern Africa.[64] Power demand in this region is low, therefore transmission capacity to Europe is proposed. This gives an incentive for strengthening the transmission network around the Mediterranean Sea.

Conclusions

The table below summarises the impact of combining infrastructure on construction costs. In general substantial savings are available.

[62] See: http://www.airtricity.com/ireland/media_center/press_releases/ireland/Supergrid%20launch.doc
[63] This could be read as a version of the *Plan Lievense*, see http://nl.wikipedia.org/wiki/Plan_Lievense
[64] See: http://www.gezen.nl/ (in Dutch)

Table 3.2 Potential physical synergies: construction costs

Construction	Rail	Electricity	Gas	Communication
Road	(P) Reduction of costs for combined crossing of obstacles (N) The construction process is more complicated.	(P) Reduction of costs for combined crossing of obstacles (N) Underground cables are the most expensive to implement.	(P) Marginal cost savings available.	(P) Reduction of costs for combined crossing of obstacles (bridge/tunnels).
Rail		(P) Reduction of costs for combined crossing of obstacles (N) Underground cables are the most expensive.	(P) Marginal cost savings available. (N) Electrified railways require mitigating measures with respect to gas lines.	(P) Reduction of costs for combined crossing of obstacles (P) Railway requires communication facilities anyway.
Electricity			(P) Marginal cost savings from combination. (N) Underground cables are the most expensive implementation. (N) Overhead power lines require mitigating measures to be applied to gas lines.	(P) Reduction of costs for combined crossing of obstacles (bridge/tunnels).
Gas				(P) Marginal cost savings available.

High potential; medium potential; low potential

Not indicated in the table is the possible advantage of combining inland waterways and electricity infrastructure, which also offer a clear opportunity.

As discussed in the previous section, a lack of tradition concerning coordinated planning across different types of infrastructure makes it more difficult to achieve the potential cost reductions highlighted above.

3.3.2 Operation and maintenance

Operating & maintenance costs

Economies of scale and scope can also lead to monetary savings with respect to operational and maintenance costs.

Road infrastructure
With respect to the road traffic network, a high grade road is a barrier to crossing traffic due to grade separation, necessitating the use of underpasses and overpasses. By locating motorways together with other types of infrastructure which also act as a barrier (e.g. railways) the total inconvenience for crossing traffic can be reduced because it is a case of a single barrier instead of multiple barriers.

Another aspect is that conduits in roads, bridges and tunnels complicate maintenance, as the infrastructure carried by the conduits must usually remain in operation for the duration of the maintenance activity. It is common practice to involve conduit owners in the planning of maintenance on roads, bridges and tunnels.

A road provides a stable and dependable environment for conduits with minimal risk of a third party unwittingly causing damage. Access to infrastructure, especially underground (cables) can be controlled. A potential benefit is that road infrastructure affords easy access to maintenance workers. Conduits may for instance be relatively easily accessible from the road.

Railway infrastructure
Operation and maintenance of a railway line is not made more complicated when the line is combined with other types of infrastructure. This is because maintenance activity on a railway line is carried out from the line itself.

On the other hand, the operation and maintenance of other types of infrastructures located alongside a railway line might be more difficult. For example, the combination gas-rail may be problematic if the two lines are located so close together that access to the gas line is impeded.

Gas and power infrastructure
A gas line may benefit from a location next to a road due to the easier access that this can afford. Furthermore the combination with other types of infrastructure may reduce the risk of digging damage due to a heightened awareness profile.

Conclusions
The table below summarises the impacts on operation and maintenance. In general impacts can be very positive. A common negative issue is that problems with one type of infrastructure may have a domino effect on the operation (eg. traffic blocks and power cuts) of other types of infrastructure with which it is combined. To ensure security of energy supply bundling different forms of energy together (gas & electricity) should be avoided.

Table 3.3 Potential physical synergies: operation and maintenance

Operation & maintenance	Rail	Electricity	Gas	Communication
Road	(P) Reduced number of barriers for crossing traffic.	(P) A road provides a stable environment with controlled access to conduits.	(P) Reduced number of barriers for crossing traffic (ground level gas lines). (P) A road provides a stable environment with controlled access to conduits.	(P) A road provides a stable environment with controlled access to conduits.
Rail			(P) Reduced number of barriers for crossing traffic.	
Electricity			(N) Risk with respect to security of energy supply.	
Gas				

High potential; medium potential; low potential

3.3.3 Environmental impacts

The clustering of infrastructure does not only have a positive effect on construction and operational costs, it can also help to reduce the (negative) environmental impacts. This is particularly the case with respect to the impact of transport infrastructure on 'third parties'. The following environmental impacts have been identified:

Fragmentation of landscapes
Clustering of infrastructure can reduce the level of fragmentation of landscapes. This is usually one of the most important reasons to concentrate transport lines in a single corridor.

Direct land use
The direct land use of infrastructure concerns the physical 'footprint' of the infrastructure itself. Clustering can reduce the total size of this footprint. A joint infrastructure corridor facilitates the efficient use of land, limiting the total cost of land expropriation (roughly estimated 10-20 % reduction of expropriation costs). This is due to the fact that additional land is nearly always required, for example in the form of safety buffers on both sides of motorways, which can be utilised for underground cables.

In theory, the clustering of infrastructure should reduce direct land use, however in practice this does not always lead to savings as demonstrated by Mätzhold (1993) in a study on the bundling of the motorway and railway line Köln – Rhein/Main. A comparison between a clustered and a non-clustered route for the railway line shows a higher amount of land use for the non-clustered alternative. Although this can be explained to a large extent by the longer length of the route of the clustered alternative, the analysis also shows that the relative increase in land use is higher than the difference in the length of the two alternatives.

Table 3.4 Comparison of impacts on direct land use of railway line Köln – Rhein/Main

Route	Length route	% length route	Direct land use	% direct land use
Non-clustered route	108 km	100%	308.6	100%
Clustered route	115 km	106.5%	332.1	107.6%

Source: Mätzholt, K., Der Landschaftsverbrauch durch die Verkehrsträger im Vergleich, in: VDIBerichte 1041, VDI-Verlag, Düsseldorf, 1993.

Noise hindrance

The clustering of infrastructure can reduce the overall noise hindrance caused by traffic and transport. Concentrating roads and railways together (in a spatial context) will general result in higher noise levels, but a smaller adjacent area will be affected (and therefore limiting the number of people affected). Furthermore, it is easier (and cheaper) to implement mitigating measures, such as noise barriers, which only have to be built once.

Emissions

The clustering of infrastructure will not reduce the amount of emissions produced by traffic, the clustering will have the effect of spatially concentrating the hindrance caused. As with noise this will in the most cases lead to a smaller number of people being affected, although emission levels may be higher.

Indirect land use

In comparison to non-clustered infrastructure clustering will reduce the size of 'hindrance zones' (for example due to noise hindrance and safety buffers), thus leaving more space available for other purposes.

In the study by Mätzhold on the railway line Köln – Rhein/Main (see above) indirect land use was also examined. The table below shows the results of this analysis, demonstrating that the indirect land use of clustered routes is less than the non-clustered alternative. The table also shows that the amount of indirect land use is highly sensitive to the distance between the sections of infrastructure that are clustered. A small distance between the sections forming the cluster leads to much lower indirect use of land than a situation where a 'large' separation distance exists.

Table 3.5 Comparison of impacts on indirect land use of railway line Köln – Rhein/Main

Clustered route	Clustered route	Clustered route	Non-clustered route
Separation distance < 40 m	Separation distance 40-120 m	Separation distance > 120 m	
261 ha	356 ha	546 ha	746 ha

Source: Mätzholt, K., Der Landschaftsverbrauch durch die Verkehrsträger im Vergleich, in: VDIBerichte 1041, VDI-Verlag, Düsseldorf, 1993.

Visual hindrance of infrastructure

Clustering can reduce the total amount of visual hindrance caused by infrastructure. A case in point are gas lines being planned alongside roads in corridors between Gerona in Spain and Perpignan in France, between Helsingborg and Göteborg in Sweden via Fuhnen in Denmark, in Hungary and in former East Germany (the latter in the form of a gas line above ground). The Gerona-Perpignan gas line also runs alongside a railway line, as are long sections of the north-south corridor in Sweden.

Conclusions

Table 3.6 summarises the possible synergies concerning external impacts.

Table 3.6 Potential physical synergies : environmental impacts

External impacts	Rail	Electricity	Gas	Communication
Road	(P) Potential for concentration of visual impact on scenery. (P) Concentration noise (and emissions)	(P) concentrated visual intrusion (P) less fragmentation; reduced (more concentrated) use of space	(P) Potential for concentration of visual impact on scenery.	No major impact
Railway		(P) concentrated visual intrusion (P) less fragmentation; reduced (more concentrated) use of space	(P) Potential for concentration of visual impact on scenery.	No major impact
Electricity			No major impact	No major impact
Gas				No major impact

High potential; medium potential; low potential

Combining different types of infrastructure in a single corridor can lead to a reduction of the total amount of land required. This is potentially true for all combinations. There will usually be additional benefits possible in terms of limiting noise, air pollution and negative visual impacts to a smaller area. With respect to noise, there are cost savings possible when it comes to building noise barriers.

3.3.4 Safety

Unlike the environmental impacts described above, clustering of infrastructure may have a negative effect on safety. Fatalities and injuries resulting from accidents will possibly be more severe on clustered sections of infrastructures networks.

Although the risk of accidents during the operation of gas lines is very small and within legally accepted limits, there appears to be resistance from a number of road designers and gas line designers to the idea of clustering infrastructure in a corridor. This is mainly due to the theoretical risk related to incidents with the gas lines, but also due to coordination and spatial planning issues. The safety zones are narrower than the risk zone in the case of accidents where everything within 500 meters may ignite (worst case). However, the risk is considered small and preventive design measures are available, for example with regard to the thickness of the steel, that can be quite costly.

Clustering infrastructure may have some serious consequences when something goes wrong. There is the risk that incidents or accidents will have an impact on neighbouring infrastructure. This occurred for example in Zutphen in the Netherlands in November 1999, when construction workers working on a cable network damaged a gas pipeline. In the resulting explosion two construction workers were injured and a parallel highway was blocked for many hours. A second incident occurred in Vise in Belgium in 2000. A freight train loaded with chemicals and flammable gases derailed and, although there were no fatalities or injuries, the parallel highway between Maastricht and Liège was closed for more than a weekend while the wreckage was cleaned up.

Both examples show that the clustering of infrastructure carries with it an extra risk. Literature on this subject[65] pays particular attention to the potential 'domino effect' when accidents occur. The heightened risk levels associated with the clustering of infrastructure may be to a limited extent offset by increased accessibility of accident locations if and when they occur.

It is difficult to find statistical evidence to back up the higher theoretical risk of clustered infrastructure with regard to transport safety. Rosmuller (2001) assessed the extent to which clustering might affect accident frequency on road (highway), rail, inland waterway and pipeline infrastructure[66]. He concluded that there is no strong empirical evidence for the assumption that clustering of line infrastructures significantly increases accident frequency or has a bearing on accident causes. On the other hand, there are several examples of cases where the clustering of line infrastructure resulted in more severe impacts when accidents occur. The effects of an accident in terms of fatalities and injuries seem to be more severe on clustered sections of line infrastructure.

In an integrated consultation process in which all aspects of a multifunctional project are discussed, the public safety will be better safeguarded as decision makers would be prevented from making incremental adjustments to the project in question. Ideally, all future restrictions/alterations of the land use are laid out for discussion at once instead of being introduced little by little. The inclusion of all new infrastructure construction into the EIA will provide a more comprehensive and fair basis for assessing the total environmental impact.

A further issue is that combined infrastructure is more vulnerable to terrorist attacks and in the event of an outbreak of war.

Conclusions

The table below summarises the safety aspects of combining infrastructure.

[65] See or example Rosmuller, N. 2001, *Safety Analysis on Transport Corridors*
[66] idem

Table 3.7 Synergies on safety

Safety	Rail	Electricity	Gas	Communication
Road	No major issues.	(N) Overhead power lines endanger traffic (icicles).	(N) Safety risk for road traffic in case of incident makes it undesirable to combine gas lines and roads.	No major issues.
Railway		(N) Overhead power lines endanger traffic (icicles).	(N) Safety risk for railway traffic in case of incident. (N) Great safety distance between gas lines and electrified railways.	No major issues.
Electricity			(N) Great safety distance between gas lines and overhead electricity lines.	No major issues.
Gas				No major issues.

High positive potential; medium risk potential; high negative potential

3.4 Financial synergies

In addition to procedural and physical synergy there may also be financial advantages resulting from the clustering of infrastructure, through the creation of additional revenue possibilities for owners and operators. This phenomenon is often referred to as "value capturing".

A mechanism that could be used to encourage this type of synergy is to allow a greater degree of freedom in the scope of use of specific infrastructure (private parties should be allowed to offer more services). For example inviting private parties to make proposals involving both the energy and transport sector could thus lead to innovating solutions and greater private participation. A more strongent approach would be to oblige private parties to include communications infrastructure in their offer.

There are various examples of cases where such financial advantage resulting from combining or bundling infrastructures occurs and can be captured. First of all, hubs or nodes of transport infrastructure are known to be valuable locations for business with a high development potential.

Furthermore, combined or bundled infrastructure can provide additional value to the infrastructure network and the services of its operators and users. In rail there are already communication networks in place to operate the rail network more efficiently and safer. Using the excess capacity for other commercial purposes by renting out or selling part of this capacity could provide extra revenues for the network owner. In India communication infrastructure previously entirely dedicated to railway operations, is now being used to provide rural areas with broadband access (see box 3.3).

Box 3.3 Using railway lines to provide broadband access in rural India

India has one of the worlds most widespread and dense rail networks with 8000 train stations nationwide and an average distance of only eight kilometres between them. Trains are a vital form of transport in India, providing affordable transportation to both the lower and the middle classes. India's railway infrastructure extends deeply into rural areas and carries the most passenger traffic in the world.

One approach to expanding the network in India has been to allow winning bidders of fixed-line services to convert their licences to wireless local loop (WLL) licences, which has led to the use of the railway network to provide Internet access.

In a plan launched in 2000, the Railroad Internet project aims to make use of some 40 000 kilometres of underused cable infrastructure already in place. This signalling cable (which is usually copper-based, although fibre is used on several main routes) runs along the train tracks and has large amounts of spare capacity. It will be used to transmit Internet traffic to outlying areas, avoiding the need to lay down a new cable network.

The project aims to set up special cybercafé kiosks (providing community Internet access and ticket services) at each train station, with computers networked together via the railway cable. This system will be integrated with the standard telephone network through high-speed digital links at major towns.

A pilot project has carried out in a small area along 40 km of railway track linking the towns of Vijayawada and Guntur in the eastern part of the country. This initial phase was carried out through cooperation between Indian Railways (State owned) and private investors.

Railtel Corporation of India, the communication arm of the Indian Railways, recently announced that it will continue the project, allowing it to leverage the existing network infrastructure in order to provide broadband services to service providers, ISPs, enterprise corporations as well as individual residents located in towns and cities all along India Railway network. In 2003, RailTel Corporation of India Ltd. has earned Rs.5.22 cr by leasing of bandwidth and other telecom infrastructure. The company earned some Rs.12.5 cr in 2004.

The first cybercafé, launched at New Delhi Station, has facilities for web browsing, e-mailing, games, Internet telephony, scanning, printing, photocopying, faxing and video-conferencing, according to Delhi Newsline news sites.

Sources: Indian Railways (2001). BBC, "Fast track for Indian Internet" (31 May, 2000), Annual Report of the Railtel Corporation of India Limited, New Delhi, for the year 2003-2004.

New and upgrade types of communication infrastructure provide new opportunities to increase the value of the network and services. For example, GSM based communication could be extended to fit the needs of railway applications. Standardised GSM-R could develop as a powerful digital telecommunication system offering new or improved applications for railway enterprises and providing European-wide interoperability, improved safety, extended or new services for the railways and their customers. At the same time these kind of networks could be used by other telecom operators as well.

Box 3.4 Value-capturing: use of the railway fibre-optic communication network. The case of Telfort

In 1996 the company Telfort was created through a joint venture between British Telecom (BT) and the Dutch Railways (NS). BT was looking to expand into continental Europe, while NS wanted to exploit its fibre-optic network more effectively. In 1998 Telfort obtained a concession for a GSM network with a national coverage in The Netherlands. In 2000, NS sold its share in Telfort to BT for 1.5 billion Euros. It was agreed between NS and the Dutch State that of this revenue some 1.4 billion would be reinvested in infrastructure.

Sources: NS Annual Report, 2001; NRC Webpagina, 12 April 2001.

Furthermore, linking different railway communication networks (ERTMS / ETCS) provides railways with the possibility of offering electronic seat reservation, freight tracking and communications with customers to control logistics and production in railway-related plants.

Box 3.5 Combining railway development with voice data/communication: the case of LGV Est_Européene

In the context of the present study a more detailed case study analysis has been carried out on the synergies that were realised with the construction of the "LGV Est_Européene", a high speed line between Paris and Strasbourg.

It can be concluded that, as the LGV project nears completion, the only synergy realised is that of voice/data communication infrastructure in tandem with the railway. This combination was achieved at a fairly late stage, as mobile telephone network operators did not engage in the sort of long term advanced planning that enabled them to provide a clear commitment during the planning and design phases of the LGV project. The difference in perspectives and planning background made the two projects incompatible with respect to the planning and design of synergy.

For a more elaborate description of this case study see Annex A.

Offering new communications services to passengers helps to improve the competitive positions of specific train operating companies as well as rail transport in general. According to a recent UK survey, some 72 per cent of business travellers would choose train over other plane or car if the carriage were equipped with wireless internet access[67].

Moreover, 78 per cent of business travellers would use the WiFi services were they to become available on trains. Respondents in the study firmly believe that wireless internet access on trains will improve their own productivity.

Box 3.6 Value-capturing: offering WiFi in trains

Mobile operator T-Mobile UK is offering broadband WiFi service on trains and to passengers on the London to Brighton rail route since spring 2005, claiming to be the world's first to offer such services. Passengers on Southern's express rail service between London and Brighton will be able to send and receive e-mail or surf the internet while travelling on the train. The WiFi service for commuters, offered passengers on a limited number of trains on this route broadband speeds from their WiFi enabled laptops or PDAs for the whole journey. The rail service between London and Brighton is one of the busiest railway routes for business people travelling to and

[67] Broadreach Networks, 2004

from London. The telecom company is working in a partnership with Southern, who are providing access to the trains and station locations.

Also Virgin Trains is planning trials of WiFi services on its West Coast main line Pendolino trains in the second quarter of 2006. Virgin has been working with Qinetiq Rail and Broadreach to test the feasibility of offering public wireless internet services on its trains.

In other countries railway operators are also experimenting with WiFi in trains. In Switzerland, passengers will also be able to access the internet aboard trains. In a first trial starting in 2005, Swiss Federal Railways (SBB) and Swisscom Mobile have equipped 35 single-decker IV coaches and 40 first-class double-decker IC-2000 coaches with the infrastructure for online access. These coaches are used for long-distance routes, primarily along the East-West axis. The radio signal is forwarded from the terminal device to an external antenna via antennas inside the train. The external antenna then sets up the online connection over the existing mobile network. If the project proves successful, first-class coaches of ICN tilting trains and the remaining IC-2000 and EW IV coaches will be equipped for internet access by the end of 2007.

Dutch railway infrastructure manager ProRail is also investigating the use of these wireless technologies to connect (through the internet) wireless cameras for monitoring station halls and railway yards. Other applications being investigated by ProRail also include the use of voice-over-IP (VoIP) technology for wireless calls; installing ‘multi-operator hotspots’ (where several operators could sell WiFi-based wireless internet-access); and monitoring rail-freight flow.

Sources: www.t-mobile.co.uk (checked March 2006); www.southernrailway.com (checked July 2006); wifinetnews July 16, 2004

As for road infrastructure, financial advantages could be created in a similar manner as those for rail (see box 3.7). Along many sections of road networks communication infrastructure has also been constructed, providing Intelligent Transport Services (ITS) such as traffic monitoring and signalling. As with rail, excess communication infrastructure dedicated to roads could be made available for other commercial purposes. Moreover, ITS services in road networks could provide valuable services to road users and traffic managers that in some cases could be expressed in terms of financial gains[68].

One particular area in which ITS provided through communication networks alongside roads could be of considerable benefit, is traffic safety. This has been one of the key drivers behind the eSafety programme of the Commission, which has identified that new active safety measures are needed to open the additional safety potential needed e.g. preventing accidents. ITS plays an important role in this. Applications will mainly involve these three areas[69]:

- advanced driver assistance, increasing road safety by reducing the number of accidents as well as reducing the impact in case of non-avoidable accidents
- decentralised floating car data, improving local traffic flow and efficiency of road traffic

[68] SEiSS, 2005; Exploratory study on the potential socio-economic impact of the introduction of intelligent safety systems in road vehicles.

[69] European Commission, eSafety website 2006.

- user communications and information services, offering comfort and business applications to driver and passengers.

Box 3.7 Value-capturing Case: WLAN based services to road users

The Austrian state corporation responsible for managing the country's roads and motorways, ASFiNAG, has invited interested companies to set up a test wireless local-area network (WLAN) in the area around Klagenfurt. The WLAN is intended to provide wireless internet access for motorway users, heralding a new era in 'mobile' services.

A WLAN is a type of local-area network that uses high-frequency radio waves rather than wires to communicate between nodes. If ASFiNAG's strategy goes according to plan, the term "information highway" could take on a new meaning as the infrastructure is put in place for the development of a whole range of new, internet-based services for motorways users. These could include in-car internet access, VoIP (voice over internet protocol) telephony, and advisory and traffic information services. With the new WLAN offer, ASFiNAG aims to create 'intelligent' motorways.

ASFiNAG announced on 13 April 2006 that at the end of 2006 a field test with a WLAN is to be started on the A2 southern highway near Klagenfurt. ASFiNAG sees the system as justified by the collection of numerical data about traffic flow and weather, as well as by the delivery of warnings to the car. With the WLAN offer on the motorway, they want to pursue the strategy of putting over the 'hard' road system a 'soft' information network in order to make the Austrian motorways 'intelligent'.

The project's particular technical difficulty is the WLAN's short range. Radio cells must be placed every few hundred metres so that a trouble-free 'handover' becomes possible, changing from one radio cell to the next without interruption. At a speed of 130 kilometres per hour, there would be approximately 20 handovers per minute. Another aim is to provide unrestricted functionality of internet telephony by means of VoIP.

ASFiNAG looks to cooperate with enterprises interested in the free installation of mobile WLAN infrastructure. ASFiNAG's optical fibre cables will be made available for backhaul communication. According to the operator, there are at present in Austria approximately 2100 km of motorway, of which approximately 1000 km now have optical fibre installed; by the end of 2007 it should be 1700 km. Free access to the infrastructure within the enterprise only lasts while the mobile net is available for the road service. Consequently access to the WLAN is also to be offered to the motorway users. The basic offer is to be financed by Austria's motorway user fee. The cost of traffic-specific WLAN services will be covered this way in the future. But any increase in value for the user from web-surfing and telephoning, would be paid for by individual users.

The possibilities of WLAN technique are even further explored. A coalition of European automobile industry companies have formed a consortium investigating the possibilities of WLAN car-to-car communications systems. The consortium hopes to deliver a European standard for the technology which enables cars to wirelessly communicate with its environment, collecting real time traffic information on accidents, traffic jams and alternative routing. Beyond the reduction of traffic risks, many other applications become possible: Imagine e.g. using a 'drive through check in counter' at the airport, forwarding travel info or music to your car from your living room PC or receiving a modified itinerary from your company at the petrol station to save time and energy. The research is amongst other funded from the FP6 and has also received funds from the German Research Ministry.

Also in the UK, British telco BT is carrying out research investigating the possibility of using vehicles on the UK's roads to create a large-scale communications network. BT's "Traffimatics" research project, which is part-funded by the UK Department of Trade and Industry (DTI), is also looking at car-to-car communications to provide better information on the volume and type of traffic will help governments implement road toll schemes where they will be most effective. The use of such information could also help to control congestion, shorten journey times and ensure optimum fuel consumption resulting in lower pollution levels.

The prototype solution, which is based on open standards, uses off-the-shelf components and open-source software to implement an on-board platform. It will also include traffic control applications such as a parking-space finder, and a system that can detect traffic jams, road congestion and obstacles on the road, all based on data related to the vehicle's position.

Source: ASFiNAG, 2006; BT, 3 November 2004; European Communities, eGovernment News, 29 April 2006; Network on Wheels, 2006

As a final example, also electricity networks have dedicated communication networks that could be used for other purposes. Moreover, the electricity lines itself can sometimes even be used for communication purposes. Also, a combination of both is possible (see box 3.7). Electricity utilities often have extensive networks of fibre-optic cables within the power grid to enable communications between electrical sub-stations in the power networks. An example of this could be found in Iceland. Once the installation of fibre-optic cables is more widespread throughout the power grid (beyond major urban areas), the excess capacity could be used to accommodate other rural users in the service area. Most of the cost of laying the fibre can be offset by savings achieved from more efficient electricity distribution. As a result, the incremental cost of opening up the network for broadband communications can be minimised[70] .

Opening of previously dedicated networks is promoted by the trend that utility companies - increasingly entering the field of telecommunication services - tend to have a so-called "open network" strategy. Whereas typical telecom providers that have started offering broadband tend to provide all the services themselves, companies like Reykjavik Energy see themselves only as the providers of the infrastructure, not the actual service providers. Anyone that wants to offer services on the fibre-optic network can sign up with the utility company according to a set pricing scheme, regardless of their offering. This model is also very tempting for service providers. With access to the utility company's infrastructure, they can dedicate their resources to the equipment and services that are needed to offer their specific service, rather than spending money on catching up with infrastructure already in place by the competition[71].

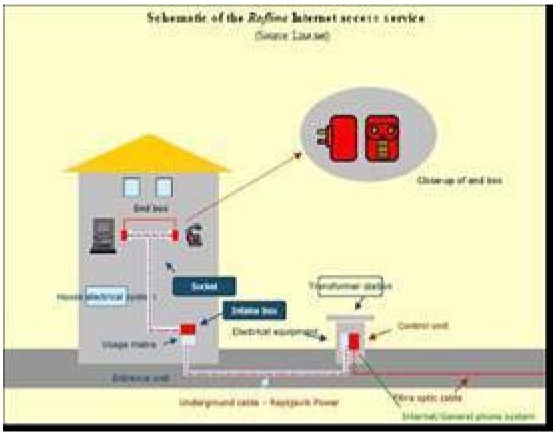
Utility companies and telecom operators are also increasingly realising that when building Fibre-To-The-Home networks, an "overbuild" strategy pays off quickly. Overbuild in this case means not merely connecting the household, but actually installing Customer Premises Switches in homes regardless of whether the household has already bought any services that use the connection. If the engineers are in the building to connect one apartment, they connect all other apartments in the building at the same time, free of charge to the home-owners. Once the CPS is there, the barrier for the customer to sign up for a service has become a lot less high[72].

[70] ITU report "Birth of Broadband", 2003
[71] Hjalmar Gislason, Digital Reykjavik conference report, December 14, 2003.
[72] Idem.

Box 3.8 Value-capturing Case: Internet over power lines

Iceland has one of the highest Internet penetrations in the world. Following a major change in local telecom regulations in 1999, power companies could enter the telecom market and start implementing an advanced core fibre network. Since then, two of the key players in telecom are Orkuveita Reykjavikur (Reykjavik Energy, OR), whose operations are through Lina.net, and National Power Company, through Fjarski.

The Reykjavik Power Company has established a data transmission network over its power grid that connects its power transformer stations around the capital. Supplemented by fibre and fixed-wireless access, the company currently offers broadband solutions to corporate customers. OR's service, branded as “Raflína”, started in 2001 using the company's distribution stations and power grid to connect to the metro fibre network.



Using their fibre network, OR is planning to connect every home with a fibre connection, also called Fibre to the Home (FTTH) deployment. Fibre to the Home (FTTH) or Fibre to the Premises (FTTP) is a broadband telecommunications system based on fibre-optic cables and associated optical electronics for delivery of multiple advanced services such as the triple play of telephone, broadband Internet and television all the way to the home or business. In the near future, FTTP, also referred to as Extreme Broadband, will deliver performance speeds exceeding 100 Mbps downstream.

OR has begun connecting the towns of Seltjarnarnes, Akranes and parts of Reykjavik, and it is estimated that 50% of Reykjavik will be connected by 2008 and all of Reykjavik, Seltjarnes, Akranes, Mosfellsbær, Þorlákshöfn and Hveragerdi by 2012, whilst connections to other areas are pending an agreement by city officials.

The infrastructure for the electrical grid has proven to be of special value. The core network connects 450 substations of the city's electrical distribution network with fibre optic cables. The distance from each household in Reykjavik to one of the substations is usually less than 400 meters with an average distance of about 200 meters. This infrastructure is utilised when installing the fibre optic network to offer fibre connections to businesses and residential connections over power lines. Moreover, as major utility service provider OR has already got a business relationship with every single home in the area. It has allowed OR to build a distribution layer ready for FTTH when it became viable, yet to capitalise on the distribution network right away.

OR only owns the FTTH network, offering it at an access or usage charge to third party communication service providers. Internet Services (ISPs) are provided by HIVE, Skýrr, Vortex and VoIP[73] service is now available

[73] Voice over **Internet protocol**,

from HIVE and video will be provided by other third party providers. Shortly, eServices and data from Idega eGovernment solutions and other Idega products will be available through the TV set. The Digital TV portal and the Web portal are becoming two faces of the same system. The users simply chooses which device to use when applying eServices or viewing information. As time passes, it is expected that other companies will also take part of OR FTTH network. The monthly cost of having the FTTH in house is 1.990 ISK (approx 20 EUR) which is a little more then having a phone line in the house which costs 1.340 ISK (approx 14 EUR); this does not include any services. All FTTH connections are 100 Mbit/s but today ISP services offer speeds of 10Mbit/s, 20 Mbit/s and 30 Mbit/s.

Iceland not the only country where power companies have moved into the telecom business to capitalise on the ability to use their electric power infrastructure for telecommunication. In Denmark the northern parts of Zealand north and west of Copenhagen the Power Company Nesa is providing FTTH to areas where they are laying airborne power cables in the ground, with 100 Mbit/s connection. The services on the FTTH will be provided by external providers. The plan is to have all of these areas provided with FTTH by 2010 and then follow up on those areas that haven't been giving the opportunity during that time. While also FTTH projects elsewhere - notably in Japan, South Korea and Italy - already have fibre-connected areas with larger populations than Reykjavik, the Reykjavik plan might be the first where an area that represents a whole society is to be connected with FTTH.

Sources: Lara Srivastava (ITU) & Ari Jóhansson (PTA), New Initiatives Workshop on Promoting Broadband Geneva, Switzerland April 9, 2003; Idega, 2/16/06; Hjalmar Gislason, Digital Reykjavik conference report, December 14, 2003.

3.4.1 Conclusions

Table 3.8 summarises the potential for synergy with respect to financial advantages. In particular combinations involving communication infrastructure with road or rail infrastructure have great potential to deliver extra financial benefits.

Table 3.8 Synergy in the form of financial benefits

Financial	Rail	Electricity	Gas	Communication
Road	√, as business locations	Unlikely to generate additional benefits	Problematic because of safety and security	√
Rail	N/A	Possibly, when lower capacity (rail) power lines are integrated into the distribution network	Problematic because of safety and security	√
Electricity		N/A	Maybe	Use of existing fibre-optics infrastructure and LV electricity lines (tertiary network); not through HV cable
Gas			N/A	Maybe
Communication				N/A

4 Conclusions and perspectives

Trans-European Networks play an essential role in the implementation of the Commission's Lisbon Agenda in promoting economic growth. A high level of political urgency has been attached to all three TEN sectors (Transport, Energy and *e*TEN) and ambitious targets have been formulated. Achieving these ambitions will involve major efforts from all parties involved, not only in terms of funding but also with respect to far reaching levels of cooperation.

Creating synergy between networks could help to accelerate the pace of implementation of the TENs and contribute to an enlargement of the potential benefits.

In the study three types of potential synergy have been distinguished:
- ***Procedural synergies***, arising from the integrated planning of various infrastructure networks.
- ***Physical synergies***, lower costs and impacts due to the combined construction of sections of infrastructure networks and structural works (eg bridges, tunnels, underpasses).
- ***Financial synergies***, being the additional value or revenues that can be created and captured when sections of infrastructure networks are combined.

Procedural synergies
The advantage of procedural synergies lies mainly in time savings during the planning process. This type of synergy can be created through various mechanisms:

- Coordinated planning across modes
- Coordinated planning across borders
- Performing Strategic Environmental Assessments
- Combined land acquisition
- A combined, integrated consultation process for packages of infrastructure.

Longer term integrated strategic planning

Longer term integrated strategic planning (across modes and sectors and across borders) enables a better co-ordination between different types of infrastructure, as well as between cross-border sections of infrastructure. Better planning, for example by identifying potential hurdles in an early stage, will help to speed the planning process, which is often cited as one of the key factors causing delays. Improved planning also involves the creation of institutional mechanisms to facilitate the combination of infrastructure. A SEA is an instrument that fits in this process. It can explicitly address the issue as to whether different sets of infrastructure lend themselves to combination and if so, how a joint process should be entered.

Synergies in reduced local resistance and improved land acquisition process

Reduced resistance from local communities and reduced delays resulting from land acquisition are common procedural advantages associated with the combined construction of different types of infrastructure. Procedural synergies are most common when combinations are made between road, rail and electricity infrastructure. These types of infrastructure are generally planned well in advance, providing time to organise combinations with other types of infrastructure. Gas line extensions usually has a shorter planning time frame (because of dominance more commercial drivers like supply contracts etc.) as does new communication infrastructure due to rapidly changing technologies.

Obstacles in creating procedural synergies

However, there are also obstacles for creating procedural synergy. Common issues concerning all combinations are:
- There may be considerable variation in the planning time frame for each type of infrastructure which stands in the way of joint or even parallel planning;
- Technical standards, regulation and policies are not harmonised;
- Specific issues related to one type of infrastructure may impede the parallel development of another type of infrastructure;
- No framework or organisational body exists to ensure the necessary long term planning across the different involved sectors, countries, stakeholders;
- A source of finance for the joint long-term planning of infrastructure across the implicated sectors has yet to be identified or established;
- The lack of formal procedural mechanisms for joint corridors is a barrier;
- The potential for real benefits needs to be clearly evident and properly/fairly allocated over the various parties involved in order to avoid an attitude of ‘business as usual’ whereby each of the parties involved is focussing on its own sector/mode and not on the potential for combinations. Nevertheless it has to be acknowledged that the party that is investing should receive a decent return on its investment;
- The organisation and regulation of the sector (independent private operators; most incentives are national based) hampers a cross-border approach. There is a "regime change" in several TEN sectors, from national systems, managed by vertically integrated companies, into unbundled (partly) private companies and national network companies (TSOs) inheriting a network that was build up over many decades. This requires new approaches and instruments to invest in infrastructures for the future.

Physical synergies

Physical advantages and disadvantages can arise from combining or bundling of (sections of) infrastructural networks along both existing and new infrastructure.

Construction cost savings are expected primarily for certain combinations especially in expropriation and combined obstacle crossings (bridges, tunnels)

The physical combination of infrastructure has an effect on construction costs. Combinations generally result in substantial monetary savings. Typical costs savings are expected due to:
- Reduced expropriation costs (10-20%);
- Reduced construction costs for combined crossing of obstacles (roughly estimated up to 60-70% cost reduction for other infrastructure that can utilise (existing) road bridges/tunnels for obstacle crossing);
- Reduced costs for measures to mitigate negative effects (e.g. noise barriers);

The largest savings are expected to result from the combined construction of structures (bridges, tunnels etc.) , for road/rail infrastructure networks in particular, but also for combinations of the road or rail with communications networks or electricity transmission lines.

On the other hand certain combinations will greatly increase the complexity or introduce additional (safety) requirements that have a negative bearing on cost levels. This includes for example combinations involving gas lines which are expected to lead to only marginal cost savings (if any).

Impacts on O&M and the environment are mostly positive, whereas safety risks are higher

The impacts of combining sections of infrastructure networks on their operation and maintenance of infrastructure are in general positive. The combined controlled environment allows easier maintenance. The environmental impacts associated with the combining infrastructure are in general positive. Clustering of infrastructure reduces the fragmentation of landscapes, visual hindrance, the amount of land used (directly and indirectly) and the negative impact of emissions and noise (although this may differ with respect to the specific location of the infrastructure). However, clustering of infrastructure may have negative impacts on safety. Fatalities and injuries as a result of accidents seem to be more severe on clustered segments of infrastructure networks.

Financial synergies

Financial synergies are mostly related to creating open access to communication networks

Combined infrastructure can provide additional value that can be 'captured' by the infrastructure provider or operator. The best instances where additional value has been created are combinations of telecommunication infrastructure along rail, electricity or road networks. Two examples are the Reykjavik power grid and the French railway (TGV). These examples demonstrate that the telecommunication infrastructure necessary for operating a power grid and High Speed Railway respectively, could be an even more valuable asset when leased to telecom operators. An additional example is that of the Indian railway network which is being used to provide broad band internet to rural areas. This shows that a combined infrastructure network can deliver affordable communications services even in poor and peripheral regions.

In conclusion

There exists a clear potential to realise synergy within and between Trans-European Networks. The largest potential gains can be obtained when:

- combining road and rail networks (already widely applied in practice), and
- allowing existing communication networks previously dedicated to rail, road (and electricity) to other (broadband) uses for a wider public (assuming that open access to the infrastructure for all market players does exist).

It should be recognised that the communications sector is in general a commercially viable market. Public interventions should therefore be directed at stimulating to open communications networks previously dedicated (e.g. to rail, road, electricity) to wider communication uses. This can also include the option to bring in private (commercial) partner to operate the communication part. Where countries fail to intervene the Commission might consider to develop new regulation on the opening of these communication networks. Obviously opening of these previously dedicated networks should be done in such a manner that it does not distort competition.

The possibility of opening up previously dedicated networks for wider use is something that can be considered for new projects (including upgrading projects) that are still in the tendering/design phase, as well as for networks already in operation. The former option will also enhance the potential for public-private partnerships (PPPs) as it introduces an additional value component in the project.

On a more piecemeal basis, synergies between electricity networks and other transport modes can be expected. The most apparent ones are the use of rail and road tunnels for HV cables in mountain areas. An interesting combination is the use of inland waterways for combinations with HV lines by combining the sheet piling of the canal as a foundation for the HV line, or bury cables in the canal bottom/riverbed.

In addition, a number of interesting technological options have been identified which reduce costs or allow increased use of existing infrastructure. These would deserve further investigation to assess their real implementation potential. It is also worthwhile to examine whether new large scale initiatives related to renewable energy sources (e.g. off-shore wind parks, large-scale application of solar energy in Northern-Africa) could be extended to play a role in connecting national electricity networks.

Gas lines are less likely to be combined with other modes. In all situations attention must be paid to the safety consequences of combining different types of infrastructures in order to ensure that risk factors are identified at an early stage.

The synergetic impacts can be optimised once potential benefits are recognised and taken into account in an integrated planning and programming approach. When this happens benefits can already be realised during the preparatory phase of projects. If a tandem development of different types of infrastructure is not possible from the outset, then a more integrated planning perspective will keep open the possibility for cost savings at a later stage (“planning ahead”). For example by expropriating a wider corridor than necessary for the project at hand; through the construction of conductor pipes; or through astute design, future additions and expansions to the network can be facilitated. However it should be realised that the organisational setting is not always optimal to realise this joint planning in practice.

List of Abbreviations

AADT	average annual daily traffic
AC	alternating current
CAES	compressed air energy storage
CPS	Customer Premises Switch
DC	direct current
EIA	Environmental Impact Assessment
EM	electro magnetic
ETSO	European Transmission System Operators
GIL	gas insulated line
HV	high voltage
HVAC	high voltage alternating current
HVDC	high voltage direct current
ITS	Intelligent Transport System (or Service)
OHL	overhead line
RES	renewable energy sources
SEA	Strategic Environmental Assessment
SF_6	sulphur hexafluoride
TEN	Trans European Network
TPA	Third Party Access
TSI	Technical Specification of Interoperability
TSO	Transmission Service Operator
WLAN	wireless local-area network
XLPE	cross-linked polyethylene

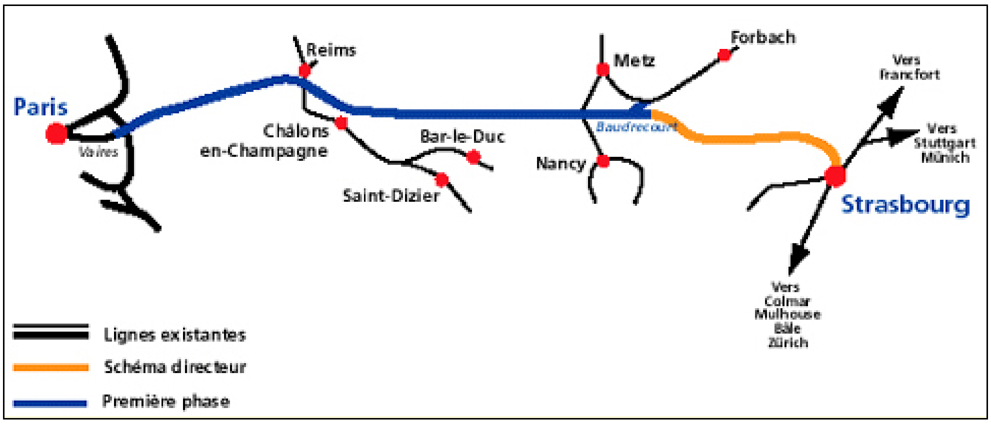
Annex A: the case of LGV Est-Européene[74]

Introduction

In the context of this study a specific case study has been carried out on the combination and synergies of voice-data communication with new railway development. This case study is centred around the development of the LGV Est-Européene.

"La LGV Est Européenne" - the construction of a high speed railway between Paris and Strasbourg is part of one of the 30 TEN-T priority projects defined by the Commission.

Figure A.1 Overview of LGV Est Européenne project (black: existing railway network, blue: LGV Est Européenne phase 1, orange: LGV Est Européenne phase 2)



The purpose of this railway, designed for speeds up to 350 km/h (in normal operation 320 km/h), is to provide a high speed connection between Paris and eastern parts of France and to provide significant reductions in travel time for international connections with Luxemburg, Germany, Switzerland and Belgium.

The project was started in 1992 and the first section of line, the 300 km stretch between Paris and Baudrecourt passing through 6 Départements, is expected to be in operation in 2007. The GSM-R communication system is already in operation and is being used as means of communication during the construction phase.

[74] This section is to a large extent based on the information gathered during a field visit. On 1 June 2006 COWI, represented by Mr. Yde, participated in a study tour arranged by Mr. Herald Ruyters, DG-TREN and Mr. Alain Cuccaroni, RFF - (assistant director of project LGV Est Européenne). Other participants included: Mrs. Sandrine Rabaseda, RFF - Responsible for environmental issues, Mr. Christophe Martineau, RFF - Responsible for Financial Management and Mrs. Marie-Helene Fassotte, DG-ENV. The objective of the tour was to gain firsthand knowledge of attempts to obtain synergetic effects when implementing major infrastructure in Europe. In addition COWI submitted specific questions to the RFF ahead of the tour.

Legislative and regulatory issues
The LGV project, being a priority project in itself, was approved without any requirements for the parallel development of other new infrastructure. Nevertheless the project management attempted to create a number of ad hoc synergies in different stages of the project, such as combinations with power lines, roads and voice/data communication over small sections of the line.

As the LGV project nears completion, the only real achievement with respect to creating synergy with other types of infrastructure appears to be the successful combination with voice/data communication infrastructure.

The initial expenditures for the "extra" installations that were needed to create synergies appears to have been made within LGV project budget. Agreements have been made between the LGV project and other infrastructure owners (i.e. mobile phone operators) to share construction, operating and maintenance costs according to actual use of each part of the shared infrastructure.

Apart from the shared infrastructure originally provided in the LGV project (RFF), e.g. masts and fibre optic cables, each of the sharing partners will install their own equipment to which separate direct physical access is to be provided. No provisions have been made to allowing easy expansion of infrastructure in the future and the issue does not appear to have been raised at any time.

RFF is not involved in the commercial exploitation of its own infrastructure to serve purposes other than those inherent in the operation of a modern railway network. Only proportional shares of actual construction, operating and maintenance costs of the raw infrastructure (fibres in cables, space in masts etc.) are being invoiced to partners.

The RFF has chosen a pragmatic approach to the merging of public and private interests. The three existing mobile phone operators in France - Orange (France Telecom), SFR, and Bouygues Telecom - were contacted directly by the LGV project team and offered the possibility to make use of masts along the track. Given the current market situation in France, this approach, in combination with the non-profit approach described above, seems to have avoided any possible conflicts of interest. Should a new operator enter the mobile market and demand equal rights access to public infrastructure a new situation will be created.

Decision making and planning issues
From the very early phases of the LGV project, the aspect of synergy was put on the agenda. For a number of years there were plans to simultaneously construct the railway together with a new road in the same corridor.

However, differing perspectives and sources of funding between the rail and the road project meant that a joint handling of the projects had to be abandoned. The road project was to be financed through private funding that was not available in time to follow the pace of development set by the railway project.

Another possibility for achieving synergy explored during the early stages of the LGV project was the parallel development of power lines. However there was no immediate need for new power lines in the region and therefore no plans were initiated. At some of the sites visited during the study tour, overhead power lines crisscrossed the landscape around the LGV corridor, but it was not possible to get an overview of the source and destination of these lines in relation to the LGV corridor. It is not clear whether the conversion of overhead power lines to underground installations in the LGV corridor has been considered as a possible improvement to the environment.

As the LGV project nears completion the only synergy realised is that of voice/data communication infrastructure in tandem with the railway. This combination was achieved at a fairly late stage, as mobile telephone network operators did not engage in the sort of long term advanced planning that enabled them to provide a clear commitment during the planning and design phases of the LGV project. Again, a difference in perspectives and planning background made the two projects incompatible with respect to the planning and design of synergy.

In this case, the eventual synergy only came about due to the LGV project accepting a small risk and building in a limited amount of extra capacity in the infrastructure that was already an inherent part of the LGV project. This through the installation of a GSM-R communication and the fibre optic cable running along the entire length of the LGV corridor.

GSM-R, a technology similar to GSM, but with functional extensions specifically designed for railway use, is intended to be the communications platform upon which certain elements of the future common European Rail Traffic Management System (ERTMS) will be implemented. Other elements of the ERTMS will be based on communication between trains and Eurobalises installed along the tracks.

The modifications to the basic LGV infrastructure in order to support additional voice/data communication were, as indicated, minimal. This was because:
- the spacing of mast sites for GSM-R was more or less equal to that requirements of mobile phone operators for general GSM coverage;
- the extra cost of installing 24 core fibre cables instead of e.g. 12 core fibre cables was marginal. For example, modifications to the design of cable ducts and number of access points were not required.

In summary, there were no significant changes necessary to the infrastructure required by RFF to accommodate the possibility to use the rail communication infrastructure by mobile telephone operators. Therefore the planning of RFF's infrastructure was not affected by the decision to allow the hosting of foreign systems.

The reluctance of the mobile phone operators to engage in a joint project from the outset is most likely due to:
- the near-full coverage that has already being achieved through the traditional planning of GSM mast sites

- the fact that areas without coverage are deemed "of little commercial interest". The balance between earning potential and the cost of installation, operation and maintenance was not favourable.

Today, only Orange (France Telecom) is hosted on all GSM-R sites along the LGV line and this is primarily in order to allow passengers of the TGV to use mobile phone communication along the full length of the LGV Est Européenne route. The other two operators have chosen to equip only selected GSM-R sites along the LGV corridor with their own GSM base stations, presumably offering full coverage to mobile phone users in areas not covered by their own network through roaming to the Orange network.

Construction issues
Primarily due to the limited nature of the integration of infrastructure and the fact the integration took place entirely on land within the LGV project, there were no specific problems during the construction phase. The cost of implementing the limited extra capabilities can be described as inconsequential for the budget of the LGV project.

On the other hand, given the GSM area coverage achieved by placing base stations at the LGV projects GSM-R sites, the cost savings for mobile phone operators must have been considerable relative to traditional planning, construction, operation and maintenance of sites:

- the process of pinpointing sites and submitting applications for new masts was made unnecessary
- the cost of establishing base stations was greatly reduced
- the cost of operating and maintaining the sites has also been reduced

This does not necessarily hold true for all the sites equipped with base stations by Orange.

Operation and maintenance issues
The cohabitation of railway and voice/data communication has not posed significant problems related to operation and maintenance. Physical access to equipment in shared masts occurs at many sites other than those provided by the LGV project. Safe physical access to the sites without compromising the safety of the LGV/TGV was a general requirement of the LGV project itself. Thus, operation and maintenance of each individual infrastructure can be planned and executed without significant impact on other infrastructure.

The impact of the LGV infrastructure on amenity values has not been significantly affected by the hosting of foreign operators equipment, as the original design of the infrastructure remains unchanged regardless of the actual number of operator installations at each site.

Summary
Experiences gathered in this case study exemplify the difficulties encountered in the quest for synergy through the combination of different types of infrastructure.

In the LGV project planning and implementing other types of infrastructure parallel with the railway has been hindered by:

- differences in scope. Each infrastructure project has a relatively limited scope that prevents budgets from being expanded to attain long term positive effects for the wider community.
- differences in the decision making and planning processes. The various types of infrastructure are rooted in different ministries or different actors within the private sector, each following independent decision making processes, sometimes influenced by political considerations and/or (short term) commercial considerations.
- different sources of funding. Some projects are primarily based on public funding (local, national, European) while others are based on private funding
- different lifecycles of essential technologies. Compared to road and railway construction, voice/data communication is a very volatile business with ever changing technologies. This poses fundamentally different requirements on infrastructure.

This case study has not touched on other aspects relevant to the exploration of potential synergy in European infrastructure projects such as cross-border issues and the "digital divide".

Further information on the LGV project can be found on the project web-site: www.lgv-est.com